UNIVERSITY
OF OSLO

Centre for Space Sensors and Systems – CENSSS

# Annual Report 2022

Norwegian Centre
for Research-based
Innovation

# CENSSS
# Annual report 2022

**Contact**
Centre for Space Sensors and Systems
Gunnar Randers vei 19
2007 Kjeller
Norway

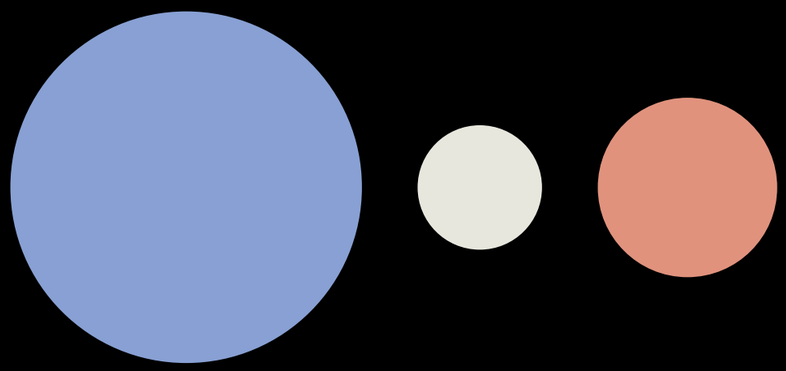
P.O box 70
2027 Kjeller

**mn.uio.no/censss**

# Contents

# Centre for Space Sensors and Systems CENSSS

CENSSS will address science and technology challenges and business opportunities within New-Space satellites for Earth Observation and within Space Exploration “to the Moon and Mars”.



# Presentation of CENSSS

CENSSS will in collaboration with Norwegian industry develop new instruments and sensor systems, New-Space satellites system integration, operation and exploitation of satellite data.

The centre aims to advance the knowledge frontiers in novel sensors for small Earth Observation satellites, as well as novel sensors for planetary resource mapping and exploitation.

CENSSS will operate the RIMFAX Ground Penetrating radar Instrument on the NASA Perseverance rover mission to the planet Mars. This includes commanding the instrument on the rover and analyzing the scientific data collected by RIMFAX.

# From the Centre Management

I would like to thank everyone who contributed to the development of our activities in CENSSS during 2022. CENSSS is slowly growing in number of positions and activities. We are still looking to increase the workforce and are looking for more colleagues.

CENSSS has arranged a number of workshops and gatherings in 2022, and among them was the National Micro Satellite Conference. CENSSS arranged a workshop and tutorial on the excellent TruePLM software that is particular useful when developing complex space projects.

CENSSS has started the work on CENSSAT-1, that will be the first CENSSS satellite in orbit around Earth. We have sent out a Request for Information and got several replies from potential suppliers of satellite platforms. The evaluation of the different replies is still going on, and will form the basis for a Request for Proposals in 2023. We have started the selection of payloads for CENSSAT-1 and CENSSS has several partners that are developing satellite instruments. One instrument with great success is a Langmuir probe for measuring the electron density in the atmosphere. Another instrument in development is a combined neutron and gamma spectrometer. These two instruments together will form the core payload of CENSSAT-1 and contribute to the understanding and forecasting of space weather.

CENSSS is in collaboration with partners developing a new combined neutron and gamma spectrometer for mapping ice on the moon. Both NASA and ESA are planning to increase the lunar activities and key scientific area is finding lunar ice.

The NASA rover Perseverance has now driven more than 15 km on the planet Mars since the landing in Jezero Crater in 2021. CENSSS is operating the RIMFAX Ground Penetrating Radar onboard the Perseverance rover and we have collected many kilometers of radar images of the subsurface beneath the rover. We have published the first results from the RIMFX instrument in the journal Science Advances and have several other articles accepted and in press.

CENSSS is looking forward to contribute to the development of space activities in Norway.

Svein-Erik Hamran

Centre Director CENSSS



# From the Executive Board

We have seen a marked increase in the activities over the last year. 2 Ph.D. candidates and one Post. Doc. positions were filled with highly competent people. In addition, three students from the Norwegian University of Science and Technology spent the summer analyzing data from the RIMFAX radar on Mars.

Digital twin technology was introduced in the processing of satellite data and we expect interesting results from this approach both for data processing and satellite operations.

The CENSSS lab has been used for test of both hyperspectral and infrared cameras showing the great value to have access to this facility for the center but also for the partners.

The satellite project, CENSSAT-1 is materialising, and payloads are proposed, a radiometer for measurements of ice temperatures and a combined gamma-neutron spectrometer using parts provided by IDEAS. The combined gamma and neutron spectrometer which is satellite version of the CLUGAS, presented in in this report will provide data on solar neutrons as well as on cosmic ray induced albedo neutrons. Data from this instrument can be an important complement to existing data from other sensors and missions.

A new master study program will be introduced with the first students starting in the autumn of 2023. This program is welcomed and will improve recruitment into the space sector in Norway.

The CENSSS staff has made visits to all partners during the year, this is important activity and improves communication and participation by the partners. The Norwegian Microsatellite Conference was arranged at Kjeller in May with contributions from partners and other invited speakers. The conference will be repeated in 2023.

CENSSS being a senter for research driven innovation, SFI, obviously needs to have focus both on the research and also the exploitation of results of this research. The activities in WP-1 and WP-5 have a path to commercialization using the sensors for terrestrial use

I stepping down as leader of the executive board after the general assembly in 2023 and I wish my successor the best in this position.

Gunnar Mæhlum

Leader of the Executive Board

# Short greeting from the Head of Department

Cecilie Rolstad Denby

Head of Department

CENSSS is hosted at the Department of Technology Systems (ITS), UiO, Kjeller. The cooperation between CENSSS and the department is very fruitful and inspiring. We have had several cooperative projects and activities in 2022, and some of them will be mentioned here.

Spring 2022 started with a tour to all the CENSSS partners. The CENSSS leader group and the Head of the department visited all the CENSSS partners, most of them as a physical visit. This tour was very interesting – the partners represent a wide variety both in size and R&D focus. Project ideas, plans and possibilities were discussed during these meetings.

Throughout 2022 the department have in cooperation with CENSSS established a new 2-years master program in Space systems. Plans for the study program was described and discussed amongst the scientific staff at CENSSS and ITS, and we contacted relevant institutions in Norway for feedback, such as e.g. NTNU, UiB, UiT, and NIFRO. The study program was approved by the university board in June 2022, and information about this master is now published on the UiO website. The department has hired a new associate professor in space systems, who is in charge of the new study program. We look forward to welcome our new space students in August 2023!

November 2022 CENSSS and ITS participated on the Spaceport Norway conference that for the first time was arranged in Oslo. A good start of the promotion that is necessary when establishing a new study profile. The master in space systems was presented at the conference, and we had contact with several potential students. We encourage all CENSSS partners to continue helping us with promotion of the new master in space systems!

In connection to the Spaceport Norway conference UiO/ITS hosted a reception with 100 national and international participants. This evening an agreement for cooperation between UiO and Andøya Space was signed by UiOs rector Svein Stølen and Andøya Space CEO Ketil Olsen, which is important for our ongoing space activities.

This year CENSSS has advertised and recruited several PhD students and post docs, and continued the development of the CENSSS laboratory. At ITS we have also celebrated the first RIMFAX publications on Mars geology in Science and Sciences Advances. Congratulations again to the authors! We look forward to cooperate with CENSSS on exciting acitivites in the years to come!

Credit: NASA

# Partner presentations

## Jotne EPM Technology AS

Jotne EPM Technology is a member of the Jotne group, specializing in system/product (PLM) information and Open Simulation Data Management, technologies required to successfully build your Digital Twin. Since 1990 the company has developed database solutions to handle product standards such as ISO 10303 STEP, PLCS, AIA/ASD S-Series, ECSS etc. These are open specifications with public availability used by aeronautics, space and defence related industries to manage information about complex systems. Jotne products are used by clients all over the world, including Airbus Defence and Space, Leonardo, BAE Systems, Lockheed martin, the European Space Agency and many other leading aeronautics, space and defence contractors. In addition, many high-end software vendors trust in Jotne solutions.

Recently Jotne sponsored a PhD student on the subject of Digital Twin, which a subject Jotne want to inject and continue to work with in the CENSSS activities. Space programmes are managed by large companies facing considerable integration challenges, both in-house and externally. Product components are often made in different countries, and when new factories are built, other companies may be responsible for maintaining the product in question. Using Standard Based Digital Twins based on open and publicly available specifications makes it easier to trace products and sensor information, and to integrate these in a well-arranged manner. This improves data exchange, sharing and archiving processes, cutting both time and cost, yet improving quality.

## KONGSBERG Satellite Services, (KSAT)

KONGSBERG Satellite Services, (KSAT) is a world-leading provider of ground station- and earth observation services based on optimized ground station locations and solutions for satellites in Low Earth Orbit. We have more than 50 years history in ground station services and a 20-year track record of advanced near real-time monitoring services using multiple satellites. The KSAT Global Ground Station Network consists of more than 20 stations around the world, providing unique uplink/downlink capabilities, enabling a cost-efficient, flexible, and optimized ground segment solution tailored to the specific needs of our clients. KSAT participation in CENSSS fits well with our ambition to extend our service portfolio in new and innovative technology areas, with focus on support for the emerging SmallSat/NewSpace industry. This includes efficient mission control and command services, optical space-to-ground communication, deep space communication and “Lunar” network, and generally to support a national R&D based effort to build, launch, and operate an innovative NewSpace EO satellite.

## Norsk Elektro Optikk AS

Norsk Elektro Optikk A/S (NEO) was established in 1985 as a privately-owned research-oriented company within the field of electro-optics. The founders had their scientific and technical background from the Norwegian Defence Research Establishment, at that time the leading research organization in electro optics in Norway.

The company has since its start grown to be the largest independent research and development organisation in electro optics in Norway and has in addition established itself as a manufacturer of advanced electro optical products for an international market.

The hyperspectral imaging activities at NEO started in 1995 with the HISS (Hyperspectral Imager for Small Satellites) project for ESA. The R&D activities in hyperspectral imaging have been internally funded through commercialization of the technology together with participation in several EU projects, as well as projects funded by the Ministry of Defense, the Norwegian Research Council, etc. Today, HySpex is established as an industry-leading brand for both airborne and ground-based hyperspectral imaging. HySpex sensors are renowned for their stability, flexibility and superior data quality.

The company has invested in laboratory and test equipment relevant for the activities for developing high-end hyperspectral cameras. The laboratories are equipped with instrumentation necessary for manufacturing, calibrating, testing, repairing, diagnosing and servicing hyperspectral cameras. Additionally, NEO has a climate chamber, electronics development laboratories and a mechanical workshop.

NEO is certified to the ISO 9001:2015 International quality standards.

NEO’s motivations for participating in the CENSSS:

- Product development, in order to remain at the forefront in the field of hyperspectral imaging.
- Market expansion following the “New-Space” development approach.

## Eidsvoll Electronics AS (EIDEL)

Eidsvoll Electronics AS (EIDEL) is an engineering company founded in 1966 and have delivered R&D and system design of advanced hardware and software-based solutions for space, defence and civil industries. EIDEL also has a long history of participating in scientific and environmental research in close collaboration with academia.

The company’s core technologies are within telemetry, data acquisition, encryption and remote control. Today EIDEL has 25 employees and an annual revenue of about 40 M NOK. EIDEL has developed several solutions for the space industry including sensors for Space Situational Awareness (SSA), telemetry decoders, payload integration systems and secure communication. EIDEL provides services within Assembly, Integration and Test (AIT) of space grade instruments and nano satellites within our labs and clean room facilities.

Through our heritage, competence and opportunities taken in the space segment, EIDEL has established a platform for further growth in the space market. Through our participation in CENSSS we will contribute with our knowledge in development of new capabilities and capacities to help strengthening the Norwegian Space industry.

Examples of our added value to CENSSS are contribution with our knowledge in sensors, communication, instrumentation and integration. Building new sensor capabilities and new satellite platform communication interfaces. EIDEL also has an ambition to be an AIT provider in the consortium. In addition, EIDEL will be supporting students' tasks and new proposals for thesis for both Master and PhD students, using the thesis to evaluate future employees. Finally, by participation we will have an arean for developing new partnerships within the consortium to strengthen our competitiveness on international proposals.

## The University of Oslo (UiO)

The University of Oslo (UiO) is Norway´s oldest and highest internationally ranked research-intensive university. The Faculty of Mathematics and Natural Sciences (MN) is a steward of a long-standing tradition of knowledge built on collegial values and free, independent research. The Faculty conducts research and education at a high international level and has extensive collaboration with external partners, both nationally and internationally.

The Department of technology systems (ITS) at MN was established in 2017 when UiO took over the activities of the University Graduate Centre at Kjeller (UNIK). UNIK was a foundation for collaboration between the research institutes at Kjeller and UiO and NTNU on education at the Master´s and PhD level.

