WASP 2029

Narrative - Strategy - Goals

Comissioned by The Wallenberg AI, Autonomous Systems and Software Program

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Foreword

In 2014 Knut and Alice Wallenberg Foundation (KAW) decided to invest in a comprehensive research program in the areas of autonomous systems and software with the objective of conducting excellent research and building competence for the benefit of Swedish industry. The program Wallenberg Autonomous systems and Software Program (WASP) was launched 2015 with an initial budget of 1.8 BSEK over 10 years, the majority from KAW but also cofunded by WASP partner universities and by Swedish Industry.

By November 2017 the program was expanded with extra funding of 1.0 BSEK for research in artificial intelligence (AI), also including the mathematical foundations of AI. The name was changed to Wallenberg Artifical intelligence, autonomous systems and Software Program but the acronym WASP was kept. The structure of WASP was expanded with WASP-AI to incorporate the AI part and the autonomous systems and software part was named in WASP-AS. Since then the program has been increased multiple times and also extended to 2026 but the objective of excellent research and competence for Swedish Industry has been unchanged.

In September 2019 the WASP International Scientific Advisory Board (ISAB) in it's report recognized the progress and success of WASP but requested a more clearly formulated narrative and strategy for the program going forward. Also, in November 2019, WASP was given added mandate and mission by new donation of 1,3 BSEK from KAW and at the same time the program was extended to continue until 2029. WASP now has a budget of 5.5 billion SEK for 14 years and is by far the largest individual research program in Sweden ever.

The start of year 2020 was also the start of a new leadership in WASP with a new board, a new chair and a change of program director planned for mid 2020. In addition ISAB has been extended with new members strengthening the competence of ISAB in AI, mathematics and software. The increased funding, mandate and extension of the program, and the request from ISAB, made 2020 an excellent point in time to thoroughly consider what we want to achieve with WASP until 2029 and how. Hence, we decided to develop and launch a new narrative and strategy for the program, where we articulate not only the vision and the mission, but also our wanted position 2029 and our instruments and initiatives that will take us there. For this purpose, initial discussions in WASP management groups and board, started late 2019 to be followed by extensive work in program management groups and board during the first half of 2020. The result is compiled into this document outlining the WASP Narrative, Strategy and Goals.

I would like to take this opportunity to sincerely thank everyone who has contributed to this document and the underlying work. It has been an extensive effort and I am convinced that this work will be of great value for WASP in the coming years until 2029.

Sara Mazur
Chair WASP

1 — Executive Summary

This report describes the current status and future directions for the Wallenberg AI, Autonomous Systems and Software Program (WASP), which is a major national initiative for strategically motivated basic research, education and faculty recruitment in artificial intelligence, autonomous systems and software development. The mission is to create a platform that strengthens, expands, and renews national competence and advances Sweden to an internationally recognized position as leader in these strategic areas.

The document begins with a description of the on-going, rapid development of the field and presents three visions for 2029, from the perspectives of the citizen, society and industry. The enabling technologies supporting the visions are then analyzed and WASP is put in the context of these trends and future applications. An important conclusion from this initial analysis is that system level approaches and multi-disciplinary collaborations will play an increasingly important role over the coming years. The current status of WASP is then described and its success in terms of recruitment's, PhD students, research program, international collaboration etc is presented. To provide context, other Swedish national initiatives are presented and an international outlook is provided.

To set the arena and path forward for WASP, nine *Wanted Positions*, describing where Sweden should stand by 2029 in the area of AI, Autonomous Systems and Software are presented. The positions fall into three main categories:

1. Positions describing an ambitious level of highest possible level of research impact, quality, and strategic coverage, underlining the core values of WASP.
2. Positions reflecting the instrumental role and need for world class level of research environments, graduate training and international collaborations hosted and initiated by WASP.
3. Positions on the fundamental and enabling role WASP plays for Swedish industry and leadership in actions to promote the Swedish position as a leading digital nation.

A comprehensive set of strategies to reach the wanted positions are then presented. A correlation analysis between the wanted positions/strategies and the current WASP instruments: **Research Program, Graduate School, Recruitment, Research arenas Internationalization, Communication events and networking** has been conducted, and shows that the WASP instruments are well positioned and contribute to multiple wanted positions. For each of the instruments, recommendations for fine-tuning and further development are outlined and put in the context of already on-going work. The analysis also gives motivation and guidance for potential new initiatives and instruments for WASP to consider. These proposed new initiatives are:

- New Cluster Structure: Building on the identified core technology areas and applications a cluster matrix is defined to increase relevance and function of the clusters of WASP PhD students.
- WASP NESTs: Supporting research environments and networks of excellence building on the keywords Novelty, Excellence, Synergy and Team.
- WARA 2.0: Identification of the need for systems demonstration and general purpose platforms forms the basis of a refocusing of the WASP research arenas.
- Career Program: Providing opportunities to establish research groups for WASP alumni with high academic potential.

The document concludes with an outlook beyond 2030 and the projected continued need for initiatives building on the success of WASP and its partners.

2 — Vision - Mission - Status

2.1 WASP

The Wallenberg AI, Autonomous Systems and Software Program (WASP) is a major national initiative for strategically motivated basic research, education and faculty recruitment in artificial intelligence, autonomous systems and software development. WASP was initiated in 2015 and its mandate extends to 2029.

The ambition is to advance Sweden into an internationally recognized and leading position in these areas. The starting point for WASP was the combined existing world-leading competence at Sweden's five major ICT universities: Chalmers University of Technology, KTH Royal Institute of Technology, Linköping University, Lund University and Umeå University, and when a large AI expansion was added parts of Örebro University and Uppsala University were included in WASP.

WASP strengthens, expands, and renews the national competence through strategic recruitment, a challenging research program, a national graduate school, and collaboration with industry.

2.2 Vision and Mission

The scope of WASP is artificial intelligence, autonomous systems, and software (AI-AS-S), in the context of complex software-intensive systems with the intelligence to achieve autonomy in interactions with humans. The field is a large and rapidly increasing part of the development of almost all engineering systems. Further, artificial intelligence and autonomous systems are scientifically challenging, disruptive technologies that will fundamentally change society and industry. Swedish industry is, by tradition, strong in systems engineering, and to stay competitive, Sweden needs to invest in research and the promotion of competence in this area.

> **Vision** – Excellent research and competence in artificial intelligence, autonomous systems and software for the benefit of Swedish industry.
>
> **Mission** - Build a world-leading platform for academic research that interacts with leading companies in Sweden to develop knowledge and competence for the future.

2.3 Strategic Instruments

The instruments implemented to achieve the vision and mission are designed to achieve leverage, renewal, and expansion. They have to meet the challenges in research, in building competence, and in strategic relevance. We provide, below, a list of the current instruments. A more detailed description of each is given in Section 5 and plans for new instruments and initiatives are provided in Section 7.

- **Research Program:** A research program aiming for disruptive developments. This can be seen as a matrix between strategic areas and thematic areas, and several different instruments have already been devised in the different calls.
- **Graduate School:** A national graduate school in close interaction with Swedish industry with the aim to raise the level of knowledge in Sweden. The graduate school is designed to produce at least 400 new PhDs, at least 100 of whom will be industrial PhD students.
- **Recruitment:** An international recruitment program, both to build the competence to establish new research areas and to reinforce existing strengths in Sweden. The program aims to recruit both outstanding younger researchers as well as established experts. This is being achieved by offering packages that are attractive by international standards.
- **Research arenas:** A joint university and industry initiative to share infrastructures and competence and conduct joint in-depth projects and demonstrations based on the resulting advanced platforms. The arenas arenas entail significant integration efforts at the intersection between industrial and academic interests.
- **Internationalization:** Partnership with selected internationally leading universities for PhD student research visits and post-doc program. Current WASP partner universities are Nanyang Technological University, UC Berkeley and Stanford University.
- **Communication, events and networking:** Organization of topical conferences and networking events among existing and potential WASP partners. Coordination of communication targeting internal partners as well as external industrial, academic and organisational bodies as well as communication to the general public.

2.4 Status

During the first period of WASP, 2015-2017, the WASP Board formed the organization, initiated the research program and the autonomous systems and software part of the graduate school with both academic and industrial PhD students, completed the first recruitment processes, and initiated the research arenas. The second period 2018-2019 has been marked by a significant build-up of the AI component of WASP. WASP-AI has admitted academic and industrial PhD students into separate tracks of the graduate school, as well as recruiting younger researchers in both machine learning and mathematics. Furthermore, a recruitment program of Wallenberg Chairs, including the Wallenberg Guest Professors, has been implemented. For the recruitment process WASP has developed novel procedures and, in this way, has been a forerunner in the Swedish academic system.

