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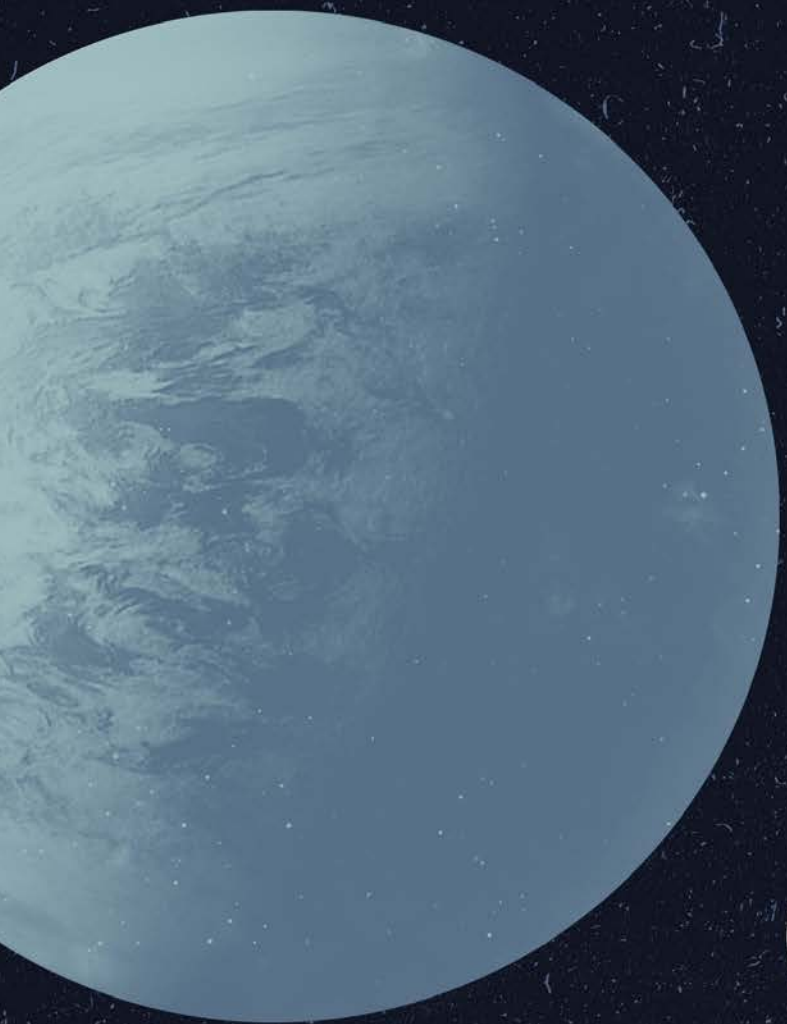
Centre for Space Sensors and Systems – CENSSS

Annual Report 2021



Norwegian Centre of Excellence
The Research Council of Norway

UNIVERSITAS OSLOENSIS
MDCCCXI

CENSSS
Annual report 2021

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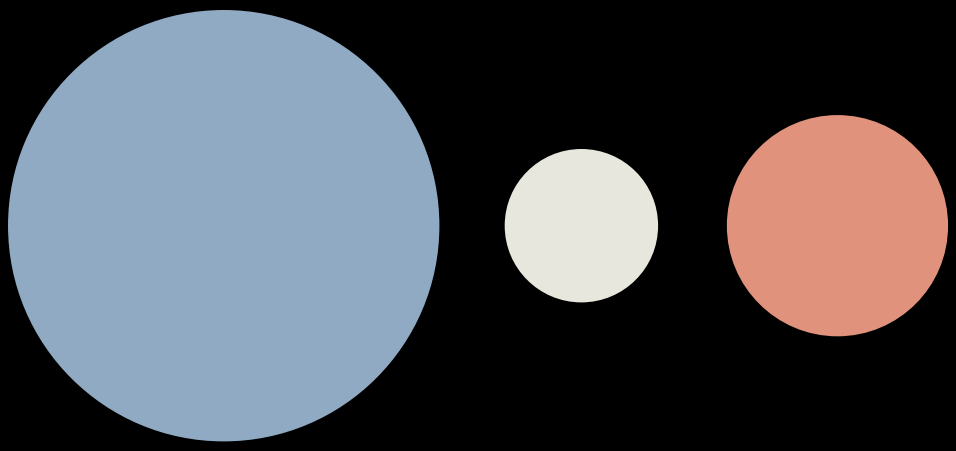
Centre for Space Sensors and Systems CENSSS



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 Centre Management

CENSSS, after a slow start due to the COVID pandemic, is gaining momentum and have advertised, and recruited several PhD students. We have just announced four new Post Doc positions that will contribute to the work in CENSSS and will be important assets in the continuation.

CENSSS have partners that span most of the activities related to space systems and are an important part of the center. The PhD's and Post Doc's will work in close cooperation with our partners and we hope that this will contribute to the education of qualified candidates for the Norwegian industry. CENSSS has started to develop a laboratory at the Department of Technology Systems that will be used in the development of new sensors and satellites.

2021 was the year the NASA Rover landed on the planet Mars with the RIMFAX Ground Penetrating Radar onboard. The development of the RIMFAX instrument took 6 years from initial design to mounting the instrument on the Perseverance rover. Landing and operating a rover on Mars during a pandemic have proven to be quite possible. The RIMFAX team have during the 6 years of instrument development learned to have internet meetings several times per week with collaborators in California, USA. The transition from this to a pandemic world where everything transitioned into Teams or Zoom meetings was straightforward for the RIMFAX and Mars 2020 Team. All the Mars 2020 and RIMFAX operational tools are made to be used in an internet browser. This makes operation of a rover on the planet of Mars from home possible, which have been the situation for the Mars 2020 Team the first year of operation. The RIMFAX team is fully occupied with analyzing data from Mars and publishing them in international scientific journals.

CENSSS are looking forward contributing to the development of space activities in Norway.

Svein-Erik Hamran

Centre Director CENSSS

2021 was the year the NASA Rover landed on the planet Mars with the RIMFAX Ground Penetrating Radar onboard.

From the Executive Board

We have CENSSS first complete year of operation year behind us and the activity in the center is gaining momentum. Several Ph.D. candidates have started their work towards graduation.

The topic of the Ph.D. work spans from characterization of infrared image sensors in research topic one, deep learning methodology development for new space services in research topic three. One candidate was also hired for research topic 5 mapping instruments for in-situ resource utilization. She was not able to start before 2022.

Research topic four, the Rimfax Science Operations was operational from the start of the centre. The RIMFAX ground penetrating radar is operating on the Perseverance rover on Mars and huge amounts of radar data over several km of Mars terrain was and is being collected. The Rimfax operation is covered in a separate article in this annual report.

The executive board has had 5 meetings throughout the year of which two were in person at the ITS at Kjeller.

The value of CENSSS for the industrial partners is increasing with the increased activity in the center. The focus for the center will be to coordinate the activities in the research topics towards the goal of a satellite mission. Important in this context is to apply for additional financing. This can be trough Horizon Europe the European Space agency or other sources.

The University of Oslo is next introducing a 2-year master program in Space systems. This will be important for recruitment to the business partners as well as to the center. This program is planned to start in 2022.