UNIVERSITY OF OSLO

## Forsvarets forskningsinstitutt (FFI)

FFI is owned by the Norwegian Ministry of defence and is the prime institution responsible for defence related research and development in Norway.

Its principal mission is to carry out applications-oriented research to meet the requirements of the Armed Forces and the defence sector in general.

The Institute provides counsel on possibilities and challenges connected to the procurement and use of military equipment and develops new solutions when necessary.

FFI develops small satellite pathfinders spanning from the mission concepts through systems and payload developments to pilot demonstrations on orbit. The missions are mainly for national government purposes. Thus, we are interested in details of payload development from design through MAIT to tests in space, including operations concepts and data exploitation. Work packages 1-3 are of larger interest to us than the others, although some synergies with satellite missions could be extracted from them too.

Our missions to date have depended on platform and integration in other countries (Canada, Denmark, Lithuania). We hope to see CENSSS contributing to enable Norwegian industry to assemble small satellite systems and prepare them for launch in Norway, essentially gaining more systems competence. Our experience and knowledge are available to contribute towards that end.

We also see CENSSS as an important tool for recruiting young scientists and engineers to the Norwegian space ecosystem of companies, research institutes and academia.

FFI Forsvarets forskningsinstitutt
Norwegian Defence Research Establishment

## Integrated Detector Electronics AS (IDEAS)

Integrated Detector Electronics AS (IDEAS) develops application specific integrated circuits (ASICs) and systems for radiation detection and imaging applications. The company was founded in 1992 with a strong background in applied physics, radiation detector instrumentation and electrical engineering. The company headquarter is located in Oslo. IDEAS' products are used in industrial applications, nuclear and space science.

With more than 20 years of space heritage, our products help to miniaturize complex instruments, reduce power consumption and enable certain instrument types to be used on satellites. In addition to ASICs, we develop instrument systems for terrestrial and space applications.

With CENSSS we want to create business related to space activities based on scientific knowledge and engineering methods. We intend to use the company's existing know-how on terrestrial applications and adapt it to the space environment or applications. We will also seek to exploit the technologies and know-how developed in CENSSS for applications on earth.

With IDEAS sensing technology we will contribute to develop methods for In Situ Resource Utilization as well as infrared imaging and spectroscopy for earth observation. We are proud of being a partner in CENSSS which brings together top academic researchers and businesses in the field of space sensors. This is a great opportunity for IDEAS to contribute to innovation and value creation in Norway in this field.

ideas
Integrated Detector Electronics AS

## Vake AS

***About Vake:***
With the flick of a switch, any ship can opt-out of legacy tracking systems to perform illegal activities. To highlight this activity Vake deliver actionable maritime insights to authorities and decision-makers. Vakes ML models are trained on ship activity from millions of global satellite data points, providing holistic insight across data sources. The company's core technologies are image processing, data fusion, big data processing, cloud and Machine Learning. The commercial goal is to support our customers in making the ocean more transparent and safe.

***In CENSSS:***
Our research goal is to extract unprecedented insight from satellite data, made possible through combining automatic multi-source analysis and domain expertise. We want to share our knowledge on big data insights with the centre, and explore the boundaries of real-time delivery through on-board inference.

Through synergies and partnerships with centre participants, we will develop the next generation of smart satellite systems. We will continue to aid Master and PhD students, and strengthen the capabilities of the Norwegian space ecosystem.

***Projects in the pipeline:***
- ESA IODs (with S&T and NEO)
- User testing (with BarentsWatch)
- ESA Environmental Crimes
- Copernicus Incubation

VAKE

## Science and Technology AS

Our business is Earth Observation within the fields of Scientific Data Processing and Intelligent Software Applications.

**s[&]t vision**
Improving quality of life with satellite data

**s[&]t mission**
s[&]t provides software and processors for new satellites to the European Space Agency and the Norwegian Ecosystem for SmallSATs.

s[&]t process and analyse satellite images for monitoring the environment, applying advanced machine learning.

**What is our business?**
s[&]t works solely within Earth Observation (EO) with a focus on SW solutions for applying satellite data to monitor environmental states and changes.

**We work "full circle";**
on-ground satellite systems - instrument data simulation and processors for instrument development, operations and data handling

on-board satellite systems - satellite instrument processors filtering out useful data, pre-process data (image equalization, clouds, land cover …), compress and downlink to Earth

use of satellite data - products and services - extracting useful information to provide digital maps with analysis tooling for monitoring state and changes in our natural environment

## UCLA

University of California Los Angeles (UCLA) – Earth, Planetary and Space Sciences One major collaborating research partner is the Department of Earth, Planetary and Space Sciences at University of California in Los Angeles (UCLA). UCLA's Department of Earth, Planetary, and Space Sciences is a preeminent academic center for studies of the Earth and Planets. It includes over thirty full-time faculty, sixty graduate students from around the world, and forty researchers engaged in a wide range of research extending from the center of the Earth to planetary systems surrounding other stars. The department maintains strong involvement in domestic and international space missions, including providing instruments and scientific leadership for DAWN, Artemis, Lunar Reconnaissance Orbiter, Insight, and Europa Clipper.

The proposed involvement in the Center for Innovation is consistent with the overall mission of the University of California as a center of higher learning to provide long-term societal benefits through the discovery of new knowledge, and the transmission of advanced knowledge through the training of students. The key contact point will be Professor David Paige who has a long record of accomplishment of developing planetary missions. These developments have been in collaboration with both industry and government-run facilities like Jet Propulsion Lab in Pasadena. UCLA is located close to the major New-Space companies leading the technological development. We foresee an exchange of both Post Doc's and PhD's between CENSSS and both UCLA and JPL.

## Ispace

A world where the Earth and Moon are one ecosystem.

Life on Earth in the future will not be sustainable without satellite-based space infrastructure. Communications, agriculture, transportation, finance, environmental sustainability, as well as a variety of industries will all depend on this extraterrestrial infrastructure. Furthermore, its importance will continue to rise as technology continues to evolve with innovations such as IoT and self-driving vehicles.

How should we develop space infrastructure to make it sustainable and efficient? The key is how we use space resources.

At ispace, we've turned our attention to the Moon. By taking advantage of lunar water resources, we can develop the space infrastructure needed to enrich our daily lives on earth—as well as expand our living sphere into space. Also, by making the Earth and Moon one system, a new economy with space infrastructure at its core will support human life, making sustainability a reality. This result is our ultimate goal, and our search for water on the Moon is the first step to achieving that goal.

However, we face many challenges. While technology is important, it alone can't overcome every difficulty. Finance, law, policy, science, education, and environmental conservation all comprise a social system that must integrate into the planning process. Our vision has attracted the attention of many potential stakeholders around the world who we need to succeed at creating this new ecosystem.

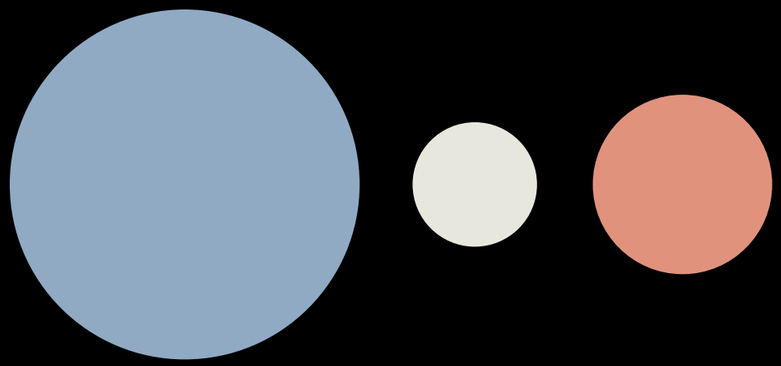
## Vestfonna Geophysical AS

Vestfonna Geophysical AS is a company owned and run by Hans E.F Amundsen.

The interest of Vestfonna Geophysical in CENSSS is centered around two main activities:

- Operating of the RIMFAX GPR on the Mars 2020 Mission
- Unsing Mars, Lunar and Terrestrial science questions as a guideline to develop instruments and technology for remote sensing of planetary bodies.

# Presentation of the projects



The research is divided in five research fields:

**1** New-Space Sensors
Led by Torbjørn Skauli at UiO

**2** New-Space Demonstrator
Led by Lars Erling Bråten at FFI

**3** New-Space Services
Led by Stian Løvold at UiO

**4** RIMFAX Science Operation Center
Led by Svein-Erik Hamran at UiO

**5** Mapping Instruments for planetary In-Situ Resource Utilization
Led by Anja Kohfeldt at IDEAS

# The Centre Management

CENSSS Centre Director

## Svein-Erik Hamran

Svein-Erik Hamran has an MSc in Technical Physics from NTNU (former NTH), Trondheim and a PhD in Physics from UiT, Tromsø. He worked for 10 years as a Research Associate at the Environmental Surveillance Programme under the Norwegian Technical Research Council - NTNF. He spent more than 20 years as a Chief Scientist at FFI where he worked on radar remote sensing techniques. He was for 10 years an Adjunct Professor in Near Surface Geophysics at the Department of Geosciences, UiO, and 6 years as an Adjunct Professor in RF-systems at the Department of Informatics. In 2017, he started as an Adjunct Professor at the Department of Technology Systems, UiO and from 2019 as a full-time professor in radar remote sensing. He is the Principal Investigator of the Radar Imager for Mars' Subsurface Experiment – RIMFAX on the NASA Perseverance Mars 2020 Rover Mission. He is Co-Principal Investigator of the WISOM GPR on the ESA ExoMars Rover Mission. He is an elected member of the Norwegian Technical Academy of Sciences.

Administrative Leader

## Marit Tronstad

Marit Tronstad has an MA in Political Science from Norwegian University of Science and Technology (NTNU) in 2010, and a Designated Degree of MA in Political Studies from the University of Aberdeen (2007). Marit has worked with higher education administration since 2010, and specifically with research administration since 2013, for The University College of Southern Trøndelag (now NTNU) and the University of Oslo.

At CENSSS she works with administrative and financial matters and works to ensure that the Centre is run in accordance with guidelines and regulations. Marit is also the Secretary for the Executive Board and the General Assembly.

Science Coordinator

## Tor Berger

Tor received the M.Sc. and Ph.D. degrees in applications of the wavelet transform in image processing from the University of Tromsø, in 1992 and 1996, respectively. Since 1996, he has been with Forsvarets forskningsinstitutt (FFI), working in different fields such as weapon effects, security sensors, and signal processing. Since 2007 Tor has been involved in radar signal processing related to ultra wideband systems and synthetic aperture radar.

Since 2014 Tor has been part of the development and delivery of the RIMFAX ground penetrating radar for the Mars 2020 mission, responsible for testing and verification and validation. Currently, Tor is the RIMFAX operations lead.

Tor still holds a part time position at FFI.



# Work Package Leaders

## Torbjørn Skauli WP1

Professor Torbjørn Skauli is the head of CENSSS work package 1. His research interests are in optics and imaging, particularly hyperspectral imaging and remote sensing. At ITS, Torbjørn teaches courses in basic optics and camera technology, and supervises research in drone-based remote sensing. Torbjørn is currently vice chair of a working group under the IEEE standards association developing a standard for technical aspects of hyperspectral imaging. Torbjørn joined ITS at the end of 2019. Earlier, Skauli worked at FFI, the Norwegian Defence Research Establishment, also at Kjeller, where he retains a part-time appointment. At FFI, Torbjørn has worked on imaging for a microsatellite development, and in the past also on semiconductor technology and electronics. Torbjørn engages in science outreach to children and youth, in volunteer networks promoting technology-related activities such as programming and amateur radio through schools and leisure activities.

## Lars Erling Bråten WP2

Lars Erling Bråten is leading WP 2 New- Space Demonstrator in the CENSSS project. He is a researcher at the Norwegian Defence Research Establishment (FFI). He is also a part time professor in radio communications at the Department of Technology Systems, UiO, teaching a course on satellite communications. At FFI he works on small satellite missions, specializing in radio communication systems. Lars Erling is currently leading the ARCSAT missions, aiming at demonstrating tactical UHF satellite communications via a CubeSat in Arctic areas. His current research interests include utilization of micro satellites for communications and improvement of system performance at various frequency ranges.

## Stian Løvold WP3

Stian Løvold has a Engineering degree in Technical Physics from NTH (now the Norwegian Institute of Science and Technology (NTNU) in Trondheim, and a PhD in physics from the University of Oslo (UiO). He worked for more than 30 years as a scientist at the Norwegian Defense Research Establishment (FFI), including 10 years as research director, with responsibilities for various project in lasers, optics and semiconductor technologies and system applications. Stian was director of the University Graduate Centre at Kjeller (UNIK) for six years until the research and education activities at UNIK were acquired by UiO in 2017. Stian was Head of Department at Departmemt of Technology Systems from 2017-2021. His current position at CENSSS is senior advisor.

