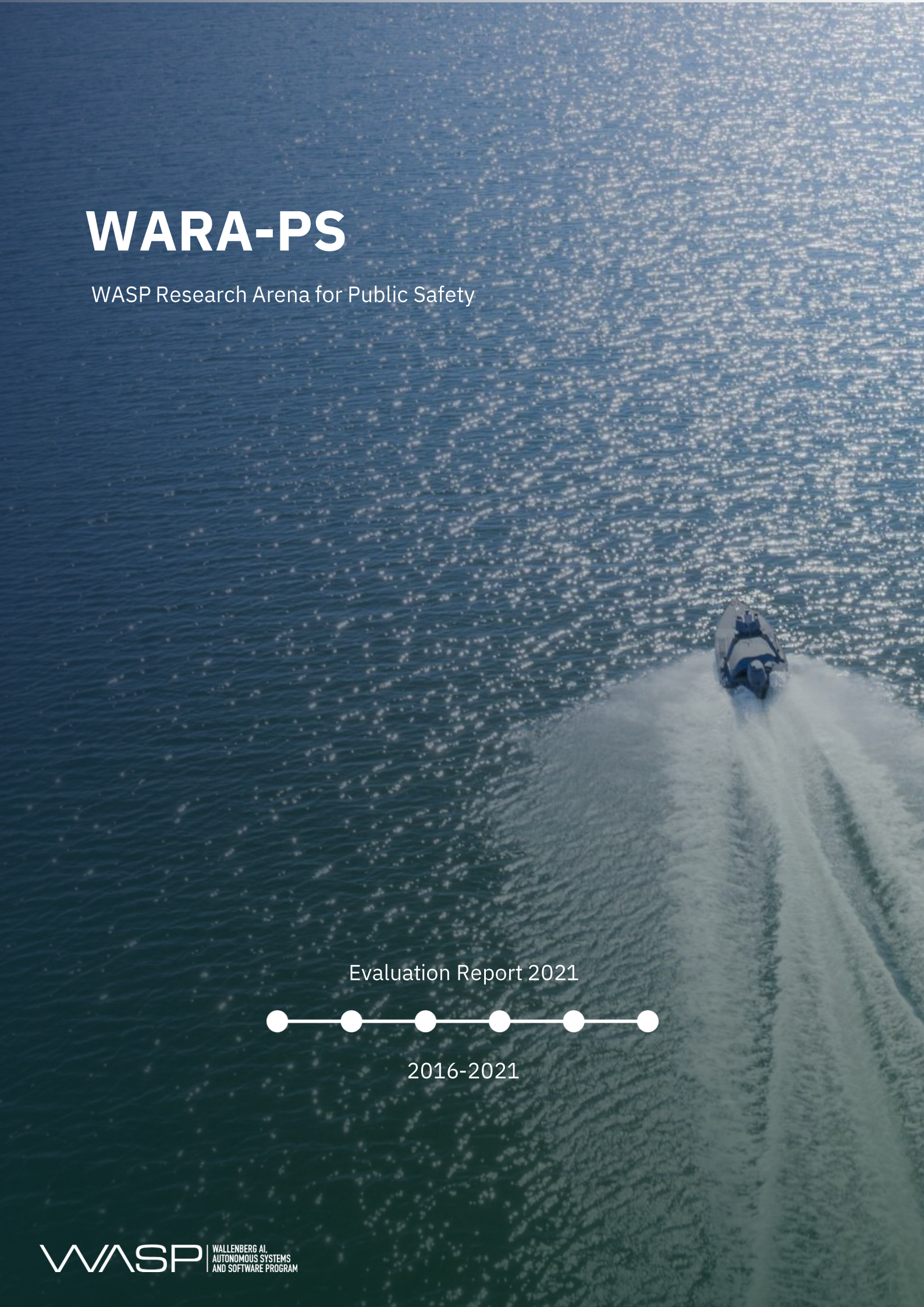


WARA-PS

WASP Research Arena for Public Safety

Evaluation Report 2021

2016-2021

WASP | WALLENBERG AI, AUTONOMOUS SYSTEMS AND SOFTWARE PROGRAM

Executive summary

This is the three years evaluation report for a WASP arena on public safety, WARA-PS, summarizing the outreach, activities and results as a self-assessment report focusing on achieved status of the arena. WARA-PS is focused on Collaborating humans and autonomous systems of systems with intense interactions and sliding combinations of human authority and systems autonomy, operating in all domains within Public Safety related scenarios. The research topics varies based on industry and research interests, and include visualization and decision support, Human Automation collaboration, Navigation, Localization, Perception, Anomaly detection etc.

The objective of the annual workshop in September (20-24th) was to expand the arena and test new technologies in. Onsite we demonstrated (1) dynamic function allocation for heterogeneous Systems of Systems including Manned/Unmanned-Teaming, (2) Autonomous vehicle systems (UAV, USV, UGV, UUV), (3) Core System, positioning & navigation, image processing, communication, (4) Data storage and access, analytics, (5) Visualization and human interaction.

Last year WARA-PS had more than 130 participants on the Gränsö21 event, from over 30 different organizations including 5 universities and 11 companies spread over at least 17 different projects (most outside of WASP). Onsite, we had 13 students including 2 post WASP PhDs' sharing their experience of WARA. New for 2021 were the 25 participants from Swedish government (FMV, FM, Sjöfartsverket, LFV), creating a full triple helix.WARA-PS also managed to reach a new level of maturity by expanding and creating a more open community for researchers and industry representatives, an accessible and configurable research infrastructure for autonomy and public safety system research, and more sharing of knowledge through data sets and media.

The way of working, where we explore activities without fear of failing, learning from experience and improve is an approach that is appreciated by both industry, academia, and government. We show what is possible to do by bringing in existing technology on high TRL (Technology Readiness Level) and combining it with changes and added low TRL technology to highlight possible research challenges. With an iterative way of working with recurring events, we continuously build experience, constantly evaluating and improving in collaboration with involved partners. This generates a value over time that is shared among the participants and managed within the arena. An important ability of the arena is to adapt to upcoming needs and still work on the long-term goal.

From 2018 WARA-PS has almost tripled in numbers of participants, active agents and represented projects, and gone from 10 contributing organizations to 45. It has gone from a pre-study in 2016 and a first system demonstration in 2018, to showcasing an established system, triple helix and wider scope in 2021. The next three years, the arena could expand to a "WARA-PS 3.0", covering a wider scope with more partners, scenarios and systems - while maintaining its focus – and working even closer with organizations involved in public safety to adapt scenarios based on the needs of the Swedish society. More focus will also be placed on communication and connectivity, as well as adding more resources for space and dynamic geographical and meteorological data, expanding the project even further and exploring more domains.

Contents

Purpose of this document

This is the three years evaluation report for a WASP arena on public safety, WARA-PS, summarizing the outreach, activities and results as a self-assessment report focusing on achieved status of the arena. It follows the content described in WARA 2.0 Strategy, Governance and Process, Ref [1]. Since this report is the first evaluation and the arena started in 2016, this report contains the history from the start. The report should also act as a base for conducting a new 3-year application for continued development of the WARA-PS arena with a chapter in the end addressing potential expansions. The target group for the document is first internal WASP Arena Management Group, but also for others interested. To fully understand the width of WARA-PS and spreading the insights and knowledge, this report has been extended with infrastructure descriptions and a historical retrospective. Hopefully this serves not only for evaluation in AMG but also as a documentation to use for introducing more people to WARA. There is also a purpose to mention contributors in making the arena living and expanding. Many have spent time on planning, executing, researching, driving boats, monitoring safety, and supporting in various ways. Some are visible but most are working in the background to make research in reality possible.

Happy reading!

Jesper Tordenlid Emma Jonsson

Mission and governance

Objective

From WARA 2.0: "*The main objective of the WASP Research Arenas is to increase the value and relevance of research by strengthening and promoting collaboration between WASP researchers and industry partners. An important part of this is to enable and support collaborative research in challenging and complex scenarios, and also to jointly identify new research challenges in the context of these. WARA thus addresses industrially relevant system-level platforms and scenarios which are far beyond the reach of individual university labs. By creating these WASP state-of-the-art research infrastructures, academic and industrial researchers can conduct and demonstrate more theoretical and component-based research in challenging real-world system applications. This also promotes the potential industrial impact and commercial applications of the WASP research. WARA also supports PhD project courses, formulation of new research initiatives, increases the visibility of WASP research both in the media and among potential PhD students, post-docs, and future faculty.*"

Research agenda/challenge

Research agenda/challenge WARA-PS has the long-term goal to support the stated research agenda on the WASP webpage: "*The main focus of the research within WASP is artificial intelligence and autonomous systems acting in collaboration with humans, adapting to and learning from their environment through sensors,*

The research arena focus is: Collaborating humans and autonomous systems of systems with intense interactions and sliding combinations of human authority and systems autonomy. Operating in all domains: Air, Sea, Underwater, Land, Space and Cyber, within Public Safety related scenarios in challenging environment with unforeseen events. This approach addresses scenarios deviating from the normal, focusing on incompletely defined missions with evolving understanding and resource availability. The types of scenarios are expected to cover situations well beyond those demonstrated, e.g., the ability to deal with deviations in many critical infrastructures such as power supply and transport systems (weather, accidents...).

Multi-domain and mixed scenarios are one of the keys to stimulate research challenges, concept development and to learn from results in other domains.

The research focus has been the same on a high level during the years of arena operation, but the research topics and content of the arena varies to adapt to ongoing projects, activities of researchers, industry interests and cluster activities. Research topics include: Visualization and decision support, Human Automation collaboration, Navigation, Localization, Perception, Anomaly detection etc.

Governance

Saab is the owner, working close together with Ericsson, LiU AIICS and Axis Communications to develop the arena and support projects and researchers. Swedish Sea Rescue Society (Svenska Sjöräddningssällskapet, SSRS) supports with real use cases, needs from society and access to test equipment. PhD students from LiU, KTH, LTH and CTH are active in their own projects and WASP project courses. The arena is very open and inclusive for collaboration and supportive of WASP external projects.

Management, development, and supervisors Saab:
Jesper Tordenlid (Project Manager), Lars Rundqwist, Jens-Olof Lindh, Jens Alfredson, Gert Johansson, Jonathan Olofsson, Emma Jonsson, Otto Carlander, Peter Stendahl, Roger Berg, Jonas Rosquist, Mattias Nilsson, Tobias Almén, Mårten Lager, Michael Petterstedt, Magnus Zetterberg, Caroline Flodin, Johanna Seger, Ronnie Poblete Vergara, Daniel Femerström, Thomas Håkansson, Christelle Wehbe, Isabelle Bühlmann, Katarina Iversen, Linus Exner, Ludvig Knast, Olivia Enroth, Robin Kalla, William Tyrsing, Pontus Nilsson, Jesper Pålsson, Albin Sjöström

Ericsson: Johan Eker, Fredrik Gunnarsson, Stig Persson, Robert Marklund, Rodrigo Berg

Axis Communications: Fredrik Hertzberg, Shubhabrata Sen

LiU AIICS: Patrick Doherty, Tommy Persson, Mariusz Wzorek, Piotr Rudol, Jonas Kvarnström, Cyrille Berger

SSRS: Fredrik Falkman

Airpelago: Fredrik Falkman, Tobias Fridén

SMaRC: Ivan Stenius, Peter Sigray, Jacob Kuttenkeuler

LiU: Daniel Axehill, Gustaf Hendeby, Michel Felsberg, Fredrik Gustafsson, Isaak Skoog, Nicolette Lakemond, Jonas Lundberg, Patric Ljung, Per Erik Forssén, Magnus Bång

KTH: Bo Wahlberg, Joakim Jaldén

LTH: Anders Robertsson, Elin Anna Topp, Jacek Malec

CTH: Petter Falkman, Torsten Wik

ORO: Amy Loutfi

UU: Johanna Björklund

AMG: Torbjörn Lundahl, Bo Wahlberg, Karl-Erik Årzén

Saab steering group: Gunnar Holmberg, Petter Bedoire

Status and achievements from 2021

Summary of 2021

The goal for 2021 was to build a larger demonstration of collaborating autonomous systems in real world scenarios with unforeseen events. Based on the work conducted since 2017, in 2021 we successfully concluded the 4th annual demonstration workshop at Gränsö. Larger than ever with onsite WASP project courses, data collection and experiments, while visitors explored and enjoyed the exhibitions, presentations, and demonstrations both onsite and remotely through our digital platforms.