Gunnar Mæhlum

Leader of the Executive Board

Short greeting from the Head of Department

Credit: Private

Cecilie Rolstad Denby

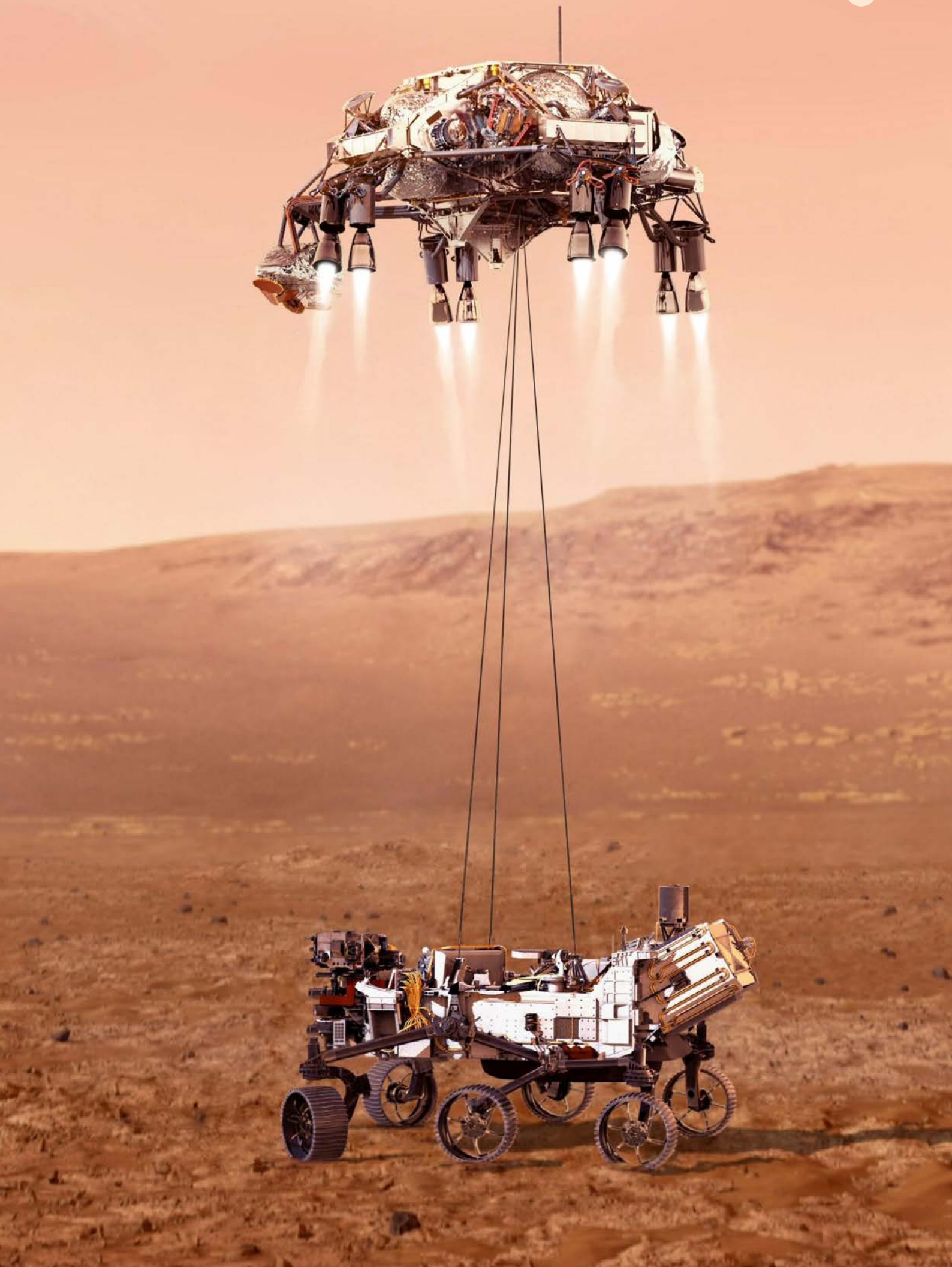
Head of Department

CENSSS is hosted at the Department of Technology Systems (ITS), UiO, Kjeller. During the year 2021 CENSSS activities have been an inspiration for both academic and administrative staff at the department, in both science and education. This has been very welcoming through the second challenging year of to the COVID pandemic.

The industrial CENSSS partners contribute to the department with information about their activities, with development of sensors and equipment for planetary exploration. Having contact with the space industry is very valuable for the department. We gain insight into the industry's research and development topics and their need for qualified candidates.

The NASA Mars 2020 Perseverance rover with the RIMFAX instrument has continuously been delivering data. The scientists have informed us and explained how they use radar profiles for the exploration of the geology at Mars. The path of the rover through the Martian landscape has been visible in amazingly detailed images. It has been exciting to learn how the rover navigates by itself through the rocky and sandy landscape. During this year the department has had several prominent visitors, such as the Norwegian Minister of Education and Research, the rector of UiO, the deans of the Faculty of Mathematics and Natural Sciences, the mayor of Lillestrøm, and the directors of the Norwegian Defense Research Establishment and the Institute of Energy Technology. The guest are always thrilled to hear about the ongoing exploration of Mars. The department is very grateful to the CENSSS scientists for their willingness to communicate their exciting research.

CENSSS has advertised and recruited several PhD students, who are vitalizing ITSs research community. This year CENSSS has also started the development of a new laboratory, which is of significant interest to the UiOs student. The department has decided to develop and offer a new Master program in Space Systems, due to the presence of CENSSS. The Department and the CENSSS scientists have an excellent cooperation, and we look forward to establishing ITSs new study program and recruit young students into the exciting world of space science.



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.

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.

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.

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

Science and Technology AS

Our business is Earth Observation within the fields of Scientific Data Processing and Intelligent Software Applications, with focus on efficient use of the Copernicus Satellite data for providing sustainable EO Services.

CENSSS participation

- Sensors and EO Services
- Networking, generating partnerships
- Projects in the pipe-line;
- ESA IODs for on-board processing for SmallSAT (with UiO, NEO, VAKE)
- R&D for S&T EO Services – application to Forskningsrådet (with UiO, NEO ++)
- Defining and supporting PhD activities in line with S&T needs

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 Year We Landed On Mars!

by Berit Ellingsen

No one knows what lies beneath the surface of Mars. Now, we'll finally be able to see what's there.

Svein-Erik Hamran, Principal Investigator

RIMFAX Location on NASA's Perseverance Rover (Illustration)
CREDIT: NASA/JPL-Caltech

NASA´s rover Perseverance and its Norwegian georadar Rimfax are celebrating their one year anniversary on Mars. What has Rimfax discovered so far, and why are scientists and space organizations alike so interested in the red planet?

Mars, Earth´s immediate neighbor, is a bone dry and ice cold desert with an average temperature of minus 60 degrees Centigrade. The freezing temperatures is mainly caused by the thin Martian atmosphere, whose density is just one percent of that on Earth.

But approximately 4 billion years ago, Mars was covered in oceans and lakes and rivers, and had a thicker atmosphere and a milder climate than it does today. This is revealed by the Martian geology and makes the red planet one of the biggest candidates for life in the solar system, except for Earth.

Did life ever appear in the waters of Mars? What happened to this water and the Martian atmosphere? What can the large differences between present day Mars and Earth tell us about how small rocky planets evolve in general in the universe?

Even with the current frigid temperatures and thin atmosphere, Mars still remains the planet in the solar system that is most similar to Earth, and which most probably can support human life. This is why both scientists and space organizations have such strong interest in Mars.