## Anja Kohfeldt WP5

Anja Kohfeldt is leading WP5 - Mapping Instruments for planetary In-Situ Resource Utilization. She is the senior space project manager at Integrated Detector Electronics AS (IDEAS) and holds a part time associated professor position at the Department of Physics at University Oslo, teaching Sensor and Measurement Technology. Her background is in micro- and opto-electronics and she has been working with space payload and satellite bus development her entire professional career. Anja is interested in optical and radiation sensing payload development for several space platforms, like satellites, sounding rockets and now recently also rovers. Currently she is involved in the development of a charged particle radiation monitor, NORM – Norwegian Radiation Monitor, suitable for high-elliptical orbit satellites.

# New faces in 2022

## Lewis Williams

Lewis has a master's degree in aerospace engineering from The University of Manchester. He has worked with space mechanisms for a couple of years before joining CENSSS.

Lewis is working with deployable antennas for small satellites. The plan is to develop a novel antenna system that could potentially be used on CENSS-Sat-1. The project is being approached practically, with emphasis placed on rapid prototyping and iterating the designs.

Lewis is being supervised by Lars Erling Bråten and is working on activities within WP2 New-Space Demonstrator.

## Deniz Ölçek

Deniz is an instrumentation scientist holding a MSc degree in Astrophysics from University of Montreal, Canada and an MA in philosophy of science from METU in Turkey.

Her previous research and engineering work includes modelling the solar dynamo, long term variations of the Sun's magnetic activity and space climate as well as building large radio interferometers in Canada and South Africa for cosmological observations to study the large-scale evolution of the universe and Dark Energy. Before joining CENSSS, she worked at the McGill Cosmology Instrumentation Lab and the Dominion Radio Astrophysical Observatory in Canada.

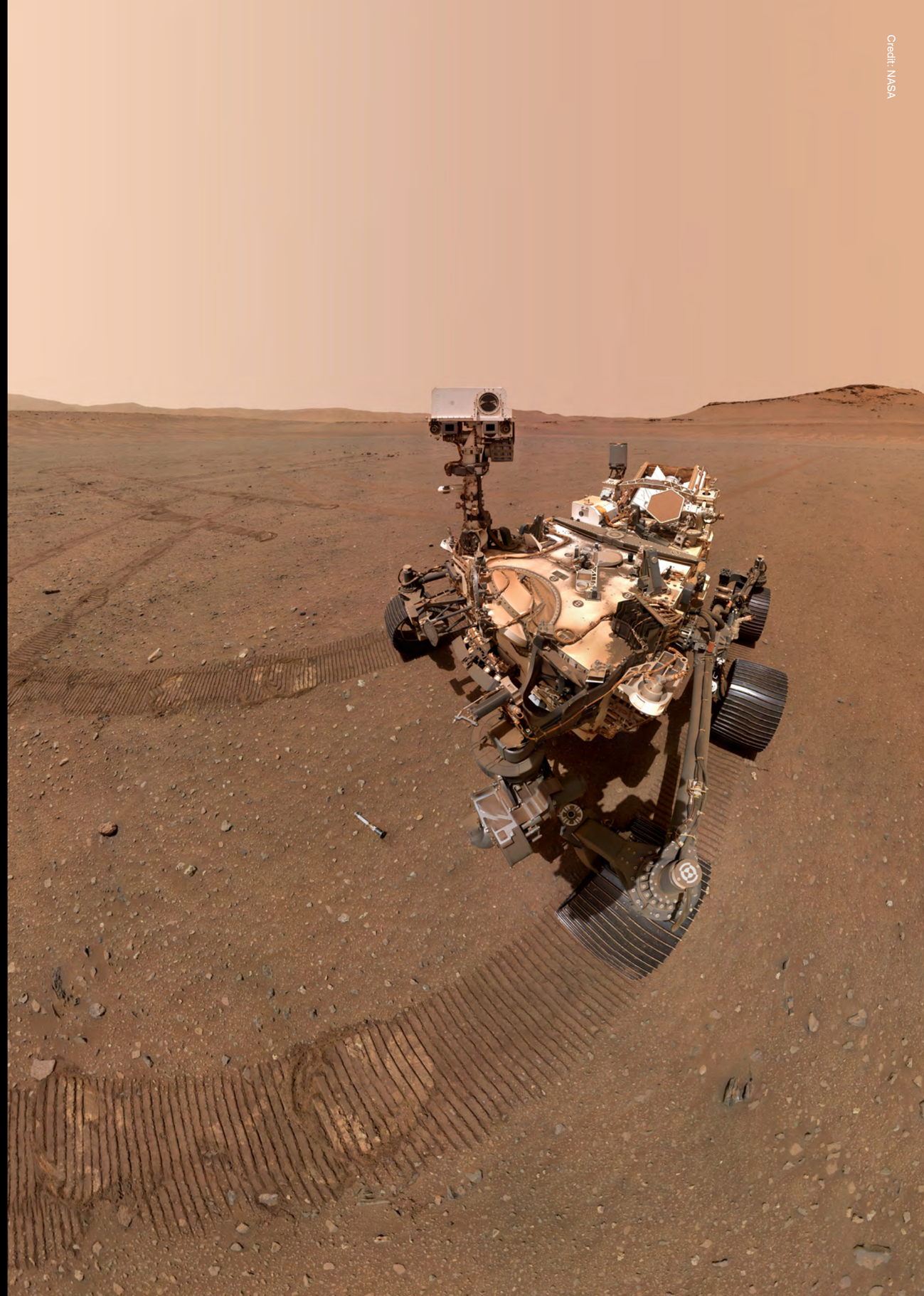
At CENSSS, she is currently working on a neutron and gamma-ray spectrometer as a part of her PhD project that can be used to identify resources in future in-orbit and rover missions on the Moon and Mars for planetary geology studies as well as the In-Situ Resource Utilization (ISRU), in collaboration with the company Integrated Detector Electronics AS (IDEAS) where she works as a systems engineer part-time

## Marco Grasso

Marco has a Master's degree in Aerospace Engineering and a PhD in Space Systems Engineering from the University of Naples Federico II, Italy.

Before joining the CENSSS team, he worked as a contract scientist in Aerospace Remote Sensing systems in the fall of 2021, and as a teaching assistant for Space Systems and Space Mission Design courses in the spring of 2022 with the Department of Industrial Engineering of the University of Naples Federico II. His research interests include advanced spacecraft modelling and simulation, design of space missions and payloads for Earth Observation, modular CubeSats, and satellite formation flying systems for distributed Synthetic Aperture Radar missions.

At CENSSS, Marco will be developing a high-fidelity Digital Twin model of a spacecraft to analyze, test, and optimize novel concepts and operational services for future Earth Observation missions based on New Space satellites. The Digital Twin can be used for various purposes as mission and platform design, digital space mission analysis, demonstration of new EO services, and design of innovative payloads.



Credit: NASA

# Summer job with developing artificial intelligence for a rover on Mars

By Berit Ellingsen

This summer three students had a very unique summer job at CENSSS. Here's what the students did and what they learned from it.

- We developed a machine learning tool for the data from the georadar RIMFAX on the Mars rover Perseverance, says Magnus Kristiansen, one of the three students.

This tool will be used for characterizing and analyzing the geological layers that RIMFAX explores on Mars on its hunt for signs of liquid water and possible life.

- CENSSS gave us access to all the data from RIMFAX, but when building a machine learning tool, it's important to first use a limited amount of data, develop the analytical processes for this subset, and then use that for expanding the machine learning algorithm to the rest of the data, Magnus Morud Vågen says, another of the three students.

The trio used data that had already been analyzed and characterized by the scientists at CENSSS, and then utilized this information to train the machine learning algorithm.

## New equipment for the job

The three students are following a five year master's degree program in computer technology at the Norwegian University for Science and Technology (NTNU). They are in the fifth year of the program and will begin their master's thesis work shortly.

- Because this program leads to a degree in computer science, we do not have the same background in physics and geology as the scientists at CENSSS. Thus, we had to learn how the RIMFAX georadar works and the accompanying physics, which was competency building, Victor Pierre Hamran says, the third of the students.

New equipment had to be acquired for the job as well.

- Machine learning algorithms are usually coded in a programming language called Python, in addition to using other kinds of framework, such as PyTorch, which is utilized by both academia and industry to set up and train neural networks and artificial intelligences, Kristiansen says.

These tools depend on powerful graphics processing units, large monitors for showing multiple windows at the same time, and high-speed internet. CENSSS therefore acquired powerful laptop computers, large monitors and other equipment that will be useful for developing more machine learning algorithms at the center in the future.




The three summer students. From the left: Magnus Kristiansen, Magnus Morud Vågen and Victor Pierre Hamran

## Relevant and useful work experience

- By spending six weeks working on machine learning every single day, developing it for specific use, and utilizing the tools commonly used for the task, we gained a lot of practical experience, hands-on problem solving skills and familiarity with important tools, Vågen says.

This will be relevant and useful for the three students' master's degree work, as well as in future jobs developing machine learning and artificial intelligence.

The three students have previously had summer jobs at the Norwegian Defense Research Establishment (FFI), where they encountered RIMFAX and the georadar's tasks on Mars for the first time.

- All three of us have an interest in space exploration and space research, so when the opportunity to work with data from a rover on Mars presented itself, we had to go for it, Hamran says.

## A rapidly growing field

The three students could envision working in the space industry after completing their master's degrees.

- Machine learning and artificial intelligence is a rapidly growing industry which we are just seeing the start of. Space is only one of the many sectors that will be using machine learning and artificial intelligence to an increasing degree, Vågen says.

Thus, the students regard their chosen field as a door opener to not only jobs in the space industry, but in sectors such as medicine, oil and gas, renewable energy and more.

The trio have yet to decide on the placement for their master's degrees, but the themes are clear already.

## Computational creativity and image processing

Both Kristiansen and Vågen wish to focus on the field of artificial intelligence development called computational creativity.

- Here, machine learning and artificial intelligence is used to generate images and artwork from text prompts and keywords, in addition to specific programming commands, says Kristiansen.

Two of the most popular artificial intelligences of this type are called Midjourney and DALL-E and have gone viral online. Both allow users to make digital art from descriptions and prompts. The artificial intelligences create the artwork from images found on the internet. The result can then be modified or enhanced by humans.

- One of the professors at NTNU is working in the field of computational creativity, and we are hoping to be able to focus on this subject in our master's thesis, Vågen says.

Hamran also aims to be working with machine learning and artificial intelligence for image processing, but in an adjacent field.

- My focus will be on what is called neural radiant fields, which allow two dimensional images to be transformed into three dimensional images. This is something for example autonomous vehicles and even future rovers in space will need to use for their image processing functions, Hamran says.

No matter what the focus of their theses will be, all three students are pleased with the experience they gained from the summer job at CENSSS.

- It felt very unique to be working with data from a georadar on Mars, and it didn't seem like a job at all, but more like exploring something you already think is very fun and interesting, then learning a lot more about it, Kristiansen finishes.

# Deep Learning for space based hyperspectral remote sensing

By Stian Løvold

In 2022, Kristoffer Langstad, our PhD candidate in WP3, started on his PhD project entitled «Deep Learning for space based hyperspectral remote sensing". Hyperspectral imaging (HSI) from space is an active area of research internationally, which is expected to have impact on resource utilization (agriculture, forestry), measurement of climate-change (greenhouse-gasses, weather, vegetation), and environmental surveillance and monitoring (coastal, land). Several of our partners are active in this area.

Special emphasis for the PhD will be on land cover classification. A target EO system is the planned Norwegian In-Orbit-Demonstrator (IOD) with a Short-Wave Infrared (SWIR) hyperspectral imager (HyperNor), funded by the European Space Agency (ESA) and the Norwegian Space Agency (NOSA). HyperNor will be built by Norsk Elektrooptikk, and Kristoffer´s main supervisor is from S&T.

In order to retrieve the true reflection properties of the earth surface using space imagery, it is necessary to correct for atmospheric effects. Atmospherics effects depend on temperature, humidity, season and local weather and illuminating conditions, among others. In imagery from ESA´s Sentinel-2 multispectral satellites, such atmospheric corrections can be done by the elaborate physics-based Sens2Cor algorithm, after the imagery has been downloaded. Kristoffers first research question is whether corrections for atmospheric effects can be learned, using deep learning (DL) technigues. If so, this could open up the possibility for faster correction algorithms on board the satellite.

The approach is to train DL algorithms to atmospheric corrected Sentinel-2 Bottom-Of-Atmosphere (L2A) images starting from Sentinel-2 Top-Of-Atmosphere (L1C) imagery. The L2A images from ESA's Sen2Coe algorithm will thus act as a the "ground truths" for training of the DL algorithm. A large number of image pairs with a wide spread of seasons and terrains from all continents have been used.

Fig. 1 shows some first attempt using a modified U-net DL architecture with skip-connections introduced by Ronneberger et al.[1] . A "top-of-atmosphere" (L1C) image taken by ESA's Sentinel 2 satellite is shown to the left and the corresponding "bottom-of-atmosphere" (L2A) image having been corrected for atmospheric effects by ESA using the Sen2Cor algorithm is shown in the middle. To the right is a result using a deep learning algorithm trained using several other pairs of Sentinel 2 L1C-L2A images.

