Project title: UAS@LU Autonomous Flight

Main applicants:

Dr. Johan Bergström
Head of Department
Lund University School of Aviation

Dr. Rolf Johansson
Professor
Department of Automatic Control

Summary

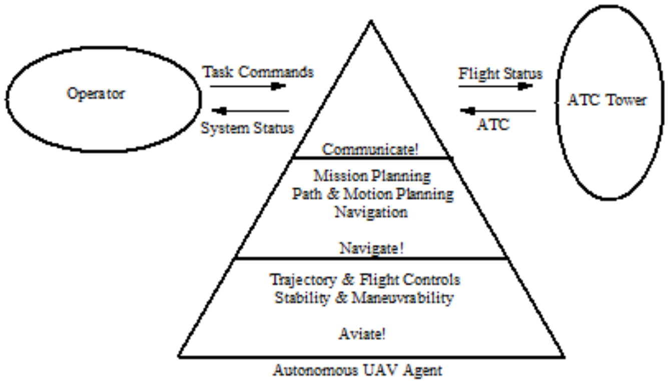
This research project addresses and develops the technologies of unmanned flying systems (UAS or drones) in order to make such systems more suitable for addressing various social challenges. A current collaboration project (UAV@LU, currently changing name to UAS@LU) addresses the potential of UAS for addressing societal challenges including, but not limited to, more efficient and sustainable forestry and farming, urban planning and landscape modelling, monitoring of critical infrastructure system, smarter transport, as well as more efficient and safe emergency service operations. A problem shared across all sectors mentioned above is making the UAS autonomous; the transition from actively piloting a drone with continuous (human) control inputs from a remote ground station while having the drone within visual line of sight to an autonomous UAS solving complex problems without continuous human control inputs but as an autonomous agent beyond the visual line of sight in an airspace populated by unmanned as well as manned aircraft. Consequently, the here proposed research project aims at developing and demonstrating autonomous flight missions in an airspace with mixed autonomous and manned aircraft under supervision and management of air traffic control. While the actors in the UAS@LU network represent a vast number of possible applications for autonomous UAS systems; this project will focus on two applications which are being developed with the purpose of enhancing societal safety: the cases of autonomous radiation detection and Sear-And-Rescue (SAR). The project serves the wider purposes of the collaboration UAS@LU and is conducted by Lund University School of Aviation and the Lund University Dept. Automatic Control in close collaboration with research conducted at the departments for Nuclear Physics and Medical Radiation Physics. External actors include those involved in Testbed Ljungbyhed as well as actors collaborating with LU researchers in UAS applications for societal safety.

Background

For purposes of unmanned autonomous flight (remotely piloted aircraft, autonomous flight beyond line of sight, fully autonomous flight missions, or autonomous formation flight), automation of flight requires automatic control of pilot operations in piloted aircraft. In all cases, such automation involves multiple hierarchically organized control-loop layers, monitoring and controlling the progress of a flight plan by means of sensor data and control actions. These hierarchical control loops correspond to pilot operation priority hierarchies represented by the pilot catch phrase *Aviate! Navigate! Communicate!*

Among the fundamental automation task for autonomous flight, there is **self-level** (*i.e.*, attitude stabilization on the pitch and roll axes), **altitude hold** (*i.e.*, the aircraft maintains its altitude using barometric pressure and/or GPS data), **hover/position hold** (*i.e.*, the aircraft keeps level pitch and roll, stable yaw heading and altitude while maintaining position using GNSS or inertial sensors), **care-free** (*i.e.*, the aircraft performs automatic roll and yaw control while moving horizontally), **take-off and landing** (using a variety of aircraft or ground-based sensors and systems; also called **autoland**), **fail-safe** (*i.e.*, the aircraft performs automatic landing or return-to-home upon loss of control signal), **return-to-home** (*i.e.*, the aircraft flies back to the point of takeoff, obstacle avoidance (*i.e.*, the aircraft avoids possible intervening obstructions such as trees or buildings), **follow-me** (*i.e.*, the aircraft maintains relative position to a moving pilot or other object using GNSS, image recognition or homing beacon), **GPS waypoint navigation** (*i.e.*, the aircraft performs waypoint navigation using GNSS to navigate to an intermediate location on a travel path), **orbit around an object** (similar to follow-me but continuously circle a target to keep a hold position), pre-programmed **aerobatics** such as rolls and loops.

Basic autonomy comes from feedback from proprioceptive sensors, measuring variables internal to the aircraft. Such questions need to be addressed with respect to specific aircraft and sensors, and relevant results developed at LU are found in [5]. Advanced autonomy calls for situational awareness, knowledge about the environment surrounding the aircraft from exteroceptive sensors, measuring variables exterior to the aircraft such as distance—*e.g.*, using GPS and radar [2]. Based on the various data sources, sensor fusion integrates information from multiple sensors. Path planning (kinematic) based on sensor data—*i.e.*, determining an optimal path for vehicle to follow while meeting mission objectives and constraints, such as obstacles or fuel requirements—is the higher-level objective corresponding to navigation. In order to maintain this path trajectory generation (motion planning; dynamics)—*i.e.*, determining control maneuvers to take in order to follow a given path or to go from one location to another—is necessary [3]. In order to maintain a trajectory in the presence of disturbances, trajectory regulation (flight control) constraining a vehicle within some tolerance to a motion planning trajectory is necessary.