Main highlights of WASP so far include:

- International recruitment of 8 professors in autonomous systems and software.
- Top level recruitment of 10 Wallenberg Chairs in AI: 6 full professors and 4 guest professors.
- International recruitment of 13 assistant/associate professors in AI.
- Development of the graduate school curriculum and network.
- 259 admitted PhD students, 137 academic PhD students, 75 industrial PhD students, and 47 affiliated PhD students. To date four students have completed their doctorates.
- 40 companies engaged in WASP.
- Research arenas in public safety and in common cloud are in operation and a number of other arenas are in the start up phase.
- New research instruments started, as WASP Expeditions, AI Collaboration projects, and

new initiatives with NTU Singapore.
- Collaborations and exchanges with Stanford, Berkeley, NTU and initial exchanges with MIT.
- Three new initiatives aimed at WASP PhD students approaching their exams: a postdoc program for continued career (with first candidates approved), an industrial network program (with its first large meeting in preparation), and a program for initial stages of innovation in terms of validation research (first case approved).
- A new, independent sister program, WASP-HS, for research in humanities and social sciences in WASP related areas.

With a new large donation from KAW on November 21, 2019, WASP now has a total budget of SEK 5.5 billion. The large grant of SEK 1295 million and the extension to 2029 will allow WASP to start further initiatives and also to build towards a longer time horizon. Thus a new and updated strategy is being formed.

2.5 Organization

Organizationally, WASP is structured in two parts: Autonomous Systems and Software (WASP-AS) and Artificial Intelligence (WASP-AI), where WASP-AI, in turn, consists of: Machine Learning and Explainable AI (WASP-AI/MLX) and Mathematical Foundations of AI (WASP-AI/MATH).

The WASP Board is appointed by Linköping University, the hosting-body for WASP, and has representatives from the WASP Member Universities and from Swedish industry. The Program Director is the executive leader of the program and is responsible for managing and developing the program in close collaboration with the Program management groups, the Graduate School management, the Demonstrator management group and the Internalization management group. A PhD student council provides an interface to the program leadership for students. The WASP management, along with researchers and PhD students active within the program, is supported by a Program Office regarding coordination, communication, administration and financial matters. The program is strategically evaluated each year by the International Scientific Advisory Board (ISAB) that provides feedback with the aim to guide the development of the program.

3 — Situation Analysis and Outlook

3.1 Society and Industry 2029

The long term vision and strategy of WASP is strongly rooted in future perspectives that relate to both industry and to society at large. The past decades have witnessed technological disruptive changes as a result of progress in fundamental research as well as enabling technologies. It is therefore of utmost importance that WASP positions its strategy within a larger context by identifying where the program can achieve the greatest impact while consolidating the strengths of academic talent and Swedish industrial interests. A useful starting point is to examine how the next decade will be changed in terms of advanced technologies from the various perspectives of (a) the individual citizen, (b) society and (c) industry.

Citizen perspective: In 2029 societal services will be based on increasingly pervasive and data driven intelligent systems with natural interfaces exhibiting human-style communication interfaces. Typical examples of this are healthcare services which can be expected to undergo dramatic changes, of course, due to advances in medical science, but also due to advances in widespread collection and availability of data combined with maturing AI-based decision-support systems. Robotics and automation will be used to complement human abilities in a variety of tasks, and will be more readily available for the individual to access. Furthermore, citizens will be exposed to and interact with intelligent systems not only at work, but also in education, entertainment, and cultural activities. Services will also be built on highly trusted technology and methodology ensuring privacy and integrity.

Societal perspective: An important example of societal change in 2029 is the realization of the fully instrumented urban area and smart city. Autonomous logistics and traffic control will be enabled by massive deployment of multi-sensor fusion networks with high speed reliable and secure data communication and distributed processing power. This will lead to improved traffic flows, environmental control, and increased safety and security. It is also important to address the common global challenges best articulated by the UN's sustainable development goals. The potential for many of the future enabling technologies to help us to confront these challenges is not only significant, but may be essential.

Industrial perspective: One of many examples of potential disruption in industry is the emerging infrastructure for exchanging and sharing data. Industries will benefit from sharing and using data across the value chains both to better predict demand and supply description. The service industries will dramatically change their way to interact with and among customers. This will affect everything from the media and entertainment industry to retail and banking. Furthermore exchanging and or buying/selling data will possibly enrich the different actors' value proposition and could even lead to new business models. Furthermore industry resilience can be obtained through technology enabled flexibility, leading to dynamic responses to extreme and rapid changes in the market. Automation and intelligence will also be one of the main drivers behind the disruption of core production and service processes in a range of traditional and emerging industrial domains.

3.2 Enabling Technologies

From the above perspectives we have identified the following core technology positions which will be necessary in realizing these scenarios:

T1. Increasingly advanced **distributed, networked, linked, real-time technologies** and services will provide the core of the information infrastructure and must be fully pervasive.
T2. Services must be linked, interoperable and consist of a complex hierarchy of **systems of systems** (of systems).
T3. Integration of techniques from AI, autonomous systems, and software is required to develop the **intelligent systems** and services of the future.
T4. **Infrastructures** for creation, curation, availability and processing of **data** will play a central role in workflows and value chains.
T5. Advanced **human-in-the-loop technologies** must provide the machinery and interfaces for collaboration, coordination, steering and control to support human reasoning and decision making in a social context (including e.g., regulations, law, ethical and moral standards).
T6. High levels of **secure and robust software** solutions must be integrated into all systems and services both at the infrastructure and at the architectural level.
T7. Society will be **instrumented with sensors** and data will be handled through distributed processing and real-time technologies as a part of the infrastructure.
T8. **Autonomous decision-making** based on a combination of data and prior knowledge plays a central role in systems and services.

The main focus of current research within WASP is artificial intelligence and autonomous systems acting in collaboration with humans, adapting to and learning from their environment through sensors, information and knowledge to form intelligent and secure systems-of-systems. Software is the main enabler in these systems and is an integrated research theme of the program.

The research currently taking place under the WASP umbrella can be clustered into a number of core technology areas and application domains as shown in Table 3.1. The connections between the current WASP core technologies and the technology positions above are shown in Table 3.2.

Whereas the core technology areas are application agnostic, the application domains mirror the development of WASP. When WASP started in 2015 the focus was on the systems developing industries in Sweden, such as Ericsson, Saab, ABB and the automotive industry. When AI was added as a separate focus area in 2018, the scope was widened to include all industrial sectors. This caused the addition of applications in, for example, finance and pharmaceuticals. There are, however, still several sectors that are largely missing in WASP although WASP remains open to them. Examples include media, entertainment, and services. The main reason for this situation is a lack of strong proposals to WASP's open calls from these sectors, and further analysis and outreach activities are most likely needed.

3.2.1 Analysis

The majority of the research in WASP has, so far, been focused on enabling technologies, in particular for autonomous systems. Relatively little direct work has been done on autonomy through, for example, architectures for autonomous systems and principles and theory of autonomous systems. Research on these topics is in general scarce in the Swedish engineering community, as enabling technologies match the traditional structure of the academic system and disciplines. However, it would be beneficial to put more emphasis on the system aspects of autonomy in the

Core Technology Areas	Applications
C1: AI Engineering and Software	A1: Finance and Business Analytics
C2: Autonomous Clouds and Networks	A2: Decision Support Systems
C3: Computer Vision and Perception	A3: Forestry and Farming
C4: Computing Infrastructures and Environments	A4: Healthcare
C5: Cryptography	A5: Logistics
C6: Distributed Coordination and Control	A6: Mobile Communications
C7: Explainable AI	A7: Navigation
C8: HMI and Intelligent User Interfaces	A8: Pharmaceutical
C9: Large-scale Optimization	A9: Predictive Maintenance
C10: Machine Learning Foundations and Development	A10: Transport Systems
C11: Natural Language Processing	A11: Process Control
C12: Privacy-Enhancing Technologies	A12: Urban Informatics
C13: Reinforcement Learning	A13: Smart Manufacturing
C14: Security for Autonomous Systems and AI	
C15: Smart Localization Systems (positioning, navigation)	
C16: Software Analysis	
C17: Software Engineering methodologies	
C18: Software Testing	
C19: Theoretical Foundations of AI	
C20: Robotic Systems	

Table 3.1: Core technologies and applications in WASP

future structure of WASP as a complement to a continued emphasis on enabling technologies.

Another conclusion from the current WASP position is that there is a need for a stronger focus on synergy between the different parts of WASP. The combination of AI and software is one such case, for example in terms of the use of AI for software development and testing and the application of software engineering techniques to machine learning pipelines. Similar combinations exist between between security and AI and between machine learning and control and decision making. It would be beneficial for WASP to put more explicit emphasis on this in the future. It is likely that this would lead to larger impact for Sweden than focusing on the different areas in isolation. This development has already started since, in recent years, it is the systems and signals research community that dominates among the accepted Swedish contributions to the best international machine learning conferences.