1 Ronneberger, O., Fischer, P., and Brox, T. (2015). U-net: Convolutional networks for biomedical image segmentation. In International Conference on Medical image computing and computer-assisted intervention, pages 234–241. Springer.



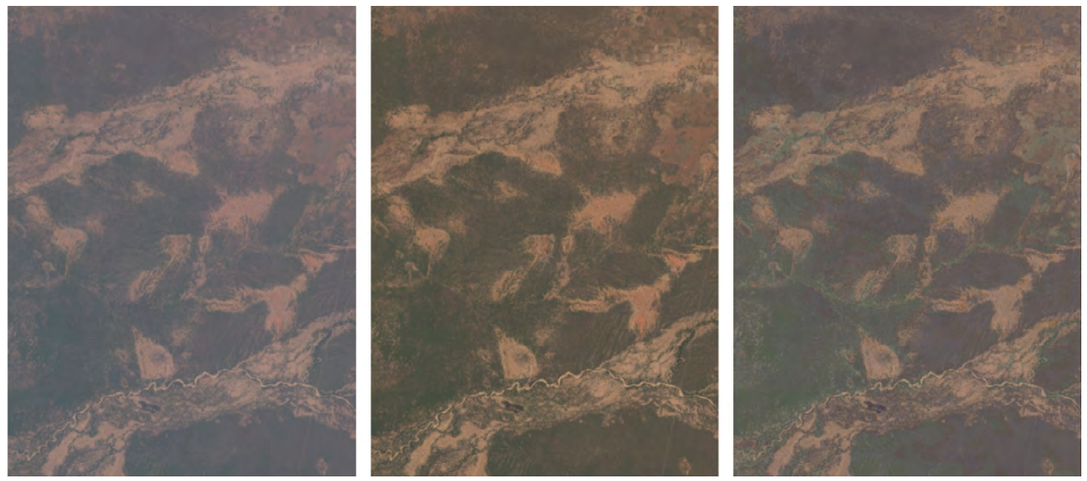


Figure 1: From left: A Sentinel 2 Top-of-atmosphere (L1C) image, the same Sen2Cor-corrected bottom-of- atm. (L2A) image, and a predicted "bottom-of-atmosphere" image obtained using a trained deep-learning model.

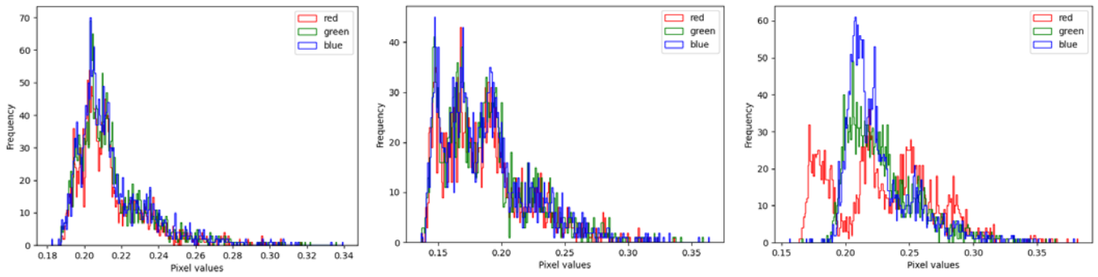



Figure 2 From the left: Histograms of pixel values in the RGB-bands for L1C, L2A and the prediction, where each band is denoted in the corresponding color.

Figure 2 shows a corresponding histogram of pixel values in the RGB-bands for L1C, L2A and the prediction.

It can be seen from both Figure 1 and 2 that there are significant differences between the physics based Sens2Cor model and the DL algorithm in these very early results. Ongoing work includes testing of different variants of the trained Unet by changing the depth of the layers, change some of the hyperparameters, use a different loss function, changing the encoder and/or decoder parts and train longer.

# End-to-End Simulation of Innovative Remote Sensing Space Systems

By Marco Grasso

Our new postdoc, Dr. Marco Grasso, from Italy, was onboarded last autumn. The main topic of his work will be “End-to-end simulation of innovative remote sensing space systems for novel Earth Observation services provided by compact satellites”. The work will encompass high-fidelity modelling and simulation of the entire satellite system and platform to obtain a one-to-one loyal virtual replica of the satellite.

The virtual satellite represents an integrated multi-domain, multi-physics digital representation of the satellite created by vertical and horizontal integration of satellite systems, subsystems, and components. The concept of Spacecraft Digital Twins will be investigated to demonstrate satellite operations and new operational services for future space missions based on compact satellites.

A schematic representation of the concept of operations describing the utilization of the digital twin is shown in Figure 2. Real data are data and information sent by the physical entity to the digital twin. These data are used to update and validate the simulation models and as inputs to the simulator for performance prediction and verification and include platform and payload data for system check status and acquisitions. *The data parsing* block oversees organizing real data into a standardized uniform format, creating a unique location for each parameter to be parsed, and extracting engineering parameters. The virtual data are the output of simulation models as a response to physical or simulated inputs. These data serve decision-making purposes, optimizing design and operations, and testing and validating components and subsystems. All these data are fused to create twin data that can be further processed. Data processing analysis can include operation monitoring, flight status visualization, data detection, data interpretation, and time series analysis. The processing serves the purpose of delivering new services by using the Digital Twin technology, such as optimization of satellite and payload operations, improvement in the execution of mission-based tasks, autonomous mission planning, and intelligent satellites. All these services are of great value for enabling the next generation of space systems based on small satellites.

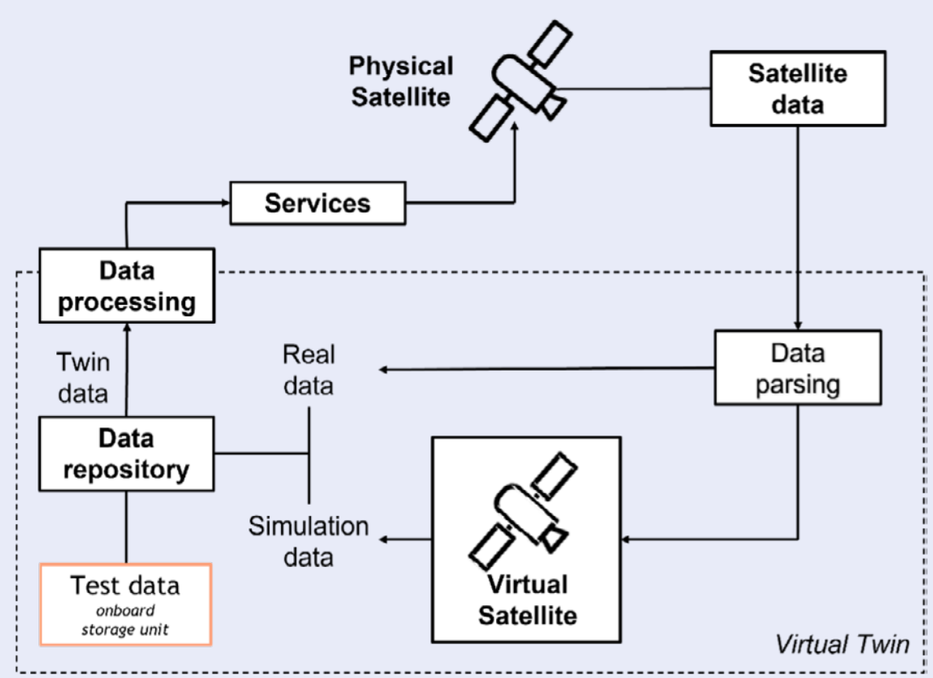


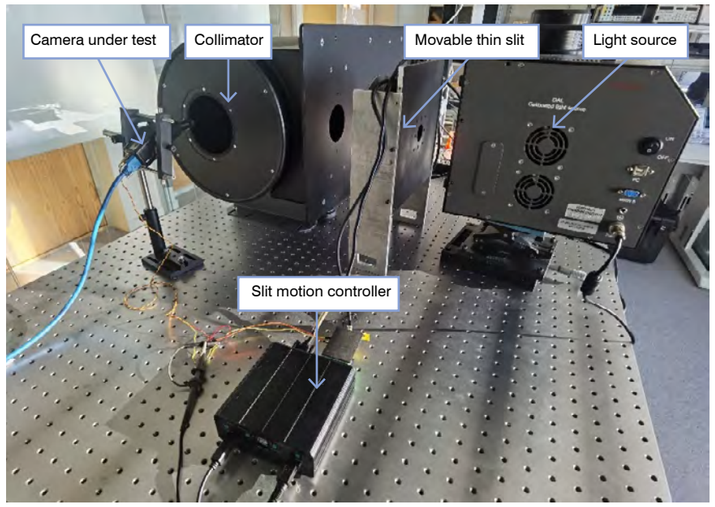

Figure: A schematic representation of the concept of operations describing the utilization of the digital twin.

# A new standard for hyperspectral imaging

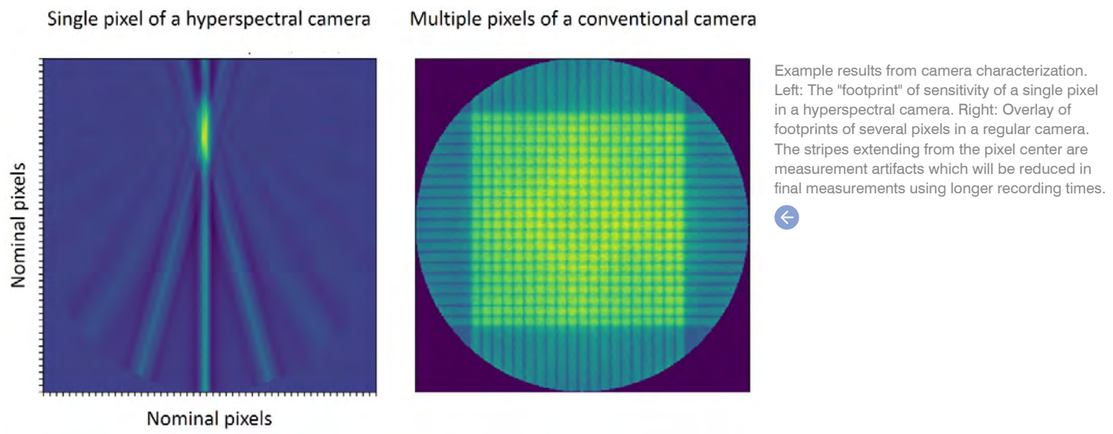
By Berit Ellingsen

There is a rapidly growing interest in hyperspectral imaging for a variety of applications, and in particular a steep growth in the interest for hyperspectral imaging from space. At the same time, it has been recognized in the hyperspectral imaging community that the current conventions for characterizing cameras does not fully cover the needs of hyperspectral imaging. In response to this, the IEEE Standards Association has created a working group, "Project 4001" or P4001, to create a new standard for hyperspectral imaging.

CENSSS participates in P4001 on different fronts: Professor Torbjørn Skauli serves as vice chair of P4001 and is actively involved in writing the standard. Also, PhD student Gard Momrak Selnesaunet is working in the CENSSS lab to set up and verify camera testing procedures that are being created or adapted for the standard. As part of this work, Gard has been assisting CENSSS partner IDEAS with testing of microbolometer-type thermal cameras. Also, Gard is collaborating with the HYPSO team at NTNU to test different generations of their hyperspectral camera design for small satellites. Not least, the work of Gard is highly relevant to CENSSS partner NEO who may adopt the measurement techniques as part of their adaptation to the new standard. The supervision team of Gard includes representatives from IDEAS and NEO.




Lab setup for camera testing. The camera under test sees a bright line of light which is being precisely scanned across its field of view. The camera here is an early version of the NTNU HYPSO camera. See text.




Example results from camera characterization. Left: The "footprint" of sensitivity of a single pixel in a hyperspectral camera. Right: Overlay of footprints of several pixels in a regular camera. The stripes extending from the pixel center are measurement artifacts which will be reduced in final measurements using longer recording times.

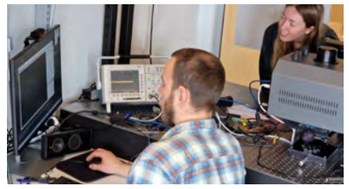
The picture here shows the setup for camera testing established in the CENSSS lab during 2022. The setup consists of a shadow mask shaped as a narrow slit, placed in front of a precisely controllable lamp. The slit can be moved and rotated precisely under computer control and presents a well-defined object to the camera under test. The collimator is essentially a telescope used in reverse, with the illuminated slit placed at its focus, and the camera under test is looking into the telescope aperture. With this arrangement, the camera sees a bright line of light appearing to be very far away, so that the camera can be tested with the same focus setting used on an actual satellite or drone.