WARA-PS has a vision to expand the arena and to make more use of the unique resourcesActivitiesport from Saab Global Innovation, the arena has been exhibited in Saab international collaborations in Brazil, US, and the UK. The arena has also been used as an example of how to build new arenas together with Cranfield University and UK based companies. Furthermore, the arena services have been discussed with government institutions. The large interest from these activities has resulted in plans and initiated work described below.

The objective of the annual workshop in September (20-24th) was to inspire and test new technologies. Onsite we demonstrated:

- Dynamic function allocation for heterogeneous Systems of
- Autonomous vehicle systems: UAV, USV, UGV, UUV
- Core System, positioning & navigation, image processing, communication
- Data storage and access, analytics
- Visualization and human interaction

Community: An open community for research, development, and innovations. Annual events, presentations and meetings, a working core team, a community with researchers, companies, and society. Access to public safety related real users and decision makers. In 2021, all of the 5 universities in WASP and some international guests were represented in demonstrations, or in exhibitions. Now Academia, Industry and Government are represented in many related research and innovation projects, sharing current knowledge in inspiring meetings to identify new challenges.

System: An accessible and configurable research infrastructure for autonomy and public safety system research. This year we have online resources running in ERDC 24/7 before, during and after the Gränsö workshop. Mixing the virtual/simulated agents with onsite physical autonomous agents (boats, drones, underwater vehicles, and humans) and cyber agent services (task planning, delegation etc.). Built on IoT technology and ROS support, the infrastructure is industry relevant and strengthens the collaboration between WASP researchers and industry partners.

Data: Data collection and knowledge generation shared in a Portal, in papers and in films and photos. Knowledge shared during the events and in presentations during the year makes the arena visible, not only within WASP but also worldwide with over 10 composed films.

Outreach

How well has the program succeeded in engaging Universities, companies, and students in its activities during last year of operation.

KPI	2021	Comment
# of Universities engaged	7	Including 3 international
# of Companies engaged as Core Team	4	Saab AB counted as one. Including SRSS.
# of Companies as associated in the program	>20	Including government organizations
# of researchers engaged (academic/industry)	40	Including engaged SMaRC students. 20 PhD students, 20 supervisors. Over 80 students and supervisors from 2018 to 2021. In addition, there have been over 20 Master/Bachelor students engaged.

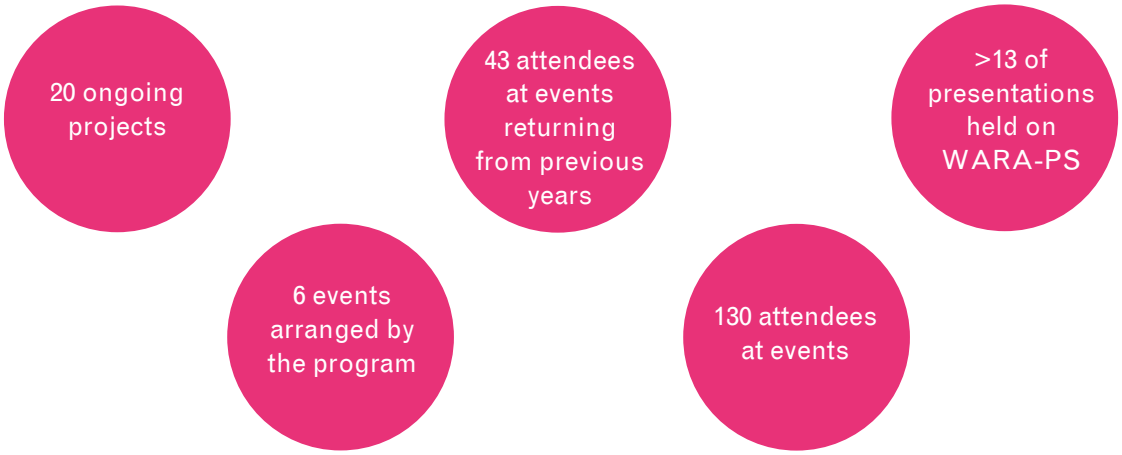
Last year WARA-PS had more than 130 participants on the Gränsö21 event, from over 30 different organizations including 5 universities and 11 companies spread over at least 17 different projects (most outside of WASP). Onsite, we had 13 students including 2 post WASP PhDs' sharing their experience of WARA. New for 2021 were the 25 participants from Swedish government (FMV, FM, Sjöfartsverket, LFV). The Gränsö workshop gathered a full triple Helix and has potential to become even larger. Due to the Covid pandemic there were many students and industry representatives who were not allowed to travel, and the event was adapted and organized accordingly.

Figure 1: A Saab Kockums Piraya with Camera/LIDAR sensor and communication equipment together with the rapidly launched SSRS Fixed Wing. The island "Ekholmen" behind is the well-known home of missing people drifting ashore after shipwreck. The Piraya's are also part of internal Saab projects and the EU project Ocean2020. The Fixed wing is also part of innovation programs at SSRS and Airpelago. At Gränsö the existing platforms are integrated in shared demonstrations delivering data to researchers.

Highlights in 2021

- WARA-PS core system in Springer article published (An autonomous Collaborative Aerial and Surface Search and Rescue System. Olov Andersson, Patrick Doherty, Mårten Lager, Jens-Olof Lindh, Linnea Persson, Elin A. Topp, Jesper Tordenlid & Bo Wahlberg. **LiU, LTH, KTH, Saab, Combitech**), Ref [2]
- Demonstrations of **SSF** funded project "SymbiCloud" was demonstrated live with drones and visualization and interaction at Gränsö21. A collaboration between **LiU AIICS** and **LiU MIT**. Patrick Doherty's PhD students Piotr Rudol and Mariusz Wzorek together with Patric Ljung are using the WARA-PS Core system.
- ROS Development environment set up and supported by Patrick Doherty's group at **LiU**. Collaboration with Anders Robertson's group at **LTH**. Used by **Saab**, **Airpelago** and **SSRS**.
- **CTH** joined Gränsö21 with autonomous water scooter "MARV", later rendered in a successful application for Viktor Lindström as affiliate WASP student.
- We have a solid Core team with members from the industry and academy working closely together and to support and continue to develop useful infrastructure and workshops.
- The growing community in Swedish government/authorities where **FM**, **FMV**, **FHS**, **FOI**, **Sjöfartsverket**, **Luftfartsverket**, **Polisen**, **Räddninsgstjänsten** are part of the community.
- WASP academia from **LiU**, **KTH**, **LTH**, **CTH** and **UU** was represented and contributed wSubjective assessmentpresentations, and exhibitions.
- **Vinnova** SweDig Autonomous Airport program work close together with WARA-PS, giving access to researchers and research engineers from **LiU MIT**, **RISE**, **LFV** and many companies.
- 3 International collaborations initiated with **ITA** university in Brazil, **Purdue** university in US and **Cranfield University** in UK.
- Two **Vinnova** projects within Public Safety Search & Rescue "EOS" and "SAR UAS" were represented and will be part of the community. With members from **Sjöfartsverket**, **FOI**, **LTH**, **SSRS**, **RISE**, **Polisen**, **Kustbevakningen**, **Svenska Sjöräddningssällskapet**, **Origon Utveckling**, **CTH**, **Smartplanes**, **Infotiv**, **Airpelago**, **Chalmers Maritime Human Factors**.
- Master thesis at **Combitech**, Caroline Flodin supervised by Sofie Pilemalm, **LiU**.
- Master thesis at **Combitech**, Kenan Sikiric and Simon Lundgren, supervised by Jalal Maleki, **LiU**
- **Trafikverket** project PNK4UTM working with U-space at **Swedish Drone Center** is a partner project in the region and with shared interest of flight tests with members from **Ericsson**, **Telia**, **Lantmäteriverket**, RISE, **T2**, **Västerviks kommun**.

Activities



The activities are recurring meetings during each year and on request from research groups or interested groups. Members from the Core team are working together with other research engineers and researchers.

- Core team meetings every week for planning and reviewing progress
- Integration meetings to expand and integrate new services and keep the system online
- Field test and data collection events, recurring in May and September. Also, on request

Core system demonstrations are activities to inspire and set focus on needed research and show examples of how resources (sensors, platforms, services, etc.) can be integrated and utilized. They are mainly performed during the Gränsö demonstrations.

The goal is to be open and inclusive and to participate in other arranged activities, taking all opportunities to promote collaboration and show what we are doing and how we can assist in other projects.

Supported projects

The core system and the team is available to support various projects, with both expertise and resources. The following list includes projects to be supported at various levels in 2022:

WASP NEST

- DISCOWER - Distributed Control in Weightless Environments (Space and sea, led by Ivan Stenius, KTH) Weightless Environments (Space and sea, led by Ivan Stenius, KTH)

Phd Projects collaborative landing

- MARV - Marine Autonomous Research Vehicle
- Anomaly detection
- USV autonomy
- Autonomous collaborative landing
- Safety critical autonomous systems
- Passive coherent location, (PCL)
- Pilot intention in autonomous systems
- User interaction in Swarms of autonomous vehicles

- Dynamic Information and Function Allocation for Expertise and Resource Coordination for Heterogeneous Human Responders and Robots Performing Search and Rescue Operations
- Explainable AI with human in the loop underwater
- 4 Brazilian collaboration projects within: HMI, Autonomy, AI, Sense & avoid, and Navigation
- Autonomous UAV for search in air accidents and disasters

Innovation projects

- Last Mile Delivery System – Vinnova Autonomous Airport Scene
- PNK4UTM - Position Navigation Communication for UTM

Master Thesis (one example)

- Victim Localization in Search and Rescue missions using Deep Reinforcement Learning

Data collection and test events. Follows the "annual wheel" (described in chapter 4) with planning, preparation, tests, Gränsö events in September.