Research questions

Whereas some aspects of these automation tasks may be available in advanced commercially available UAVs, a systematic integration of autonomous flight tasks remains to be solved as a research assignment. Hence, the project seeks to answer the research question:

RQ1: How can autonomous flight tasks be systematically integrated within the complex control structure of an UAS?

Once such functionality is available on an UAS research platform, new perspectives of autonomous flight such as flight missions beyond line of sight with attention to interaction with other UAS operator(s) and air-traffic control can be considered. In order for this to work the UAS must be able to coordinate its action not with a remote pilot but with an Air Traffic Management (ATM) system. In a controlled airspace, air traffic controllers ensure separation between aircraft by managing and controlling aircraft sequences, timing, as well as their lateral and vertical flight patterns (routes). This is only in part done in a pre-planned manner. The art of ATM is to continuously adapt behavior according to the emergent nature of traffic patterns and interactions. One conventional way of ensuring separation between manned and unmanned aircraft is to segregate traffic flows. However, in order to increase the efficiency and flexibility of the airspace usage; to share the airspace with other modes of transport is a key challenge. At that stage of the project the following research question is asked:

RQ2: How can an UAS be engineered in order to adapt its activities and actions in coordination with other aerial systems (manned and unmanned) as well as Air Traffic Management, in controlled airspace-environments?

Plan of activities and methods

The collaboration project will be organized with a graduate student in the discipline of robotics and automatic control employed at the Lund University School of Aviation. Such a position enjoys the benefits of expertise from the control department in Lund for the more theoretical aspects of the work, and the experience of the aviators at the LU School of Aviation for application-oriented aspects. In the course of the project, a research platform will be developed to demonstrate autonomous flight missions in an air traffic control environment with mixed autonomous, civil and military aviation under supervision and management of air traffic control.

The overall plan of the project is to develop and demonstrate an autonomous UAS including the following services:

1. **Flight services:** all services in charge of basic UAS flight operations: autopilot, basic monitoring, contingency management, etc.

2. **Mission services:** all services in charge of developing the actual UAS mission.

3. **Payload services:** specialized services interfacing with the input/output capabilities provided by the actual payload carried by the UAS.

4. **Awareness services:** all services in charge of the safe operation of the UAS with respect terrain avoidance and integration with shared airspace.

The tasks of developing these four essential services will be spread over three phases of the research and demonstrated in the final, fourth phase, as developed below.

Phase one (2021-2022): Systematic integration of flight tasks into the control structure of an autonomous UAS

Software engineering organization of the control hierarchies with sensor interfaces and communication results in autopilot functionality in the form of an autonomous agent.

The focus of this phase is on the flight services provided by the UAS.

A flight plan specifies the path followed by the UAS. Each flight plan is composed of a sequence of stages, such as take-off, departure procedure and others, which must come in correct order. Each flight plan stage is made up of a structured collection of legs which, in turn, are described by waypoints. For the main flight plan, a default contingency or emergency plan can be specified.

The Flight Plan Manager Service (FPMS, essentially a part of mission service as introduced above) is responsible for executing the various stages of flight plans, but it does not operate in a stand-alone fashion. To achieve such goals it collaborates with other services. The main service the FPMS collaborates with is the Virtual Autopilot Service (VAS, a part of flight services), which is the only service with direct access to the installed autopilot. Apart from the VAS, the most relevant services the

FPMS interacts with are the Ground Control Station (GCS) and the Mission Control Service (MCS). Whereas the GCS provides monitoring and control capabilities to a human operator, the MCS is in charge of evaluating conditions and in-flight updating parametric legs.

Phase two (2023-2024): Develop formation flight and fleet management

In the case of formation flight and fleet management, and in order to address the research questions asked above, the autonomous agents of each UAS need to be augmented by inter-agent communication and synchronization functionality; topics in which researchers at LU have expertise [1], [5].

The agents in a UAV multi-agent system are designed to have some characteristics important for mission proficiency:

- **Autonomy:** UAV agents are at least partially independent and autonomous;
- **Local views:** no agent has a full global view, or the system is too complex for an agent to exploit such knowledge which, in turn, leads to needs for inter-agent communication and coordination;
- **Decentralization:** each UAV agent is not designated for hierarchical control

Coordinating multiple vehicles in UAV formation flight or in UAS cooperative mission tasks in SAR often involve various types of inter-vehicle constraints, typically described by equality or inequality functions of inter-vehicle geometric variables. For example, a practical coordinated motion may be described by some inequality constraints that require a bounded inter-vehicle distance between mobile vehicles; *i.e.*, a lower bound to guarantee collision avoidance, and an upper bound for reason of limitations in payload sensors or to avoid communication loss due to excessively long ranges or distances. Whereas solutions to such motion control problems can be found using model-predictive control (MPC), there is also a need for inter-agent communication of flight state and mission state.