The first Norwegian payload on Mars

Perseverance was sent to the red planet to search for water and molecular signs of life. In addition, the rover will be taking samples of the surface and atmosphere at different locations. These samples will be collected by another rover and launched to Earth by spacecraft that will arrive later on Mars.

For the hunt for water and signs of life, Perseverance is equipped with ten different instruments. These include a laser and a drill at the end of a robot arm, a miniature laboratory for chemical analyses, and several cameras and microphones.

To see beneath the surface and discover the geological features there, for example pockets of ice or liquid water, Perseverance is equipped with the Norwegian georadar Rimfax.

Rimfax is the first georadar on Mars and the very first Norwegian payload to land on the red planet.

The georadar´s control room is located at University of Oslo´s Centre for Space Sensors and Systems (CENSSS) at Kjeller, outside Oslo. This is also where the data from Rimfax are downloaded, analyzed and stored.

Rimfax was developed by the Norwegian Defense Reasearch Establishment (FFI), with Comrod, Bitvis and Kongsberg Defence & Aerospace

July 30, 2020: A United Launch Alliance (ULA) Atlas V rocket carrying the Mars 2020 mission with the Perseverance rover lifts off from Space Launch Complex-41 at 7:50 a.m. EDT on July 30, 2020. CREDIT: United Launch Alliance

as subcontractors. Researchers from FFI, the University of Oslo, the Norwegian Polar Institute and Vestfonna Geophysical contributed with their knowledge to the development of Rimfax. The project was financed by FFI, the Norwegian Space Agency, and the European Space Agency ESA.

A long and demanding development

The development of Rimfax took five years and included several rounds of testing on Svalbard, located in the high Arctic and considered a cold desert, just like Mars. The development fulfilled the extremely high standards for project progression, testing and operational stability that NASA demands of all its technology.

In 2019 Rimfax was completed and was sent to NASA for integration on the rover and preparations for launch. On the 30th of July 2020 Perseverance and Rimfax were launched from Cape Canaveral Air Force Station in Florida to begin the six month long space flight to Mars.

The landing site on the red planet is Jezero Crater, just north of the equator on the northern hemisphere. This crater is a former lake where water flowed in on one side and drained on the opposite side. Jezero Crater also features an ancient river delta where the researchers hope to find signs of fossilized life.

However, landing on the red planet is never a routine job, due to the thin atmosphere, windy conditions and rocky surface. Almost half of the number of spacecraft that have attempted to land on Mars have failed.

At 21.55 Central European Time the first signal from Perseverance, indicating a successful landing, reached the control room at NASA´s Jet Propulsion Laboratories.

FEBRUARY 2021 – Seven minutes of terror

On Thursday the 18th of February it was Perseverance and Rimfax´turn to run the Martian gauntlet. Because of the delay in communication between Earth and the red planet, any landing must be fully automatic with no direct help from the control room.

At 21.47 Central European Time the radio signal from the spacecraft that carried Perseverance and Rimfax disappeared. The spacecraft had entered the Martian atmosphere and started on the seven minutes long landing.

Despite the atmosphere on Mars being just a fraction of the density of the atmosphere on Earth, it can nevertheless brake the speed of spacecraft. The friction from the atmosphere gives rise to an intense heat around the spacecraft, against which Perseverance and Rimfax had a thick heat shield.

As the spacecraft continued down into the Martian atmosphere, the heat shield was discarded. Then several parachutes developed for landing on Mars shot out to reduce the speed of the spacecraft even more.

A few kilometers from the surface, the landing platform which Perseverance and Rimfax were stowed beneath, fired up its rocket engines, until the platform hovered just 20 meters above the surface. Then Perseverance was quickly lowered to the ground and the landing platform flew away.

At 21.55 Central European Time the first signal from Perseverance, indicating a successful landing, reached the control room at NASA´s Jet Propulsion Laboratories. Just a few minutes later the first photo from Perseverance arrived, showing that the rover was safely on the ground.

-Seeing that made me very relieved and happy, because the development of Rimfax has been a considerable part of my life for many years, said Sven-Erik Hamran at the live broadcast on Norwegian TV of the landing. Hamran is the director for CENSSS and was project manager for the development of Rimfax.

In the hours and days following the landing Perseverance´s instruments, including Rimfax, were switched on and given software updates. The rover sent the first high resolution images of its surroundings in Jezero Crater.

Then followed a few weeks of testing the instruments and the software, until the technology demonstration Ingenuity was ready for its first flight.

JULY 2021 – The hunt for water and life begins

In July 2021 Perseverance and Rimfax started the search for water and life. The rover began to drive towards an area of Jezero Crater called Séitah. While Perseverance was on the move, Rimfax collected data of the structures underground.

Perseverance receives its driving commands from Earth over night and then executes the commands the following day. The rover also uses an automated system called AutoNav, which creates a three-dimensional map of the surroundings, spots hazardous obstacles, and plots a course around these.

AutoNav enables Perseverance to monitor and calculate its own driving, while the rover is moving. The automated system uses a separate computer so that the main computer on board can perform other tasks while Perseverance is driving.

An illustration of NASA's Perseverance rover landing safely on Mars. Hundreds of critical events must execute perfectly and exactly on time for the rover to land safely on Feb. 18, 2021. Credit: NASA/JPL-Caltech

Because Perseverance has larger and more solid wheels than earlier rovers on Mars, it can drive at a higher speed, of up to 120 meters per hour. The taller wheels also allow Perseverance to drive over rocks, enabling the rover to pass through areas with obstacles instead of going around them. By February 2022 Perseverance had covered a distance of more than three kilometers in Jezero Crater.

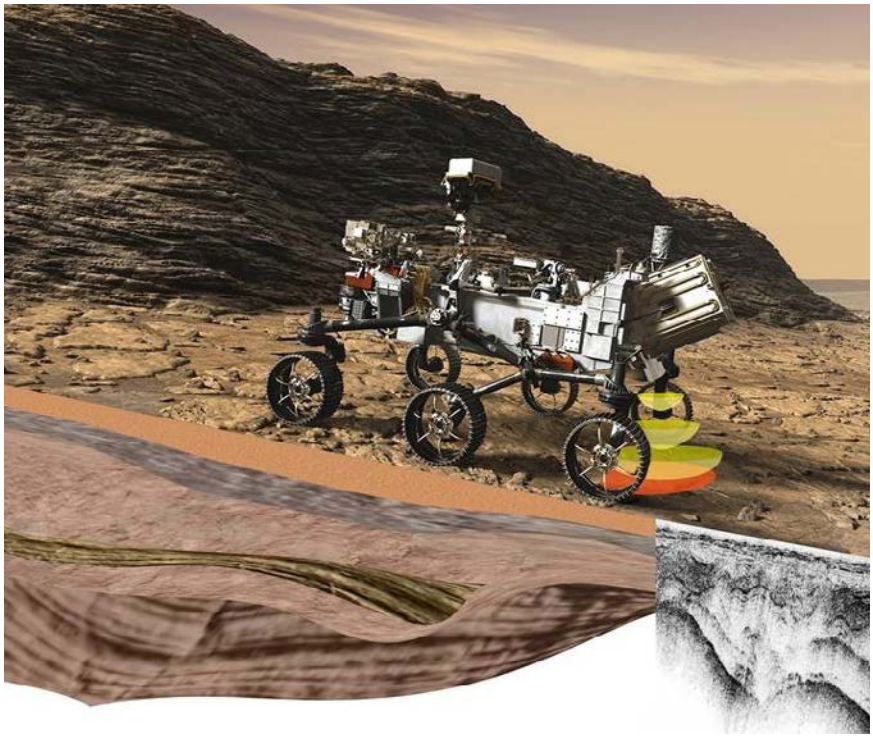
SEPTEMBER 2021 – First sample for return to Earth

On the 1st of September 2021 Perseverance collected the first geological sample on Mars to be sent back to Earth.