- January: Planning with core team
- May: Data collection and test at Gränsö. USV and positioning tests
- June: SMaRC underwater and surface integrations and tests at Kristineberg
- September: Preparation workshop with tests at Gränsö
- September: Main Gränsö 21 event described above. Including Government capability workshop
- November: WASP Project course test campaign at Gränsö part 1
- November: WASP Project course test campaign at Gränsö part 2

Presentations. Some of the information spread for the academy, industry, and governm

- Cranfield arena workshop – Keynote speech (Feb 22)
- WASP WARA 2.0 webinar (Mars 3)
- Presentation on Trafikverket PNK-UTM project workshop (April 20)
- Presentation and interview for FMV Autonomy report (April 21)
- Presentation and collaboration meeting Sjöfartsverket SAR-UAS meeting (April 21)
- Presentation on Gränsö21 event, Mattias Tiger, Mårten Lager, Patrick Doherty,... (Sept 23-24)
- Presentation on CISB Brazil-Sweden collaboration meeting (Oct 6)
- Presentation on LiU Autonomous system course (Oct 7)
- Presentation on Saab Innovation and Technology Council board meeting (Oct 14)
- Presentation on WASP Board Gränsö result (Oct 27)
- Participation with mini exhibition on KÖMS 250 year (Nov 10)
- Presentation and panelist on WASP Job Fair 2021 (Dec 07)

Figure 2. Project course and core team members during test event at Gränsö in November.

Figure 3. Breaking the ice to support more field tests at Gränsö in late November. The dedicated members of the WARA-PS core team are always prepared for an extra data collection run when needed.

Results

Academic results, patents and contribution to commercial ideas have been generated, shown for the last year and total.

KPI	2021	Total 2017-2021
# of PhD thesis referring to the arena	4	6
# of publications filed	11	>20
# contributions to commercial ideas	Many	Many
# of WASP Project courses	3	10
# of Master/Bachelor thesis referring to the arena	1	>10

Academic results and commercial ideas are hard to measure. There has been an official routine to follow up conference presentations from the whole community. Often projects and PhD students do not refer to smaller contributions from arenas. Publications known to WARA-PS core team are listed in Chapter 7.

Below are some of the recognized results summarized and sorted on benefits for Academia, Industry and Government.

Academia: Universities, supervisors, and students. Want to access to real problems, resources, and engineers.

- Mattias Tiger, LiU, has given many presentations on events and webinars to share his experience of WARA-PS resources and way of working, inspiring other PhD students
- Olov Andersson, LiU: Postdoc ETH Zürich, winnPlatforms and servicese. Elected "WASP Alumni of the year"
- The academic ROS based simulation and development environment at LiU AIICS is now upgraded, and now also used outside LiU together with industry
- Collaboration with SMaRC maritime research contributes to the WARA-PS multi-domain research and expands the community with more researchers, supervisors, and industry/government representatives
- New collaboration with Purdue University (Barrett S. Caldwell) in autonomy research with Saab and LiU KMC (Erik Prytz). The core system and data collection events has spread to US universities
- Start-up of Vinnova Advanced digitalization program within Autonomous Airport
- Expanding the usage of the WARA-PS Core system introducing new standards for air space restrictions and drone radio communication and positioning. Addressing research together with LiU MIT within Human Automation in transport systems, Jonas Lundberg, and Magnus Bång, LiU. A larger community with more engineers and researchers now work together

- Support letters and assistance to over 6 PhD student applications and 6 Bridge and NEST applications with relevance to industries and connections to WARA-PS. At least 2 PhD students and 1 NEST project have been accepted and some PhD students applications are yet to be filed
- In general, there has been a growth in collaboration between universities, RISE and involved companies with autonomous systems. This have resulted in more access to shared resources and research engineers.

Industry: Strategists, decision makers, managers/leaders, employees. Want to explore ideas and collaborations and support recruitment.

- Alumni Bertil Grelsson, LiU. Continued with positioning solution in new product at Saab.
- Alumni Linnea Persson, KTH. Developing control in small start-up company "Airforestry"
- Alumni Mårten Lager, LTH. Continuing at Saab Kockums and part of research team further exploring ML in sea environment.
- Technologies from core system used in Industry 4.0 together with private networks. Collaboration between Saab, Combitech and Ericsson have been positive due to WARA-PS as one of many contributors.
- Reuse of core system and integrations to setup a Training lab at Saab as tool to identify and minimize risk in a new large product. General parts of useful development was brought back to WARA-PS. This is one example of how ideas open up for new ways of working internally at companies.
- At least 5 employments at Saab can be counted due to attraction from WARA-PS.
- New collaboration between Smartplanes and Combitech in new AI product development initiated by contacts at Gränsö21.
- Axis Communications network cameras are operated in new environments (sea and underwater) which opens up for collaborations.

Government: Strategists, decision makers, real end users. Want to understand and explore early phases of new technology in order to define their potential operational needs.

- Swedish-Brazilian Research and Innovation Centre – Vinnova funded study with FMV, Saab, Innovair and universities in Sweden and Brazil to setup collaborations using demonstrations. WARA-PS serves as an example and hosts some of the Swedish projects.
- WARA-PS arena used as a model in a Saab innovation where a business model to collaborate with defence agencies was developed. This resulted in invitations to government days and workshop at Gränsö21.
- WARA-PS was high-lighted in FMV Magazine" Teknisk prognos 2021 (Technical Forecast 2021)". Multiple full-page descriptions of the arena, activities, and interviews with Mattias Tiger, Fredrik Falkman, Åke Sivertun and Jesper Tordenlid.

Figure 4. Digital Cognitive Companions for Marine Vessels: On the Path Towards Autonomous Ships, Mårten Lager, LTH 2018-2021. Mårten Lager on a data collection run with Combat Boat 90 "Enforcer III", and Linnea Persson studies the moving platform for landing trials with drones. Photo: Thor Balkhed, LiU.

Figure 5. Robust Learning for Autonomous Robots - Obstacle Avoidance under Uncertainty, Olov Andersson, LiU 2018-2020. From live demonstration at Gränsö21. https://liu.se/en/news-item/harviker-roboten-artigt-undan.

Figure 6. GPS Free Positioning – Neural networks, Bertil Grelsson, LiU 2018-2019. The Piraya from Saab Kockums on a data collection run in the archipelago outside Gränsö/Västervik 2018. On top of the boat is a 360-degree camera mounted, recording the surrounding terrain together with reference positions. The dataset created was used in Bertil Grelssons PhD thesis.

Figure 7. Model Predictive Control for Cooperative Rendezvous of Autonomous Unmanned Vehicles, Linnea Persson, KTH, 2018-2020. Several field trials were conducted at GräWay of working and the core system demonstrationen the first test was performed.

Figure 8. Mattias Tiger, LiU presented WARA-PS from a PhD student perspective at Gränsö21. Mattias is one of the students making use of WARA-PS from the start. With his and other students' expressed needs for efficient development environments, the arena has adapted and formed to what it is.

Figure 9. Håkan Carlsson, KTH, tests a sensor array mounted on Enforcer III during data collection 2020 for PhD research "Inertial Sensor Arrays: Sensor Fusion and Calibration".

Subjective assessment

This chapter describes some of the main assets that WARA-PS has built over the years. A lot of the generated value from the arena lies in all the meetings and open discussions regarding inspiring environments with exhibitions and demonstrations. The arena has often inspired individuals and projects to take the next step, doing activities together and learning from each other. The multi-domain focus in WARA-PS gather people with different perspectives to share knowledge and gather new insights.

The way of working, where we do things - fail or success - learning from experience and improve is an approach that is appreciated by both industry, academia, and government. We show what is possible to do by bringing in existing technology on high TRL (Technology Readiness Level) and combining it with changes and added low TRL technology to highlight what could be the research challenges.

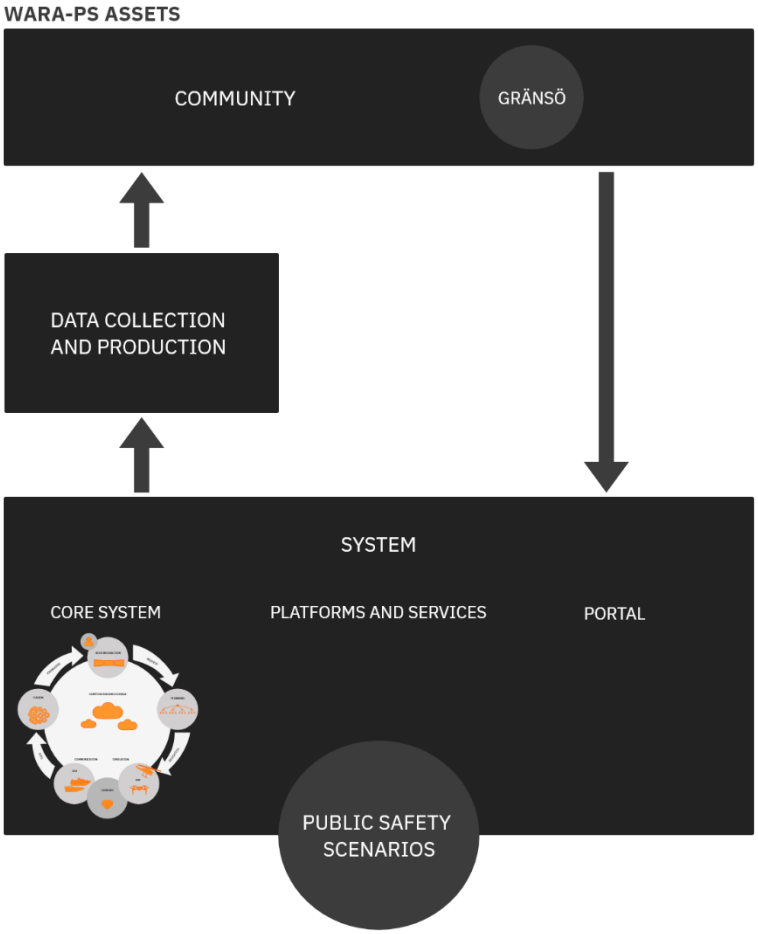


Figure 10. An overview of the assets in WARA-PS described in this chapter.

Arena evolvement and focus over time

Initially defined in 2016 and started in 2017, the research arena has been under constant evolvement. The activities have changed from initially setting up the arena and the system, to creating the community surrounding the system and recently to focusing on data collection and building infrastructure for knowledge distribution. More work has been put towards adapting to available researchers and projects, company needs and maturity of resources, and adapting to unforeseen events in society, that changes prerequisites and societal focus. We have had a different focus each year to build a living and adaptive arena according to a long-term plan to establish and grow multi-domain research on autonomous system of systems.

With an iterative way of working with recurring events, we build experiences over time, constantly evaluating and improving in collaboration with involved partners. This generates a value over time that is shared among the participants and managed within the arena. An important ability of the arena is to adapt to upcoming needs and still work on the long-term goal.

The WARA-PS arena way of working is studied in a WARA-HS research project and was reported in a paper 2020 by PhD student Youshan Yu, Ref [3].

In 2021 the arena was discovered by Cranfield University when the university together with companies and government conducted a pre-study of a similar arena concept. Jesper Tordenlid was invited for exchanging experiences and held a keynote speech on the Cranfield pre-study workshop. A reflection was that the WARA-PS arena is a unique concept. While we are building the arena, we are also developing a method useful for other arenas and in creation of new ones.

The following part of this section gives a brief of the annual Gränsö events in figures and summarizes the focus, activities, and outcome for each year:

Year	Participants at September workshop	Contributing organizations	Agents active in system	Projects represented
2018	53	10	4	11
2019	111	17	6	15
2020	83	29	11	25
2021	130	45	11	30

2016

Pre-study and Definition

Pre-study, definition and forming the research arena setup. Participating partners was Saab, Ericsson, Axis Communications and LiU. The outcome contained a pre-study report.