Multi-agent planning is concerned with planning by and for multiple UAV agents. It may involve UAV agents planning for a common goal, an agent coordinating the plans (plan merging) or planning of others, or agents refining their own plans while negotiating over tasks or resources. The topic also involves how UAV agents can do this in real time while executing plans (distributed continual planning). Multi-agent scheduling differs from multi-agent planning the same way planning and scheduling differ: in scheduling often the tasks that need to be performed are already decided, and in practice, scheduling tends to focus on algorithms for specific problem domains.

Phase three (2024): Integration of UAS system into a controlled airspace-environment

The final step of addressing RQ2 is to integrate the autonomous UAS into an airspace environment in which not only other UASs but also manned aircraft might be operating. This includes the development of the Awareness Services as introduced above. Such services needs to integrate and combine systems to detect and avoid surrounding actors (manned and unmanned aircraft), systems to make the UAS itself visible to surrounding actors, systems to be visible to air traffic controllers and systems to take direction from air traffic controllers as well as remote operators.

In this phase we will collaborate closely with two providers of air traffic management (ATM)-services: ACR and LFV who are both external participants in the wider collaboration project UAS@LU. Close cooperation will be ensured especially with ACR wich is the ATM service provider at Ljungbyhed airport (the project testbed), manning the control tower with flight controllers approving and directing all air traffic within the Ljungbyhed airspace. The aim of the phase is to present a solution for an integrated ATM-UTM method in which UTM stands for Unmanned Traffic Management.

Phase four (2025): System demonstration

The final step of the research project is to demonstrate the system in a testbed environment. The research will be conducted within the Lund University research infrastructure UAS@LU, providing equipment, supporting staff, operational procedures and a complete aeronautical testbed including an airport with a controlled airspace. UAS@LU is coordinated from Lund University School of Aviation (LUSA). LUSA operates at Ljungbyhed airport which is a certified airport able to control and coordinate manned and unmanned aircraft in an airspace controlled by air traffic controllers. The demonstration will take place in this testbed environment and in coordination with other actors including other UAS operators, manned aircraft and Air Traffic Control.

The aim is to be able to demonstrate a system able to address a particular task, addressing challenges of societal safety, as defined by one or several of our external partners; primarily within the fields of radiation detection and/or Search-And-Rescue operations.

Expected effects for society

This research project fits into the larger, and quickly growing, field of developing autonomous agents intelligently conducting a number of different tasks in interaction with physical and biological systems; in more popular terms labelled the ‘fourth industrial revolution’. Ultimately the aim is to create safer, smarter and more sustainable societies by means of artificially intelligent agents interacting with social and socio-ecological systems. Fields which could benefit from this technology include farming in which autonomous sensors could analyse parameters such as water or nitrogen levels, plant scabs, readiness for harvest, etc., but in which an autonomous sensor making autonomous analyses could also adapt their movement and behaviour by zooming in to conduct further analysis if finding particular signs of interest. Autonomous (aerial) agents are also seen to have great potential to autonomously monitor critical infrastructure systems such as roads, railways, power and water supply, and transport goods (and people). However; In this project we, together with our external partners, focus on two use cases which both aim at enhancing societal safety.

The first case for which the system developed within this research would have effects is so called Search-And-Rescue operations (SAR) at sea. Traditionally done using a system of manned vehicles (helicopters, aircraft and boats), SAR would become both safer and more efficient if partly conducted by autonomous vehicles (aerial and marine). Such vehicles could form important actors within a system designed to search for, locate and rescue missing people or vehicles at sea – being deployed quickly even in weather conditions which are too poor to send traditional manned aerial systems.

The second case of societal safety applications origins in the fact that autonomous UASs also have the potential to conduct tasks in environments considered too risky for humans—sometimes called D3, dirty, dull, dangerous. Good examples of such environments are those with high levels of radiation. Ongoing research, originating in UAS@LU, shows the potential. Within the ESS project, LU nuclear physicists a couple of years ago raised the question of using drones to detect sources of radiation within a confined indoor space (the ESS tunnel) and contacted Lund University School of Aviation. Through contacts established in the collaboration project UAS@LU, Lund University School of Aviation raised the issue with LU researchers in robotics and ultimately the original idea from the nuclear scientists turned into an interdisciplinary basic research project on autonomous indoor flight (with the need for the development of completely new kinds of small unmanned aerial vehicles) and gamma radiation source detection and mapping and several flight mission experiments at the Barsebäck nuclear power plant. A postdoctoral project has now been funded by the research program

ELLIIT to collaborate on the issue with CERN and a PhD project has recently been awarded the Department of Medical Radiation, by the Swedish Radiation Protection Agency, to study aerial measurement of radiation following a nuclear accident. The here suggested project (and associated PhD student) would join the emergent research group studying radiation detection using UAS, and contribute to the development towards making such systems autonomous.

These examples of outcome of research into autonomous vehicles conducting autonomous sensor analysis and adaptation are just a few out of an almost infinite number of potential societal applications ultimately leading to societal impact. For all these to get implemented fundamental research into the engineering of autonomous agents, and their interaction with their surroundings, is key and what this research project seeks to address.

