University of Maribor

FRAMEWORK PROGRAMME OF EARLY STAGE RESEARCHER TRAINING[1]

1. BASIC DATA

Mentor's name and surname	**Iztok Kramberger**	Mentor's register number at ARIS (SICRIS):	**18590**
Mentor's e-mail:	iztok.kramberger@um.si	Mentor's tel. no.:	02 220 7178
Research programme (RP) leader's name and surname:	Zdravko Kačič	RP leader's register number at ARIS (SICRIS):	06821
Title of research programme:	Advanced methods of interaction in telecommunication	RP's Register number at ARIS (SICRIS):	P2-0069
Research organisation (RO) of University of Maribor, where training shall be conducted:	Faculty of Electrical Engineering and Computer Science	RO Register number at ARIS (SICRIS):	0796
Research field according to ARIS classification:	2.09.02	Research field according to EURAXESS classification	Engineering and Technology

2. DEFINITION OF RESEARCH PROBLEM AND GOALS OF DOCTORAL RESEARCH[2]

Starting point of research task of the early stage researcher and its position in the research programme, where the mentor is included, work hypothesis, research goals and foreseen result with emphasis on an original contribution to science:

The research addresses the use of highly-miniaturized, ultra-low-power imaging systems to enable full visual awareness of spacecraft and their application to attitude and orbit determination. In recent years, satellites have increasingly been deployed in orbital regimes where traditional navigation sources, such as GNSS and conventional inertial sensors, are limited, degraded, or unavailable, including MEO, GEO, and deep-space missions. Nevertheless, most existing attitude and orbit determination systems still rely on combinations of specialized sensors, increasing system complexity, power consumption, and vulnerability.

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[1] *Term early stage researcher (ESR) is written in male form and used as neutral for women and men.*

[2] *Research and study programme of training have to harmonise with contents of the research programme, where the mentor is a member.*

Recent advances in imaging sensors with miniature apertures enable continuous environmental imaging, including direct observation of the Sun without damage to the sensor. In this context, the so-called "black Sun effect" provides a novel mechanism for precise Sun vector estimation and angular velocity measurement based solely on image data. However, the systematic use of such imaging systems for autonomous spacecraft navigation has not yet been thoroughly investigated, particularly with respect to achievable accuracy, robustness, and comparison with conventional navigation approaches.
The research is positioned within the broader context of autonomous spacecraft navigation and builds upon ongoing research activities at the University of Maribor and the industrial-research ecosystem of SkyLabs. It is closely linked to the development of miniaturized European attitude determination and control systems (eADCS) and directly addresses the strategic objectives of the European Space Agency in autonomy, miniaturization, and reliable spacecraft systems.

The research will be divided into three interrelated yet conceptually independent parts:
(A) Experimental investigation of visual awareness in realistic orbital conditions.
This part focuses on the behavior of ultra-miniaturized imaging sensors under different orbital geometries and illumination conditions, with particular emphasis on full-view imaging, Sun detection, and the identification of limitations arising from sensor miniaturization.
(B) Investigation of visual navigation methods in a controlled laboratory environment.
Laboratory experiments will be used to develop and validate methods for Sun vector estimation, angular velocity estimation, coarse attitude estimation, and coarse position estimation based on image data. This enables isolation of individual effects, repeatability, and robustness analysis of the algorithms.
(C) Analysis, modeling, and development of theoretical tools for visual navigation.
This part addresses mathematical modeling of imaging processes, error analysis, data fusion, and assessment of achievable accuracy of visual-based attitude and orbit determination compared to conventional navigation methods.

Working hypotheses
(H1) Ultra-miniaturized imaging systems enable reliable estimation of the Sun vector and spacecraft angular velocity using full-view image data, even under direct Sun observation conditions.
(H2) Visual-based navigation approaches enable coarse attitude and position estimation with accuracy comparable to or complementary to conventional navigation sensors, while simultaneously reducing size, weight and power (SWaP) and increasing system redundancy.

