VITEN

75TH ANNIVERSARY MAGAZINE FROM THE NORWEGIAN DEFENCE RESEARCH ESTABLISHMENT (FFI)

1946–2021

PROUD PAST, EXCITING FUTURE

VITEN IS NORWEGIAN FOR 'KNOWLEDGE' AND IS FFI'S MAGAZINE AIMED AT A WIDER AUDIENCE.
THIS IS A SPECIAL EDITION TO CELEBRATE FFI'S 75TH ANNIVERSARY.

NORWEGIAN DEFENCE RESEARCH ESTABLISHMENT

On 11 April 1946, the Norwegian Parliament (Stortinget) decided to establish the Norwegian Defence Research Establishment (FFI). FFI has now been supplying knowledge and ideas for an effective Norwegian defence for 75 years. The story continues. Here are the stories of a proud past and an exciting future.

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The space scouts

How can tiny satellites reveal sinister ships in Norwegian waters? What secrets can be found around Saturn and on Mars? Several outer space scouts have been developed at FFI.

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He was the first man on the moon. But what was Neil Armstrong (on the left) doing with FFI's Olav Blichner at the Spåtind Mountain Hotel? See the pictures photographer Bjørn Fremstad will never forget.

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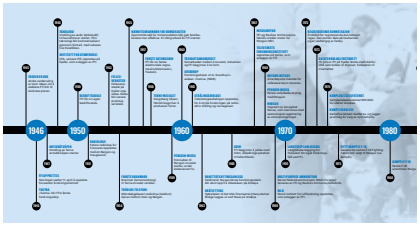

80 The complete history

We will recount the highlights from the past 75 years. Find out which seven success stories researchers at FFI rank the highest.

WE ARE JAMES BOND'S Q

Departing Director General John-Mikal Størdal believes FFI should be shrouded in a certain aura of mystery.

"We should be open and communicate everything we are at liberty to disclose. At the same time, it is clear that there are things happening on the inside that relatively few will know about", says Størdal.

"I can tell you what I said in an interview with my local newspaper: 'If the Norwegian Armed Forces is James Bond, then we must be Q'. You know, the scientist who in each movie provides Bond with newly developed equipment and technological gadgets that appear to come in handy at crucial moments".

He will soon be leaving such moments to a successor. If everything goes to plan, the Director General from Hardanger will soon be departing his FFI. This departure will occur in the early summer of 2021. Following nine years in the Director's chair at Kjeller, Størdal is moving to Paris. There, he will become the Director General of another three-letter organisation: CSO. The acronym stands for Collaboration Support Office. CSO is part of the NATO Science and Technology Organization. Duties include coordinating and strengthening research and development in member states.

"NATO must become even better at inviting research and development communities to take part in innovative collaboration, across departments and national borders. This task is just as important there as it is here", he says.

John-Mikal Størdal grew up on the north side of the Hardanger Fjord, in the village of Herand in Jondal. Artist Herborg Kråkevik undoubtedly put the town on the map. There is also a connection between the two of them: Herborg's father was John-Mikal's teacher in lower secondary school. His childhood home in Herand is now a holiday home and is frequently used by the entire family of five.

Størdal has a master's degree in Aeronautics and Astronautics from the Massachusetts Institute of Technology (MIT) in United States and holds a Master of Science in Engineering Cybernetics from the Norwegian Institute of Technology (NTH). Størdal served as Chief of Staff at FFI for three years before he took over the helm after Paul Narum, who stepped down as Director General in 2012.

At age 75, is FFI in good condition?
"Our coat of arms has been redesigned. This is symbolic: During our anniversary year, we will be presenting a new long-term plan, a new vision and a new structure. All this gives us a new lease on life. It bodes well for our future".