Origin and relevance of research questions for collaboration initiative UAS@LU

The various different research groups, and external collaborators, in the ongoing collaboration project UAS@LU have highlighted the need for a development towards more autonomous aerial systems. With academic actors representing fields such as remote sensing in agriculture systems (Physical Geography and Ecosystems Science), landscape analysis (Archaeology; Engineering Geology; Water Resource Engineering), critical infrastructures (Water Resource Engineering; Transport and Roads) a continuous discussion within the collaboration project has been the common denominator of increasing the automation of UASs for all their purposes. Our external collaborators even go as far as to, in our dialogues, state that until these airborn systems of sensors become autonomous they will be too inefficient, economically and regarding necessary workload, to be implemented in their respective domains.

The researchers involved in the here proposed project would be able to join a currently emerging research group into the topic of autonomous aerial systems for applications of societal safety (radiation measurements and SAR). Both use cases for autonomous UAS (SAR and radiation detection) originate in the collaboration project UAS@LU and in a dialogue between LU researchers and external stake holders. The external participants participating in the research represent organisations involved in the two 'problem areas' or represent organisations dedicated to facilitate the integration of autonomous UAS in the airspace. As witnessed by the letters of intent issued by ESS, The Swedish Maritime Administration and SSRS, our research agenda is relevant and timely for the long-term application needs of autonomous flight in these organisations. These applications will also serve as case studies for the here proposed research project.

References

1. M. Greiff, Z. Sun, A. Robertsson, and R. Johansson, Temporal Viability Regulation for Control Affine Systems with Applications to Mobile Vehicle Coordination under Time-Varying Motion Constraints, Proc. 2019 Eur. Control Conf., Jun 25-28, 2019, Naples, Italy, pp. 3571-3576.
2. M. Greiff, A. Robertsson, and K. Berntorp, "Performance bounds in positioning with the vive lighthouse system," in 2019 22th Int. Conf. Information Fusion (FUSION), IEEE, 2019, pp. 1–8.
3. M. Greiff and A. Robertsson, "Optimisation-based motion planning with obstacles and priorities," IFACPapersOnLine, vol. 50, no. 1, pp. 11 670–11 676, 2017.
4. E. Lefeber, M. Greiff, and A. Robertsson, "Filtered output feedback tracking control of a quadrotor UAV," in 21st IFAC World Congress, Elsevier, 2020.
5. Z. Sun, M. Greiff, A. Robertsson and R. Johansson. Feasible Coordination of Multiple Homogeneous or Heterogeneous Mobile Vehicles with Various Constraints, Proc. 2019 Int. Conf. Robotics and Automation (ICRA2019), May 20-24, 2019, Montreal, Canada, pp. 1008-1013.

Team List

LU Participants

This research project provides the opportunity to contribute to an emergent research group studying UAS applications for societal safety. The main funding is for a PhD student employed by the Lund University School of Aviation (LUSA) while being supervised from the Department of Automatic Control. This means that the PhD student will join both the LUSA community of university lecturers and research engineers, which forms the central node for the collaboration project and LTH research infrastructure UAS@LU, but also the research community into robotics and automatic control. The project will also join the wider UAS@LU community of more than 20 internal partners for which this research provides important contributions. As stated above; planning and conducting UAS operations are time and resource consuming tasks. Several research groups would benefit greatly from autonomous UAS carrying sensors to gather research data into fields such as remote sensing, biology, infrastructure surveillance and planning, archaeology, spatial analysis, etc. Below the directly involved partners and persons are described in more detail.

Lund University School of Aviation (LUSA), LTH. LUSA will serve as the employer, and the LUSA UAS Lab as the physical employment location, for the PhD student recruited in the project. Project participants from LUSA also includes:

Dr. Johan Bergström, Head of Department and Reader in Risk and Safety; a highly relevant subject for this particular research which aims at contributing to applications increasing societal safety in different ways. Since 2018 Johan has had the role of project coordinator for UAS@LU. Johan will be funded 5% by the project, mainly for project management purposes.

Dr. Anthony Smoker, researcher with a background as air traffic controller. Anthony will be particularly involved in the research focusing on the development of interfaces for the integration of autonomous UAS into a controlled airspace-environment. Anthony will not be funded by the project.

Rikard Tyllström, University lecturer in Aeronautical Sciences and head of the UAS Lab. Experienced pilot, UAS operator and teacher. Rikard participates with aeronautical expertise in all phases of the project as well as with particular expertise on the operation of UAS. Rikard will be funded 10% by the project.

Rohith Prem Maben, research engineer at the UAS Lab, background in Aeronautical Engineering and subject matter expert in both software and hardware of UAS. Rohith participates in, and facilitates, the development and tests of software and hardware for the autonomous UAS. Rohith not be funded by the project, but is a resource made available to the project by strategic LTH funding.

Automatic Control, LTH. The Department of Automatic Control will provide subject matter expertise and supervision within the areas of autonomous systems and autonomous flight. The department will supervise the PhD student within its research subject and the PhD student will become part of the wider research group studying system autonomy. Project participants from Automatic Control includes:

Rolf Johansson, Professor in Control Science, subject matter expert in studies of autonomous systems and autonomous flight. Rolf will, together with Bergström serve as project director and as the co-supervisor of the PhD student. Rolf will be funded 5% by the project.