The lab setup produces detailed information about the resoluion of cameras in the form of maps of the sensitivity distribution for each pixel. Some examples are shown in the figure above. These measurement data can be used to understand the properties of a camera in full detail, which is needed in particular for space missions. These measurements arguably advance the state of the art in resolution characterization, and it is foreseen that Gard will have opportunities to write a series of good papers based on his work.

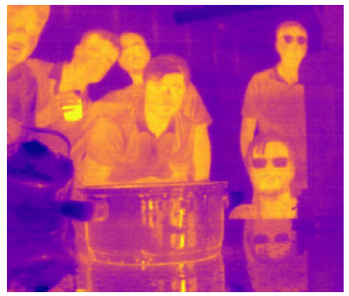
The CENSSS lab has also proved useful for testing of thermal cameras together with IDEAS. Measurements were carried out in two sessions, each over several days, where Gard and Torbjørn from CENSSS worked closely with a team from IDEAS and their collaborators to characterize the performance of prototype cameras, as illustrated in the pictures here.

## Developing concepts for a sensor suite on the CENSSS satellite

A series of meetings has taken place in CENSSS during 2022 to develop concepts for the CENSSS satellite mission - CENSSAT-1. These deliberations have had to take into account the potential scientific benefits as well as the interests and resources of CENSSS partners, and of course the budget available. Postdoc Marco Grasso and PhD student Lewis Williams have been cenral to this process. This work is still ongoing. The current plan is to fly a combination of a Langmuir ionospheric probe from EIDEL, a gamma spectrometer from IDEAS, and a commercial software defined radio for preliminary studies of passive radiometry as well as radio propagation through the ionosphere.



CENSSS PhD student Gard Momrak Selnesaunet and NTNU PhD student Marie Bøe Hentiksen working in the CENSSS lab to set up a detailed measurement of the resolution of a hyperspectral camera built by the HYPSO satellite group at NTNU.

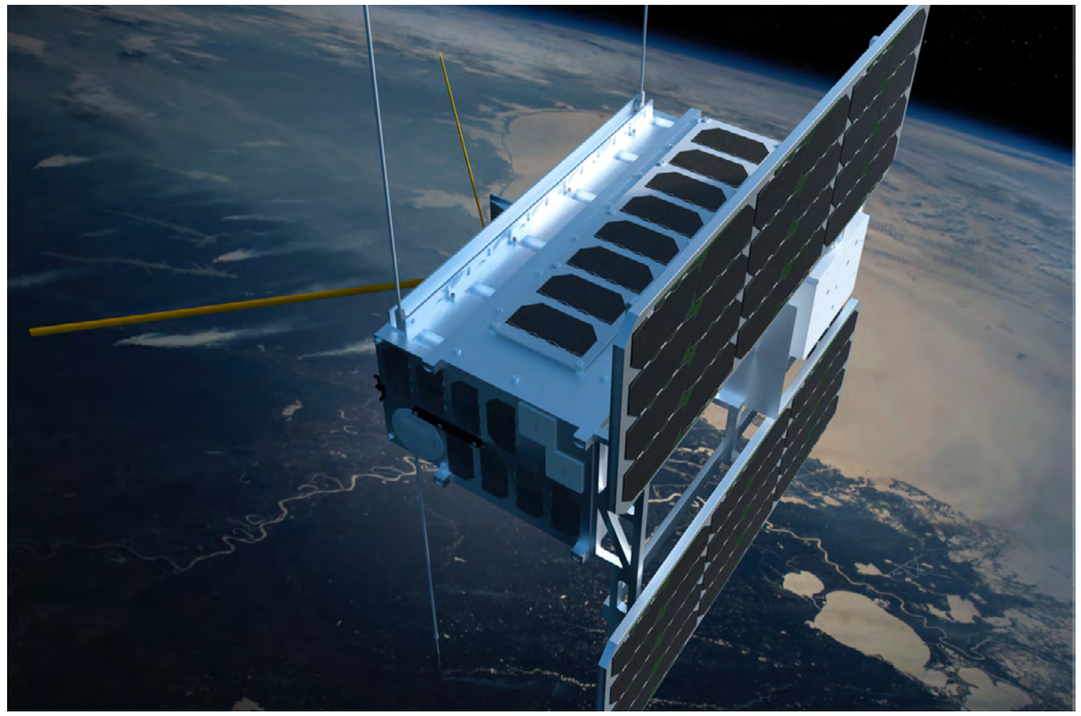


Testing of thermal cameras in collaboration with IDEAS. This image is recorded with the prototype thermal camera, which basically records an image of temperature differences. The lab team consisted of Torbjørn Skauli (ITS Professor and CENSSS WP1 leader), Nishant Malik (IDEAS Project Manager), Dirk Meier (IDEAS CTO), Gard Momrak Selnesaunet (ITS PhD candidate), Torbjørn Østmoe (IDEAS Scientist), Thomas Nesjø (IDEAS MSc candidate), Rihard Novickis (EDI Scientist).

# New-Space Demonstrator

By Berit Ellingsen





NORSat-1: 6U CubeSat with m-NLP. Credit: Trond Abrahamsen

New-Space, the new commercial space industry, aims to develop satellites and other spacecraft faster and at less cost than is typical for the conventional space industry. This is often done by using commercially available components and technology, along with streamlined development processes.

The CENSSS project CENSSAT-1 (work package 2) plan to design, integrate, test and operate a small satelloite, CENSSAT-1, in Norway, with the reduced development time and cost that characterizes the New-Space market.

The steps in the development cycle of CENSSAT-1 will be completed at the various Norwegian partners in the project, making it the first satellite to be developed and tested in its entirety in Norway.

CENSSAT-1 will be launched in 2025, possibly from the new spaceport at Andøya in Northern Norway.

## Will provide invaluable practical experience

-Designing, integrating, testing and operating a small satellite in Norway will provide invaluable experience for all our academic and the industrial partners, says Lars Erling Bråten, project manager for work package 2 at CENSSS.

He is also at the Institute for technology systems at the University of Oslo (UiO) and the Norwegian Defence Research Establishment (FFI).

Norway's current satellites have only been partly integrated domestically, and launched abroad. Keeping both integration and testing in-country will reduce developmental time as well as cost for the New-Space Demonstrator.

- The earlier in the development cycle the testing of a satellite can begin, the earlier potential problems can be discovered and solved, which improves the entire development process, Bråten says.

- We do not plan to build the entire satellite bus ourselves, but use commercially available components, integrate them, and then take the small satellite through the environmental tests necessary for all spacecraft, says Bråten.

New-Space Demonstrator will have systems for power, communication, navigation and computing, as all satellites do.

- This first fully Norwegian satellite will also carry a science payload. That will most probably be a Langmuir probe and a combined neutron and gamma spectrometer. A potential payload for CENSSAT-1 or a follow-up CENSSAT-2 is also a radiometer, developed by CENSSS for research on the polar ice caps and permafrost, Bråten says.

## Looking deeper into the ice and permafrost

The satelitte's radiometer will peer deeper into the world's ice masses and permafrost soil than any other satellite has done so far. In order to achieve this, the radiometer will use a greater wavelength than other small satellites have.

- However, a larger wavelength reqires a longer antenna, and that is challenging to find room for on a small satellite, says Lewis Raymond Williams. He is a PhD student at the Institute for technology systems at UiO and will be developing the antenna for the radiometer onboard the satellite.

Because of the limited room on such a small satellite, the New-Space Demonstrator's antenna will have to be stowed in a folded configuration during launch, and then folded out in space once it reaches the right orbit.

- Moreover, the radiometer is a passive sensor and on the large wavelengths it will be utilizing, interference from various radio sources on Earth, such as mobile phone signals, is a potential problem, Williams says.

But because the radiometer will be operating over the polar regions where there is less human activity and fewer radio sources, the interference may be less of an issue than it would elsewhere.

## Big antenna on a small satellite

Folding out complex mechanisms such as antennae in space is challenging in itself.

-In the vacuum of space there is a lot more friction between materials and mechanical parts than there is in the atmosphere on Earth. Thus, folding mechanisms that work well on the ground may fail completely in orbit, says Williams.

In addition, outgassing of particles from materials onboard the satellite may affect its instruments, as well as vibrations and other disturbances from the satellite itself.

- These challenges are usually solved by choosing the right kind of materials and methods, as well as good design. For example do the structures on a satellite need to be rigid enough to prevent vibrations, but they also have to be lightweight and small enough to be used in space, Williams says.

A small satellite to be developed, integrated, and tested in Norway CENSSAT-1.

**Advantageous hands-on experience**

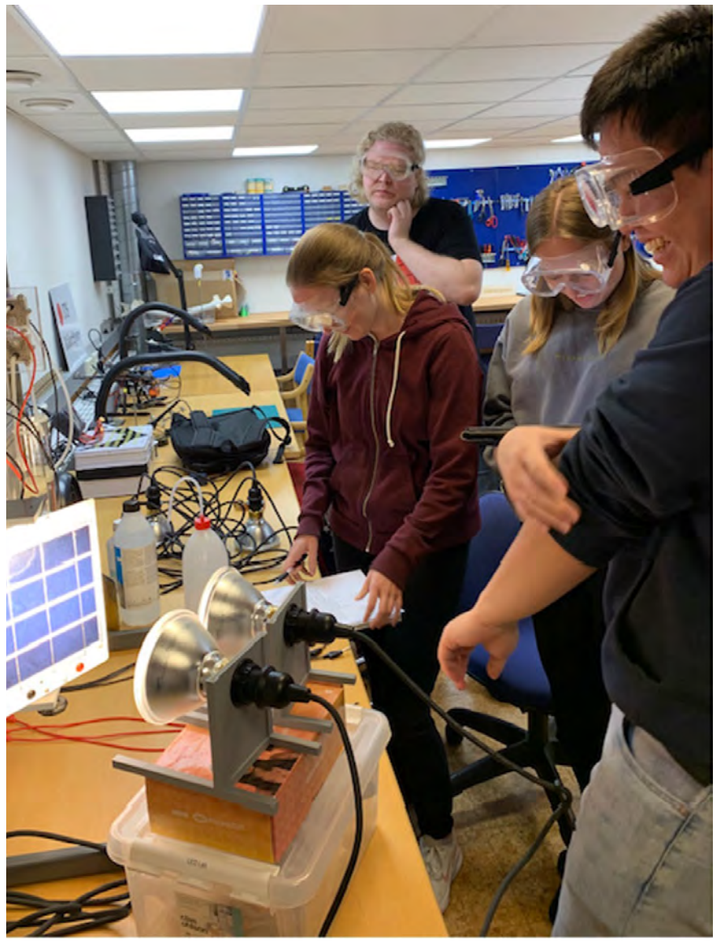
The main challenge for a small satellite such as CENSSAT-1 will nevertheless be the limited amount of room onboard the bus.

- We expect having to come up with and test several different solutions, and therefore plan on spending as much of the project time as possible on building various prototypes of the satellite and testing them. Only this way can we find out what works or not, and then improve the design until we have a solution that meets most of our needs, Williams says.

He's looking forward to working with the satellite, finding the right solutions for the design, and gaining lots of practical experience.

- In 2023 we will begin building the first prototypes and testing them, as well as publishing the results, says Williams.

His previous work experience includes building mechanisms for pointing the antenna onbord the European weather satellites MetOp Second Generation and the upcoming space telescope Plato, as well as the solar cell array pointing mechanism of the Jupiter space probe Juice.



- I've always been interested in space flight and gained a master's degree in aerospace engineering after having worked with helicopters in the British air force. After that I moved to Norway to work in space engineering with the Kongsberg Group, Williams says.

He decided to apply for the PhD position with the New-Space Demonstrator because the project suited his professional aims.

- In this project having lots of hands-on experience with building solutions for satellites and other spacecraft previously has been very advantageous, says Williams, who plans on living in Norway for a long time.

**Seeking Master's and PhD students interested in space**

- CENSSAT-1 is a collaboration between CENSSS and several partners in Norwegian research and industry, as well as between several of the work packages at CENSSS, Lars Erling Bråten says.

Work package 1 is named New-Space Sensors and will be developing the sensor instruments for the new Norwegian satellite. Work package 2 has the title New-Space Demonstrator and will be developing the satellite bus. Work package 3, called New-Space Services, will be processing and analyzing the data from the satellite after launch.

-We are looking for Master's degree and PhD students for all the work packages, so students with an interest in space and space technology are welcome to contact me or Sven-Erik Hamran, director for CENSSS, for more information about our student opportunities and research projects, says Bråten.

**A new master's program in space technology**

Bråten has also led the development of a two year long Master's degree program in space technology at the Insititute for technology systems at UiO. The new program will begin in the fall of 2023.

- Here we will be offering three new courses. The first is called Space Systems and is an introduction to space systems and their basic components for communication, navigation and research, Bråten says.

The second course is named System Development and teaches how space systems such as satellites are developed, integrated and tested.

- The third and last of our new courses is titled Sensors and Communication and will focus on these systems for satellites and other spacecraft, says Bråten.