2017

Starting Activities

Initial coordination of teams and starting of research project courses with the outset of a three-year focus. Project courses for WASP Batch 1 PhD students formed the focus area of collaborating autonomous agents within sea rescue scenarios with cameras, boats, and quadcopters. The outcome of the project courses resulted in a Core team, a group of PhD students and useful resources to aim for the first demonstrations to open the arena for more participants.

2018

First system demonstration

Creation of the SAR system demonstration for stakeholders, onboarding of research students and first workshop at Gränsö. Resources and support were provided to WASP Batch 1 PhD students. Multiple integration meetings were arranged in core team participants lab where students were invited. Information about the WARA-PS concept and work was presented as follows.

- Presentation at 2018 UAS Forum
- Participation in Brazil-Sweden innovation
- Presentation at conference OpTech North USNaval Postgraduate School in Halifax

There was a lot of interest from companies with related projects, but the supervisors and students were still in a too early phase to make full use of the arena.

Figure 11. The first demonstrations at Gränsö 2018.

2019

Expanding the Community

As a community increases, we performed larger workshops with demonstrations. Resources and support were provided to WASP Batch 1 PhD students. Batch 2 students were onboarded through

Figure 12. Gathering at the beach to experience the live demonstrations.

Multi domain Data Collection

For WARA-PS the outset was now a new two-year plan. The focus was on data collection and building the infrastructure for knowledge distribution and research by Batch Increase and add in 2021. There was more Saab involvement and activities together with Swedish government organizations FMV and Sjöfartsverket. Integrated data collection from underwater and space nodes was tested. The covid pandemic had the impact that it was difficult to meet live in large groups, but also increased the need to make the arena resources and data more remotely available.

2020

WASP project courses. Films and presentations were spread together with Vinnova and Saab on international workshops to increase interest for Sweden and AI.

SMaRC, SRSS and Airpelago joined the workshops and the Core Team and Community, bringing more platforms,Plans for coming years end users to the arena. Telia collaboration added free 4G access for WARA-PS and Carmenta added free geographical map licenses. A number of preseContinue and collaborations were made, e.g.

- Visits and presentations by Jesper Tordenlid and Gunnar Bark, following the Batch 2 researchers during their onboarding in WARA.
- WASP Smart Localization workshop at Gränsö arranged with Fredrik Gustavsson and FOI, in parallel to WARA-PS demonstration preparations.
- Canada-Sweden innovation in Montreal presentations and meetings with Saab, RISE, AI Sweden and Mila.
- India-Sweden Innovation "AI for All" in New Delhi.
- UAS Forum presentation from WARA-PS Saab and SRSS.
- Presentation at Ericsson Kista mobility Day.
- Ericsson studio visit with PhD students.
- Presentation for Prof Barrett Caldwell, Purdue, and Department of Homeland Security, during their visit to KMC (Katastrofmedicinskt centrum)

Despite travel restrictions, a relatively large data collection event at Gränsö was still possible. Among the participants were Jonas Lundberg, LIU MIT, in the area of Human Automation research. During the event it was decided to conduct improvised tests and data collection from human workload in high-speed navigation use cases with the CB90 boat. Some of the highlights during 2020 was:

- Large scenario with flying drones beyond line of sight (BLOS).
- Data collection containing sounds, images and tracks from underwater, sea surface, air and space was performed.
- High precision Networked RTK GPS reference system together with Combitech and Ericsson added as true position in data collection.
- Relayed AIS data from SSRS Fixed wing via Sjöfartsverket, a SSRS innovation "Synthetic AIS" realized by Airpelago, Kockums, Combitech and Sjöfartsverket.

Figure 14. A composition containing contributions from all universities and core team industries.

Figure 13. Underwater nodes together with sea surface nodes and airborn nodes. High above satellites produced images while the vehicles, equipped with positioning systems, performed a joint SAR mission.

2021

Established System, triple helix and wider scope

There was an increased interest from, and more activities involving Swedish governments, creating a true triple helix. This year's demonstration utilized more heterogeneous autonomous agents in collaborative scenarios. We hosted a large exhibition with an increased number of related projects sponsored by Vinnova, FMV and Trafikverket. The WARA-PS Core system was up and running 24/7 with large number of real and simulated actors. We also included more scenarios within Public Safety, such as forest protection and firefighting. The arena has also opened to international actors. There as still Covid restrictions for travelling and meetings, but WARA-PS managed to perform workshops and at least 6 data collection activities.

Figure 14. Multirotor

Figure 15. CB90

Community

Individuals from different organizations participated and contributed to the Core Team. People participated through activities in projects related to PhD students or through a shared interest in resources, scenarios, and data. Participants came from over 40 organizations all over Sweden. We recorded participations from over 20 different geographical sites showing up at the Gränsö event, showcasing an open and including arena, easily attended and highly beneficial to participants, regardless of the magnitude of their contribution. Different types of participating groups are listed below.

Community type	Contribution	Benefits	Number of organizations
Core Team	Active participation in Core team, provides significant resources and workforce	Full core team member	4
Large contributors	Provides significant resources, Active project, PhD students	Request resources, test, or support	8
Contributors	Provides a service or a resource at planned workshops, Bachelor or Master student	Support and use resources during workshops	9
Interested	Participate with presentations, exhibitions, looking for opportunities to contribute	Invited to workshops and gets information	26
Observers		Access films and news	

Figure 16. Fredrik Falkman from Airpelago demonstrates drone information security for the audience at Gränsö21, as well as logotypes from participating organizations. Government organizations to the left, industry to the right/up and academia in front/down.

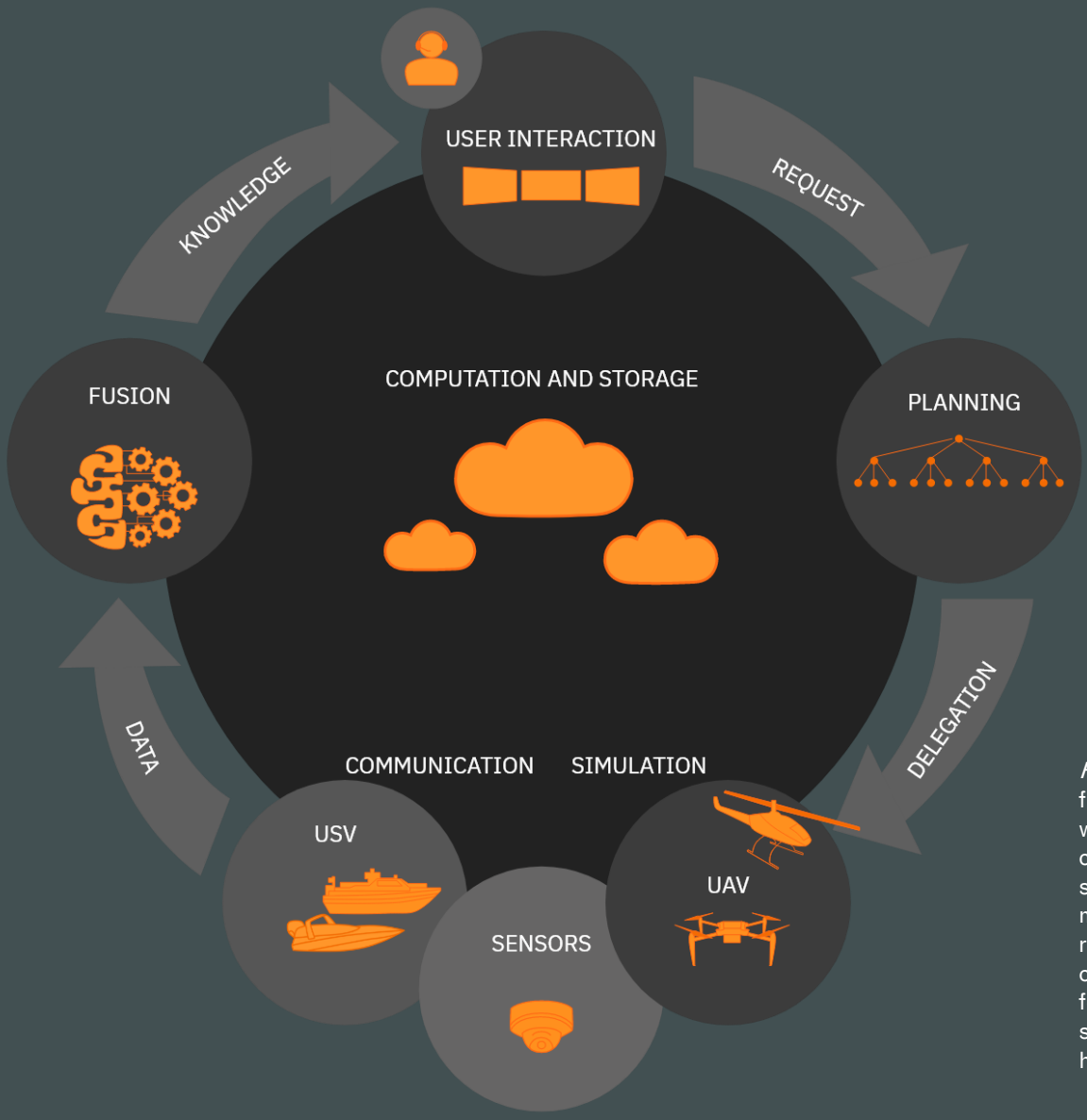


Figure 17. The schematic figure of the core system with feedback loops to connect the different systems. Autonomous mission planning on the right and AI data collection on the left to form an autonomous system of systems with human in the loop

The Core System

During 2021 the Core System has grown through integration of more systems as well as being tested in a search and rescue mission with heterogeneous agents – including a human agent – during the Gränsö21 event. The main goal for the WARA-PS Core System is to boost research on collaborating autonomous agents, starting from a higher level. This Core System enables an infrastructure for system research with different agents, systems, and services. A mix of simulated and physical systems can be integrated and shared in a common overall system. It is also easy to take advantage and contribute to the system. This Core System enables an infrastructure for system research with different agents, systems, and services. A mix of simulated and physical systems can be integrated and shared in a common overall system. It is also easy to take advantage and contribute to the system.