Anders Robertsson, Professor in Control Science, PI of the ELLIIT project studying radiation detection in nuclear facilities. Anders will serve as the main supervisor. Anders will be funded 10% by the project.

ELLIIT postdoctoral researcher. A postdoctoral researcher is currently being recruited for the ELLIIT project on radiation detection using SAR. The postdoctoral researcher will not be funded by the project but contribute with case study material and input for the case of radiation detection using autonomous UAS.

Department for Medical Radiation Physics, Faculty of Medicine. The department has recently started to collaborate with the other LU-partners involved in autonomous radiation detection in a project studying radiation measurement following a nuclear accident. Project participants from the department includes:

Professor Christopher Rääf is the principal investigator of the four-year project, funded by the Swedish Radiation Safety Agency (SSM), studying the assessment of radiation levels following nuclear accidents by use of UAS. Christopher will serve as the main supervisor for the future PhD student in the SSM project. Christopher will not be funded by the here proposed project, but involved in providing case study material for the use of autonomous UAS for radiation detection following nuclear accidents.

PhD student studying mobile radiometry for decision support for decontamination measures in residential areas. This PhD student is not yet recruited, but will become part of the research group currently being formed around autonomous UAS applications for purposes of societal security. The PhD student will not be funded by the project.

Department for Nuclear Physics, Faculty of Sciences. The department is involved in the various projects studying the analysis of radiation using autonomous UASs. Project participants from the department includes:

Dr. Emil Rofors was the nuclear physicist who originally identified the potential for autonomous measurement of radiation using UAS. Emil will not be funded by the project.

External partners

The collaboration project UAV@LU already involves around 20 external partners (most recent list at http://uav.lu.se/partners/) who will all benefit from the conducted research. For this particular project we specifically work with external partners facilitating Testbed Ljungbyhed, as well as with partners defining the problems related to radiation measurements and Search-And-Rescue operation, namely:

Ljungbyhed Air – the consortium of actors working to establish Ljungbyhed as a state of the art-testbed for aeronautical sciences and applications.

ACR – The private company providing Air Traffic Management-services within the controlled airspaces of Ljungbyhed and Ängelholm

ESS – The accelerator facility north of Lund has a great interest in the development of autonomous applications for radiation detection and analysis.

The Swedish Maritime Administration – Currently collaborating with LU researchers on research projects studying future systems for Search-And-Rescue. A great interest in the development of autonomous agents for solving particular tasks within the SAR system and willingness to participate with members of a reference group.

The Swedish Sea Rescue Society (SSRS) – A part of the intended research consortium studying SAR operations at sea. Also interested in participating in the project with defining problem areas and design requirements for autonomous systems as members of a reference group.

Appendices

Appendix A: Budget
Appendix B: Short CV Rolf Johansson
Appendix C: Short CV Johan Bergström
Appendix D: LOI from ESS
Appendix E: LOI from Ljungbyhed Air
Appendix F: LOI from ACR
Appendix G: LOI from LFV
Appendix H: LOI from the Swedish Maritime Administration
Appendix I: LOI from the Swedish Sea Rescue Society

Appendix A: Budget

Project costs

	2021	2022	2023	2024	2025	**Total**
Salary, PhD student	216000	446000	449500	458500	234000	**1804000**
Salary , other participants	156000	319000	325000	331000	169000	**1300000**
Travel and expenses	20000	20000	20000			**60000**
Material and equipment	0	0	0	0	0	**0**
Direct costs	392000	785000	794500	789500	403000	**3164000**
Indirect premises costs	46256	92630	93751	93161	47554	**373352**
Indirect costs	66640	133450	135065	134215	68510	**537880**
Total cost	**504896**	**1011080**	**1023316**	**1016876**	**519064**	**4075232**

Budget justification

The staff costs funded within this proposal accounts for one full-time graduate student in the discipline of automatic control employed at the Lund University School of Aviation. The PhD student is funded 80% by the project. Other participants funded by the project includes the main applicants (Johansson: 5%, Bergström: 5%), supervision (Johansson/Robertsson, 10%) and a 10% resource from the UAS Lab (Tyllström). Equipment for the project will be funded through the LTH research infrastructure UAS@LU and testing of equipment (hopefully) funded through an extension of the collaboration project UAS@LU.

Additional financing

As explained above, the project will receive co-finacing from other ongoing projects or activities at LU; mainly LTH funding through UAS@LU infrastructure equipment (funded with 375000 per year by LTH), and 20% time from the LTH funded research engineer working for the UAS Lab.

CURRICULUM VITAE

PROF. ROLF JOHANSSON, M.D., PH.D., IEEE FELLOW, LUND UNIVERSITY

EDUCATION:

University exams: Master of Science in Physics, Lund Institute of Technology, Lund University, Technical Physics, 1977; Bachelor of Medicine, Lund University, 1980; Doctorate (Ph.D) in Control theory, 1983 (Title: *Multivariable Adaptive Control)*, Doctor of Medicine (M.D.), Lund University, 1986. *Other education:* Military education: Defence Language School, Uppsala; Russian language (40 cr.); Political Science (40 cr.); Private pilot license 1977; *Qualifications:* Docent, January 1985; Assoc Professor 1986; Full Professor, Control Science, May 1999.