Technology Positions	Core Technologies
T1	C2, C4, C6
T2	C2
T3	C1, C3, C6, C7, C9, C10, C11, C13, C15, C19, C20
T4	C1, C9
T5	C3, C7,C8, C11, C20
T6	C4, C5, C12, C14, C16, C17, C18, C20
T7	C2, C3, C6, C9, C15
T8	C1, C3, C6, C9, C10, C13, C20

Table 3.2: Connections between Technology Positions and WASP Core Technologies

3.3 The International Forefront

WASP is situated in a domain which is developing extremely rapidly and the international forefront is continuously moving forward. It is, therefore, of uttermost importance to place WASP in an international context and form alliances with leading international players. The term AI is currently used in a very broad sense, often including areas such as intelligent autonomous systems and automated software technologies. The term digitalization has a similarly broad meaning but with more focus on upcoming societal and industrial transformations. It is worth noting that, in 2017, China started a new strategy (New Generation Artificial Intelligence Development Plan) with massive investment in AI research in order to catch up with the USA. Recent reports indicate that China is now on track in terms of high impact AI publications. A full account of international initiatives is beyond the scope of this report but there are many international initiatives with close connections to WASP. Our international partner universities so far have launched:

- BAIR, Berkeley Artificial Intelligence Research
- Stanford Institute for Human-Centered Artificial Intelligence
- Data Science & Artificial Intelligence Research Centre at NTU

WASP also has an ongoing discussion with respect to collaboration with the recently established MIT Schwarzman College of Computing, which focuses on ubiquitous computing, including autonomous systems and artificial intelligence.

In Europe a number of different EU initiatives have recently emerged. Notably, a Feb 2020 white paper, "On Artificial Intelligence - A European approach to excellence and trust," provides a recent summary of the EU strategy on AI. In this white paper a strong focus on "human-centered" and "trustworthy" AI was raised. A pronounced goal is to increase the yearly funding for European AI research activities in a very broad sense to 20 billion Euros per year. Sweden is developing a strategic role in several of the main European AI-related initiatives. For example, one of the networks of AI research excellence centres focused on learning and reasoning, TAILOR [1], is led by Linköping University. WASP researchers are also involved in the following EU AI groupings:

- AI4EU - The European Platform for AI
- Confederation of Laboratories for AI research in Europe (CLAIRE)
- European Lab for Learning and Intelligent Systems (ELLIS)
- HumanE-AI, another network of AI research excellence centers focused on human-centered AI

It should also be noted that the European Research Council (ERC) is awarding grants in domains relevant to WASP and several senior researchers in WASP have received ERC grants.

3.4 Related Swedish National Initiatives

The WASP program is an important cog in the Swedish ecosystem of research funding and it is relevant to recognize initiatives by other national funding agencies to leverage and complement other sources of funding for projects, environments and infrastructures. These are briefly described below. In addition to this there are, sometimes quite substantial, local sources of funding, such as the two research centres on digitalization, IT, and mobile communication: KTH Digital Futures, and ELLIIT shared between Linköping University and Lund University, as well as the Chalmers AI Research Centre (CHAIR).

[1] https://liu.se/en/research/tailor/about

The Swedish Research Council (VR) is Sweden's largest governmental research funding agency and supports fundamental research in all areas at a level of almost 7 BSEK per year. Most of this is disbursed through project grants and establishment grants of a size concomitant with one PhD student or postdoc per year for a period of four years. In addition VR occasionally funds framework grants and distinguished professor grants that are larger both in terms of size and duration. The Scientific Council for Natural and Engineering Sciences, one of three scientific councils within VR, has 19 review panels that decide which applications should be funded. The panels that are closest to WASP are Mathematical Sciences, Computer Science, and Signals and Systems.

The focus of VR is fundamental research rather than strategically motivated research, as such there are no calls directed towards autonomous systems or AI. During the last four years the amount of funding that is granted to WASP-related research is between three and seven percent of the total amount allocated to the Natural and Engineering Sciences. A substantial fraction of this is awarded to researchers who also are active in WASP.

The Swedish foundation for strategic research (SSF) has individual grants for junior researchers and starting grants for future research leaders. Several of these individual grants have been awarded to researchers engaged in WASP. SSF also awards framework grants in strategic areas related to the WASP domains. Examples of recent grants are the calls for projects on 'Big Data' and 'Cybersecurity'. It should also be noted that SSF has an industrial PhD program similar to the WASP initiative.

Swedish Agency for Innovation Systems (VINNOVA) is the leading governmental funding agency in the field of innovation. Its mission is to promote sustainable economic growth by financing needs-driven R&D and by developing innovation systems. Although VINNOVA currently uses the term AI to describe a number of their activities and projects, the part that relates most closely to WASP is VINNOVA's involvement in AI Innovation of Sweden, which it will fund with 100 MSEK in 2020-2024. AI Innovation of Sweden aims to be a national centre for applied AI research and innovation with the aim of strengthening the competitiveness of Swedish industry and welfare. Compared to WASP the projects performed here are more applied and targeted towards a shorter time horizon. The strategic innovation program (SIP) "Drive Sweden" with Vinnova as one of the funding agencies involves a large number of industrial partners and is highly relevant to the AS part of WASP.

3.5 Other Wallenberg Initiatives

The Wallenberg foundations are the major private funder of research at universities in Sweden with yearly funding of approximately 2.5 SEK billion. The Knut and Alice Wallenberg Foundation (KAW), the largest of the Wallenberg foundations, has decided to invest at least 7 SEK billion in strategic research programs in science and technology over the coming ten years (2020–2029). The largest program is WASP (4.2 SEK billion) followed by WACQT (Wallenberg Center for Quantum Technology) (1 SEK billion), Mathematics (500 SEK million)

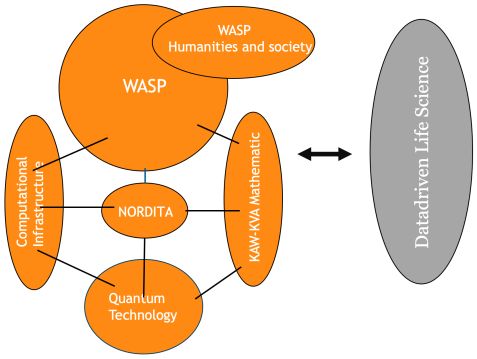

Figure 3.1: Related initiatives funded by the Wallenberg foundations

and Theoretical Physics at Nordita on the topic “Physics for Computing and Computing for Physics” (200 SEK million).

Together these strategic initiatives form a network of competence in the areas of AI, autonomy, computation and software as well as their foundations in mathematics and physics. Specifically the WASP program and the WACQT program have obvious connections in the areas of machine learning for quantum computers and the use of quantum computers for machine learning. WASP and the Nordita program are, together, focusing on Complex Dynamical Systems and the Nordita program and the WACQT program are connected in the area of Quantum Information and Processing. The program on mathematics is closely connected to the Mathematics for AI part of the WASP program as well as to the Nordita program. The foundation also intends to invest 300 SEK million in computational infrastructure for the benefit of the strategic research programs. This investment in computational infrastructure will be used by WASP and the other programs but will also connect to the WASP research areas around cloud computing and machine learning.

In addition, KAW is planning to launch a new strategic research program on Datadriven Life Sciences on top of the 7 SEK billion already awarded. The intention is to connect the life science program to the AI part of the WASP program through joint project leveraging strengths in WASP and Life Science.

Furthermore, the WASP program has been complemented by WASP-HS, funded with 700 SEK million from the Marianne and Marcus Wallenberg Foundation and the Marcus and Amalia Wallenberg Foundation. WASP-HS targets research in humanities and social sciences covering ethical, legal, economic and social issues raised by the introduction of autonomous systems and AI. There is a strong link between WASP and WASP-HS underlined by the fact that one of the WASP recruitees is the appointed director of the WASP-HS program.

KAW is also investing in an innovation platform pilot called the Wallenberg Launch Pad (WALP). The objective of WALP is to facilitate innovation arising from KAW’s investment in research in the strategic areas of Artificial Intelligence, Autonomous Systems, Software Technology and Quantum Technology. WALP is a concept and framework to foster technology transfer, and orchestrating innovation for KAW scientists, fellows and scholars, as well as KAW financed projects in the areas of AI, autonomous systems, software and quantum technologies. WALP will support and enable professors and researchers to validate their research results outside of academia and to verify what kind of industrial or societal impact they may have by providing funding specifically for research validation.

4 — WASP Wanted Positions 2029

4.1 Wanted Positions

To place WASP in the context of the vision and underpinning technology trends described in Section 3, we define nine wanted positions for WASP in 2029. The starting point for the definition of the positions is the main mission for the program, which is to work towards the betterment of Sweden and, in particular, to the benefit of Swedish industry. The wanted positions are therefore expressed as positions for Sweden, but from the perspective of the WASP scope and research domains covered in AI, Autonomous Systems and Software (AI-AS-S). The underpinning intention is that the success of WASP is measured in terms of significant, and in some cases main, contributions to the national journey towards these positions.

In conjunction with each of the positions a set of strategic efforts, the vehicles required to reach the positions, are defined. These form the basis for the definition of instruments and specific initiatives, described in Section 5.