CENSSS will contribute to both the content of the new Master's degree program and instructors for the three courses.

- Many of the elements needed for a proper space education are already in place at several universities in Norway. With the new Master's degree we have created a comprehensive program that will cover various space systems and give our students the opportunity to work with real satellites to give them as much hands-on experience as possible. That will be useful both for academic studies as well as job opportunities later on, Bråten says.

Credit: NASA/JPL-Caltech/University of Arizona

# Integrated Detector Electronics AS and CENSSS

By Berit Ellingsen

The Norwegian company Integrated Detector Electronics AS (IDEAS) has developed detectors for high energy particle and infrared radiation for many space probes and satellites, for both NASA and ESA, as well as other space organizations and commercial actors.

These detectors are used for measuring the radiation and space weather around the Earth, or the radiation in orbit around other planets and in interplanetary space in the solar system.

One example is the upcoming satellite Arctic Broadband Mission, which will provide high speed internet for both the Arctic and Antarctica. This satellite is being developed by the Norwegian military and the US military, together with various civilian and commercial partners, including Space Norway. https://spacenorway.no/home/

Arctic Broadband Mission will carry a radiation detector from IDEAS to measure protons and electrons in the satellite´s orbit, which is unusually elliptical and will provide new information about the space weather around the Earth.

## Infrared sensors for small satellittes

IDEAS are cooperating with the CENSSS in two different work packets, number 1 and number 5.

- In work packet 1, which focuses on sensors for the NewSpace market, we´re cooperating with professor Torbjørn Skauli and his PhD student and their lab, says Gunnar Mæhlum, CEO of IDEAS.

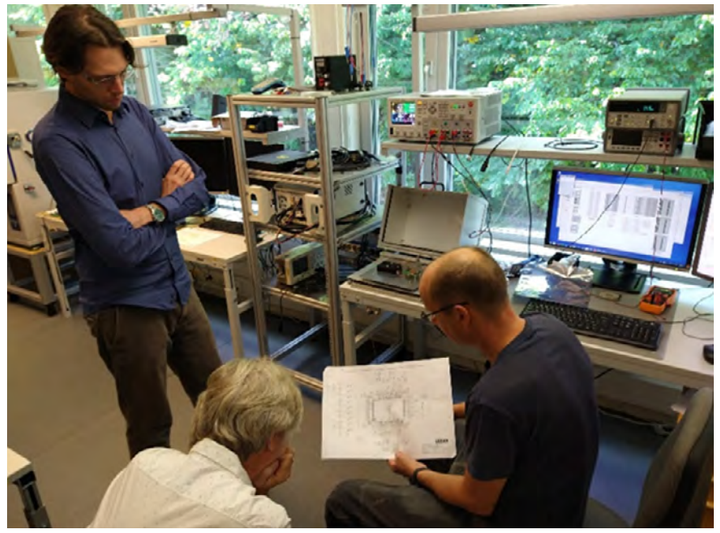
This research includes testing and validation of both cryogenic infrared sensors, which need to be cooled, and infraed sensors that can operate at room temperature.

- The cryogenic infrared sensors are the best but they are also the most expensive, and we do not have the capability to develop them ourselves so they must be purchased, Mæhlum says.

Infrared sensors that do not need cooling are called microbolometers. They resemble ordinary digital cameras but see in infrared wavelengths instead of visible light.

- We are developing our own microbolometer together with a partner in Germany. Because these sensors are made for use on Earth, we are investigating how they can be modified to work on a small satellite in orbit, says Mæhlum.





This type of sensor will be able to detect for example wild fires on the ground, the amount and distribution of moisture in the soil, and the surface temperature on land.

- This would provide information about soil moisture on a medium scale and the surface temperature on land on a large scale, says Mæhlum.

## How to fit a large sensor on a small satellite

But infrared sensors, like optical sensors, need to be as large as possible in order to see in as high resolution as possible.

- This is caused by the laws of physics and limits how small an infrared or optical sensor can be, even on a nanosatellite, Mæhlum says.

Therefore, IDEAS is working to develop sensors that can be stowed in a folded or compressed confirguration during launch, and then folded out or expanded when the satellite is safely in orbit.

NASA and ESA´s new space telescope, James Webb, the succesor of the space telescope Hubble, had parts of its mirror as well as its five-layer sun shield folded up during launch. These were then carefully folded out in a complex sequence in space.

- Thus, a sensor on a small satellite of just 40 x 20 x 20 centimeters for example, can be folded out or expanded to around 200 centimeter in length. We want to see if this is possible to develop for small satellites, Mæhlum says.

## Where is the water on the Moon?

In CENSSS´ Work Package 5, IDEAS is developing an instrument to map resources on the Moon for in situ use by astronauts. This IDEAS team consists of a researcher, a post-doctoral fellow and a PhD student.

- This project utilizes detectors for gamma radiation, electrons and other particles made for use on Earth. The main challenge will be to modify these detectors for use on the Moon at a low cost, says Mæhlum.

The Moon is continuously exposed to cosmic radiation that penetrates a short distance into the surface. This causes the regolith to emit secondary radiation in the form of gamma rays, electrons and neutrons, which give valuable information about the minerals and substances present, including water.

- This secondary radiation can be measured at a distance of several meters, but must be done over time because of the limited amount of cosmic radiation present, Mæhlum says.

Such measurements will be done by an autonomous rover or one controlled by astronauts onboard the Gateway, the planned international space station in orbit around the moon.

## Extreme cold and week long nights

- Perhaps the greatest challenges on the Moon are the extremely low temperatures, the night that lasts for fourteen Earth days, and the lack of sunlight to power a rover in the areas where water is present, Mæhlum says.

On the Moon water is found as ice in craters with constant shade. These are mainly located in the lunar polar regions where the temperature can drop to minus 150 degrees Centigrade or lower.

Thus, rovers for hunting water on the Moon may have to enter shaded areas for a limited time only and then return regularly to sunlight to generate electrical power, says Mæhlum.

- In a prolonged absence of power, batteries and other electronics tend to fail even when supplied with power again. But we have tested special electronics down to minus 170 degrees Centigrade and they have survived. Perhaps the instruments on a lunar rover must be heated slighly in order to survive the long nights, Mæhlum says.

Radioactive sources for power are much more expensive than solar panels and therefore not suitable for smaller rovers and projects.

- But in the long run both larger rovers and nuclear energy will probably be needed, says Mæhlum.

IDEAS are working together with ESA and their strategy group for the exploration of the Moon to develop the lunar landings of the future.

# CLUGAS, the Compact Lunar Neutron and Gamma-ray Spectrometer

By Anja Kohfeldt

In work package 5, CENSSS is developing a Mapping Instrument Suite for In-Situ Resource Utilization (ISRU). During 2022, the work in exploration instrument development finally kicked off.

Goal of this activity is to develop an instrument suite, combining a gamma ray and neutron spectrometer (GRNS) with a ground-penetrating radar (GPR) and an electro-magnetic induction spectrometer to analyse subsurface properties of celestial bodies. More specifically, this instrument suite can be used to identify, localize, and quantify water on the Moon and Mars.

The GPR RIMFAX was featured heavily in the 2021 edition of the Annually Report of CENSSS. This year, the focus will be on the GRNS instrument.

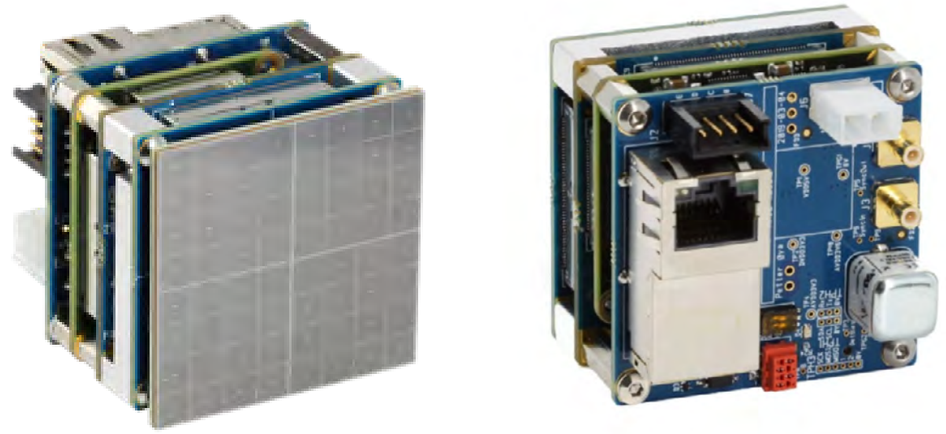
Gamma ray and neutron spectroscopy (GRNS) is a well-known concept in geo-physics to remotely determine the bulk chemical composition and elemental abundance of the shallow sub-surfaces (ca. 1m depth) of celestial bodies. Galactic cosmic rays (GCR) and high energy particles bombard all objects in the universe. When the radiation is absorbed by the elements at the surface and subsurface of an object, they emit gamma rays and potentially neutrons with a distinct signature as response. By mapping the gamma ray and neutron flux response and comparing it to known elements, the composition of the surface material can be determined. Areas with hydrogen abundance can be identified, supporting the search for water which is useful for future human exploration. GRNS also supports an assessment of mayor rock-forming elements, volatiles and other constituents to provide lithology, mineralogy, and chemistry of the site of interest.

In 2022 CENSSS, together with the CENSSS partner IDEAS and the UiO Centre for Earth Evolution and Dynamics (CEED)[1] proposed the Compact Lunar Neutron and Gamma-ray Spectrometer (CLUGAS) to the ESA SciSpacE AO – Reserve Pool of Science Activities for the Moon.

CLUGAS hosts a solid-state detector, based on scintillator and semiconductor technology targeting a size factor of a large softdrink bottle and a weight of less than 3 kg. The instrument will be capable of detecting gamma rays in the energy range of 30keV - 8MeV with energy resolution of less than 4% at 662 keV (Cs), as well as thermal and epi-thermal neutrons with energies of 0.025 eV - 1 MeV.

1 CEED is a Centre of Excellence at the department of Geoscience at UiO. CEED co-authors for this proposal are Stephanie C. Werner and Agata Krzesinska, with Stephanie in the role as main coordinator.





IDEAS' ROSSPAD module.

The instruments baseline is IDEAS' ROSSPAD module, a variant of the detector read-out module, that is used in the SoNDe[2] project, a solid-state neutron detector at the European Spallation Source in Lund, Sweden. An alternative readout platform in discussion is an adapted version of the GDS-100, one of the best gamma spectrometers.

The backend includes data handling, power distribution, and an ethernet communication interface. The front-end electronic consists of an application specific integrated circuit (ASIC), that IDEAS originally developed for space applications. The ROSSPAD module hosts the IDE3380 ASIC, a dedicated readout circuit for photon detectors, such as photomultiplier tubes (PMTs), silicon photomultipliers (SiPMs), and multi-pixel photon counters (MPPCs). IDE3380 provides 16 input channels and a summing channel, with pulse-height spectroscopy and timing capability for each channel.

The detector is formed by a pixelated SiMP array, outperforming the alternatives in terms of robustness, volume, and reduced bias voltage. The scintillator will contain Lithium-6 for neutron detection. If an additional gamma ray scintillator, such as Caesium-Iodine (CsI), is required is still under consideration.

The detector response will be simulated with the Geant4 toolkit, developed at CERN for simulating the passage of particles through matter. Simulation results will later be verified in measurement campaigns at neutron test facilities, such as the Source Testing Facility (STF) at Lund University, Sweden, before a prototype of the instrument will be taken into the field for demonstration in relevant environment. This shall prove the suitability of the instrument for analysing the composition of sub-surface elements and ultimately finding water on extra-terrestrial bodies.

In 2022 Deniz Ölçek started as PhD research fellow at CENSSS with the focus on a neutron detection demonstrator that shall be used in CLUGAS. In the past year, she familiarized herself with the IDEAS readout module ROSSPAD, attended ECSS and Geant4 courses, identified a scintillator that serves the purpose and made connections to international experts in various fields. For next year, a first iteration of simulation and a prototype instrument for initial characterisation are planned.

2 The Solid-State Neutron Detector (SoNDe), detector project at European Spallation Source (ESS) in Lund, Sweden, coordinated by Forschungszentrum Jülich, Germany. https://doi.org/10.3030/654124

# Norwegian students working with a georadar on Mars

By Berit Ellingsen

Lisa Juliann Nystad

Søren Blåberg Tvingsholm

Amalie Sjursen Nyheim

Kristin Lund

The RIMFAX team at CENSSS includes several Master's students. What are their tasks and how did they get the job?

Since Perseverance and RIMFAX landed in Jezero Crater on Mars on the 18th of February 2021, they have investigated several locations in the crater.

- So far Perseverance and RIMFAX have covered more than 15 kilometers and taken several samples of the surface and atmosphere. These will be sent back to Earth by a sample return mission later on, says Tor Berger, science coordinator at CENSSS and instrument operations lead on the RIMFAX team.