What has made you most proud during your leadership of the institute?
"We can look back at many achievements, and my colleagues here have now ranked seven of these (see the fold-out on page 80). In my opinion, it would be difficult to point to specific moments. I take pleasure in our people succeeding and seeing that the results of things we have done here are important and useful. Some of the things we are especially proud of are things no one on the outside will know about. This is challenging for the researchers in question. Therefore, it is all the more

JOHN-MIKAL STØRDAL
(55)

Director General, FFI

RESIDENCE
Asker

EMPLOYED SINCE
1992

FIELD OF EXPERTISE
Astronautics and Cybernetics

Photo: Espen Wang-Naveen / FFI

Even in 2020, the year of the coronavirus, FFI had 75 summer interns. John-Mikal Størdal is pleased that FFI is now such an attractive workplace for young technologists. *Photo: Christian Tandberg / FFI*

important that we appreciate them within the organisation. Recently, a colleague here delivered a statement to the Prime Minister. We received feedback that the person in question had done a phenomenal job and highlighted a complex topic in an exceptional manner. This was a ten-minute briefing.

I also look back at many other proud moments. Of course, it is a big moment when the United States purchases missiles from Norway, that FFI has been part of developing. Similarly, what happened when we presented our long-term plan in the spring of 2017 was pleasant. We had announced a presentation at Oslo Military Society's premises. We had not thought that many people would attend, but we had a full house. Both the Minister of Defence and Chief of Defence were in attendance. In addition, the Minister of Research and Education and several of the heads of the major defence works and technology companies were present.

Another thing that makes me proud is to make the rounds and look at what our summer interns are accomplishing in the months they spend here. We have now received a record number of applications. This is extremely pleasing. A winning formula for us has always been to recruit good people. As such, it is a positive tradition at the institute to assign challenging tasks to young researchers. You have to learn on the job. I have noted that those who developed the Apollo Programme and the Moon missions had an average age of approximately 30 years. Now, the average age at NASA is 60 years, while Space X employees have an average age of 30 years. It is apparent to all who is taking the lead: It is the young people at Space X".

You arrived at FFI as a conscript in 1989. What was your initial impression?

"That I would not be here for long! How wrong I was. I arrived fresh out of NTH, where I had written my thesis on Kongsberg's dynamic positioning of ships in the North Sea, i.e., the 'locking' of vessels in fixed position relative to the seabed. To begin with, I though the conditions were a bit shabby at Kjeller. I wanted to return to Kongsberg. The pace was so much slower here than I experienced it in commercial industries. But the tasks were appealing. I remember my first boss here, Emil Brodersen, told me: 'Here at the institute, we throw you in at the deep end. Then we come back in a year and see if you are floating'.

I began working on missile development, which later became Naval Strike Missile (NSM). I saw how it was possible to utilise information from digital maps. At that moment, I felt that I was being tested to the limits of what I had learned. Though it was not down to me; When Teknisk Ukeblad (Technical Weekly Magazine) in 2015 ranked the biggest engineering achievements post-WWII, Kongsberg's dynamic positioning was ranked number one. FFI's missile development came in second. Imagine that I was able to be involved in both.

The thing about being thrown in at the deep end came true, literally: I was later given the opportunity to go on a

In the beginning, I felt like I was stepping into shoes that I did not quite fill. I felt like I was being thrown in at the deep end.

mission and examine new submarine technology. In collaboration with the industry in Kongsberg, we developed methods and explored Ula-class submarines. For three-four years, we were involved in research and development of methods for tracking. One problem with submarines is that they are vulnerable when they are close to their target, especially with the periscope raised. Based on passive information and advanced mathematics, we were able to demonstrate a new way of doing things. This resulted in torpedoes being able to strike targets at greater distances than anyone had thought possible, with the submarine remaining submerged. Simply put, we used the submarine in a novel way. During an exercise in which we participated, commanders of foreign vessels were unable to quite comprehend how we accomplished this".

You became the top executive at the institute in 2012. How did that feel?
"In the beginning, I felt like I was stepping into shoes that I did not quite fill. Once again, I felt like I was being thrown in at the deep end. The job required a lot of learning in the beginning. As the head of FFI, you have to be both skilled and extremely motivated. This is why it is a fixed-term post. Your term should not be too short, but it is just as detrimental to hold such a post for too long. The modernisation efforts we began a few years ago were based on the fact that we were too poorly equipped in some areas. The potential of FFI's role was and continues to be enormous. However, the manner in which it was structured, was not conducive for me or the organisation to be able to maximise the potential of our role".