P1: AI-AS-S research in Sweden has generated far reaching impact in society and industry and has thus been a key component in maintaining Sweden's role as a leading digital nation

Strategies:

- Fund research addressing strategic societal and industrial problems
- Foster collaborations and networks with industry, and between academic disciplines
- Continuously analyse needs and trends to position Sweden at the forefront of the international research agenda in this subject area

P2: The general level of AI-AS-S research in Sweden is at the international forefront both in terms of quantity, quality and coverage of strategic areas

Strategies:

- Operate with dynamic funding instruments that balance between quantity and quality, and follow along a strategic dimension
- Have wide coverage of research domains in project selection
- Apply an open and competitive process for the selection of projects
- Conduct evaluations and follow-up of project results and their impact

P3: Swedish universities host a large number of internationally renowned scientists (senior as well as junior)

Strategies:

- Provide attractive career paths for promising junior researchers
- Recruit top international researchers in strategic areas
- Build-up strong and attractive hosting research environments
- Host networks of excellence including academic researchers and industrial partners
- Offer postdoc opportunities in Sweden and repatriation opportunities

P4: Sweden offers the most attractive PhD program in AI-AS-S for national and international students

Strategies:

- Operate a national graduate school with a coordinated syllabus
- Engage the best teachers to offer courses on central topics
- Offer both broad courses accessible to many students as well as specialized courses
- Provide mechanisms for networking among students, with academic groups, industry, and the international research community

P5: Sweden has world-leading research environments, networks and laboratories in AI-AS-S

Strategies:

- Fund environments with the best researchers who have a focused research agenda
- Build-up networks of excellence in strategic research domains
- Offer attractive packages for international recruitment as well as retention of Swedish talent

P6: Swedish industry is thriving at the top of innovation and competence, accelerated through exchanges of knowledge and in-depth collaboration with universities

Strategies:

- Operate joint academic/industrial research arenas
- Fund shared positions for academic/industrial mobility
- Host networking events to identify synergies and joint projects
- Form strategic alliances with top international universities

P7: Successful spin-off companies are continuously being created in Sweden and strengthen the attractiveness and competitiveness of the Swedish industrial environment

Strategies:

- Take commercialization aspects into account in reviewing and the creation of incentive mechanisms
- Form alliances with innovation and commercialization support organizations
- Provide information to PhD students on commercialization possibilities
- Fund proof of concept research

P8: Sweden is a premier partner in strategic alliances and exchanges with world-leading universities, organizations and companies in these areas, leading to investment in Sweden

Strategies:

- Participate and take a leading role in EU level initiatives
- Operate a program for exchanges of students and researchers with leading universities and companies
- Coordinate, package and communicate Swedish opportunities
- Form strategic alliances with international top universities

P9: Sweden is leading by example and serves as a role model for other countries and participates in the formation of the international agenda for future directions of AI-AS-S by hosting meetings, conferences and policy bodies

Strategies:

- Support organization of conferences and networks
- Document and communicate success stories and organizational concepts
- Engage in international policy bodies

4.2 From Wanted Positions and Strategies to Actions

The challenge for a program working towards the positions stated above and the strategies identified is to define the instruments and initiatives that will contribute, both directly and indirectly. The initial WASP instruments have evolved over time and have, as shown in section 2.4, had a significant impact on the Swedish position in the AI-AS-S domain. In the next section an overview of the existing WASP instruments is given and in Section 6 an analysis of the correlation between positions, strategies and instruments is made, leading to a set of proposed improvements as well as the set of new initiatives described in Section 7.

5 — Current WASP Instruments

This section specifies the current (2020) WASP instruments. The instruments can be seen as actions in response to the strategies described in Section 4.1. An instrument, however, covers several wanted positions and, for each of the instruments, the targeted wanted positions are specified. The instruments and their relevance and contribution to the positions and strategies are discussed and analyzed in Section 6.

5.1 Research Program

The WASP research program is described in two parts. The first consists of all the PhD projects admitted into the program and the second part is other initiatives at the project level that have been used to fund both postdocs and PhD students.

PhD students

Targeted wanted positions: P2, P4

Funding and educating PhD students is the backbone of WASP, and is the main instrument to both increase competence and create new knowledge. PhD students are accepted in batches of 40-60 PhD students that start at roughly the same time. Through the WASP Graduate School, see Section 5.2, they take courses and participate in activities to grow together and form a stronger community.

Each PhD student has an associated PhD project where the research that is the basis for the PhD thesis is performed. An addition to this is the collaboration projects in AI/MLX (see below) where two PhD students collaborate on the same project. This is done under the supervision of WASP researchers and often in collaboration with other projects in the hosting research group. PhD student projects constitute the bulk of the academic research conducted both within WASP and within the WASP domain of the total Swedish academic research system.

RP:1 Academic

The majority of the WASP-funded PhD students are academic PhD students at one of the partner universities. They have at least two WASP supervisors. The students are recruited by the supervisor and have to be approved by WASP prior to receiving funding. Several different approaches to selecting the supervisors have been used, but all are based on research excellence and projects and topics are initiated by the researchers themselves.

RP:2 Industrial

A WASP industrial PhD student is employed by a company, partially funded by WASP, and admitted as a PhD student at one of the partner universities. There is at least one industrial supervisor and one academic supervisor. The industrial PhD students are selected through open calls, in which a company together with an academic partner proposes a project including a specific named candidate. The project has to be both relevant to WASP and in line with the strategic plans for the company.

RP:3 Affiliated

The WASP Affiliated PhD Student Program provides the opportunity for PhD students not funded by WASP to be enrolled in the WASP Graduate School, with calls matching the WASP-funded batches of PhD students. Affiliated students are part of the graduate school on equal terms with the WASP students. A WASP-affiliated PhD student has to commit to take part in the WASP courses and activities.

Projects

Targeted wanted positions P1, P2, P3, P5, P6, P7

The initial strategy for WASP was to identify the international research leaders at the partner universities. This paved the way and established the strong research basis for WASP, together with the first batch of PhD students. As WASP progressed that strategy was to build strength by addressing both breadth and depth, as well as considering more high risk/high reward initiatives. Two instruments were deployed to achieve this: (i) expedition projects, and (ii) collaboration projects.

RP:4 Expeditions projects (postdocs)

Expedition projects are high risk/high reward projects addressing a specific and challenging research topic. An expedition consists of two WASP researchers as PIs and two to four PostDocs over two years. The PIs are a part of research groups across different departments or universities, commonly suggesting a new collaboration and a new research topic rather than continuing an existing one. Overall, the aim is to address compelling research topics that promise disruptive innovation in AI, autonomous systems and software for several years to come.

RP:5 Collaboration projects within AI/MLX:

The initial idea for collaboration projects was born from the desire to increase the collaboration between strong PIs to further deepen and broaden their individual research as well as establish new areas at the intersection of ongoing research. Collaboration projects were announced within the broad field of artificial intelligence with a specific focus on machine learning. The ongoing projects address fundamental research problems and have a strong visionary and novelty nature. The first round of collaboration projects in 2018 resulted in ten accepted projects that each involved two academic PhD students and two PIs from two different universities. The second call in 2019 had the possibility to include industrial partners and four projects were accepted.

5.2 Graduate School

Targeted wanted positions: P4, P2

The WASP graduate school provides the skills needed to analyze, develop, and contribute to the interdisciplinary area of artificial intelligence, autonomous systems and software. The curriculum for the graduate school provides the foundations, perspectives, and state-of-the-art knowledge in the different disciplines taught by leading researchers in the field. Through a program of research visits, partner universities, and visiting lecturers the graduate school supports formation of a multi-disciplinary and international professional network between PhD-students, researchers and industry.

G1: Courses

The WASP graduate school offers PhD courses tailored to the WASP mission, designed and taught by leading researchers. A six credit course (four weeks of full time study) normally consists of three modules and combines physical meetings with local studies at the partner universities. Normally, there are three two-day meetings in each course to introduce the topics

and to examine the students. In the Autonomous Systems and Software track, the courses are designed to introduce important tools and to provide an understanding of the broad field. In the AI and mathematics track, the courses are more focused on specific topics within AI and machine learning. The reason for the difference is that in AI there was a need to create new in depth courses, while there were more established courses in control theory, signal processing, and the other topics of autonomous systems.

G2: Summer school

Every year a thematic summer school is arranged for each track (AS/AI). The PhD students gather to network and conduct in-depth studies in specific subjects. Topics of previously arranged Summer Schools are “Mobile Robots”, “Machine Learning”, “Autonomous Driving”, “Security for Autonomous Systems" and "Modern Topics in AI”.

G3: Cluster structure

WASP organizes clusters of PhD students to promote cooperation between related projects and create scientific and social networks. Each PhD student belongs to one major cluster and may also be a member of a second minor cluster. WASP is currently divided into twelve clusters. Ten clusters mainly consist of PhD students from WASP-AS and two clusters consist of students from WASP-AI. Each cluster involves university, industrial, and affiliated PhD students and is coordinated by an academic researcher.