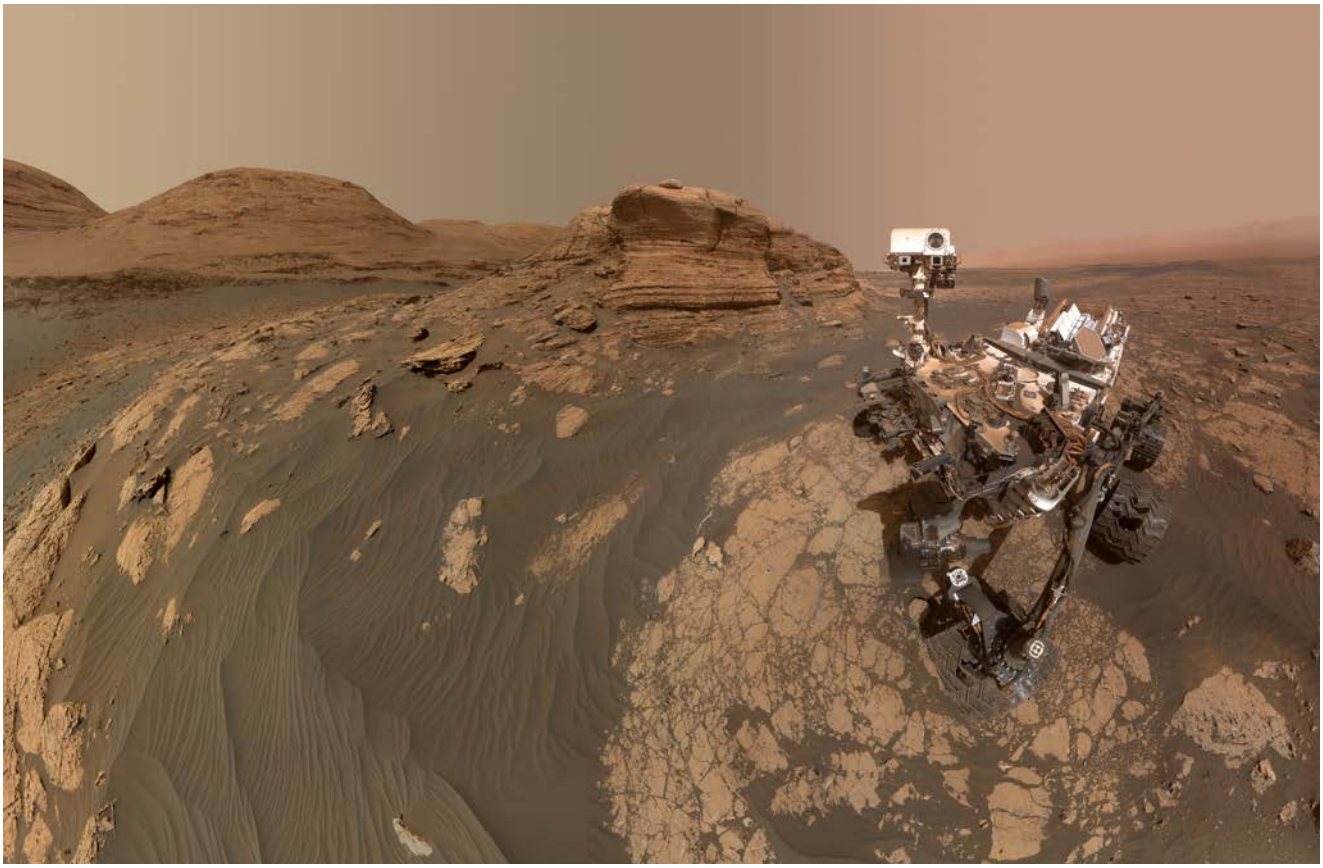
Perseverance first used one of the drills on the robot arm to scrape dust and pebbles from the surface of a test site for control. Then the rover used the instruments on the robot arm to analyze the exposed rock chemically and mineralogically.

Subsequently the sample that will be sent to Earth was taken from a rock that was as similar to the test site as possible. The sample was the size of a pencil and taken by the drill on the robot arm. The sample was immediately transferred to a sample tube, which was measured, photographed, sealed and stored on the rover.

By February 2022 Perseverance had taken six samples of the geology and atmosphere on Mars. A total of 43 samples will be collected and sent to Earth.



Perseverance's Radar Imager for Mars' Subsurface Experiment (RIMFAX) uses radar waves to probe the ground, revealing the unexplored world that lies beneath the Martian surface. Credit: NASA/JPL-Caltech/FFI



Curiosity's Selfie at Mont Mercou. Credit: NASA/JPL-Caltech/MSSS

The mini-lab on board Perseverance has indicated that some of the geological samples contain organic molecules, which may show if the mineral was formed in water. But the big question whether these molecules are a sign of life will only be answered when the samples arrive on Earth for a much more thorough analysis than any rover can do.

Rimfax and radargrams of the subsurface

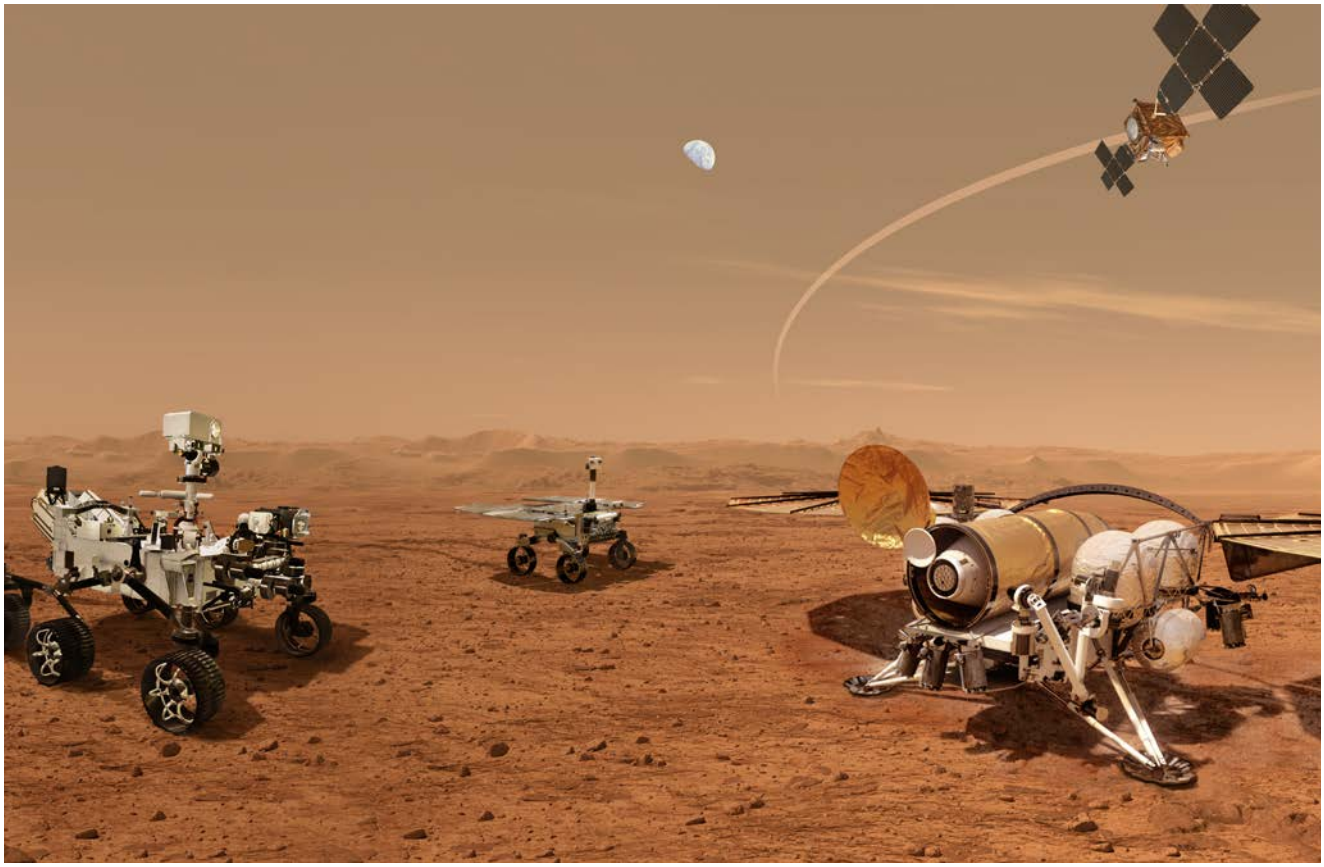
While Perseverance traverses the surface of Mars, Rimfax collects data of the geological structures down to 15 meters below the surface.