PROFESSIONAL EXPERIENCE:

POSITIONS: Environmental investigator, 1973-74, Osby County, Public Health Board; Electronics maintenance engineer, 1979 Dept. of Clinical Physiology, Lund Univ. Hospital; Teaching Assistant, 1979-1980 (part time), Dept. of Mathematical Statistics, Lund University; Teaching Assistant, 1976-77, 1978-80 (part time), Div. Automata Theory; Teaching Assistant, Research Assistant, Assistant Professor, 1979-1985, Dept. Automatic Control, Lund Institute of Technology; Docent, 1985, Uppsala University; Postdoctoral Researcher (*Chercheur*), 1985, Centre National de la Recherche Scientifique (CNRS), Grenoble, France; Associate Professor, 1 January 1986; Professor, Control Science, Lund University, 1999—Dept. of Automatic Control, Lund Institute of Technology, Lund University; Visiting scientist CalTech, Pasadena, CA, June 1997, June 2001; Rice Univ., Houston, TX, May 1998, May 2001; Supélec, Paris, France, June 1998; Univ. Illinois at Urbana-Champaign, 1999; UC Santa Barbara, Aug. 1999; Univ. Napoli Fed II, Politecnico Milano, July 2000; Norwegian Univ. Science & Technology, Trondheim, August 2001; Univ. Colorado at Boulder, June 2002; Univ. Newcastle, Australia, July 2003; Tsinghua Univ., Beijing, China, Nov. 2003, Aug. 2004; University of California at Berkeley, April 2004; Universidad de Jaén, Spain, July 2005; Supélec, Gif-sur-Yvette, France 2007; SIMTech Fellow, A*Star, Singapore, 2010-2011, 2013; Tsinghua Univ., Beijing, Sep-Dec 2012.

RESEARCH: System identification, adaptive and learning systems, nonlinear systems, algebraic system theory, multivariable system theory, robotics, biomathematics, medical statistics, mathematical modeling.

LEADERSHIP IN RESEARCH & EDUCATION: Development of new regular graduate courses FRT040 System Identification and FRT075 Nonlinear Control. Postgraduate courses in system identification, optimal control, adaptive control; Vestibular Lab, ENT, Lund Univ.; Thesis advisor of 30 Ph.D:s and 230 M.Sc. and current thesis advisor of 3 PhD students; Postdocs: A. Herreros, R. Lenain, Cho Jang Ho, P. J. From; Member of competence centers KCPP, LCCC, eLLIIT; Director LU Robotics Laboratory 1992—.

BOARD ACTIVITIES AND OTHER ASSIGNMENTS:

Faculty representative in the Board of studies for Technical Physics, Electrical Engineering, and Computer Science, 1986-1993; Director of Studies, Control theory, 1986-96; Chairman of mathematics curricula for computer science major, Lund Inst. Technology during 1989-1990; External examiner in dissertations for doctorate and licentiate degrees; Associate editor of IEEE CDC&ACC Conf. Editorial Board 1997-2000; Assoc. Ed. *Int. J. Adaptive Control & Signal Processing*, 1999—; IEEE TCST Outstanding Paper Prize Committee 2003. Editor *Mathematical Biosciences*, 2013—; Editorial Board Member *Robotics and Biomimetics*; Editorial Board Member *Intelligent Service Robotics.*

AWARDS AND HONORS:

``Innovation Cup 88", 1988; Included in *Who's Who in the World*, 12th ed., 1994, p. 679; *Who's Who in Science and Engineering*, 3rd Ed., p. 479; *Who's Who in Medicine*, 2nd Ed., p. 414; Recipient of the Biomedical Engineering Prize (*Ebeling Prize*) of the Swedish Soc. Medicine, 1995; Hon.Visiting Professor, NCUST, Taiyuan, Shanxi, China, 2003; Russell S. Springer Visiting Professor 2004, UC Berkeley, Berkeley, CA; Hon.Visiting Professor, WUST, Wuhan, Hubei, China, 2003; Euron Technology Transfer Award 2004, 2007; Fellow Royal Phys. Society 2007; ICRA2012 Best Automation Paper Award; IEEE Fellow, Citation: *For contributions to system identification and adaptive control*;

PUBLICATIONS:

More than 430 published papers and conference papers and the book Johansson, R. (1993): *System Modeling and Identification*, Prentice Hall, Englewood Cliffs, NJ, USA, ISBN 0-13-482308-7 (hard cover), ISBN 0-13-145889-2 (soft cover)—research monograph; R. Johansson & A.Rantzer (Eds.), *Nonlinear and Hybrid Systems in Automotive Control*, Springer-Verlag, London, 2003, ISBN 1-85233-652-8. Bibliometric H-index 55.