What have been your proudest moments during your leadership?
"A combination of two things: One is the overarching social mission; to safeguard Norway's freedom and independence. The other is to be able to offer meaningful tasks to colleagues at the institute. I often face the accusation that 'you only think about our researchers'. Not true. Here, we are a big machine where everyone plays their part. Staff and support functions are essential to our work. Our deliverables are big, so, naturally, I do not have an overview of everything. For a long time, I attempted to at least read the summaries of all reports. I had to give up on this.

Not being here anymore will be strange. On the other hand, I think an eight-year directorship is long for FFI and it is long for me. Change will be good for both parties".

Do you see areas at FFI where there is room for improvement?
"We need to improve at communicating our results. It is part of the nature of researchers to account for what he or she is doing. However, we often fail to account for why. What utility does our research and development work have for its recipients? I liken it to smartphones: The utility for us lies in what they do, not how they are built. We defence people talk too much about the inner workings and too little about the utility of our research projects.

We are unable to adequately highlight our specialist expertise or our unsurpassed results. In the field of space technology, we launched our own mini-satellite in 2001. And the early decision to begin developing missiles, which came to fruition with Penguin, was especially future-oriented.

It is an important point that we, throughout our history, have been good at making changes before anyone sees the necessity thereof. Here, there is a direct correlation with assigning responsibility to the right people and focusing on recruitment. We must be at the cutting edge. I view it as a considerable freedom for us to be able to determine our own course. If we lose our lead, others will determine our course for us. Increased research and development on autonomy and use of artificial intelligence are examples of important initiatives".

The Norwegian Armed Forces will always be FFI's biggest customer. What is this collaboration like?
"Generally, very good, and incredibly important for our results and deliverables. It is one of our unique strengths that FFI staff members can work closely with the Norwegian Armed Forces and other clients in the real world, with an emphasis on use and utility. In this context, we must be aware of the fact that

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Chief of Defence Eirik Johan Kristoffersen in conversation with John-Mikal Størdal, during a visit to Kjeller.
Photo: Espen Wang-Naveen / FFI

02
Researcher Magnus Baksaas explaining to FFI's Director General John-Mikal Størdal how the self-driving off-road vehicle Olav works.
Photo: Christian Tandberg / FFI

there is considerable respect for FFI employees in the Norwegian Armed Forces. This is nice, but it can, at times, be a barrier to communication. An example of this is when we had delivered considerable research for the development of the Nansen-class frigates. The first commander had been handpicked. We got in contact and wondered if he could come and deliver an introductory statement for us. What were his views on these ships that we had done so much work on? He was scheduled to arrive at 09:00. He arrived at 08:00. I was bewildered. This is a genuine tough guy, but now he was nervous. What was the problem? Indeed, here he was tasked with telling the leading researchers in the country about weapon technology. There was no way this could end well! Naturally, it went just fine. The FFI researchers were equally starstruck to meet the commander as he was to meet them. I have experienced similar reactions on several occasions: All it takes is a call from us and the recipient is reporting for duty.

Those who know FFI well, know that researchers and management are relaxed. But such misunderstandings are confirmed by reputation surveys we have conducted. The answer is that we need to achieve more interaction with the outside world".

What will you miss the most when you leave?
"All the inspiring colleagues, of course. First and foremost at FFI, but also in the rest of the sector. Then, all the meaningful tasks. Truth be told, I find FFI to be a challenging organisation. Difficult to become truly fond of, but my word, how difficult to leave".

Why?
"I don't know. Perhaps it has to do with the very analytical and cold approach that FFI takes. I know of people who have quit out of frustration and anger. A year later, they have wanted to return. Most former FFI employees I meet, however, talk about their time here very fondly. At one point in time, I was heading full speed for the exit, myself. I was furious; at my boss, at inadequate cooperation across the organisation, at the system and the whole thing. Then, I was told that it would be unwise to resign. Instead, I was able to cool off during a one-year stay in the United States. That is when you understand that your superiors can be understanding".