On entering the area of Séitah, Perseverance observed several geological formations that slanted downward into the ground. The radargrams created by Rimfax revealed that these geological formations extended below the surface in the same angle.

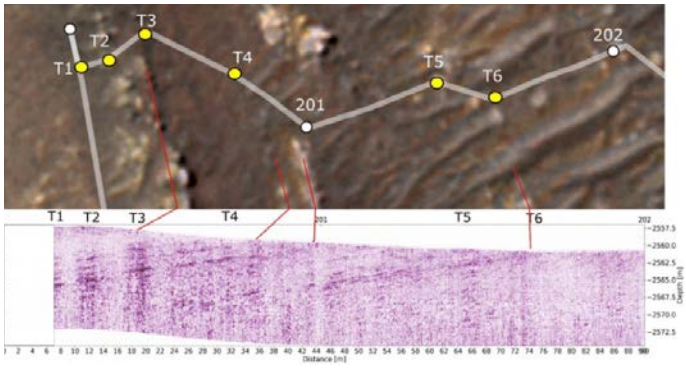
Moreover, Rimfax showed that the geological layers in the area Perseverance arrived at were older than the layers of the site that the rover had left.

-During the past year Rimfax has collected subsurface radar data for a distance of more than 3 kilometers. So far the terrain has consisted of what we believe are volcanic rocks. Perseverance will soon increase speed and drive towards the ancient river delta in Jezero Crater. We are very excited to see what Rimfax will discover in the sedimentary layers there. This river delta is the main reason for Perseverance landing in Jezero Crater and we will spend this year investigating it thoroughly, says Hamran.

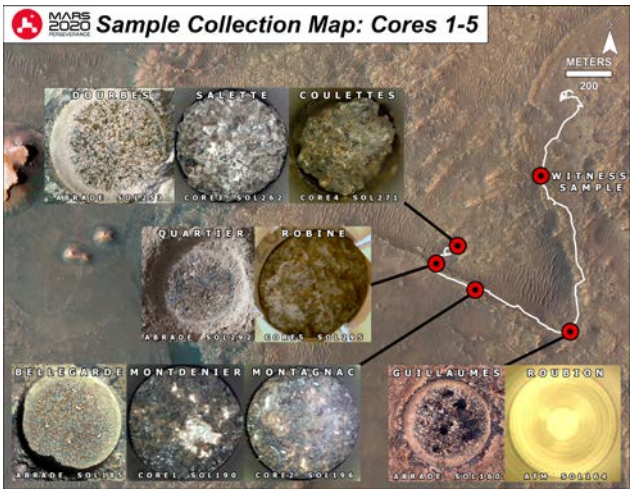
NASA's Mars Perseverance rover acquired this image using its left Mastcam-Z camera. Mastcam-Z is a pair of cameras located high on the rover's mast. This is one still frame from a sequence captured by the camera while taking video. This image was acquired on Apr. 22, 2021. Credit: NASA/JPL-Caltech/ASU/MSSS



This illustration shows a concept for a set of future robots working together to ferry back samples from the surface of Mars collected by NASA's Mars Perseverance rover. Credit: NASA/ESA/JPL-Caltech