G4: Networking with Industry

WASP has started to organize study visits in smaller groups to various Swedish industries. As an example, in November, 2019 WASP PhD students visited the Ericsson headquarters in Kista.

5.3 Recruitment

Targeted wanted positions: P1, P2, P3, P5, P6, P8, P9

The WASP program aims to strengthen and renew Swedish competence by top international recruitment in the highly competitive areas of AI-AS-S. The overall aim is to establish more than 60 research groups. WASP has completed more than 30 senior and junior international recruitment processes to date, and has ongoing processes for additional positions described in detail below.

RE1: Professors in AS

The recruitment of senior professors within autonomous systems and software is an initiative to strengthen research within these research areas in Sweden. Eight internationally distinguished professors have been recruited to WASP and four additional profiles have been approved by the WASP Board.

RE2: Wallenberg Chairs and Wallenberg Guest professors

The Wallenberg Chairs in AI program was initiated 2018 with the intention to recruit high-level international academics to positions in AI. Through attractive recruitment packages and, for Sweden, a new process involving the WASP Board, an internationally recognized recruitment firm, the WASP universities and representatives from Swedish industry and the Wallenberg Foundation, six full professors and four guest professors have been recruited to WASP.

RE3: Assistant professors in AI/MLX and AI/Math

WASP has the mission to strengthen and develop Sweden’s knowledge and competence in the areas of AI and machine learning and to increase our understanding of fundamental mathematical principles behind AI. The first call for assistant professors within AI resulted in seven assistant

professors within AI/Maths and six assistant professors within AI/MLX. The processes for the second call for positions are ongoing.

RE4: PhD recruitment and Postdoc-recruitment

The recruitment packages for senior faculty and assistant professors include a number of PhD students and postdocs that will take part in the WASP graduate school and other activities in the WASP community.

RE5: WASP Postdoctoral Scholarships

the WASP Postdoctoral Scholarship program was launched in 2019 in cooperation with The Knut and Alice Wallenberg Foundation. There is an exclusive scholarship open for WASP doctoral students after dissertation but WASP PhDs can also apply to the general KAW call for international postdoc scholarship applications. The two-year WASP scholarship grants support postdoctoral studies at a leading university anywhere in the world. The WASP Postdoctoral Scholarships also include a repatriation grant to return to Sweden.

5.4 Research Arenas

Targeted wanted positions and impact: P1, P4, P5, P6

The main objective of the WASP Research Arenas, WARA, 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 demonstrate 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.

RA1: Arenas

Initially two larger research arenas with important industrial relevance were identified. The first, WARA Public Safety, addresses a complex integrated search and rescue scenario with heterogeneous autonomous vehicles and a systems integration platform. The second was WARA Autonomous Driving with a focus on collaborative self-driving cars, buses and trucks. However, much of the WASP experimental work on automated transport systems is currently done within the large Swedish automotive companies or at university labs. The main focus so far has thus been on WARA public safety. It should also be noted that the Ericsson Research Data Centre has been included in WARA under the name WARA Common, and has served as a resource for several research groups in Machine Learning and also been utilized in the WARA public safety scenarios.

5.5 Internationalization

Targeted wanted positions: P1, P3, P4, P5, P8, P9

The WASP strategy for internationalization has been to establish closer collaboration with a small group of top-ranked international universities. The choice of partner universities have been based on previous long-term faculty and university collaborations. Current WASP international partners are Stanford University, University of California at Berkeley and Nanyang Technical

University. There are ongoing discussion with MIT. In addition to the KAW/WASP postdoc program, the main instruments for internationalization are:

I1: International study trips

There are two mandatory international study visits offered during the PhD student's time in WASP. The first trip targets a strategic location in Europe and the second reaches further abroad. North America and Asia, for example, have a large number of relevant sites for WASP students to visit. The trips often include both university and company visits and offer students the opportunity to network and pave the way for future exchanges. In addition to these study visits it is also possible for the WASP students to themselves organize smaller group study visits.

I2: Research periods abroad

WASP PhD students are also able to apply for a short-term visiting researcher position abroad, in the range of one to six months. This exchange program aims to foster meaningful long-term collaborations between researchers at WASP, Stanford University, UC Berkeley, NTU and other university research groups abroad.

I3: NTU–WASP Collaboration Projects

One of our main international partners is Nanyang Technical University (NTU), Singapore. During the winter of 2017 the NTU-WASP Collaboration Projects initiative was started. A typical project involves one team from each of the universities consisting of one PI and one postdoc. Six projects were approved in the first round. During 2018/2019 a follow up call was issued focusing on software and security, where three projects were accepted.

I4: Wallenberg-NTU Presidential Postdoctoral Fellowship Program

The Wallenberg-NTU Presidential Postdoctoral Fellowships program funds selected promising young researchers from all over the world for one year at NTU and one year at one of the Swedish WASP partner universities. In 2019 the first five new postdocs started the program. Five more post-docs have been selected for 2020. All of those selected have outstanding track-records.

5.6 Communication, Events and Networking

Targeted wanted positions: P5, P6, P9, P4, P2, P7

C1: Communication

The main goals of the centrally organized communication are to support the program's strategic instruments and wanted positions. This means, communicating scientific results and supporting strategically motivated activities as well as spreading knowledge about the program and its larger impact on society and industry. The communication strategy also aims to strengthen the sense of community among the WASP program's participants.

The communication efforts in WASP can thus be described as consisting of both enabling actions and of outreach and branding. The first level focuses on supporting internal communication, maintaining the website and social media platforms, presenting open calls, dissertations and publications. The second level consists of actions such as active multi-channel news work, media relations, dialogue and coordination of mutual communication interests with external partners and networks, event communication and advertisement.

C2: Networks within the WASP community

WASP supports the establishment of networks that are initiated by individual WASP researchers or groups in the WASP community. The main aim of the networks is to optimize collaboration

within the WASP community to increase the long term impact of the program. In addition to the networks generated through the research clusters and the graduate school a number of special networking initiatives have, so far, been implemented from senior recruitment, assistant professors, postdocs and female researchers. The aim is also to initiate and support a WASP alumni network.

C3: Meetings and conferences

To increase collaboration within the community and to attract new industries and researchers, WASP arranges three larger meetings annually.

- **WASP Industry Meeting:** aims to identify, initiate and catalyze exchanges and collaborations between WASP researchers and industry. The focus of the meeting is to connect researchers from academia and industry to discuss leading-edge research challenges as well as to facilitate career discussions between WASP PhD students and industries. One of the aims is to showcase possible career paths into Swedish industry.
- **WASP4ALL:** a conference arranged for a larger audience beyond the WASP consortium. With selected topics from the technical forefront each year, the conference aims to attract participants from a large portion of the WASP community as well as researchers from different disciplines in academia and industry. The aim is to highlight specific topics through invited keynote speakers addressing the latest results at the international forefront, mixed with WASP research presentations.
- **WASP Winter Conference:** an annual WASP-internal event. It includes a kickoff for new PhD students and supervisors and a common conference where everyone in the WASP community is invited. The purpose is to give new WASP researchers an introduction to the program, to meet the WASP management team, as well as to allow for discussions related to research conducted and to strengthen the community spirit.

6 — Strategy – Instrument Analysis

This section presents a reflection and analysis of how well the current WASP instruments address each of the wanted positions (P1-P9). Figure 6 depicts an overview and snapshot of the current situation, which can be read as follows:

- For each wanted position and each strategy, we assess the relevance of each instrument to that strategy. This assessment is graded on a scale of 1-3. A score of 3 indicates that an instrument is highly relevant and contributes towards that strategy. A score of 2 indicates that an instrument is somewhat relevant and contributes somewhat towards that particular position/strategy. A score of 1 indicates that an instrument contributes only to a small extent to a given strategy. Instruments which do not contribute in any way to a strategy are not assigned any score and are left blank.
- For each of the instruments and each of the strategies, we have also provided an assessment of the extent to which the instrument has met our expectations. In other words, we assess the performance of the instrument thus far. The green color indicates that the instrument has met (or even exceeded) the expected contribution to a given strategy. For the cells marked in yellow, the instrument still has not come to fruition for a particular strategy, either be due to the fact that it is still too early in the programme to see results or, alternatively, due to modifications that are needed. For the cells marked in red, the instruments are not considered to be making the expected contribution to the given strategy and some attention should be given to determine whether changes should be made. We have also added the program office (PO)as an instrument for completeness of actions.

The subsequent sections in this chapter briefly discuss possible developments for each of the existing instruments given this analysis. Where relevant further consideration of specific instruments, and possible new alternatives, is provided in Section 7.