The WARA-PS Core System is based on the following principles:

Domain agnostic

- Uniform ontology as far as possible, independent of domain (air, sea, ground, space, cyber)
- Defined API for systems-systems, systems-subsystems, systems-agents and agents-to-agents

Easy integration

- Agents can be incrementally integrated at different levels with MQTT or ROS
- Adaption to developer needs to connect more agents and services

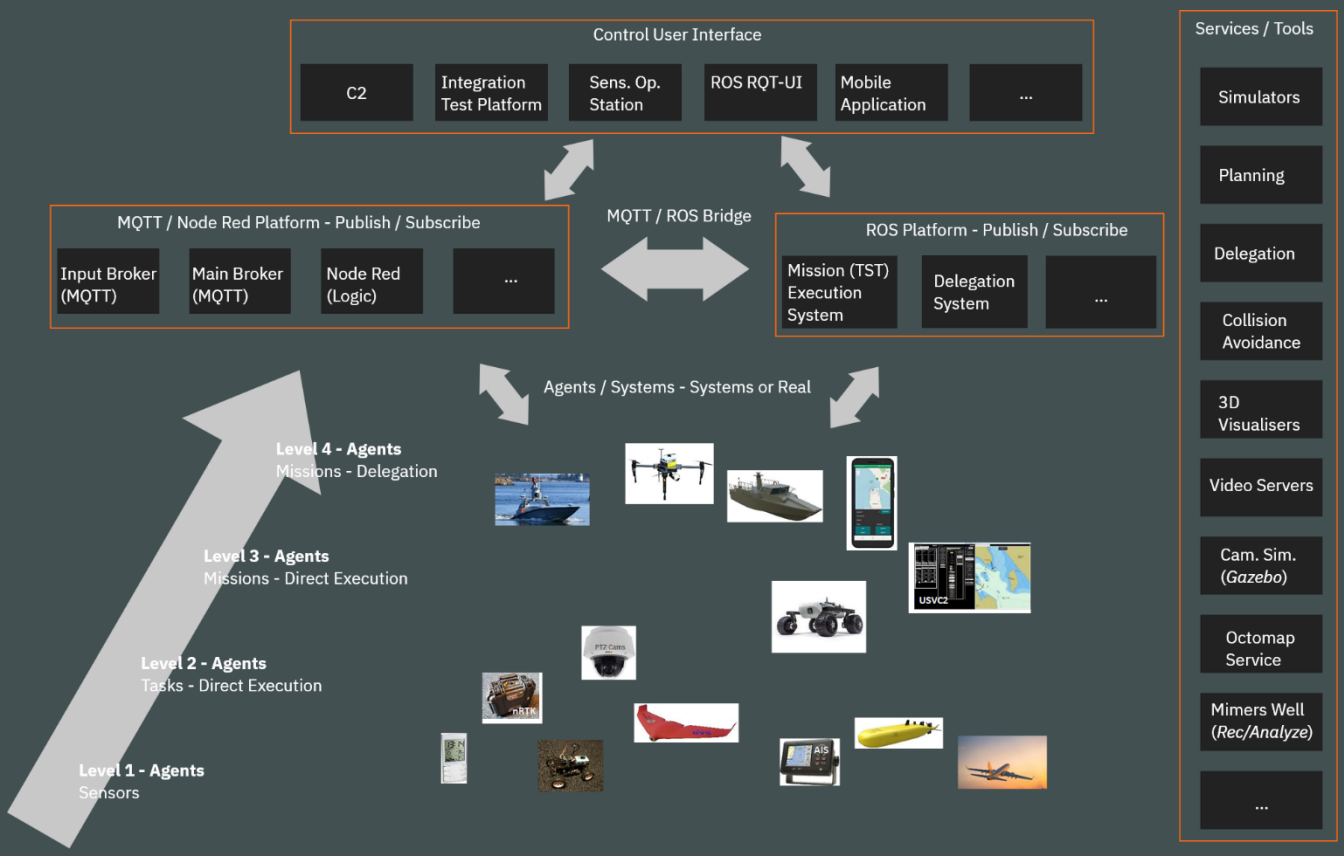


Figure 18: The above image provides an overview of example systems, subsystems, types of agents, communication platforms as well as services that make up the WARA-PS Core System. Integrations are done on different levels (1-4).

Available 24/7

- Core System is constantly in service for e.g. integration tests
- Virtual copies of agents exist to allow some tests without needing the physical agent
- Services can be configured and run locally if needed (Testing, Private Network, ...)
- Graphical Test User Interface on webpage for experimental interaction
- Positioning, sensors, video, commands etc. is accessible through the WARA-PS Integration Test Tool for development and debugging purposes

Capability for recording and analysis

- Recording functions for temporary events, e.g. MongoDB and Maria DB, for further analysis
- Repository for storing media, GPS-tracks and other data is available

Portal

The portal makes resources available to PhD students involved in WARA-PS in a way that simplifies access and use, while giving better insight into the project and its processes.

The resource portal works as both a platform and a guide, helping users locate the information, data set or tool needed. Via the portal the online storage space for media and data is accessible. During 2021 our work was more focused on making the Gränsö Demonstrations days more accessible both onsite and remote, due to Covid restrictions. By recording more of the demonstrations and live streaming events, more people could follow along, making WARA-PS even more accessible. Due to the developments in the project, the needs of the ever-growing user group have changed significantly. During 2022 the portal will therefore be upgraded with more information about the project, related work and resources, a better structure, more tutorials for easier use of the resources, as well as continuing the work with remote participation by posting updates from the events.

- https://portal.waraps.org
- https://wasp-sweden.org/research/research-arenas/wara-ps-public-safety
- https://internal.wasp-sweden.org/graduate-school/wara-ps-internal-page

Data collection and production

With available resource in the mixed environment at Gränsö and other places, there is a capability to generate scenarios and collect unique datasets. PhD students like Mårten Lager, Bertil Grelsson and, Mattias Tiger have used this service, where datasets have been collected at events to bring the reality into models for development and simulations in the lab/desktop. There is a data collection process developed and used. However, each project has specific needs, which implies that there are work to be done to offer a general and efficient data collection process. There is a lack of relevant datasets containing annotated video and images with corresponding movement tracks and user behavior to be used for public safety research.

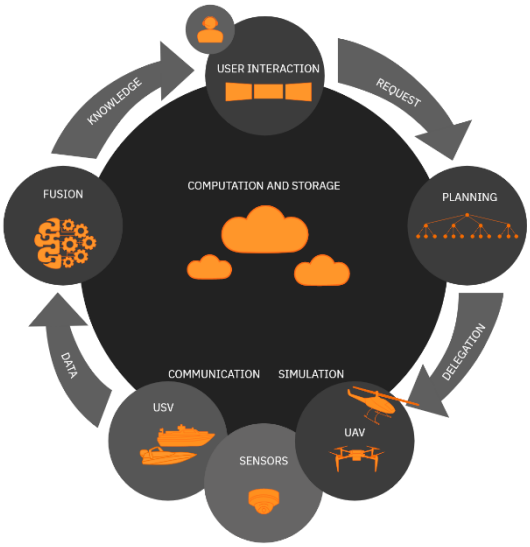


Figure 19. The schematic figure of the core system with feedback loops to connect the different systems. Autonomous mission planning on the right and AI data collection on the left to form an autonomous system of systems with human in the loop

To increase visibility, the arena has been documented over the years through films, photos, and descriptions. One film for each Gränsö workshop documents the arena status and shows examples of resources and research experiments. In 2020 there were four films produced showing different perspectives of the WARA-PS arena. Another four films illustrate the way of working through interviews with WASP PhD students and industry supervisors:

- Real World Research • Research in the Air
- Research in Water
- Simulations and Development Environment
- Experiences from WARA-PS #1-4

All films are available on YouTube and can be found by searching for WARA-PS. Chapter 7 contains the full list of films and news reports. There is also a Springer article published 2021 describing WARA-PS core system and research examples. "*WARA-PS: a research arena for public safety demonstrations and autonomous collaborative rescue robotics experimentation*", Ref [2].

Platforms and services

Through connected labs at universities and at companies, unique platforms are available. The resources are hosted at the labs and are part of related projects where they are developed and adapted to new experiments. The development plans are aligned with WARA-PS to support collaborative testing and data collection together with other partners in the community. New resources are integrated in the Core System when needed by projects or for inspirational core system demonstrations to show what could be done next.

Examples of accessible Unmanned Surface/Aerial/Ground/Underwater Vehicle (UxV) resources:

- USV: Enforcer III, Piraya, mini-USV from Saab.
- UAV: Matrice 100, 300 and 600 and ROS development environment from LiU AIICS.
- UAV: SSRS Fixed Wing and launch pad.
- USV: MARV Water scooter from CTH.
- UUV: SMaRC LoLo and Underwater communication nodes from SMaRC.
- UGV: LeoRovers from Saab Dynamics.

Examples of sensors and service:

- Positioning and communication system. Network RTK from Combitech and Ericsson.
- Cameras from Axis Communications attached to vehicles for see surface and underwater.
- Computation and storage in WARA-Common and Ericsson Research Data Center.
- Mobile application to be used by human agents on foot, in cars, boats or in airplanes.
- LIDAR, Radar and other sensors are provided on USV Piraya and Enforcer III.

Figure 20. Mini USV

Figure 21. The Autonomous Combat Boat 90 "Enforcer III" from Saab Kockums equipped with Camera sensors from Axis Communications serves as a floating lab both for WARA-PS and other projects. A manually operated Saab Fireboss (Air Tractor AT-802) picks up water to drop at requested spot.

Figure 22. There are also spontaneous resources showing up at events. The photo show Gustav Häger, LiU, working with stereo cameras and LIDAR on (right) Combat Boat 90 "Enforcer III" and the same system on (right) a Gränsö hotel On-site-built "Drink wagon" as a hardware emulation of the moving boat. More stable than the offered Golf car. A good example of cooperation between PhD students, hotel manager Per Johansson and Lars Rundqwist.

Public safety scenarios

The public safety related scenarios in WARA-PS offers a research context relevant to the participants. The scenarios have been formulated with the help of domain experts from rescue organizations such as Swedish Sea Rescue Society and the Swedish Maritime Administration. The goal of showcasing realistic scenarios is to put the technology and systems in a representative and interesting context, with unforeseen events and a changing environment.

Events are most often taking place in the Västervik archipelago. This environment is ideal for exploring different types of use cases taking place both on land and in the water – both on the surface and under water. The varying topography means that the collaborative nature of the scenarios is even more important, to cover all areas.

The first scenarios in WARA-PS focused on detecting objects in a sea rescue mission. It has now broadened to include more use cases applicable in more scenarios, such as traffic management, surveillance, transportation in smart cities, forest protection, more dynamic search, and rescue missions, etc. The scenarios are used to display the capabilities of the WARA-PS systems in a way that could be useful in society. Lessons learned and research results are applicable also to a wider range of applications and domains through similarities and analogy. Scenarios also bridge the gap to real users.

Figure 23. A Search and rescue scenario overview where the Gränsö environment are used together with Core system and resources. This figure shows an example mission where blue search agents trying to find missing red agents and distinguish them from the green not interesting agents. A grey agent act as a commander directing and follows up the mission. Agents are a mix of human and robots.

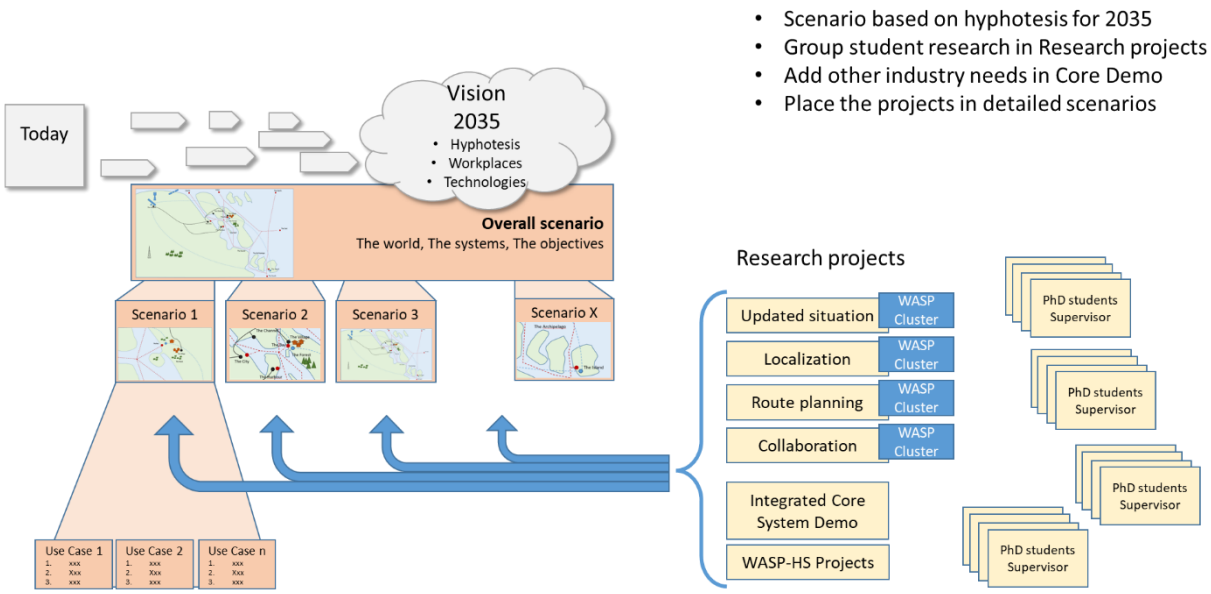


Figure 24. An illustration of how scenarios are used to support projects in WARA-PS. Often there are only parts (use cases) of a scenario that are of interest for a research project. Considering the large scenario brings important realistic details to the use cases and makes the experiments more relevant.