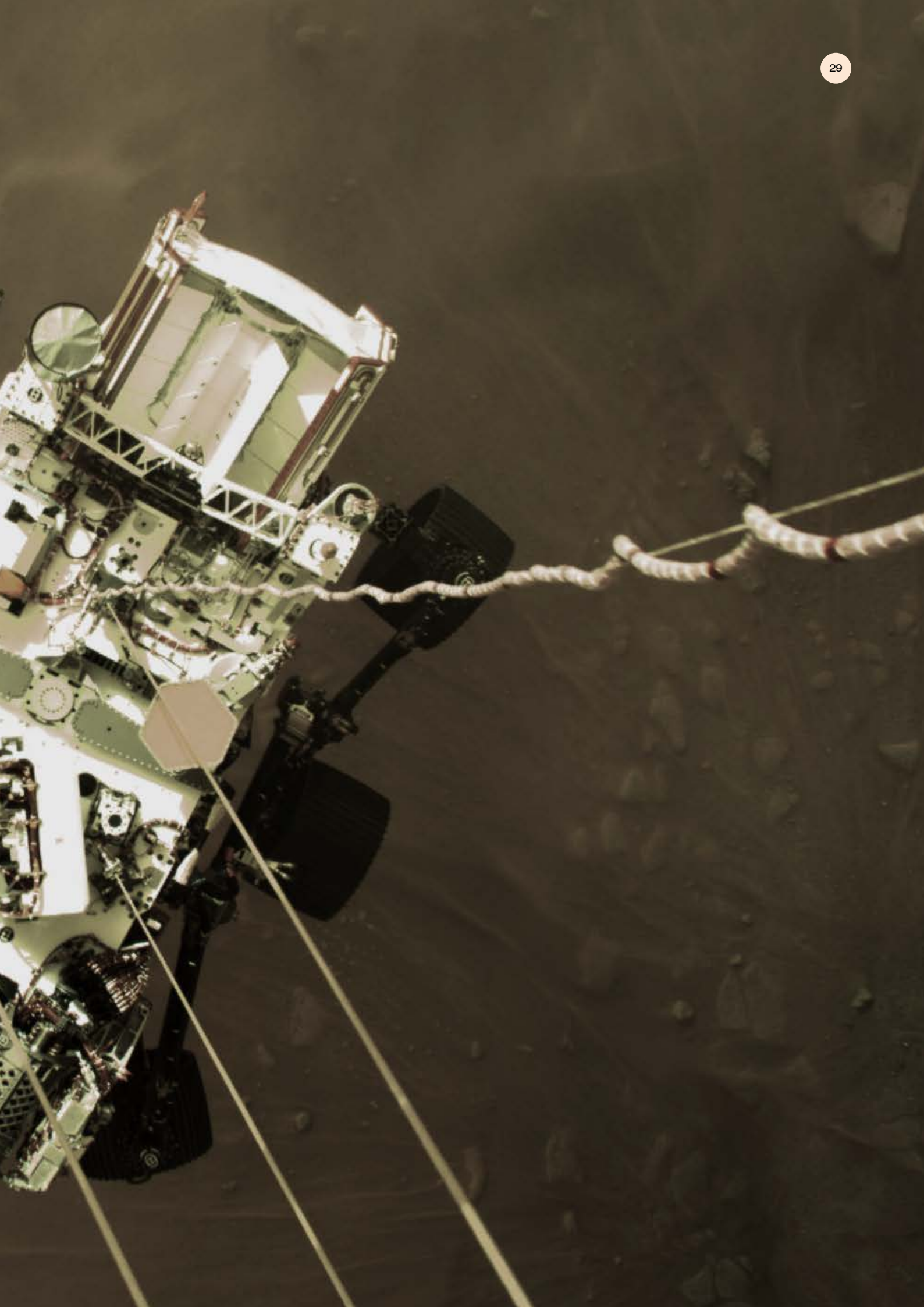


This annotated-composite graphic shows the entry of NASA's Perseverance rover into the "South Séitah" geologic unit from both an orbital and subsurface perspective. Credit: NASA/JPL-Caltech/ University of Arizona/USGS/FFI



This annotated map shows the locations where NASA's Perseverance Mars rover collected its first witness tube and filled its first six samples. Credit: NASA/JPL-Caltech/ASU/MSSS

The Mars 2020 descent stage lowers NASA's Perseverance rover onto the Red Planet on Feb. 18, 2021. The image is from video captured by a camera aboard the descent stage. Credits: NASA/JPL-Caltech



New-Space

In the Workpackages 1-3 (WP1-3), CENSSS will research new earth-observation sensors (WP1), new services that can be delivered by small (New-Space) satellites (WP3), and also design, build, test, launch and operate a New-Space satellite (WP2).

In order to get started also with WP2, we are considering building a Cubesat with primarily commercially available payloads. Together, therefore, we have worked on a feasibility study identifying possible mission concepts. The base assumptions are a mission consisting of a CubeSat platform located in a Low Earth Orbit, carrying out Earth observations. The main discussion has revolved around selection of one or more sensors, or payloads. At the current stage of the project a software defined radio with suitable antenna(s) and RF front-end electronics is identified as one payload candidate. The radio can be utilized for tasks such as sensor network communications and possible also radiometric applications.

In addition, we have identified commercially available sensor such as hyper/multi spectral cameras and spectrometer as possible candidates. A spectrometer can be used to measure greenhouse gas concentration, relevant for monitoring for example industrial pollution sources and the effect from the melting Arctic tundra.

An imaging spectrometer, either a hyperspectral imager or a multi-spectral imager, can provide a 2D image of spectral features on the ground,

Figure x. Example of a Software Defined Radio suitable for sensor network communications and radiometric applications.

Figure z. Example of a multispectral camera.

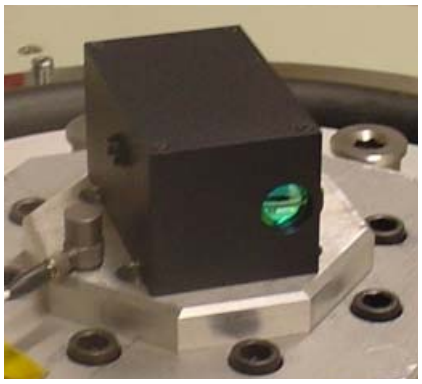


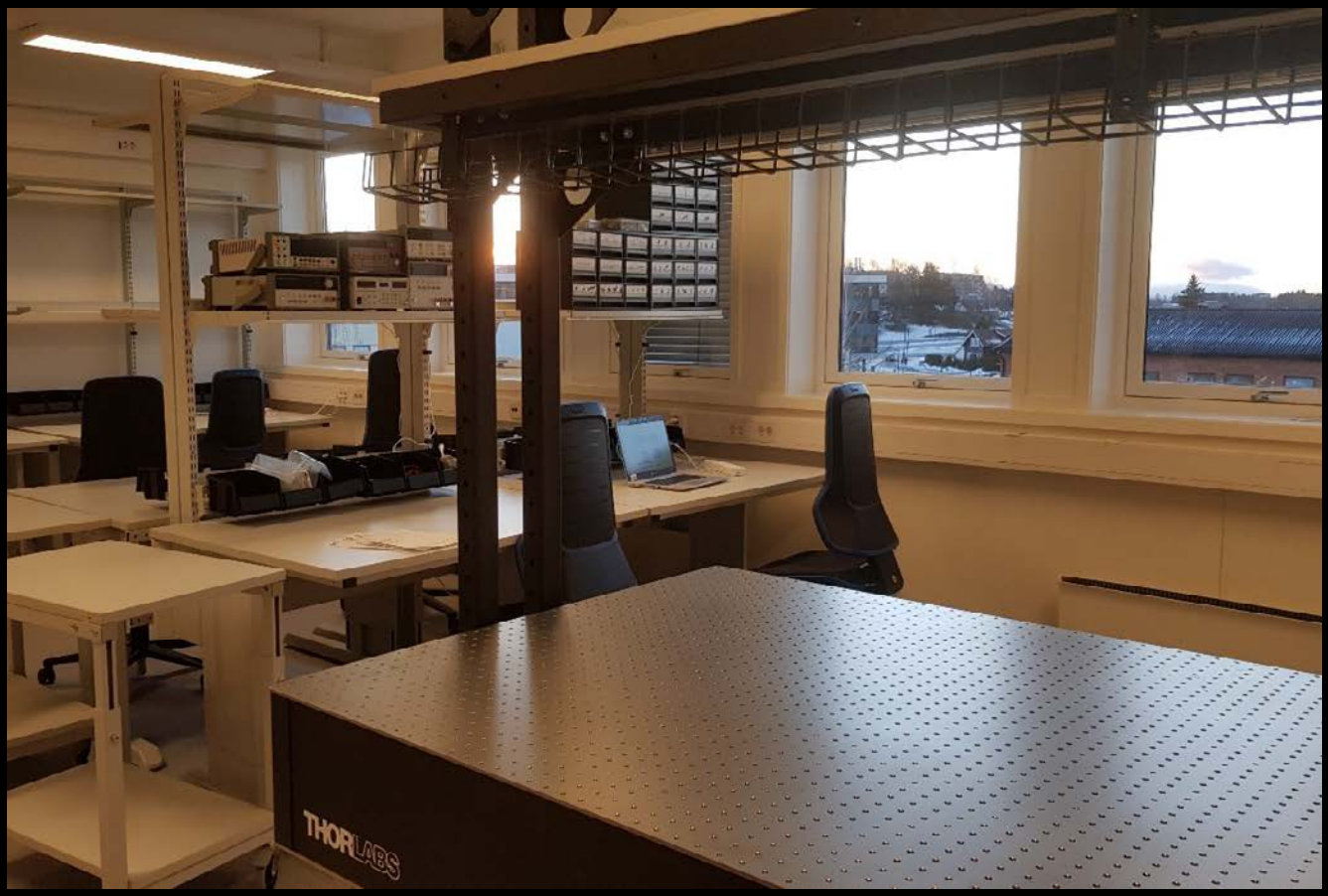
Figure y. Example of a spectrometer for measurements of greenhouse gas concentrations, that has been flown in a Cubesat.

or in the air-column underneath the satellite. An example is the Hypso imager developed at NTNU, which has been launched quite recently to detect algae in the ocean. The ocean color can also reveal other information regarding characteristics of the ocean.