For convenience, the positions and instruments (detailed in previous chapters) are reiterated here:

P1: AI-AS-S research in Sweden will have generated far reaching impact in society and industry, and have thus been a key component in maintaining Sweden's role as a leading digital nation
P2: The general level of AI-AS-S research in Sweden will be at the international forefront both in terms of quantity, quality and coverage of strategic areas
P3: Swedish universities will be hosting a large number of internationally renowned scientists (senior as well as junior)
P4: Sweden will be offering the most attractive PhD program in AI-AS-S for both national and international students and attracting top students to the AI-AS-S domain
P5: Sweden will have world-leading research environments, networks and laboratories in AI-AS-S
P6: Swedish industry will be thriving at the top of innovation and competence, accelerated through exchanges of knowledge and in-depth collaboration with universities
P7: Successful spin-off companies will be being continuously created in Sweden and strengthening the attractiveness and competitiveness of Sweden in this field
P8: Sweden will be a premier partner in strategic alliances and exchanges with world-leading universities, organizations and companies, leading to significant investment in Sweden
P9: Sweden will be serving as a role model for other countries and participating in the formation of the international agenda for future directions of AI-AS-S by hosting meetings, conferences and policy bodies

		INSTRUMENTS																						PO
		RP1	RP2	RP3	RP4	RP5	G1	G2	G3	G4	RE1	RE2	RE3	RE4	RE5	RA1	I1	I2	I3	I4	C1	C2	C3	
P1: AI-AS:S research in Sweden has generated far reaching impact in society and industry	Fund research addressing strategic societal and industrial problems	3	3	3	3	3					3	3	3	3	3	3	1	1	3	3				
	Foster collaborations and networks with industry, and between academic disciplines	2	3	2	3	3			3		2	2	1	1	1	3	2				2	2	2	
	Continuously analyse needs and trends to position Sweden at the forefront of the international research agenda										2	2												3
P2: The general level of AI-AS:S research in Sweden is at the international forefront	Operate with dynamic funding instruments that balance between quantity and quality, and follows along a strategic dimension	3	3	3	3	3					3	3	3	3	3				3	3				
	Have wide coverage of research domains in project selection	3	3	3	3	3																		
	Apply an open and competitive process for the selection of projects	3	3	3	3	3					1	1	2						1	3				
	Conduct evaluations and follow-up of project results and their impact	1	1	1	1	1			1		1	1	1	1	1	1			1	1				3
P3: Swedish universities are hosting internationally renowned scientist	Provide attractive career paths for promising junior researchers				2								1		2									
	Recruit top international researchers in strategic areas	1	1	1	1	1					3	3	3						2	3				
	Ensure dynamic and efficient recruitment processes	2	2	2	2	2					3	3	3	2					2	3				
	Build-up strong and attractive hosting research environments	1	1	1	1	1					2	2	2	2		2			1	1				
	Host networks of excellence including academic researchers and industrial partners								1		2	2	2			2								
	Offer postdoc opportunities in Sweden and repatriation opportunities				3									3	3				3	3				
P4: Sweden offers the most attractive PhD program for national and international students	**Operate a national graduate school with a coordinated syllabus**	1	1	1	1	1	3	3	2	3														
	Engage the best teachers to offer courses on central topics						3	3			1	1	1											
	Offer both broad courses accessible to many students as well as specialized courses						3	2	1															
	Provide mechanisms for networking among students, with academic groups, industry, and the international research community						1	2	3	3							3	3				3	3	
P5: Sweden has world-leading research environments	Fund environments with the best researchers who have a focused research agenda	1	1	1	1	1					2	2	2	2	2							2	2	
	Build-up networks of excellence in strategic research domains								1		2	2	2	2	2	1					3	3		
	Offer attractive packages for international recruitment as as well as retention of Swedish talent										3	3	3	3	3						2			
	Offer attractive packages for international recruitment as as well as retention of Swedish talent										2	2	2	2	2	2						3	3	
P6:Swedish industry is thriving at the top of innovation and competence	Operate joint academy/industry research arenas	1	1	1	1	1										3								
	Fund shared positions for academy/industry mobility		2																					
	Host networking events to identify synergies and joint projects								3							3						2	2	
	Form strategic alliances with international top universities								2		1	1	1				3	3	3	3	1	1	1	
P7:Successful spin-off companies are created in Sweden	Take commercialization aspects into account in reviewing and general incentive mechanisms	2	3	2	2	2								3	3						1	1	1	
	Form alliances with innovation and commercialization support organizations																							3
	Provide information to PhD students on commercialization possibilities																				3	3	3	
	Fund proof of concept research															2								
P8: Sweden is a partner in strategic alliances	Participate and lead in EU level initiatives																							
	Operate a program for exchanges of students and researchers with leading universities and companies	1	1	1	1	1	1	1		1							3	3						
	Coordinate, package and communicate Swedish opportunities																			2	3			
	Form strategic alliances with international top universities																3	3						
P9: Sweden serves as a role model for other countries and participates in hosting meetings, conferences and policy bodies	Support organization of conferences and networks								3													3	3	
	Document and communicate success stories and organizational concepts								2							2					3	2	2	
	Engage in international policy bodies																							

Figure 6.1: Correlation between positions/strategies and instruments. Number indicates relevance and color indicates current performance. The matrix is currently a working version and should be used for discussion.

Instruments

RP1:Academic PhD students
RP2:Industrial PhD students
RP3:Affiliated PhD students
RP4:Expedition projects
RP5:Collaboration projects within AI/MLX

G1:Courses
G2:Summer school
G3:Cluster structure
G4:Networking with Industry

RE1:Professors in AS
RE2:Chairs and Guest Professors
RE3:Assistant professors in AI/MLX and AI/Math
RE4:PhD and Postdoc Recruitment
RE5:WASP Postdoctoral scholarships

RA1:Research Arenas

I1:International study trips
I2:Research stints abroad
I3:NTU-WASP collaboration projects
I4:NTU-WASP Postdoc Fellowships

C1:Communication
C2:Networks within the WASP Community
C3:Meetings and Conferences

PO:Program Office

6.1 Analysis of Current Instruments

For each of the current instruments multiple aspects can be noted in the correlation matrix. A discussion on these aspect of the instruments is provided below, together with other reflections leading to suggestions for the development of the instrument and potential new initiatives complementing the instrument. It should be noted that the matrix should be seen as a reflection of the current status of the instruments with respect to the wanted positions. As such, it can mean that even if an instrument receives a 'green 3' rating, further development of the instrument may be motivated/necessary. The matrix should, in view of this, be regarded as an evolving documentation of the status of the instruments. It will be updated at regular intervals to include perspectives on future instruments and strategies, and can then serve as a valuable resource for WASP to act dynamically and with agility in response to changes and challenges appearing during the progress of the program.

6.1.1 Research Program

Status: The work done by PhD students and their supervisors constitutes the majority of the research conducted within WASP with the projects spanning the full range of WASP topics. By mainly funding individual PhD student projects selected in (mostly) open and competitive calls, WASP can achieve scientific excellence while strategically directing research. As shown in Figure 6, we judge that the research program has been successful in creating individual research projects where cutting edge topics have been investigated. The research program has so far demonstrated both a depth and breadth.

Analysis: As indicated in the correlation matrix, attention should be given to the evaluation of the impact of the research projects and on following up the career progression of the PhD students. Further mechanisms, such as the new cluster structure presented in Section 7.1, are also needed to increase exchanges and collaborations between PhD student projects. There is now an opportunity for individual researchers to establish themselves in new research areas through collaboration with other strong researchers that are outside their immediate area of research. Also, given the long-term nature of the program, WASP is in a position to test various models for research structure and governance. The collaborative projects and expeditions instruments are two examples of this.

Development and new initiatives: To achieve a sustainable national position in all WASP research areas, it is important to continue to support both strong individual researchers and strong research teams as new research ideas and solutions arise in-between areas, resulting in an increased number of publications at internationally leading venues. New instruments may thus be needed such as WASP NESTs (see Section 7.2) and the WARA connected Industry Bridge (see Section 7.3.2). Given new initiatives and modifications it is important to develop monitoring and assessment tools to make sure that the instruments give desired results. The assessment can also be used as a tool to further disseminate project results within WASP even while the instrument is ongoing. At this stage we also foresee an increasing number of self-sustained leading research supported by highly competitive, international funding sources such as the ERC.

6.1.2 Graduate School

Status: There is, today, a coordinated syllabus and a strong engagement among the WASP teachers with the graduate school. The syllabus varies in content depending on which track students are following: WASP-AI or WASP-AI/MLX, but there are several interaction points between the two tracks. By involving WASP researchers and industrial representatives in the teaching of the graduate school we also further strengthen the industrial relevance and attractiveness of the program. A sense of community is also created by organising the PhD students into batches, each batch consisting of approximately 50 students, where these students take the various courses together. Clusters are important organisational structures to reinforce the sense of community and relevance of the graduate school.