The Gränsö site

The main location of WARA-PS events is Gränsö, Västervik. This has become a physical arena for testing and demonstrating capabilities in the project. Due to its location, it is both accessible for visitors and participants by train or airplane, as well as boat accessible, without being located too close to the city center. This allows airborne vehicles to fly over the area. This area is also a common test ground for drones due to the collaboration with the Västervik municipality and collaboration with UAS Forum, Drone Center Sweden (Urban Wahlberg) and PNK4UTM (Åke Sivertun).

The location in the archipelago combines air, land, and water in an optimal way when it comes to search and rescue scenarios and displaying system capabilities in such contexts. It offers a mixture of open waters and the more topographically challenging nature of the archipelago. Gränsö Slott is located right by the water, making it a good location for demonstrations right by the harbor. It offers 800m2 indoor space for presentations and fairs, and large outdoor areas with room to expand if needed. Gränsö Slott combines hotel and conference center with good logistics regarding drone flights and boats on the premises.

WASP project courses

During the years from 2017 to 2021 WARA-PS has hosted 10 affiliated project courses in a variety of research domains. During the autumn semester, the projects have been supported to different degrees where the WARA-PS core team has provided: test resources, test events, access to real users, ideas and education, contacts, development framework, film production etc.

These projects where then presented at the WASP Winter Conference as well as being featured in the WASP poster collection. Each project was performed by a group of 5-6 PhD students from a mix of universities. The WASP project courses are a great tool for students to discover the WARAs and after that continue to use the WARA support and contacts in their continued research education. Some of the students' work have resulted in published conference papers. Selection and support 2019-2021 have been together with Daniel Axehill who have managed the WASP project courses.

2017

- Collision Avoidance (Kockums, Axis)
- Kolmården (LiU)

2019

- Autonomous Calibration of 3D Computer Vision System (Axis)
- Robust optimal video encoding for streaming over wireless communication (Axis)
- Multimodal interfaces for decision support (Combitech)
- Secure Federated Learning (Ericsson)
- Improving Quadcopter Obstacle Avoidance in Complex Environments (LiU AIICS)

2021

- Data driven decision support with multi-characteristic analysis for location scouting (LiU AIICS)
- Docking and planning for unmanned boats (Kockums)
- Secure & Privacy-Preserving Participatory Sensing of Wireless Interference (Combitech)

Way of working and the core system demonstration

One of the methods in the way of working for WARA-PS is the "Annual Wheel" with recurring events and workshops. New partners and people interested are invited to observe and enjoy the demonstrations, containing both the work that has been done, as well as inspiring presentations of future or potential work. The core system demonstration serves to inspire demonstrations for the upcoming year and direct attention to missing research. Demonstrations are complemented by exhibitions and presentations. The mix of different partners participating and contributing results in an inspiring demonstration event to find collaborations for next year. Having a fixed time and place for the demonstration and letting the content be formed by the community interests makes it filled with relevant content.

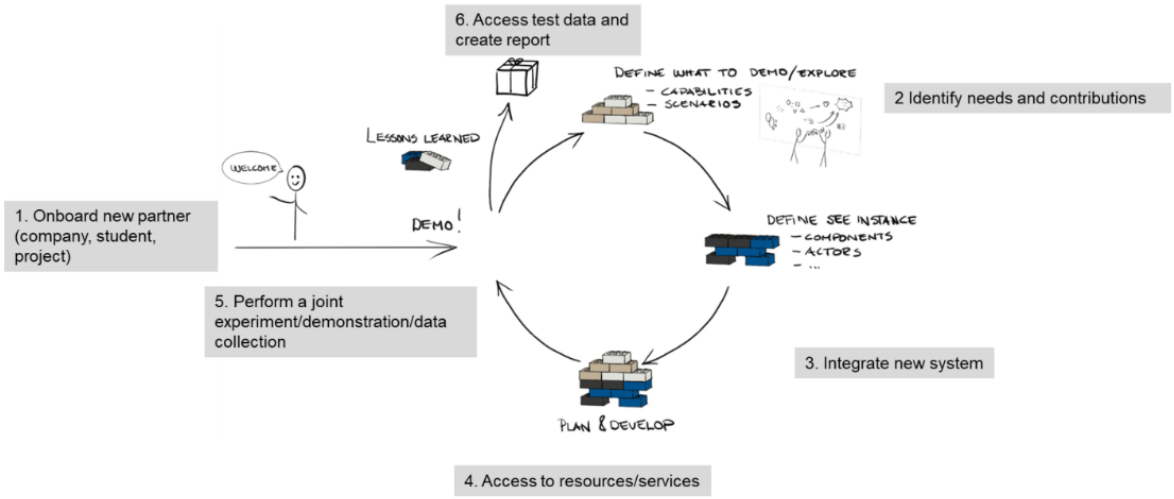


Figure 25. The "Annual Wheel" with support from the core team in WARA-PS in 5 steps. It is a general model; reality is far more complicated. All research projects and students tend to be quite different. A period of two years is common for larger projects and new partners. The first year is more of an observation and the next year is more focused on making use of the resources and services.

Company contribution and in-kind

One of the key prerequisites to this arena has been the large contributions of resources and experts from the companies involved. The largest contribution is from all sub companies within Saab and the Ericsson Research Data Center. The execution of WARA-PS would not have been possible without having senior engineers working both in large Saab related projects and still spend large amount of time in WARA-PS activities.

Below is a list of some of the related projects where experiences, know how and systems have been exchanged and codeveloped. The related projects are used as part of in-kind from Saab and are described more in Chapter 7. There have also been presentations on Gränsö events and on other events from those projects.

- Ocean2020
- FCAS
- Human Factors and interaction with drones
- SUM
- MIDCAS
- SweDemo

The financing of the arena follows WARA instructions and is built up with contributions from In-kind, KAW and from collaboration with other projects.

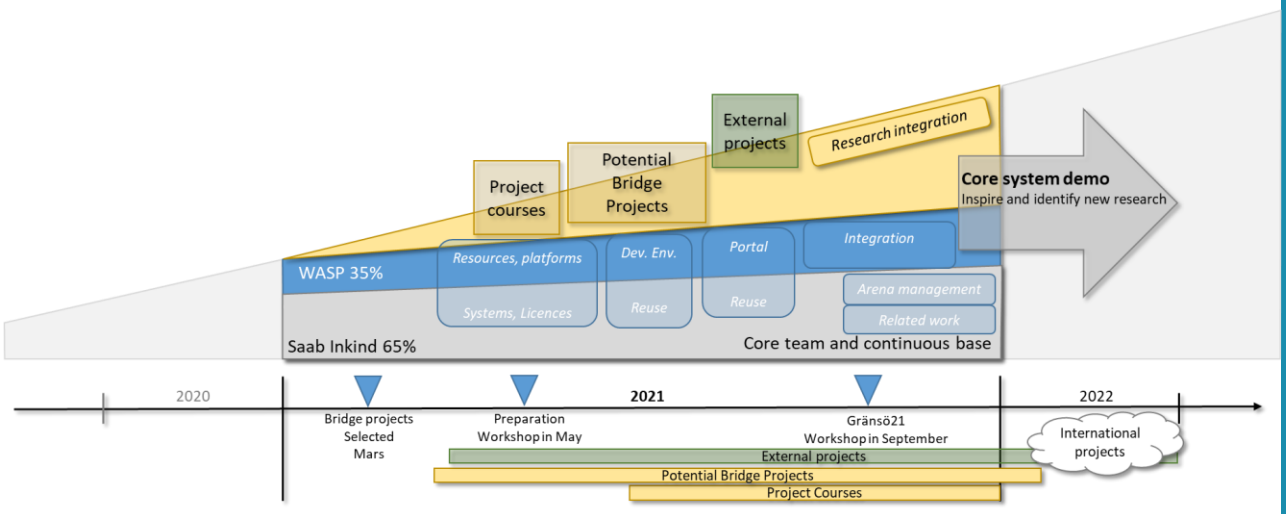


Figure 26. A generic illustration of how financing is allocated to main activities during a year. The figure also illustrates that the infrastructure with resources, platforms, development environments, portal and integrations support different projects, where one is the core system demonstration with aim of addressing topics for next year.

Lessons learned

This chapter contains a self-assessment based on a summary of the annual retrospective and feedback from other parties.

Success factors for WARA-PS

A leading organization with a long-term vision

Dedicated people who enjoy creating, adapting, and learning together

Public Safety and Search and Rescue is meaningful and collaborative

Neutral non-competitive challenge

Inclusive and open collaboration

If you share, you will get something back

With large support from Saab technology lead the WARA-PS is an important research and innovation tool for Saab. It is also an important arena for matching researchers with end users and society needs:

"*WARA-PS is an excellent way to bring together the cutting-edge research of the academia with the needs of the government and challenges for the industry. By executing WARA-PS, we are creating consensus about which problems needs to be solved, and how to best solve them by working together. We can thereby make sure that we are all working in the same direction. WARA-PS hence becomes a creative innovation platform in the best of triple helix spirits.*"

- Petter Bedoire, Saab CTO

"*WARA-PS is an exciting opportunity for us to connect with top researchers and companies that develop advanced technologies and to influence work in fields that may one day help us save lives in new, efficient ways.*"

- Fredrik Falkman, Head of Innovation at the Swedish Sea Rescue Society

Proactive and responsive core team

The Core Team is proactive and responsive, adapting and prioritizing according to the needs of the project. It consists of a small team with a wide focus and set of skills, managing a broad spectrum of activities all year around. Part of the activities include researching and improving resources in the project, as well as developing and integrating platforms