We haves worked on identifying suitable satellite platforms for realization of a CENSSS satellite. Two CubeSat manufacturers were contacted and information on available platform sizes, various sub-systems and payloads were received. A 6-unit CubeSat platform (10x20x30 cm3) seems suitable for integration of two sensors, depending on the actual sensors selected. In addition to the activity at ITS, partners are working on building competence on Assembly, Integration and Test (AIT) of both payloads and satellites. Eidel is working on required test facilities for environmental testing (thermal vacuum). FFI is working on integration and testing of satellites, and also on development and AIT of payloads.

A laboratory at ITS has been set up, suitable for CubeSat and sensor AIT. The first instruments were ordered, enabling initial utilization of the lab.

We employed two PhD students in 2021 working on optical sensors and analysis of sensor data. The PhD students will carry out long-term research on key technological problems relevant for the new space effort in CENSSS. We started the process of employing Post Docs for WPs 1-3 in 2021, with application deadline in January 2022.



Lab

In WP2, CENSSS will model, design, assemble, integrate and test a New-Space satellite demonstrator, which will subsequently be launched and operated by the centre. CENSSS will also research novel optical sensors as well as other sensors and sensor systems, in WP1. While some of the work in WP1 and WP2 may be carried out in partner laboratories, we also need our own laboratory at UiO/ITS for this. We have therefore established a new 40 sqm laboratory at ITS for this purpose. The laboratory satisfies ESD (Electro Static Disharge) protection requirement, having a surface conducting floor as well at ESD specified inventory. The laboratory also has a special optical table for test of optics and optical instruments.

Credit: NASA/JPL-Caltech/ASU/MSSS

The Centre Management

Credit: UiO

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.

Credit: UiO

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.

Credit: FFI

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, Skauli teaches courses in basic optics and camera technology, and supervises research in drone-based remote sensing. Skauli is currently vice chair of a working group under the IEEE standards association developing a standard for technical aspects of hyperspectral imaging. Skauli 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, Skauli has worked on imaging for a microsatellite development, and in the past also on semiconductor technology and electronics. Skauli 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. He 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. Dr. Løvold 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. Dr. Løvold 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 2021

Tor Berger

Tor joined the CENSSS team in February 2021 as Science coordinator.

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.

Credit: FFI

Hans Erik Foss Amundsen

Hans joined the CENSSS team in February 2021 as research scientist.

Hans received the Dr. Philos. degree in volcanology and geochemistry at the University of Oslo in 1991. In 1992 he joined Saga Petroleum working on sedimentology and seismic interpretation in volcanic basins along the N Atlantic margin. He later founded the consultancy companies SAGEX (2000) and Vestfonna Geophysical (2009) working as a geological- and geophysical advisor to the oil industry within geological interpretation of seismic and EM imaging data (CSEM, MT, GPR) and development of protocols for CSEM data analyses for EMGS. He founded the Arctic Mars Analog Svalbard Expedition (AMASE) in 2003 running annual field expeditions testing Mars rover instruments and rover platforms for NASA and ESA.

Since 2014 Hans has worked with geological interpretation of RIMFAX data and he has been a Long-Term Planer on the Mars 2020 mission since 2020.

At CENSSS he will focus on using current science questions within planetary exploration as a driver to develop new EM imaging technologies.

Hans holds a 20% position at CENSSS.

Credit: Johnny Vaet Nordskog

Gard Momrak Selnesaunet

Gard was the first PhD fellow to join the CENSSS team in October of 2021.

Gard has a master degree from the MENA program here at the University of Oslo. He wrote his thesis with the Semiconductor Physics group at the Department of Physics. The title of his thesis was "Nanostructuring of SiC for novel defect-based quantum technologies"

Gard will work on developing standards for hyperspectral cameras under the supervision of Professor Torbjørn Skauli and in close collaboration with IDEAS and NEO. The plan is that Gard will work on incorporating such optical systems to small satellites set to orbit the Earth.

Gard is supervised by Professor Torbjørn Skauli, and will primarily focused on activities within WP1 New-Space Sensors.

Credit: Private

Kristoffer Langstad

Kristoffer joined the CENSSS team in November of 2021 as a PhD fellow.

Kristoffer has a Bachelor's degree in physics and astronomy, and a Master's degree in Computational Physics, both from the University of Oslo. His Master thesis was titled "Multiclass classification of leptons in proton-proton collisions at sqrt(s)=13 TeV using machine learning".

Kristoffer aims to work with deep learning on specific data sets or data fusion of different types of data sets to provide new insights on some satellite data.

Kristoffer will primarily work on activities linked to WP3 New-Space Services.

Credit: Private

CENSSS in media

Articles online

- **Torsdag lander norsk teknologi på Mars**
  www.ffi.no,15.02.2021
  https://www.ffi.no/aktuelt/nyheter/torsdag-lander-norsk-teknologi-pa-mars

- **Neste skritt i letingen etter liv: NASAs nye rover skal snart lande på Mars**
  www.forskning.no, 13.02.2021
  Neste skritt i letingen etter liv: NASAs nye rover skal snart lande på Mars (forskning.no)

- **Rover med norsk georadar lander på Mars 18.februar**
  www.mn.uio.no/its, 13.02.2021
  https://www.mn.uio.no/its/om/aktuelt/rimfax.html

- **Medlemsblad Astronomi**
  Norsk Astronomisk Selskap. Medlemsblad Astronomi 1/2021, 04.02.2021
  https://www.astronomi.no/?page_id=170

- **Klart for Mars-landing med stor norsk representasjon**
  Aftenposten, 16.02.21
  https://www.aftenposten.no/verden/i/jBKp49/klart-for-mars-landing-med-stor-norsk-representasjon

- **Fra Fauske til krater på Mars**
  Saltenposten, 17.02.2021
  https://saltenposten.no/nyheter/det-blir-nervepirrende-minutter-a-vente/19.27648

- **Norsk georadar lander på Mars torsdag**
  Titan, 17.02.2021
  https://titan.uio.no/universet/2021/norsk-georadar-lander-pa-mars-pa-torsdag

- **Tror det kan finnes vann på Mars**
  Uniforum, 20.02.2021
  https://www.uniforum.uio.no/nyheter/2021/02/Tror-det-kan-finnes-vann-pa-mars.html

- **Se ny animasjon: Slik lander Nasa på Mars om to dager**
  NRK Nordland, 16.02.2021
  https://www.nrk.no/nordland/nasa-mars-2020-perseverance-rover-lander-18.-februar-__slik-lander-nasa-pa-mars-1.15377389

- **Vellykket landing for Mars-roveren – nå skal norskutviklet georadar lete etter vann**
  NRK Nordland, 18.02. Oppdatert 19.02
  https://www.nrk.no/nordland/i-dag-lander-nasa-roveren-_perseverance_-pa-mars-med-norskutviklet-georadar-1.15380464

- **Perseverance og Rimfax landet trygt**
  Norsk romsenter
  www.romsenter.no, 18.02.2021
  https://www.romsenter.no/no/Aktuelt/Siste-nytt/Perseverance-og-Rimfax-landet-trygt

- **Romfartøyet er landet på Mars**
  TV2, 18.02-2021
  https://www.tv2.no/nyheter/11965254/