What would you say to the next Director General?
"One piece of advice is as follows: A researcher must be given enough space. I see that requirements for deliverables have become stricter. It worries me if we are not given enough time before we are asked to deliver. In my first year at FFI, I was assigned a task that stretched over the course of a year. That gave me considerable freedom. I was given the chance to thoroughly tackle the assignment. With short deadlines, you will not have the peace that is required. Once bitten, twice shy, I would also add this advice: Seek to understand, before you ask to be understood".

In terms of military technology, the world is more complex than ever before. In what fields can FFI assert itself?
"If we are to be a partner to those with whom we are interested in collaborating, we must continue to be a world

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leader in carefully selected areas. There, we must have in-depth knowledge.

We are heading full speed in the direction of a technologically bifurcated world: China versus the West. Not only the Norwegian Armed Forces, but also the industry may face the following choice: 'Either you are with us or against us', as was the case in the discussions regarding the 5G expansion. This adjustment is challenging. The turmoil surrounding Huawei is only the beginning. This is potentially a big issue, where we have to both give advice and understand. It will hit us long before we see it coming. Secretary General of NATO, Jens Stoltenberg has gone very far in making his views heard on this matter. It will be exciting to see what Europe will do".

Will FFI exist 50 years from now?
"Absolutely. There will be an even greater demand for knowledge and fact-based support than there is now, especially in the area of technology. A future institute will continue to be based on military technology. However, I think we will offer far more research directed at the civil sector, in areas where FFI has especially good prerequisites for involvement. Long-term planning, with which we are now assisting the judicial sector, is an example of a field that may grow".

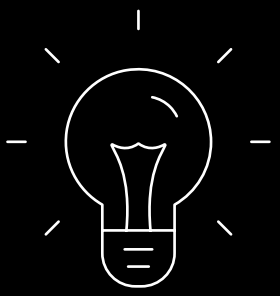
Størdal has also been engaged in long-term planning in his private life. He was an active football coach for his children, one girl and two boys, who are now adults, in Snarøya Sports Club.

"I was involved from little league to the junior level. I miss those times. When I walk by the pitch today, I meet some of those I coached, who are now between 25 and 30 years of age. They come over and greet me and say they remember how we used to do things. Several of them still play football. That is certainly a good reward for the efforts".

As low-key a figure as you are at FFI, it is perhaps a bit difficult to picture Størdal shouting from the sidelines?
"The whistle came in handy. Perhaps I should have had a whistle here, too?" ■

I will miss all the inspiring colleagues. First and foremost at FFI, but also in the rest of the sector.

THIS IS FFI



The Norwegian Defence Research Establishment (FFI) is the Norwegian Armed Forces' central research institute whose objective is to conduct applied research and development in response to the needs of the defence sector. The institute is subordinate to the Ministry of Defence. FFI is one of Norway's biggest research institutions, with operating income exceeding NOK 1 billion (2020).

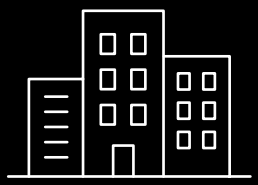
11.04.1946

Our birthday!
On page 14 you can read the story of how we came to be.

THE RESEARCH

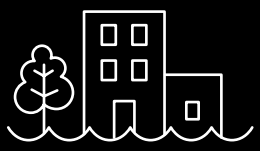
The research at FFI is divided into five divisions:

Defence Systems,
Strategic Analyses and Joint Systems,
Sensor and Surveillance Systems,
Innovation and Industrial Development
and Total Defence.



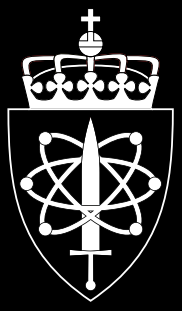
KJELLER, LILLESTRØM

707 employees are currently working at FFI Kjeller.