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Short CV, Dr. Johan Bergström

Academic appointments

2019-07	Head of Department and Accountable Manager, Lund University School of Aviation
2014-	Senior Lecturer, Lund University, Lund, Sweden
2014-2016	Director, Lund University Centre for Societal Resilience
2013-2014	Assistant Professor, Lund University, Lund, Sweden
2013-2015	Affiliated researcher, Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS), Porto Alegre, Brazil
2013	Visiting researcher, Griffith University, Brisbane, Australia
2008-2012	PhD Student, Lund University, Lund, Sweden

Non-academic appointments

2013-	Owner and CEO at JB Safety Education and Consulting AB (part time)
2010-2012	Freelance lecturer and course developer
2008	Trainee, ÅF (part time)
2005	Trainee at the fire rescue service, Strängnäs

Higher education

2016	Reader in Risk and Safety, Lund University
2012	Doctor of Philosophy in Risk and Safety, Lund University, Lund, Sweden
2007	Master of Science in Risk Management Engineering, Lund University, Lund, Sweden
2007	Bachelor of Science in Fire Protection Engineering, Lund University, Lund, Sweden

Course responsibilities

The New View of Human Factors and Systems Safety; 7,5 ECTS
The sociology of accidents, 7,5 ECTS
Accountability and learning from accidents, 7,5 ECTS
Methods in Safety Science, 15 ECTS
MSc thesis in Human Factors and Systems Safety, 15 ECTS

Research projects

Riskanalys av konsekvenser av att tillgängliggöra luftrummet för drönare
Bergström, J.
Swedish Transport Agency : SEK250,000.00
2018/07/09 → 2018/12/31
Award date: 2018/08/16

Resiliens vid bearbetning av fem informationskällor (RE5)
Bergström, J.
Luftfartsverket (LFV): SEK350,000.00
2017/11/01 → 2017/12/30
Award date: 2017/11/01

CenCIP - Centre for Critical Infrastructure Protection Research
Tehler, H., Norrman, A., Hassel, H., Bergström, J. & Falkheimer, J.
Swedish Civil Contingencies Agency (MSB): SEK18,500,000.00
2015/09/01 → 2020/09/01
Award date: 2015/09/01

Innovation för internationella katastrofinsatser. Utveckling av hållbara produkter, tjänster och processer.
Bergström, J.
Swedish Government Agency for Innovation Systems (Vinnova): SEK40,000.00
2015/01/01 → 2016/12/31
Award date: 2015/01/01

Perspective on capacity development - Center for Societal Resilience
Bergström, J.
Swedish Armed Forces : SEK2,232,000.00
2014/01/01 → 2016/12/31
Award date: 2014/01/01

Försvarsmakten - Överenskommelse avseende forskning vid CSR
Bergström, J.
Swedish Armed Forces : SEK3,000,000.00
2013/10/01 → 2016/06/30
Award date: 2013/10/01

Postdoktoralt stöd för Johan Bergström. Samhällelig Resiliens: en internationell diskursanalys
Bergström, J.
Swedish Civil Contingencies Agency (MSB): SEK1,268,455.00
2013/03/30 → 2015/03/30
Award date: 2013/03/30

Decision-making during obstetric emergencies
Raoust, G., Hansson, S., Bergström, J. & Amer-Wåhlin, I.

Riskanalys av konsekvenser av att tillgängliggöra luftrummet för drönare
Bergström, J.
Swedish Transport Agency
2018/07/09 → 2018/12/31

UAV@LUND: The future of drones: technologies, applications, risks and ethics
Bergström, J., Dell'Unto, N., Eklundh, L., Johansson, R., Revstedt, J. & Lindemann, J.
2018/04/01 → 2021/03/3

Work and Organization in the Digital Age
Schaefer, S., Andersson, M., Bjarnason, E., Hansson, K., Sikström, S., Rosengren, C., Bergström, J., Nilsson, C., Nilsson, L. & Aili, C.
2016/09/15 → 2017/05/18

Dr. Sigrid Kozielski

Group leader for Radiation Protection

Environment Safety and Health division

Letter of Intent

ESS has the intention to act as an external partner for the collaboration project UAS@LU and the proposed research project UAS@LU Autonomous flight at Lund University.

ESS expresses an intention to engage actively in the project which aims to establish an interdisciplinary research platform for autonomous flight missions.

ESS will contribute to the project with expertise and project activities, such as assisting with planning and performing flights outside or inside the ESS facility and with the evaluation of results.

Lund, 13th April 2021

Sigrid Kozielski

European Spallation Source ERIC
Visiting address: ESS, Odarslövsvägen 113
P.O. Box 176
SE-221 00 Lund
SWEDEN
www.ess.eu

Letter of Intent

Parties;

Ljungbyhed Air

Lunds University

Whereas;

Ljungbyhed Air has the intention to continue to act as a partner to the research collaboration the Future of Drones: Technologies, Applications, Risks and Ethics, at Lund University.

As the association working to develop Ljungbyhed airport (a testbed in the project), Ljungbyhed Air expresses an intention to engage actively in the project which aims at establishing an interdisciplinary platform for the development and application of autonomous drone systems for a variety of societal sectors. Within the platform, the aim is to bring together technology development (e.g. robotics, AI, image processing), research applications (e.g. remote sensing and the study of cultural heritage), and applications in different societal sectors (e.g. forestry, agriculture, energy, construction, rescue operations) to make them inform each other in a collaborative learning environment.