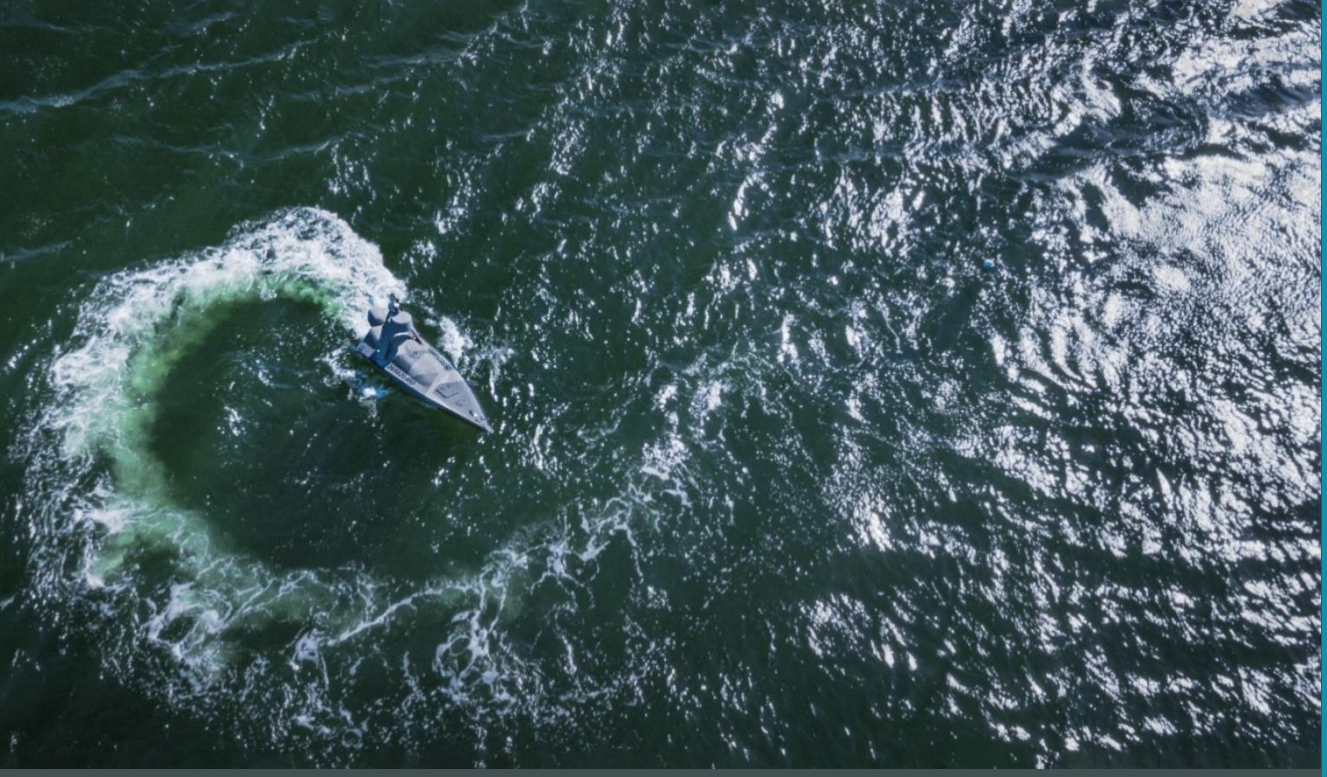


Figure 27. Piraya USV

Figure 28. CB90, equipped with sensors and camera from Axis Communication

and system, supporting researchers and projects, and producing media to be distributed about the work conducted in WARA-PS.

By being highly responsive, events and focus can be adapted to better fit the changing circumstances, such as during the pandemic. This meant putting a larger focus on remote participation and being able to conduct tests and demonstrations virtually, as well as making the events more remote.

Going forward it is important to use the lessons learnt from previous years to develop the arena further. There is now both an experienced Core Team, a large community, and a way of working together, constantly developing and improving the project.

Building and keeping experience in the Core team is challenging due to the reality that the most wanted engineers are also involved in other important projects. Priority in research projects is often lower than product delivery projects. Still, we want a core team with access to hands on experience and real products in the company organization. The working solution for WARA-PS has been to have a mix of seniors and young employees. The seniors have a broad contact network in the organizations and can usually, due to experience, cover for others when someone must work more internally. The mix allow the young talents to get experienced fast and only people that wants to collaborate are attracted. Starting the career in the Core team allows the young talents to keep contact with universities, which broaden the understanding of tools and methods to use together between universities and industry.

Attract researchers

Attracting new PhD students and supervisors to the arena has been a challenge. The supervisors involved are researchers with a tradition of experimental research. When they have students that are in the phase of exploration and data collection there is often a match, and the arena can offer useful support. Initially WARA-PS approached PhD students active in the first WASP project course and they got useful outcome and data. Bringing in more students without the project course was hard. The solution was to approach the supervisors known for conducting experimental research and hope that there are PhD students in the right phase. This resulted in few (5-10 yearly) but very dedicated students and supervisors. WARA-PS originally targeted PhD students in Autonomous System research school. Students from AI research school and their supervisors have been hard to attract for different reasons. One reason has been that the projects course was mainly for Autonomous Systems students.

In 2021 we changed strategy and tried to find public safety related projects in definition phase or recently started that had need for real data and challenging environments. The list in chapters above with projects shows that WARA-PS are of interest, not only for projects within WASP, but also small and large projects funded by other instances. The mix of research and innovation projects with different triple helix partners and researchers from multiple universities and companies seems to be the larger scope to deliver short and long-term results “In the benefit of the Swedish Industry.” For WASP researchers WARA-PS offers a large network of Swedish and international contacts to use in their research and future career planning. Innovation projects raises the Technology Readiness Levels, adds more system focus and helps to identify and fit the novel research in real systems. Another benefit of searching for relevant projects

is that we now have brought together projects from multiple domains with shared research interest. The WASP brand and the broad community of well-known organizations, providing knowledge and resources, makes WARA-PS today a unique arena not available anywhere else.

Fulfillment of objective

Reflecting in the objectives in chapter *mission and governance*, WARA-PS has delivered value on the objective statements. The chapters in this report describes how the objectives have been achieved. Below, each statement in the objective description summarized with reference to relevant chapters can be found.

Relevance of research

The research focus has been under constant discussion within the core team, companies and with researchers. In chapter *mission and governance* the research focus is described in line with the WASP overall research agenda.

Strengthening and promoting collaboration between WASP researchers and industry partners

The outreach in chapter *status and achievements from 2021* contains multiple collaboration projects with various combinations of organizations and researchers.

Collaborative research in challenging and complex scenarios

Activities in chapter *status and achievements from 2021* describes some of all activities. Also, in chapter *subjective assessment* the evolvement of the arena describes activities during the years of operation.

Jointly identify new research challenges

Our adapted way of working uses inspiring demonstrations, exhibitions, and moderated workshops to highlight missing research and match industry interest.

Industrially relevant system-level platforms and scenarios which are far beyond the reach of individual university labs

Involved companies provides own research equipment and resources. Experts from industries and government works on scenarios to identify relevant capabilities.

State-of-the-art research infrastructures

The core system uses latest technologies and methods to integrate and execute system functions, both academic and industrial. See chapter *subjective assessment*.

Academic and industrial researchers can conduct and demonstrate more theoretical and component-based research in challenging real-world system applications

Activities are described in chapter 3 together with the evolvement of the arena in chapter *subjective assessment*, which describes e.g., the demonstrations at Gränsö.

Promotes the potential industrial impact and commercial applications of the WASP research

Demonstrated research are often small pieces of a system. By presenting the demonstrations together with the core system in real environment, the potential industrial impact and commercial applications are high-lighted to relevant industries.

WARA also supports PhD project courses

The courses are described in chapter *subjective assessment*. WARA-PS contribute both by promoting the courses in general and hosting some courses each period.

Formulation of new research initiatives

Many initiatives are initiated by gathering the WARA-PS community at workshops. In chapter 3 the results contains some examples.

Increases the visibility of WASP research both in the media and among potential PhD students, post-docs, and future faculty

In chapter *subjective assessment* the data collection and production are described, containing film production and academic reports. Each year promotion videos are recorded and spread.

Figure 29. Jens-Olof Lindh and Lars Rundqwist on Gränsö20 moderates the daily briefing before the research groups starts field tests in air, sea and underwater. An important moment where experienced engineers from industry prepare researchers for a safe and efficient work in the field.

Plans for coming years

We have a momentum and interest to expand the community with WASP as a core, supported by Saab and other partners, national and international.

The WARA-PS team has highlighted problem definitions within "*Collaborating humans and autonomous systems of systems with intense interactions and sliding combinations of human authority and systems autonomy*" and have started to work with other projects funded by Vinnova, Trafikverket, FMV and other. International and national related projects and test beds want to use WARA-PS and collaboration are in the planning stage. Now it is important to keep the Arena "WASP branded" and continue to be "independent", and inclusive. We are also seeing a growing interest for public safety and civil defence due to the pandemic and conflicts in Europe.

The next three years, the arena could expand to a "WARA-PS 3.0", covering a wider scope with more partners, scenarios, and systems, still focusing on collaborating autonomous systems in real world scenarios with unforeseen events.

To grow the arena and build more a robust and scalable data collecting core system, a proactive core team with wide experience and network needs to be even more stable over time. The aim is to fulfill current WARA 2.0 objectives and beyond, and to expand with a budget to cover all WASP university robot labs, more companies as well as selected active government organizations.

Continue

- Develop an experimental "Mission Autonomy" that can be accessible and explored by multiple universities and companies. Promote collaboration between research groups.
- Closer collaboration with SMaRC where components of the core system are developed and used together to stress usage in the under-water domain where communication is very
- The mix of simulation and real agents and systems together should be further investigated to promote more research on "digital twins" in multi-domain with virtual environments covering both land and seabed.
- Promote the existing infrastructure and broaden the community of users. Support and further development of the integration API together with Patrik Doherty's research group and more. Include more resources and labs. Increase usage and number of users.

Lowering the threshold by showing how to participate and use resources. Develop examples and courses.
- Invite government institutes to workshops and continue to uphold the full triple helix.

Increase and add

- There is an increased interest for Public Safety and civil defense. Scenarios should be adapted to what Swedish society needs. More Public safety scenarios can be added, Forest and Firefighting, Transportation at sea and in air for example. Highlight challenging events. More collaboration with the Autonomous airport project with introduction of unforeseen events.
- Increase structure in the arena and organization with working groups. Use more of formal agreements and calls for participation. This is needed to scale up and manage the growth of interest. Add more formal partners in Community as Large Contributors or Contributors.
- Investigate and add more support and resources for space and dynamic geographical and meteorological data in order to support the NEST project DISCOWER.
- More pedagogic visualization of scenario, concepts, and technologies to gain experience from all demonstrations and systems. This will come with LiU MIT as partner.
- Increase focus on communication, connectivity, and positioning services to open for Ericsson to have a more interesting role in the arena. Together with Saab and Combitech the Private Network will have an interesting role in public safety and industry 4.0 use cases.
- In 2021 one focus has been to make implementation of autonomous agents easier. Now useful services and implementations for AI/ML research in the core system need a focus. Cyber agents with services allowing software cyber security research should be able to make use of the system.
- Better process for tracking papers, conference presentations, etc. Implement a method together with other WARAs to follow up contributions and impacts from the arena and measure requested KPIs
- Develop data collection process together with WARA-Common and WARA-Media for efficient production and support of data to projects
- A *Challenge* to be announced to university groups and to be demonstrated on site
- Publish more own papers from core system demonstrations and way of working in the arena

To achieve and make use of these extensions the arena should aim for increased collaboration with new partners: LiU MIT, Sjöfartsverket, MSB, FMV, FOI and FHS. WARA-PS could also expand by adding small startups to promote innovation and new business. There shall also be more collaboration within WARA and we should aim for adding research projects from ORU and UU.