Analysis: As the field develops so will the need to constantly adapt and improve the courses and activities. Most apparent is the cluster structure which receives a slightly lower rating, which indicates the need for a modified cluster structure. One major challenge is that the influx of PhD students is changing, from large batches of students every two years, to a more continuous flow of PhD students mainly hired by the recruited researchers using their funding packages. The batch approach has been very successful in building a tight community while also facilitating the structuring of courses and other activities. We should, therefore, actively try to find a structure that still allows for a strong community to be formed among the students despite the expected changes in the influx of new students.

Development and new initiatives: The most urgent development is a new cluster structure and WASP has recently analyzed the cluster instrument from a content and organisational perspective. Based on the analysis a new structure has been derived and will be introduced during 2020 (see Section 7.1). While evaluating and improving the WASP Graduate School two further opportunities have been identified: tighter integration between the various branches of WASP – such as between WASP-AS, WASP-AI, and the various subjects including control theory, AI, and mathematics, and synergies with other "sibling programs", such as the WASP-HS graduate school. This could provide even greater added value to the PhD students and result in a truly globally unique graduate school. WASP is also planning to introduce an alumni initiative for PhD students who have completed their studies within the WASP programme. The alumni network will be important for attracting and inspiring new PhD students and for WASP to evaluate the longer-term outcomes from the different instruments within the WASP program.

6.1.3 Recruitment

Status: The combination of an attractive university position, industry collaboration and the WASP community has enabled WASP to offer recruitment packages to international top scientists that none of the Swedish universities could have offered alone. The success of the recruitment

strategy constitutes a large part of the WASP investment and the source of its success. Already, attractive research environments have begun to be built-up around recruits and, in turn, have attracted international PhD students and postdocs to Sweden. The success ranges from senior professors to assistant professors in AI/MLX and AI/Math. The recruitment of these junior scientists, who build up research groups within the WASP community, is essential to establish a critical mass in AI research in Sweden.

Analysis: The recruitment initiatives have been quite successful up to this point, and in the matrix we see that the recruitment of the top level senior and researchers is receiving top ratings. It has exceeded expectations, and several of Europe's strongest senior researchers are now affiliated with the program via Swedish host universities. Even though WASP has worked with the universities for a smooth recruitment process while maintaining a high level of quality in matching the WASP objectives for its recruited positions, further harmonization of recruitment processes are needed.

Development and new initiatives: During the coming years our senior professors in AS, Wallenberg Chairs and guest professors are expected to recruit PhD students and postdocs and build up substantial research groups that can boost AI-AS-S research in Sweden, both in academia and industry. A focus going forward will be to ensure that recruited faculty will have the possibility to increase their interaction within the WASP community and to develop their collaborations through several of the proposed new instruments, such as NESTs, WARA, and Industry Bridge (see Section 7). It should also be noted that the chairs and guest professors are beginning to form a network of WASP recruits. Through WASP meetings, conferences and networks new synergies and multidisciplinary research projects will thus take form, bringing research in Sweden to the forefront of international science. Retaining talent in Swedish academia and industry is a key component in this and, as the WASP program progresses, development of a career program for WASP alumni (see Section 7.4) will be of increasing importance. This is not only relevant to the PhD students, but to all of the academic recruits, post-docs, assistant professors and even the senior professors.

6.1.4 Research Arenas

Status: The research arenas are a central concept with great potential to increase informational and scientific exchanges leading to collaborative research agendas between industry and academia. It is clear that the current research arenas, in particular WARA Public Safety, which has delivered on this goal and organized two successful and well-attended demonstration events in September 2018 and 2019. The main challenge in this has been the system integration of the commercial command, control, and communication information system with a delegation research framework for planning and control of autonomous vehicles (unmanned air and surface vehicles) in a realistic real-world setting.

Analysis: From the matrix it is also apparent that more results could be obtained. This is primarily in terms of an increased number of arenas and increased engagement by partners, in particular researchers, on both the academic and industrial side. It can be concluded that, after the first years of WARA operations, it has been more challenging than anticipated to engage researchers, PhD students and companies in such joint efforts.

Development and new initiatives: An analysis conducted during the autumn of 2019 showed the need to refine the instrument to address the issues and increase engagement in existing arenas and set up new initiatives. A new WARA strategy is thus under preparation and implementation. A more detailed account for this is provided in Section 7.3.

6.1.5 Internationalization

Status: Research and higher education are international by nature. Cooperation across borders is necessary to meet the new research challenges in a global context. Swedish universities and researchers have been very successful on the international stage but the current competition in research is intense. The solution is to further promote interaction and collaboration with the very best international researchers and top-universities in the world. WASP is an attractive partner, which is confirmed by our ongoing collaborations with Stanford University, UC Berkeley and NTU.

Analysis: The scores for internationalisation in the matrix show that internationalisation is working well in WASP and is helping WASP in building a strong brand while facilitating the careers and development of the individual researchers. Still WASP may need to expand its current preferred partnerships in an international context. The next step is to increase the activities of WASP through the current instrument research visits and postdoctoral programs and also to initiate faculty exchange programs with some selected top-universities in the USA, Asia and Europe. This will lead to higher research impact and even more attractive conditions for international recruitment.

Development and new initiatives: WASP has ongoing discussion to set up a partnership with the MIT Schwarzman College of Computing, and is also investigating potential partner universities in Europe and in China. For internationalisation, the time is now right to leverage the strategic networks which several of our senior recruits possess. This will further ensure that there is a good representation of WASP researchers at relevant policy and decision making levels both inside and outside of Sweden. It is also worth noting that, given the current global situation with CoViD-19 at the time of writing of this document, there may be a need to determine how to foster international collaboration while minimizing, or even eliminating, travel for large groups of students. Specifically, the international study trips may need to be re-examined.

6.1.6 Communication, Events and Networking

Status: Communication, events and networking are essential for ensuring that many of the strategies can reach a high level of documented success. Recently, significant effort has been made to raise the level of communication from WASP and so increase the programme's visibility. The new communication efforts reach out to a large audience to create a visible impact in society. The effect of this effort has been verified by the increased interest from media and external conference organizers. It is also apparent from the increasing number of visits to our webpage, the increase in subscriptions to our newsletter and the high interest in participation in our open events.

Analysis: As we are now past the initial stage of WASP, it is important to focus on further deployment of the communication strategies. From evaluations made we see a clear willingness by all WASP affiliated researchers to engage in networking activities and more events with this objective are requested from within the community. We also see that in this phase of WASP it is critical that we actively communicate the success stories of the WASP programme as well as effectiveness of the various organisational concepts in the WASP strategy. An item that calls for attention is comprehensive documentation and communication of research results in media such as the WASP home pages and throgh other channels.

Development and new initiatives: As mentioned previously, several new and highly desirable networks have been identified: A network for postdocs, for female researchers, for the Wallenberg Chairs in AI and for the Wallenberg Guest Professors. These will serve to foster a stronger sense of community within the program. Another area of development is to educate the doctoral

students in the process of commercialization of scientific results. This could also be done through networking and events by putting it on the agenda and through collaboration with relevant partners. WASP will need to continue and increase its communication activities to make WASP research visible, promote success stories and create a strong national and international brand. The underlying mechanisms for this have already been put in place.

6.1.7 Program Office

Status: The task of the program office spans multiple instruments and is, strictly speaking, not defined as an instrument in itself. We have, however, decided to include the program office in the correlation matrix since it is instrumental for many of the strategies defined: most notably the support in the recruitment processes and the management of the graduate school. The program office hosts the efforts in communication and the inclusion of communication officers has been instrumental in creating a presence in social media and improved web pages.

Analysis: It is clear from the matrix that the program office has a substantial responsibility for the analysis and evaluation processes of instruments and strategies, and support for this is of high priority. The work on supporting interfaces to other related initiatives such as the innovation support structure is also of great importance.

Development and new initiatives: An expansion of the program office should be made to further strengthen the capacity for evaluation and analysis, as well as documentation and communication efforts. There is also a need for continued support for recruits in close collaboration with hosting universities. The program office can also provide administrative support when developing current instruments and when establishing additional instruments according to the results of the analysis.

6.2 Need for Additional Instruments

As is clear from the correlation matrix some positions and strategies are represented by instruments to a lesser degree. This is clearly indicated by strategies for which a level three relevance is missing. These can be grouped into five categories:

1. Analysis, evaluation and policy (P8:1, P9:2)
2. Career paths for junior researchers (P3:1)
3. Research environments and networks (P3:3, P3:4, P5:1, P5:2)
4. Academy/Industry researcher mobility (P6:2)
5. Innovation and commercialization (P7:2, P7:3, P7:4)

For item 1 WASP should consider the formation of a new instrument for evaluation and policy in the form of a task to either one of the existing bodies in the governance structure or a new task force group. For item 2 a new instrument is currently under development and consideration by the board (see Section 7.4). For item 3 a new instrument named NESTs (see Section 7.2) is under development and consideration by the board. For item 4 an added initiative to the research instruments funding mobility efforts should be considered to further promote exchanges between university and industry partners. The notion of industrial postdocs is currently being discussed. For item 5 we anticipate a close collaboration with the Wallenberg initiative, WALP, as described in section 3.5.