KARLJOHANSVERN, HORTEN

64 employees are currently working at FFI Karljohansvern, Horten.



FFI's coat of arms with the heraldic royal crown was designed by herald and Major General Thorbjørn Bergersen and approved by King Olav V on 2 December 1989. The figure on the escutcheon shows a raised sword surrounded by an atom with electrons at either end. The visual design symbolises the institute's scientific relationship with the Norwegian Armed Forces. The coat of arms was updated in December 2020.

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EMPLOYEES

SOCIAL RESPONSIBILITY

FFI conducts applied research and development that contributes to providing Norway with an effective and relevant defence, a secure society and a competitive defence industry. The institute is involved in strengthening the Norwegian Armed Forces' operational capability and NATO's capabilities for collective defence. FFI enjoys extensive collaboration with close allies.

80 %

The research is 80 percent project funded. 20 percent are budgetary allocations.

VISION

FFI turns knowledge and ideas into an effective defence

FFI employees practicing emergency preparedness: A suspicious package is inspected. *Photo: Christian Tandberg / FFI*

EVERYTHING IS TOP-SECRET, RIGHT?

Many associate the acronym FFI with closed doors and total secrecy. The reality is somewhat different.

Anyone who has visited FFI in Horten or at Kjeller know that there are strict routines. You must be registered at the reception and be escorted. Phones must be left outside the meeting rooms.

FFI's employees must have a security clearance in order to be able to work 'inside the fence'. When they tell people where they work, some may receive the comment: 'Wow! Everything is top secret there, right? I won't ask any more questions'. In other words, many believe there is a parallel between e.g., the Norwegian Intelligence Service and FFI, possibly that FFI always works on 'secret matters'.

A visit to the website ffi.no shows a great desire for openness. The public should know what FFI is doing and, as long as a research report is not classified, it will be published in its entirety.

Not even all defence staff are aware that FFI is involved in EU projects, takes assignments from government agencies and is an industrial partner in non-military contexts. It is also important to communicate the institute's total defence efforts.

FFI wants to show what the institute is working on. News is published on social media weekly. Open meetings and conferences are an important part of the job, whether it concerns overarching topics for the entire defence sector, or expert knowledge on drone piloting and 3D printing.

At the same time, balance is important. Although FFI employees are civilian staff, the institute is an important part of the Norwegian Armed Forces.

"There are essential matters that cannot be discussed publicly, and that concern the work here at FFI", says Espen Skjelland, Director of Research at the Department for Strategic Analyses and Joint Systems. He elaborates:

"These matters relate to political, strategic and operational assessments regarding various types of conflicts. It goes to the heart of why we have a military defence and what kind of defence we require. We are exploring an uncertain future involving a broad range of scenarios. We model and simulate military operations with a considerable degree of detail, and, if necessary, we use highly classified data. The unique aspect for the Norwegian Armed Forces is that it is to operate based on the presumption that another actor – its opponent – will make considerable efforts to ensure that we fail. This means that a single critical omission or misjudgement in an operation may lead to a collapse of practically the entire organisation.

The visible and invisible security measures at FFI are there for good reason. However, there are equally obvious reasons for freely communicating much of what happens at the institute. A top-secret research institute is unlikely to benefit Norway. The more insight the rest of society has regarding activities at Kjeller and in Horten, the better". ■