Possible in-kind with existing and new partners

- Saab project management, existing and additional resources, and related work
- Ericsson via WARA Common supports with data center (ERDC)

- Ericsson Positioning and communication
- Axis Communications support with networked cameras, sensors on request
- LiU supports with integration and development environment and related projects
- SSRS supports with real use cases, society needs and access to test equipment
- New partners could contribution with data and resources

Figure 30. WARA-PS leave Gränsö21 event with Swedish flag raised. We are ready for a new 3-year period with multi-domain autonomy research "in the benefit of Swedish industries

References

[1] WARA 2.0 Strategy, Governance and Process "Arbetsordning för WASP Arena Management Group (AMG)"

[2] WARA-PS: a research arena for public safety demonstrations and autonomous collaborative rescue robotics experimentation,https://rdcu.be/cBtFo.

[3] "THE EMERGENCE OF AI SOLUTIONS IN COMPLEX INTELLIGENT SYSTEMS - ENVISIONING DESIGN CONSEQUENCES" Yu, Youshan CINET2020, LiU

[4] WARA-PS Web page: https://wasp-sweden.org/research/research-arenas/wara-ps-public-safety/

News from 2021

- *Film 2021: https://www.youtube.com/watch?v=bVWN-RRIpSo*
- *Teknisk prognos 2021 - WARA-PS.pdf*
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Sensor Management for Target Tracking Applications	Per Boström-Rost	Doctorial Thesis	2021
Exploiting Direct Optimal Control for Motion Planning in Unstructured Environments	Kristoffer Bergman	Doctorial Thesis	2021
Digital Cognitive Companions for Marine Vessels: On the Path Towards Autonomous Ships	Mårten Lager	Doctorial Thesis	2021
Designing visualization and interaction for industrial control rooms of the future	Veronika Domova	Doctorial Thesis	2021
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Self-Calibration of Inertial Sensor Arrays	Håkan Carlsson, Isaac Skog, Joakim Jaldén	IEEE Sensors Journal	2021

Future Combat Air System (FCAS)

The project Future Combat Air System (FCAS) is a long-term concept and technology study within Saab Aeronautics with the goal to integrate and validate disruptive technologies within the product development. FCAS works on three time horizons 2025 – 2035 – 2045 in order to combine a more open-minded long-term perspective with a more pragmatic short-term needs and restrictions of current customers and products. The FCAS study includes technology areas that are highly relevant to WARA-PS, such as: Command and control of collaborating systems-of-systems, Model Based Systems Engineering, Methods, Tools and Architectures, Verification of complex dependencies, cyber physical systems, Virtual lab development (for students), Sliding autonomy, Mixed initiative, Distributed Command & Control. The studies and demonstrators within FCAS will also be an important channel for Saab to absorb the research produced in WASP/WARA and integrate it into Swedish industrial development.

MID-air Collision Avoidance System (MIDCAS)

The MIDCAS project was a European cooperation under the framework of the European Defence Agency, with a total budget of €50 million. The objective was to provide the possibilities for RPAS to fly into civil airspace alongside manned aviation. A prerequisite for this is that RPAS can detect and avoid other aircraft which the flight tests now have proven. The MIDCAS system uses sensors integrated on the RPA that can detect and track other aircraft. The sensor information is used to determine if there is a collision risk and if so how and when to carry out an avoidance manoeuvre.

EUropean Detect and Avoid System (EUDAAS)

EUDAAS is follow-on project to MIDCAS, financed by the European Commission and 5 Member states. In addition to the MIDCAS task of Collision Avoidance, the purpose of EUDAAS is to draft a European standard for Collision Avoidance for RPAS and to define a tentative Detect and Avoid system product.

European Technology Acquisition Program (ETAP)

The ETAP cooperative program is the result of the six LoI nations' desire to unite their efforts in fostering the development of technologies for Future Combat Air Systems. This program, called European Technology Acquisition Program, was set up in its present form on 26 November 2001 when the related Memorandum of Understanding (MoU), signed by France, Germany, Italy, Spain, Sweden and United Kingdom, entered into effect. Aiming to develop the technologies needed for Future Combat Air Systems (FCAS) post 2020, the Program, which is funded project by project on an equitable basis among the interested participants, comprises a set of Technology Demonstration Projects (TDPs) sorted into eight technological domains, The TDPs related

to WASP/WARA PS are: Avionics, Integrated Vehicle Systems, Mission guidance and control.

Human factors and interaction with drones

The work is performed with a human factors perspective when analyzing the user needs. Relevant factors for the study are possible tasks for the drone swarm; system co-operation; autonomous co-operation in a command hierarchy, decision support, and autonomy.

These efforts including Saab Aeronautics, Linköping University, ITA in Brazil and RISE SICS East AB. The implementation, demonstration and test will be conducted at Linköping University (LiU) at the Department of Computer and Information Science (IDA). This project enables current and future research within aeronautic human factors to progress from lower to higher TRL levels. The work also enables demonstration of technologies and concepts for the aerospace industry already at lower TRL-levels at the human factors lab. This is important for the industry to be able study relevant technologies and concepts as well as to get input to future design decisions with possible implications on human factors, such as future concepts for manned and unmanned aircraft and their control.

The project has strong relevance to the areas around WARA-PS and Saab will share results from the project, and methods, tools and equipment to be re-used in WARA-PS. It will be possible (after the actual interactions are defined) to name people being part in the communication/collaboration.

SweDemo UAV integration in non-segregated airspace: SweDemo

Swe-Demo is a program under the Swedish innovation agency (Vinnova), focused on aeronautical demonstration, TRL4-6, with one area being integration of UAV/UAS/RPAS in non-segregated airspace. Saab is leading the project to demonstrate RPAS integration in non-segregate airspace including development and demonstration of a Detect & Avoid system. Detect & Avoid is considered the key enabler of RPAS integration in non-segregated airspace and thus a key enabler of the RPA integration in non-segregate airspace including development and demonstration of a Detect & Avoid system. Detect & Avoid is considered the key enabler of RPAS integration in nonsegregated airspace and thus a key enabler of the RPAS (civil and military) market as well as key product by itself. Saab is also a part of the European Unions project MIDCAS and EUDAAS studying the same area.

Involvement with WASP research related to the WARA-PS scope will be in the form of research discussions, sharing of results, lectures (i.e. safety), feedback, participation in workshops and meeting, or others.

OCEAN2020

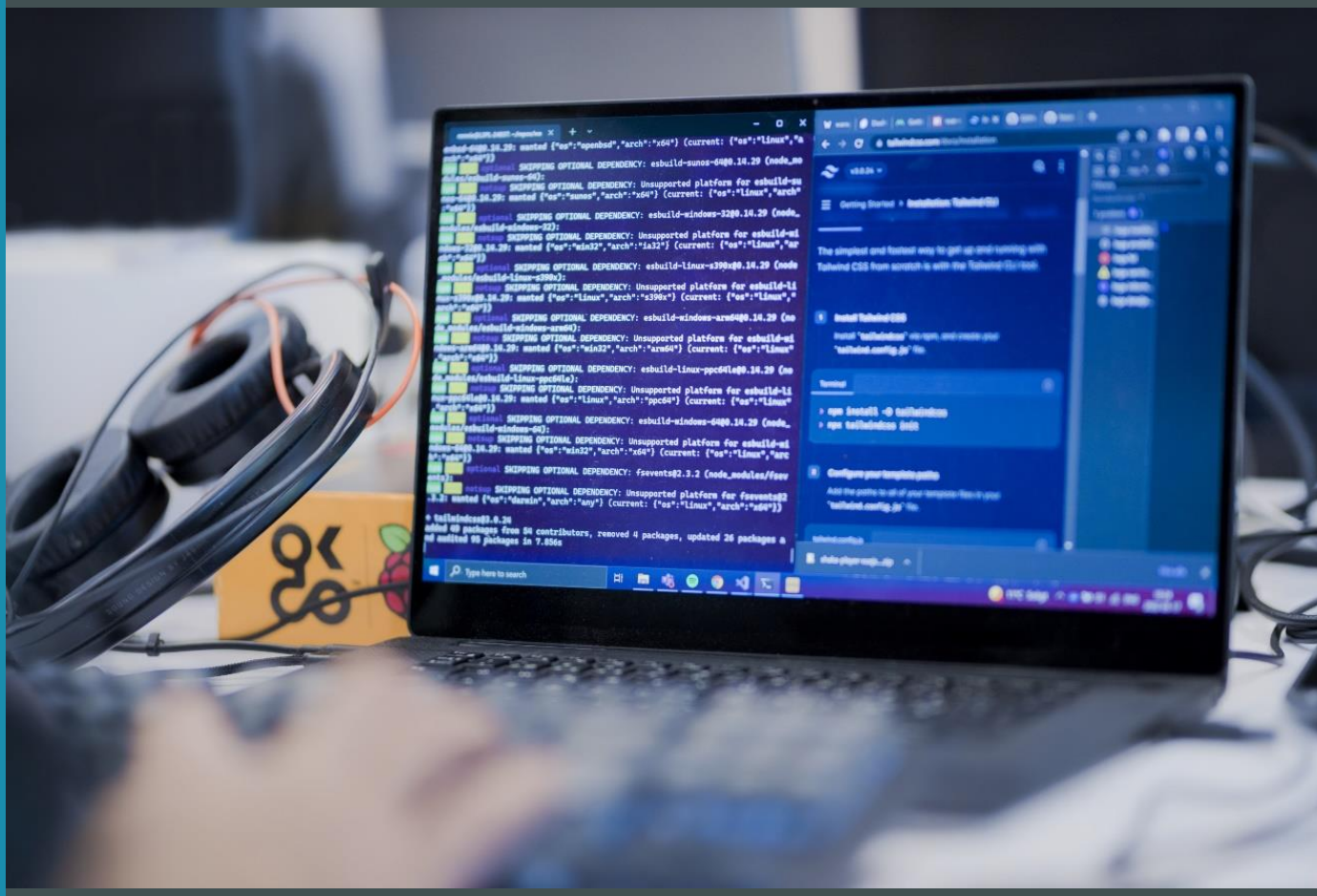
The purpose of OCEAN2020 is to boost technological research in the naval domain by the integration of unmanned platforms also in surveillance and interdiction missions. Leonardo is a leader in systems integration and will lead a team of 42 partner companies from 15 European countries including Saab, Safran, PGZ and MBDA, research bodies such as Fraunhofer NATO CMRE and the defense ministries of five countries. A major demonstration was held in the Baltic Sea in August 2021. There OCEAN2020 displayed unmanned platforms of different type (fixed wing,

rotary wing, surface and underwater) integrated with naval units' command and control centres, allowing for data exchange via satellite, with command and control centres on land. The joint and cooperative use of both manned and unmanned vehicles was also demonstrated as part of the project.

The project has strong relevance to the areas around WARA-PS and Saab will share results from the project, and methods, tools and equipment can be re-used in WARA-PS. The OCEAN2020 demonstrations are in the same area as WARA PS.

Sustainable Underground Mining (SUM)

After 2030 LKAB must be ready to mine at greater depth in the Kiruna and Malmberget mines. For this, one of Sweden's biggest industrial investments ever, decisions will have to be taken in the mid-2020s. The sustainable mine of the future requires new control systems, new and improved mining equipment, as well as complex and efficient management systems that meet future demands for a sustainable industry. The goal of the collaboration is to find new methods and smarter solutions for future mining. Within the framework of the testbed the best means of building an efficient autonomous production system that is carbon-dioxide-free and has the highest conceivable level of safety will be studied. In the future autonomous and digitalized mine people and machines will work side by side. The virtual test mine allows to simulate data flows and scenarios, which cannot be tested in the physical testbed.



Graphic Layout: Katarina Iversen

The WARA-PS Core Team at Gränsö 2022

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