It should be noted that there can also be situations when an initiative has very high relevance for one aspect of a strategy but other, or even new, instruments are needed to cover the full strategy. An example of this is position P1:1 and P1:2 where the research program and its current instruments are receiving a “green” status. It is, however, clear that a strategic effort on environments such as NESTs would be given a relevance rating of 3 for all P1 strategies.

6.3 Conclusion

The analysis conducted above gives a comprehensive overview of the status of the program and provides valuable input for future development of the program in terms of refinement of instruments and new initiatives. The main conclusions that can be drawn from the analysis are:

- It is clear that, for the most part, the WASP instruments all contribute to multiple wanted positions. Thus, the current instruments are well justified, but the analysis indicates a potential for further improvement and tuning.
- Industrial relevance and collaboration should be increased across the instruments and research arenas should be given attention to reach the full potential.
- New instruments addressing research environments and networks of excellence should be considered, and career paths for junior researchers should be supported.

The following chapter outlines initiatives defined in response to this analysis.

7 — Proposed New Instruments and Initiatives

7.1 Cluster Structure 2020

The existing WASP cluster structure specifies 12 clusters spanning the WASP domains. Each PhD student is affiliated with one primary and one secondary cluster. A senior WASP researcher is appointed cluster leader and is hosting meetings, such as cluster gatherings in conjunction with the annual winter conference, and organizing other activities. The activities are, however, significantly varying between the clusters and some clusters are tightly organized, whereas others are struggling to find their identities and roles in WASP. A new cluster structure with clearer definition of scope and task is therefore suggested.

The new structure follows the analysis made in Section 3.2, and the lists shown in Table 3.1, and is based on a set of smaller *core technology groups* coupling PhD students with similar research topics together. A core technology group is typically of the order of 10 PhD students and can be headed by a senior PhD student or a WASP postdoc. It is expected that the core technology groups have frequent meetings and organize joint activities such as paper reading groups etc. As most PhDs in WASP also have one or several applications in focus it is also suggested that *application clusters* are formed. An application cluster brings together PhDs from different core technologies, addresses application specific challenges and catalyzes multi-disciplinary approaches within an application domain. An application cluster can be a larger group of students and senior researchers and with industrial representation. It is also possible to connect application clusters to the research arenas to leverage efforts in arenas with cluster activities.

7.2 NESTs

As indicated by the analysis of wanted positions and instruments in Section 6.2, it is clear that even though there are many instruments and initiatives in WASP that will generate the components out of which leading research environments and networks are formed, there is no single initiative that has this as main focus. With a starting point in the identified technology trends described in Section 3.2, we propose to include such an initiative under the research program instrument. It has been given the name WASP NESTs, where NEST stands for:

- **Novelty:** Addressing specific strategic research challenges with international impact and visibility.
- **Excellence:** Engaging top researchers in Sweden and their collaborators world-wide.
- **Synergy:** Finding collaborations between environments, with companies and arenas (WARA).
- **Team:** Forming constellations of the best researchers across multiple disciplines with a common goal, and creates “homes” for recruited WASP researchers. Can be a physical environment or a network of excellence.

The NESTs should be based on the selection of a number of WASP technology areas aligning with the prioritized areas presented in Section 3.2 that are of key interest to Swedish industry, and where Swedish research could have an international impact. NESTs should be appointed

after an open call for proposals and evaluated by a panel of international experts. A NEST should be granted funding for a time period of at least 4 years.

7.3 WARA Forward

As indicated in Section 6.1.4, an understanding has matured that the wanted impact of the investment in WARA has not yet been fully met. The analysis in the fall of 2019 and beginning of 2020 has concluded that the basic objective is still valid but that the strategy has to be evolved. To attract industry engagement, the respective contexts have to be closer to the reality which the industry experiences. Also, for the academic engagement, the WARAs have to be more integrated and leverage on the other parts of the WASP program and focus should move towards senior academic and industrial researchers collaborating, advising students in the context of the arenas and scenarios.

In addition, it is also clear that another category of arena is asked for, that is the development of basic general purpose technology e.g. SW technology, Cloud infrastructure etc. In this case the participants and driving forces are quite different from that of a more industrial context and this has to be acknowledged and addressed.

At last, for leading industry representatives and senior researches to meet and to find common grounds for collaboration projects, new activities have to be initiated as conferences, seminars etc. For example the possibility to conduct smaller "bridging" projects with the help of limited engineering efforts has been asked for both in the context of the arenas and in a wide range of collaborations outside of the defined arenas. This leads to the definition of the “Industry Bridge” initiative described below as a complement to the arenas.

7.3.1 Resarch Arenas 2.0

With a starting point in the experiences of WARA public safety and the analysis performed a new concept for the arenas has been developed. Central in this concept are:

- Build on five to eight new smaller arenas with a more focused context and possibly limited in time.
- Seek and leverage on industrial/institutional motivation and ownership.
- Integration of WARA in other WASP instruments, e.g. in calls, expedition projects etc.
- Two categories of arenas have been identified: systems demonstration with high industrial relevance and general-purpose technology platforms to serve as research infrastructure.

The detailed plans for the research arenas 2.0 are being developed and the first initiative that has been approved by the WASP board is to initiate a new arena in the area of software.

7.3.2 Industry Bridge

A flexible instrument to increase the number of participating companies is seen as an important addition to the WARA portfolio. Funding of engineering time to implement research results for proof of concept has been identified as a bottleneck in bridging the gap between research groups and industry. In many cases a limited effort in terms of man months would explore the possibilities offered and form the foundation for longer and deeper collaborations, and participation in the other instruments such as research arenas or industrial PhD projects.

A new instrument is proposed to address these items and is based on:

- A collaboratively defined win-win project involving at least one academic and one industrial WASP partner.

- Funding of engineering time at three levels 3, 6, 12 months.
- In-kind contributions from the industrial partner.
- Connection to existing WASP research projects.
- Relevance to research arenas.

To identify industry bridge projects the intention is to organize industry/academia match making meetings, see Section 5.6, which will generate proposals for consideration by the board.

7.4 Career Program

Until 2029 at least 400 top PhDs will graduate from WASP. It is in-line with the WASP mission that many of them will find career opportunities in industry and thus serve as personifications of the industrial relevance of WASP. However, some academically outstanding PhDs will look for careers at universities and may form the basis for the next generation of research leaders. An instrument for support of the top tier PhDs can be a way to leverage other investments made and capitalize on the vast pool of highly competent WASP alumni. Assuming that 10% of the WASP PhDs would be of this caliber and have an interest in pursuing an academic career 40 would be eligible to apply. A 25% acceptance rate would mean that 10 establishment packages (similar to WASP recruitment of assistant professors, see Section 5.3) would need to be made available.

8 — WASP Beyond 2030

By 2030 Sweden will be a leading nation in AI, Autonomous Systems and Software in Europe, and will possess several of the world's leading research groups within the area. An important component in this is that Swedish universities will be in the top 10 in the world in subject rankings connected to WASP. Swedish industry will also be world leading in digitization technology with several global companies having its origins in Sweden. The ambition is that WASP will have served an essential role in positioning Sweden as a globally competitive nation, and the WASP initiative will be in a position to serve as a role model for future research and education programs in science and technology.

As we move beyond 2030, the initiatives that WASP has created will have shown an added value and will be sustained by the Universities through excellent research environments and via other funding initiatives which bring together academia and companies. Three important aspects will persist beyond 2030:

- **Research Excellence** By 2030 WASP will have led to the establishment of more than twenty sustainable high profile research environments, producing internationally competitive research. Beyond 2030, these research environments will be active in forming new national and international research collaborations and will be aiming towards the next level in major national and international recognition in the research community. WASP has already resulted in outstanding quality scientific output in AI, autonomous systems and software in Sweden, and there are many more successful scientific breakthroughs to be made based on high risk, high reward WASP projects.
- **Strategic integration of WASP within the Swedish universities:** The WASP Graduate School will have resulted in an even more attractive engineering education at all levels, reaching larger numbers of students and resulting in a very positive image of Sweden. The groups hosting the WASP recruits will be essential components in the development of strategic research efforts within the universities. Many of the graduated PhD students will have faculty positions at renowned international universities and, upon their return to Sweden, career opportunities will be available. This close interaction and integration of WASP with the participating universities also paves the path for university ownership of WASP.
- **Societal and industrial impact of WASP research:** The major societal and industrial impact of WASP is through the education of very talented researchers and engineers. This impact will still be needed and will be of even higher importance by 2030. The continued development of digitalization technologies will be a key component in the transformed Swedish society and industry over coming decades, and the WASP legacy must therefore be maintained through renewed initiatives and university commitment to the field.

To conclude, the success of WASP will to a large extent be shown in the impact the program has had until 2030 and how well the strategies have worked towards the wanted positions, but also in the persistence beyond 2030 of the WASP initiatives and the long term effect it has had on the development of Swedish research.