Berger is responsible for the day to day operations of RIMFAX, as well as the testing and debugging of the RIMFAX software when JPL releases new versions of their own software. He's also involved in the development of processing tools for the RIMFAX data.

### RIMFAX, the Norwegian georadar on Mars

- With RIMFAX we can look into the subsurface and see various layers and geological structures, Berger says.

The RIMFAX team has also matched RIMFAX profiles with the main map and photographic data that JPL has constructed of the area based on orbital imagery.

- There's been no major surprises yet. The bottom of the crater contained a lot of volcanic material and there RIMFAX could see from 10 to 15 meters into the subsurface. Now that Perseverance has reached the old river delta, we're seeing other materials underground, and can peer up to 20 meters down into the subsurface, says Berger.

This is deeper than it is possible to see with a georadar on Earth in many places, because the subsurface on Mars is much drier, with less attenuation of the radar waves.

Currently Perseverance will be driving up the river delta until about the middle of March 2023. When Perseverance is on the move, RIMFAX is active.

### The student tasks

- We have 4 students from the University of Oslo on our team. Two are Master's degree students and two are finishing up their Bachelor's degree and moving on to their Master's degree, says Berger.

The students have been part of the RIMFAX team for more than a year. They started in November 2021 with an initial period of training and participated in the day to day operations during all of 2022.



The daily work with RIMFAX includes uplinking new commands to tell the georadar what to do next, and to coordinate RIMFAX's activities with those of the other instruments on Perseverance.

- The other part is downlinking the data from RIMFAX and then process and analyze these, along with telemetry to check the health status of the instrument, Berger says.

The students on the team are involved in both the uplink as well as the downlink activities. Thus, they can cover when someone is sick, traveling or away from the team for other reasons.

### Trained by doing, not just by reading

- We started by training the students for some months. Our procedures for RIMFAX are collected in a manual and the students read this, and then learned by performing the procedures themselves, says Berger.

The team has nearly daily telecon meetings with the entire Perseverance team at JPL and all the teams working with the other instruments on the rover. Here the day to day operations are planned and coordinated.

- At first our students sat in with us during these meetings. Then the students took part in the meetings with us teachers sitting in. Finally, the students participated in the meetings on their own, with the possibility of contacting members of the team for questions or unexpected events, says Berger.

Not many students in Norway have the opportunity to be part of controlling a rover on Mars.

- The feedback we get from the students is that they really enjoy this and find it very exciting, Berger says.

### Works from home

- Of the uplink and downlink shifts on RIMFAX, my favorite is the downlink shift because I enjoy taking part of the telecon meetings and doing the presentation of the day's activities to the rest of the teams, which also include several students, says Lisa Julianne Nystad, one of the students working with RIMFAX.

She's about to start her Bachelor's thesis in Geophysics and Climate and will be going on to a Master's degree in the fall of 2023.

Nystad and the other students on the RIMFAX team work approximately 30 hours a month, on shifts that last about 5 hours.

- In the beginning, during the training period, there was a lot to learn and a lot of new procedures to get used to. But now that the uplink and downlink processes have become routine, I know what to expect and can do the job from home, Nystad says.

I first check the list of parameters to downlink the data from RIMFAX, before doing so. I also check that everything that should be included in the data is there, and transfer them to the Perseverance server at JPL. Then I make certain that we are green and go for the next day of work on Mars, she continues.

### A ten out of ten job

Nystad plans on using the data from RIMFAX in her Bachelor's thesis, and one of the scientists on the team will be her thesis advisor.

- I haven't decided on a Master's degree and theme for my Master's thesis yet, but it will be natural to expand on the data and results from the Bachelor's degree, Nystad says.

It was a personal interest in space science and space exploration that made her apply when she saw the message from the RIMFAX team inviting students at the Department of Geological Sciences to work with the Norwegian georadar.

- It's really fun and absolutely ten out of ten to be one of the students in Norway who is working with a rover on Mars. If you ever get a chance to do something similar, I will recommend everyone to send in an application. You never know who will be picked for the job, and it might just be you, Nystad says.

### Space science – a new Master's degree at UiO

There has been no shortage of students interested in space, space science in general and in working with RIMFAX.

The team is very happy to include the Master's students and pleased with the interest the student body has in RIMFAX, Perseverance and other space related activities at the University of Oslo.

- We are enjoying working with the students as they are very enthusiastic and inquisitive, and asking the right kinds of questions. They are learning a lot from being part of our team, but so are we from teaching and training them, says Berger.

From the fall of 2023, the Institute of Technology Systems at the University of Oslo will be offering a Master's degree in space technology.

- CENSSS is involved in the courses for this new degree. We are hoping to have many enthusiastic and interested students, and that the new degree will contribute to Norway's growing space sector, Berger concludes.

# Master’s degree in Space Systems: A new study programme at ITS

The University of Oslo introduced a new Master's degree programme in Space Systems, established by the Department of Technology Systems and CENSSS. The programme's objective is to provide students with an in-depth understanding of satellite and space probe development and usage, taking into account user needs, technology, operating environment, and economy. This new study programme was approved by the UiO board in June 2022.

The two-year, full-time study programme consists of 120 ECTS credits, with a structure that includes mandatory courses (40 credits), optional courses (20 or 50 credits, depending on the thesis length), and a master’s thesis (60 or 30 credits). Students must complete and pass all courses before their last semester reserved for thesis work.

The programme offers several mandatory courses, including Space Systems, Systems Engineering, Sensors and Communication, and Projects within Space Systems. Students can choose optional courses in consultation with their supervisors based on their interests and desired specialization. The programme suggests three primary specializations:

1. Sensors for Earth Observation and Planet Exploration: This specialization focuses on space systems for exploring inner solar system planets and observing Earth, climate, and maritime movements.
2. Design of Satellites and Payloads: This specialization emphasizes the design, development, testing, and integration of small satellites and payloads, involving practical laboratory work.
3. Satellite Communication / Navigation: This specialization covers satellite communication and navigation topics.

Students can tailor their course of study depending on their chosen specialization, courses, and thesis type, allowing for a customized learning experience in the field of Space Systems.

### Master’s Thesis

The master's thesis in the Space Systems programme is an independent research project under supervision. While a long thesis (60 ECTS) is typical, a short thesis (30 ECTS) is an option for students interested in studying abroad for a semester.




**Introducing the new master programme in Space Systems:** Head of Institute at the Department of Technology Systems, Cecilie Rolstad Denby launches the innovative new programme at “The Old Library” - the location for Spaceport Norway 22.

**Signed the deal:** Rector Svein Stølen (UiO) and Ketil Olsen, CEO Andøya Space on the signing of the new cooperation agreement between the University of Oslo and Andøya Space.

### Cooperation with the University of South-Eastern Norway – USN

ITS cooperates with the University of South-Eastern Norway – USN on the course Systems Engineering (TEK4000), starting autumn 2023. The course will be taught by academics from USN. ITS is in charge of the administrative part of the course that will take place at UiO, Kjeller. The course description is made by USN. The 10 ECTS credit course will be offered to 25 students. It will consist of several workshops at UiO, Kjeller throughout the semester. The course is an option for master students at ITS, enrolled in all the master programmes being offered by the institute.

### Excursion to Andøya Space

ITS is planning for a five-day excursion to Andøya Space for the students joining the new study programme. Early in the semester, the students will be building a microsatellite, based on the «CanSat» system that has been developed by Andøya Space Education. At Andøya Space, the plan is that the students are to launch their own CanSat weather balloon. Before the launch, they will go through a detailed preparation and planning phase. Data will be gathered throughout the process, as part of the mission. The candidates will go through an Assembly, Integration and Test (AIT) training.

### Master thesis, supervision and common industrial Phds from 2025

UiO would like the industrial partners in CENSSS to contribute with master thesis and supervision of the institute’s master students in the future. UiO is also aiming for common industrial PhDs in the future, once the candidates have finished their master degree.

Good luck to our 10 future candidates starting on UiOs new master programme in space systems this autumn! The application date for the programme is April the 15th.

**About the programme**

Additional details regarding this study programme can be found on the programme webpage: https://www.uio.no/english/studies/programmes/space-systems/

# Events

## CENSSS and ITS/UiO represented at Spaceport Norway 22

On the evening on the 24th of October, UiO kicked off the Spaceport Norway 22 conference with a reception – a space oriented evening at Sommero Hotel. The highlight of the evening was the signing of new cooperation agreement between the University of Oslo and Andøya Space. On October the 25th and 26th 2022, CENSSS and ITS was represented at the conference and exhibition Spaceport Norway. The new master programme in space systems was launched at the conference by The Head of Institute at the Department of Technology Systems, UiO, Cecilie Rolstad Denby. “The ambition is to make a study programme that is inspiring and attractive for students, researchers and for the industry”, was her message on her speech on the 26th of October. Followed by the words: “The research and the education at the university shall be of high quality. The ambition is to educate students that are relevant for the industry and/or that qualifies for PhD studies”. She highlighted the cooperation with CENSSS in her speech on the second day of the conference.

Debatt med Cecilie som deltager på Spaceport.

## Round trip - Partner visits in Winter of 22

From mid-February to mid-march of 2022 the Centre Management for CENSSS and the Head of Department at ITS visited all CENSSS partners, and Andøya Space. For our Norwegian partners this meant an on-site visit, for our international partners, a digital visit.

The main purpose of the visits was to start the discussion with our partners about their goals and interests for the CENSSS based activity going forward.

The visits took the Centre management from Andøya and Tromsø to Oslo and Eidsvoll.

Andøya visit.

EIDEL visit.

## Mars 2020

In early June, Jet Proulsion Laboratory – JPL - in Pasadena, California, hosted a Mars 2020 Science Team meeting with more than 250 participants from USA and Europe. CENSSS participated as part of the RIMFAX team. The four-day meeting was the first time the Mars 2020 Science Team met in person since 2019. During the meeting, the team discussed mission achievements and planned for future Mars campaigns with the Perseverance rover and its scientific instruments. Participants external to JPL also got the chance to perform Mars operations from the operations centre at JPL.

Svein-Erik Hamran at Norsk mikrosatellitt-konferanse 2022

## Norsk mikrosatellittkonferanse 2022

SFI CENSSS, NTNU and EIDEL welcomed Norwegian actors within the Space segment to Norsk mikrosatellittkonferanse 2022, 9th of May 2022. This event was to fourth conference, the last of which was held in Trondheim in 2018. The move to Kjeller and the greater Oslo-region reflects the aim to establish the conference as an annual event to be held the day before the annual NIFRO Space Dinner in Oslo.

Norsk mikrosatellittkonferanse aims to be a bridge between students, academia and Norwegian industry. The conference focused on various aspects of small- and-microsatellites with presentations from students, universities, research institutes and industry

# CENSSS in the media

## Scientific talks

**International Mars Ice Mapper Team Meeting**
Place: Teams
Date: 27.01.2022
Talk: RIMFAX lesson learned for I-MIN
Presenter: Svein-Erik Hamran

**Rimfax og Mars 2020**
Place: Nittedal Rotary
Date: 03.02.2022
Presenter: Svein-Erik Hamran

**RIMFAX og Mars 2020 roveren**
Place: Lillestrøm Rotary
Host: Lillestrøm Rotary
Date: 05.04.2022
Presenter: Svein-Erik Hamran

**The RIMFAX Ground Radar on the Mars 2020 Perseverance Rover - Gaining Insight to the Martian Past**
Place: Sem Sælands vei 1, 0371 Oslo.
Arrangement: Extra-terrestrial Geophysics
Host: OSEG - Oslo Society of Exploration Geophysicists
Date: 31.05.2022
Presenter: Titus Casademont

**Norsk Mikrosatellitt-konferanse**
Date: 10.05.22
Presenter: Svein-Erik Hamran

**CENSSS - Status og planer for framtiden**
Presenter: Svein-Erik Hamran, Centre Director CENSSS
Arrangement: Norsk Mikrosatellitt-konferanse
Dato: 10.05.22

**IDEAS - Infrared and other sensor possibilities for microsatellites from Integrated Detector Electronics AS**
Presenter: Gunnar Mæhlum, CEO IDEAS
Arrangement: Norsk Mikrosatellitt-konferanse
Dato: 10.05.22

**EIDEL – Space Tech at EIDEL in the New Space Revolution**
Presenter: Elizabeth Frances Prentice, Assembly, Integration, and Test Manager at EIDEL
Arrangement: Norsk Mikrosatellitt-konferanse
Dato: 10.05.22

**KSAT Ground Services - A unified interface for all operational activities**
Presenter: Eivind Kristoffersen de Badts
Arrangement: Norsk Mikrosatellitt-konferanse
Dato: 10.05.22

**FFI – Status mikrosatelliter**
Presenter: Richard Olsen, forskningsleder FFI
Arrangement: Norsk Mikrosatellitt-konferanse
Dato: 10.05.22