- **Slik ser det ut når du lander på Mars**
  Norsk romsenter
  www.romsenter.no, 23.02.20221
  https://www.romsenter.no/no/Aktuelt/Siste-nytt/Slik-ser-det-ut-naar-du-lander-paa-Mars

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- **NRK Radio**
  Programserie: Abels tårn.
  Forgård: Landingen på Mars
  19.02.2021
  https://radio.nrk.no/podkast/abels_taarn/l_1bb55e48-7329-4904-b55e-487329a904c1

- **Slik styrer Svein-Erik georadaren på Mars**
  Teknisk Ukeblad
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- **Ferdig med å teste utstyret på Mars. I dag starter leitingen etter liv**
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- **Henrik Asheim fekk ei Mars-oppleving på Kjeller**
  UNIFORUM, 29.06.2021
  https://www.uniforum.uio.no/nyheter/2021/06/henrik-asheim-fekk-ei-mars-oppleving-pa-kjeller.html

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  Forfatter: Lars Aarønæs, publisert på FFI nettsider, 10.12 2021
  https://www.ffi.no/aktuelt/nyheter/rimfax-er-ffis-pioner-pa-mars

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- **Universitetsplassen – podkast from UiO**
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- **NRK2, Mars-landingen**
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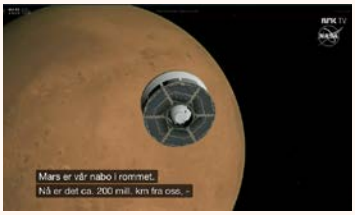

Publications

Radar Imager for Mars' Subsurface Experiment – RIMFAX

Publication: The Mars 2020 Mission Edited by Kenneth A. Farley, Kenneth H. Williford and Kathryn M. Stack.

Authors: Svein-Erik Hamran[1] · David A. Paige[2] · Hans E.F. Amundsen[3] · Tor Berger[4] · Sverre Brovoll[4] · Lynn Carter[5] · Leif Damsgård[4] · Henning Dypvik[1] · Jo Eide[6] · Sigurd Eide[1] · Rebecca Ghent[7] · Øystein Helleren[4] · Jack Kohler[8] · Mike Mellon[9] · Daniel C. Nunes[10] · Dirk Plettemeier[11] · Kathryn Rowe[2] · Patrick Russell[2] · Mats Jørgen Øyan[4] Received: 15 May 2020 / Accepted: 25 September 2020 / Published online: 3 November 2020

Abstract

The Radar Imager for Mars' Subsurface Experiment (RIMFAX) is a Ground Penetrating Radar on the Mars 2020 mission's Perseverance rover, which is planned to land near a deltaic landform in Jezero crater. RIMFAX will add a new dimension to rover investigations of Mars by providing the capability to image the shallow subsurface beneath the rover. The principal goals of the RIMFAX investigation are to image subsurface structure, and to provide information regarding subsurface composition. Data provided by RIMFAX will aid Perseverance's mission to explore the ancient habitability of its field area and to select a set of promising geologic samples for analysis, caching, and eventual return to Earth. RIMFAX is a Frequency Modulated Continuous Wave (FMCW) radar, which transmits a signal swept through a range of frequencies, rather than a single wide-band pulse. The operating frequency range of 150–1200 MHz covers the typical frequencies of GPR used in geology. In general, the full bandwidth (with effective center frequency of 675 MHz) will be used for shallow imaging down to several meters, and a reduced bandwidth of the lower frequencies (center frequency 375 MHz) will be used for imaging deeper structures. The majority of data will be collected at regular distance intervals whenever the rover is driving, in each of the deep, shallow, and surface modes. Stationary measurements with extended integration times will improve depth range and SNR at select locations. The RIMFAX instrument consists of an electronic unit housed inside the rover body and an antenna mounted externally at the rear of the rover. Several instrument prototypes have been field tested in different geological settings, including glaciers, permafrost sediments, bioherme mound structures in limestone, and sedimentary features in sand dunes. Numerical modelling has provided a first assessment of RIMFAX's imaging potential using parameters simulated for the Jezero crater landing site.

Mars 2020 mission overview.

Publication: Space Science Reviews 2020 ;Volum 216:142. (8) p. 1-41

Authors: Farley, Kenneth A.; Williford, Kenneth H.; Stack, Kathryn M.; Bhartia, Rohit; Chen, Al; de la Torre, Manuel; Hand, Kevin; Goreva, Yulia; Herd, Christopher D.K.; Hueso, Ricardo; Liu, Yang; Maki, Justin N.; Martinez, German; Moeller, Robert C.; Nelessen, Adam; Newman, Claire E.; Nunes, Daniel; Ponce, Adrian; Spanovich, Nicole; Willis, Peter A.; Beegle, Luther W.; Bell III, James F.; Hamran, Svein-Erik; Brown, Adrian J.; Hurowitz, Joel A.; Maurice, Sylvestre; Paige, David A.; Rodriguez-Manfredi, Jose A.; Schulte, Mitch; Wiens, Roger C.

Radar imager for Mars' subsurface experiment – RIMFAX.

Publication: Space Science Reviews 2020 ;Volum 216.(8)

Authors: Hamran, Svein-Erik; Paige, David A.; Amundsen, Hans E. Foss; Berger, Tor; Brovoll, Sverre; Carter, Lynn; Hanssen, Leif; Dypvik, Henning; Eide, Jo; Eide, Sigurd; Ghent, Rebecca; Helleren, Øystein; Kohler, Jack; Mellon, Mike; Nunes, Daniel C.; Plettemeier, Dirk; Rowe, Kathryn; Russell, Patrick; Øyan, Mats Jørgen.

Photogeologic Map of the Perseverance Rover Field Site in Jezero Crater Constructed by the Mars 2020 Science Team.

Publication: Space Science Reviews 2020 ;Volum 216.

Authors: Stack, Kathryn M.; Williams, Nathan R; Calef III, Fred; Sun, Vivian Z; Williford, Kenneth H; Farley, Kenneth A.; Eide, Sigurd; Flannery, David; Hughes, Cory; Jacob, Samantha R; Kah, Linda C; Meyen, Forrest; Molina, Antonio; Nataf, Cathy Quantin; Rice, Melissa; Russell, Patrick; Scheller, Eva; Seeger, Christina H; Abbey, William J; Adler, Jacob B; Amundsen, Hans; Anderson, Ryan B; Angel, Stanley M; Arana, Gorka; Atkins, James; Barrington, Megan; Berger, Tor; Borden, Rose; Boring, Beau; Brown, Adrian; Carrier, Brandi L; Conrad, Pamela; Dypvik, Henning; Fagents, Sarah A; Gallegos, Zachary E; Garczynski, Brad; Golder, Keenan; Gómez, Felipe; Goreva, Yulia; Gupta, Sanjeev; Hamran, Svein-Erik; Hicks, Taryn; Hinterman, Eric D; Horgan, Briony N; Horowitz, Joel; Johnson, Jeffrey R.; Lasue, Jeremie; Kronyak, Rachel E; Liu, Yang; Madariaga, Juan Manuel; Mangold, Nicolas; McClean, John; Miklusicak, Noah; Nunes, Daniel C.; Rojas, Corrine; Runyon, Kirby; Schmitz, Nicole; Scudder, Noel; Shaver, Emily; SooHoo, Jason; Spaulding, Russell; Stanish, Evan; Tamppari, Leslie K; Tice, Michael M.; Turenne, Nathalie; Willis, Peter A; Yingst, R. Aileen.


Credit: NASA/JPL-Caltech/ASU/MSSS

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