Ljungbyhed Air has a great interest in establishing Ljungbyhed Airport as a centre for innovation and development of drone technology and sees this collaboration project as an important part of this work. In particular Ljungbyhed Air will work to facilitate all uses of the airport and its airspace for testing of technologies and applications on commercial terms. Ljungbyhed Air will also work to expand the network of partners for the project given its vast network in the field of Swedish aviation. Ljungbyhed Air will be happy to continue to organize, and participate in, workshops and symposiums on the site of Ljungbyhed Airport – just as we have done over the last three years.

yours sincerely

Ljungbyhed Air

Gustav Eriksson

Lunds Universitet

Johan Bergström

ACR has the intention to continue to act as a partner to the research collaboration the Future of Drones: Technologies, Applications, Risks and Ethics, at Lund University.

As the provider of air traffic management services at the Ljungbyhed airport (a testbed in the project), ACR expresses and intention to engage actively in the project which aims at establishing an interdisciplinary platform for the development and application of autonomous drone systems for a variety of societal sectors. Within the platform, the aim is to bring together technology development (e.g. robotics, AI, image processing), research applications (e.g. remote sensing and the study of cultural heritage), and applications in different societal sectors (e.g. forestry, agriculture, energy, construction, rescue operations) to make them inform each other in a collaborative learning environment.

ACR has a great interest in how to let drones coexist with manned air traffic in the Swedish airspace. In particular ACR participate in experiments related to the air traffic control of drones in the Ljungbyhed/Ängelholm airspace. ACR will also continue to function as an informant regarding the risks currently in focus when it comes to drone traffic in Swedish airspace. ACR is also invited to participate in other activities within the research project and will be happy to do so.

yours sincerely

OSLO, 29.3.2021

Norrköping 2021 04 15

LFV has the intention to continue to support the research collaboration the Future of Drones: Technologies, Applications, Risks and Ethics, at Lund University.

As the largest Swedish provider of air traffic management-services, LFV has the knowledge for airspace management and future operational concepts (including UTM). LFV is already involved in various interdisciplinary projects, however a weak area for many of these are the lack of safety and risk assessment methodologies related to this disruptive technology. This area is of high relevance for the actors involved and an implicit requirement from society and the new regulatory frameworks.

LFV is motivated to continue its collaboration with Lund University in the development of risk assessment methods comprising novel concepts and technology as manifested within autonomous systems.

yours sincerely

Billy Josefsson
Manager Automation & Human Performance
LFV Research & Innovation , System Development
+46 7080 192331

SJÖFARTSVERKET

Göteborg, 13 april 2021

Samverkansprojektet the Future of Drones: Technologies, Applications, Risks and Ethics

LETTER OF INTENT

Sjöfartsverket avser att gå in som referens i samverkansprojektet the Future of Drones: Technologies, Applications, Risks and Ethics, at Lund University (UAV@LU), samt eventuellt forskningsprojekt sprunget ur ovan nämnda samverkansprojekt.

Sjöfartsverket ser samverkan med Lunds universitet som strategiskt viktig och vi kan bidra till samverkan och forskning på olika sätt. Vi befinner oss nu i en gemensam process med forskare vid Trafikflyghögskolan där vi ansöker om forskningsmedel för att studera utformningen av framtida, mer autonoma, system för så kallad Sök och Räddning (SAR). Detta skulle bli ett samverkansprojekt i vilket LUs forskare leder en bakgrundsstudie, samt det arbetspaket som gäller utformning av prototyp och test i olika typer av miljöer. Sjöfartsverket har ursprungligen lyft problemformuleringen samt agerar som en nod i det nätverk av samverkansaktörer som projektet utgör.

Kopplingen till LU ger oss också tillgång till testbädden Ljungbyhed vilken vi ser som en viktig del i att testa och utvärdera föreslagna system i ett kontrollerat luftrum.

Sjöfartsverket kan också bidra med fallstudier till eventuella forskningsprojekt för framtagande och test av autonoma flygsystem; exempelvis inom området SAR. Vi deltar gärna i referensgrupper och motsvarande till projekt som berör dessa områden utifrån Sjöfartsverkets tid och möjlighet.

Vänliga hälsningar,

Mattias Hyllert

Direktör, Sjö- och Flygräddning

Sjöfartsverket

SJÖRÄDDNINGS SÄLLSKAPET

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WWW.SSRS.SE

Letter of Intent

Sjöräddningssällskapet, SSRS, has the intention to act as an external partner for the collaboration project UAV@LU Autonomous Flight at Lund University.

SSRS expresses an intention to engage actively in the project which aims to establish an interdisciplinary research platform for autonomous flight missions.

SSSR will contribute with needs, use cases, expertise and if applicable access to infrastructure such as rescue stations, rescue boats, etc. to the project and project activities.

Göteborg, 2021-04-14

Signature

Fredrik Falkman
Innovation, Sjöräddningssällskapet