**The RIMFAX radar onboard the NASA Perseverance Rover Mission**
Event: Sensor Decade
Date: 02.06.22
Presenter: Svein-Erik Hamran
https://www.sensordecade.com/

**Lunar Surface Prospecting Mobile Payload Package Pre-Phase A Study**
Event: ISRU workshop
Host: Norsk romsenter
Presenter: Svein-Erik Hamran
https://www.romsenter.no/no/Aktuelt/Arrangementer-og-hendelser/Norway-s-Roadmap-to-Space-Resources-Development

**One year of the RIMFAX radar on the Perseverance Rover in Jezero Crater, Mars**
Event: Deep Sky Exploration
Date: 03.04.2022
Presenter: Titus Casademont

**RIMFAX GPR imaging the subsurface of the Jezero crater floor on Mars**
Event: GPR 2022- 19th International Conference on Ground Penetrating Radar
Date: 13.06.2022
Presenter: Svein-Erik Hamran



CENSSS and ITS at Spaceport Norway


Gazelle diploma

**UiO på Mars**
Host: UiO, Domus Bibliothecia
Date: 31.10.2022
Presenter: Svein-Erik Hamran

**RIMFAX on Mars**
Host: Norsk astronomisk selskap
Date: 15.10.2022
Presenter: Titus Casademont

**RIMFAX on Mars**
Arrangement: Geophysical Colloquium ETH Zuerich
Date: 04.11.2022
Presenter: Titus Casademont

**P32D-01 - Characterization of the Martian subsurface with RIMFAX. (Invited)**
Event: AGU Fall Meeting 2021
Presenter: Svein-Erik Hamran

**FFI's space activities and role in new master program at UiO**
Event: Spaceport Norway
Date: 25-26 Oct 2022
Presenter: Kenneth Ruud (FFI)

**The CENSSAT-1 mission; Integration of satellites in Norway**
Event: Geminisenter for småsatellitter
Presenter: Lars Erling Bråten (FFI)

**New master program for sapce systems from 2023-ambitions and goals for the University of Oslo**
Event: Spaceport Norway
Presenter: Cecilie Rolstad Denby

**Digital twin for Space applications**
Event: Spaceport Norway
Presenter: Remi Lanza (Jotne)

**Next stop, next Month: The Moon**
Event: Spaceport Norway
Presenter: Julien-Alexandre Lamay (ispace)

**What does the space industry look like in 2030? Do we have boots on the Moon and Mars?**
Event: Spaceport Norway
Presenter: Svein-Erik Hamran

**The buisness case for building a smallsat factory in Norway**
Event: Spaceport Norway
Presenter: Truls Andersen (EIDEL)

**Short route to space reserach and academia - how they enable rapid innovation to realize quick return on microsatellite projects**
Event: Spaceport Norway
Presenter: Richard Olsen (FFI)

**Introduction to CENSSS nf our current mission on Mars**
Event: Spaceport Norway
Presenter: Svein-Erik Hamran

**ESA DEFINE**
Event: GSTP Industry Working Days 2022
Presenter: Remi Lanza (Jotne)

## Awards

For the second year in a row, Eidsvoll Electronics (EIDEL) is recognized with the Gaselle award by the business and financial paper Dagens Næringsliv!

## Popular scientific talks

**Rimfax og Mars 2020**
Host: Nittedal Rotary
Presenter: Svein-Erik Hamran

**RIMFAX og Mars 2020 roveren.**
Host: Lillestrøm Rotary
Presenter: Svein-Erik Hamran

**Fra Kjeller til Mars**
Host: Lillestrømsbilbiloteket
Presenter: Svein-Erik Hamran

**Vi snakker om Plancks strålings-lov: klima, energi, kvanter og kameraer som kan se i mørke**
Host: UiO
Presenter: Torbjørn Skauli

# CENSSS in the media

## Conference preceedings

**P22B-01 - Subsurface geology of the Jezero crater floor as characterized with the ground penetrating radar RIMFAX**

Conference: AGU Fall Meeting

Authors: Svein-Erik Hamran et.al

**P25I-2262 - Rock outcrop appearance as proxy for subsurface structures in RIMFAX modelling**

Conference:AGU Fall Meeting

Authors: Sigurd Eide, Henning Dypvik, Hans E. F Amundsen (Vestfonna), Titus Casademont, Tor Berger, Svein-Erik Hamran

**RIMFAX ground penetrating radar observations of subsurface stratigraphy along mars 2020 perseverance's traverse**

Conference: 53rd Lunar and Planetary Science Conference

Authors: Svein-Erik Hamran2 , David A. Paige1 , Daniel C. Nunes3 , Hans Amundsen2 , and the M2020 RIMFAX Team. 1 D

**Development of test methods for hyperspectral cameras characterization in the P4001 standards development**

Authors: Emmet Ientilucci, David Conran, Raymond Soffer, David Perry, Torbjørn Skauli, John Gilchrist, Christopher Durell

**Metadata definitions for a set of notional use cases in the IEEE P4001 standard for hyperspectral imaging**

Authors: Jan Makowski, Barbara Eckstein, Chris Durell, John Gilchrist, Torbjørn Skauli

**Developing the IEEE P4001 standard for characterisation and calibration of hyperspectral imaging devices**

Authors: John Gilchrist, Torbjørn Skauli, Christopher Durell

**Specification of hyperspectral camera performance: status of the IEEE P4001 standard development**

Authors: Torbjørn Skauli, John Gilchrist, Christopher Durell

## Poster Presentations

**Below the Rover Tracks: RIMFAX investigates Rock Density and Dielectric Permittivity in Jezero**

Arrangement/konferanse: Lunar and planetary science conference 2022

Presenter: Titus Casademont

## Podkasts

**Podcast: Romkapsel**

**Rimfax-far Svein-Erik Hamran om "livet" på Mars**

Date: 07.03.2022

RIMFAX on Mars. Romkapsel talking to Svein-Erik Hamran.

## News articles

Om EIDEL:

**Snuoperasjon ga romfartsselskapet et kjempeløft. Nå skal teknologien sendes fra Eidsvoll til månen**

Publisher: Dagens næringsliv

Date: 27.01.2022

Snuoperasjonen ga romfartsselskapet et kjempeløft. Nå skal teknologien sendes fra Eidsvoll til månen | DN

**Den norske radaren Rimfax har vært ett år på Mars**

Publisher: www.titan.uio.no

Date: 18.02.2022

Forfatter: Berit Ellingsen

https://titan.uio.no/teknologi/2022/den-norske-radaren-rimfax-har-vaert-ett-ar-pa-mars

**Norske Rimfax har klart seg på Mars i ett år**

Publisher: www.forskning.no

Date: 06.03.2022

Forfatter: Berit Ellingsen

https://forskning.no/geologi-mars-partner/norske-rimfax-har-klart-seg-pa-mars-i-ett-ar/1989148

**Kortnytt: Feiret forskere som har kapret eksklusive stipender**

Publisher: www.titan.uio.no

Date: 07.04.2022

https://titan.uio.no/forskning-og-vitenskap/2022/feiret-forskere-som-har-kapret-eksklusive-stipender

**Et steg nærmere å finne liv på Mars: – Et av de beste stedene å lete**

Publisher: NRK Nordland

Date: 02.05.2022

Mars-roveren Perseverance leter etter liv i tidligere innsjø på Mars – NRK Nordland

**Første rapport fra Rimfax: Geologien på Mars er mer kompleks enn antatt**

Publisher: Titan.uio.no

Date: 25.08.2022

https://titan.uio.no/teknologi-geologi/2022/forste-rapport-fra-rimfax-geologien-pa-mars-er-mer-kompleks-enn-antatt

**Første rapport fra Rimfax: Geologien på Mars er mer kompleks enn antatt**

Publisher: Teknisk ukeblad

Date: 25.08.2022

https://www.tu.no/artikler/forste-rapport-fra-rimfax-geologien-pa-mars-er-mer-kompleks-enn-antatt/521754

**Resultater fra norsk instrument på Mars-rover gir nye hint om vann**

Publisher: Forskning.no

Date: 25.08.2022

https://forskning.no/geologi-planeter-romfart/resultater-fra-norsk-instrument-pa-mars-rover-gir-nye-hint-om-vann/2068116

## Social media


# Publications and Presentations

## Ground penetrating radar observations of subsurface structures in the floor of Jezero crater, Mars

**Publisher:** Science Advances, 8(34), eabp8564, (2022)

**Authors:** Svein-Erik Hamran, David A. Paige, Abigail Allwood, Hans E. F. Amundsen, Tor Berger, Sverre Brovoll, Lynn Carter, Titus M. Casademont, Leif Damsgård, Henning Dypvik, Sigurd Eide, Alberto G. Fairén, Rebecca Ghent, Jack Kohler, Michael T. Mellon, Daniel C. Nunes, Dirk Plettemeier, Patrick Russell, Matt Siegler, Mats Jørgen Øyan.

## Abstract

The Radar Imager for Mars Subsurface Experiment has conducted the first rover-mounted ground-penetrating radar survey of the Martian subsurface. A continuous radar image acquired over the Perseverance rover's initial ~3-kilometer traverse reveals electromagnetic properties and bedrock stratigraphy of the Jezero crater floor to depths of ~15 meters below the surface. The radar image reveals the presence of ubiquitous strongly reflecting layered sequences that dip downward at angles of up to 15 degrees from horizontal in directions normal to the curvilinear boundary of and away from the exposed section of the Séitah formation. The observed slopes, thicknesses, and internal morphology of the inclined stratigraphic sections can be interpreted either as magmatic layering formed in a differentiated igneous body or as sedimentary layering commonly formed in aqueous environments on Earth. The discovery of buried structures on the Jezero crater floor is potentially compatible with a history of igneous activity and a history of multiple aqueous episodes.


High Resolution Imaging Science Experiment (HiRISE) orbital color image map of the Perseverance rover sol path from Sol 0 to Sol 204.

### P22B-01 - Subsurface geology of the Jezero crater floor as characterized with the ground penetrating radar RIMFAX.

**Publisher:** AGU Fall Meeting Abstracts (pp. P22B-01).

**Authors:** Svein-Erik Hamran et.al

Subsurface geology of the Jezero crater floor as characterized with the ground penetrating radar RIMFAX. (confex.com)

### Aqueously altered igneous rocks sampled on the floor of Jezero crater,Mars.

**Publisher:** Science, 377(6614), eabo2196.

**Authores:** K. A. Farley et.al.

https://www.science.org/doi/abs/10.1126/science.abo2196

### P25I-2262 - Rock outcrop appearance as proxy for subsurface structures in RIMFAX modeling

**Publisher:** AGU Fall Meeting Abstracts (pp. P25I-2262).

**Authors:** Sigurd Eide, Henning Dypvik, Hans E. F Amundsen (Vestfonna), Titus Casademont, Tor Berger, Svein-Erik Hamran

Rock outcrop appearance as proxy for subsurface structures in RIMFAX modeling (confex.com)

### RIMFAX ground penetrating radar observations of subsurface stratigraphy along mars 2020 perseverance's traverse

**Publisher:** 53rd Lunar and Planetary Science Conference (2022)

**Authors:** Svein-Erik Hamran, David A. Paige, Daniel C. Nunes, Hans Amundsen, and the M2020 RIMFAX Team.1 D

2857.PDF (usra.edu)

### Development of test methods for hyperspectral cameras characterization in the P4001 standards development

**Publisher** Proceedings Volume PC12094, Algorithms, Technologies, and Applications for Multispectral and Hyperspectral Imaging XXVIII; PC120940 (2022)

**Authors:** Emmet Ientilucci, David Conran, Raymond Soffer, David Perry, Torbjorn Skauli, John Gilchrist, Christopher Durell

https://doi.org/10.1117/12.2623490

### Metadata definitions for a set of notional use cases in the IEEE P4001 standard for hyperspectral imaging

**Publisher**: Proceedings Volume 12094, Algorithms, Technologies, and Applications for Multispectral and Hyperspectral Imaging XXVIII; 1209404 (2022)

**Authors:** Jan Makowski, Barbara Eckstein, Chris Durell, John Gilchrist, Torbjorn Skauli

https://doi.org/10.1117/12.2623491

### Developing the IEEE P4001 standard for characterisation and calibration of hyperspectral imaging devices

**Publisher:** Proceedings Volume 12094, Algorithms, Technologies, and Applications for Multispectral and Hyperspectral Imaging XXVIII; 1209402 (2022)

**Authors:** John Gilchrist, Torbjorn Skauli, Christopher Durell

https://doi.org/10.1117/12.2623487

### Specification of hyperspectral camera performance: status of the IEEE P4001 standard development

**Publisher:** Proceedings Volume 12094, Algorithms, Technologies, and Applications for Multispectral and Hyperspectral Imaging XXVIII; 1209403 (2022)

**Authors:** Torbjørn Skauli, John Gilchrist, Christopher Durell

https://doi.org/10.1117/12.2623489

Credit: NASA

Credit cover photo: NASA

# CENSSS

Centre for Space Sensors and Systems