Research objectives
The objectives of the research are to develop a comprehensive experimental and analytical framework for spacecraft visual awareness, to define the applicability limits of ultra-miniaturized imaging systems for autonomous navigation, to develop and evaluate image-based attitude and orbit determination algorithms, to establish error models and reliability criteria, and to contribute to new concepts for autonomous navigation of small satellites.

The expected results include the development and validation of visual-based navigation methods, the establishment of experimental and simulation environments, and the formulation of mathematical models for accuracy and reliability assessment. The original contribution of the research lies in the holistic treatment of visual awareness as a primary or complementary navigation source, enabling new approaches to autonomous spacecraft navigation in challenging orbital environments.

3. STUDY PROGRAMME

Foreseen study programme, to which early stage researcher shall be enrolled in academic year 2026/2027:

The training of the young researcher will be organized in accordance with the doctoral study programme Electrical Engineering at the Doctoral School of the Faculty of Electrical Engineering and Computer Science, University of Maribor. Detailed program can be seen at: https://feri.um.si/studij/programi/tretja-stopnja/dr/e/

During the first year, the early-stage researcher will complete the curricular requirements of the first year of the doctoral programme, including compulsory and elective courses and seminar assignments, providing advanced knowledge in electrical engineering, signal processing, sensor systems, and research methodology. In parallel, the researcher will be integrated into the ongoing research activities of the research group and into research activities carried out within a project »Attitude and Orbit Determination based on Visual Awareness« funded by the European Space Agency (ESA). This phase will focus on preliminary research in the selected research area, an in-depth review of the scientific literature, identification of key research challenges, and the preparation of initial scientific publications of a review nature.

In the second year, the researcher will complete the curricular requirements of the second year, with an emphasis on elective courses, seminar work, and individual research activities. During this period, the research problem and working hypotheses will be precisely defined, and intensive research work will be undertaken. Research results will be disseminated through original scientific papers submitted to peer-reviewed international journals and conferences. Research activities will continue within the ESA project, which will serve as a relevant experimental and application-oriented environment for the validation of research methods. In addition, the researcher will present research results at national and international scientific events and actively establish professional and research collaborations.

In the third year, the early-stage researcher will complete all remaining study obligations and prepare the doctoral dissertation proposal. Research activities will focus on consolidating the achieved results, performing in-depth analysis of the research hypotheses, and structuring the doctoral thesis as a coherent scientific contribution.

The fourth year will be dedicated to the final validation of the scientific hypotheses, confirmation of the dissertation's eligibility, preparation and submission of the doctoral dissertation, and its public defense. During this period, the researcher will further strengthen international research collaborations and continue the dissemination of research results.

4. DESCRIPTION OF WORK AND TASKS

The tasks are derived from the description of the work program from point 3.

5. REQUESTED LEVEL OF EDUCATION

Level VII (7) – Master's degree, second-cycle Bologna qualification

6. REQUESTED FIELD OF EDUCATION

Electronics

7. KLASIUS SRV

17003 – Master's level education (Second-cycle Bologna qualification)

8. KLASIUS P

0714 – Electronics and Automation

9. REQUESTED KNOWLEDGE

Knowledge of electronics and signal processing

10. REQUESTED SPECIAL REQUIREMENTS

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11. REQUESTED LANGUAGES

English, Slovene

12. REQUESTED WORK EXPERIENCE

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13. FORESEEN POSTDOCTORAL TRAINING

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Mentor's signature:

Iztok Kramberger Digitalno podpisal Iztok Kramberger Datum: 2026.02.05 11:20:43 +01'00'

Research programme leader's signature:

Digitalno podpisal ZDRAVKO KAČIČ Datum: 2026.02.05 14:11:57 +01'00'

Name and surname of Dean or authorised person[3]:
red. prof. dr. Gorazd Štumberger

Signature of dean or authorised person:

Gorazd Štumberger Digitalno podpisal Gorazd Štumberger Datum: 2026.02.06 08:22:31 +01'00'

Barbara Ojsteršek

[3] The training program is signed by the dean of the member where the ESR's employment and training will take place.

Place and date:

Kliknite ali tapnite tukaj, če želite vnesti besedilo.

Kliknite ali tapnite tukaj, če želite vnesti datum.

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