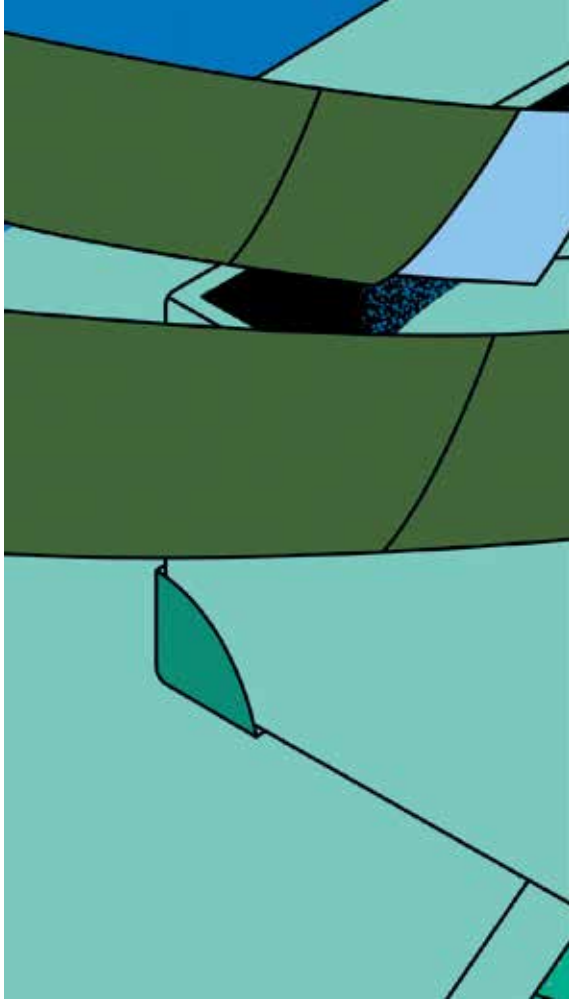
THE SECURITY ACT

The Act relating to protective security services regulates access to information that may harm the interests of Norway or our allies, relationships with foreign powers or other vital security interests. Documents are subject to four levels of security classification:

- Restricted
- Confidential
- Secret
- Top Secret

THE IDEA OF FFI

Made in England



He was a chemistry professor and resistance figure. Already in the first year of the war, Leif Tronstad began thinking aloud about something the British had and that Norway was missing: military research.

It all began in England. The idea of a Norwegian military technology research institute was raised already in 1941. The war was underway. The Germans were succeeding on all fronts. One of the researchers who had fled to the United Kingdom, however, was certain: The end result would be different. And the Norwegian Armed Forces would then require such an institution. Its establishment was essential. Otherwise, the country would probably not be able to keep up with the accelerating development in the field of military technology.

The researcher behind this idea was Leif Tronstad. In London, he was affiliated with the Norwegian High Command and held the rank of Major. He would become one of the most famous figures in the resistance.

Tronstad had an important role in the Norwegian heavy water sabotage operation at Vemork in 1943. This was a plant that he had personally been involved in planning. Now, he had to plan its sabotage. Already in 1948, the operation became the subject of a feature film, in the Norwegian-French production Operation Swallow: The Battle for Heavy Water. Hollywood tackled the operation in 1965 in The Heroes of Telemark with Kirk Douglas in a supporting role. The operation also became a popular tele-vision series on Norwegian public broadcaster NRK in 2015.

The Bærums-born Tronstad had started out as a chemist. He had studied in both Berlin and Cambridge. He was a professor at NTH. In the United Kingdom, he had become a known and well-respected name in the preceding decade. This would come to benefit Norway. The Norwegian Government-in-exile appointed Tronstad head of the Technical Committee in the Norwegian High Command (FOTU). This was the precursor to FFI. FOTU's goal was to recruit Norwegian technologists and scientists for military research in the United Kingdom. The Committee was to serve as the Norwegian Armed Forces' High Command's advisor on military-engineering matters.

The core of FFI existed in the form of 30-40 Norwegian engineers with a Master of Science and scientists who worked at British research institutes. Very many of them became part of the institute's early research staff.

The defence leadership in the Norway they had left behind did not prioritise science and technology development. In the 1930s, there was no organised research in the Norwegian Armed Forces, whatsoever. Older military leaders did not think technological expertise should take precedence over traditional, professional military knowledge. However, if the World War had proved anything, with the atomic bomb as the most terrifying example, it was that science and defence research had now become essential.

The natural leader of the newly established FFI could well have been Leif Hans Larsen Tronstad. This would not be the case. He wanted to be in the field, rather than behind a desk. From late 1944, he led an expedition of Norwegian paratroopers from Linge's Company. They operated in the mountain ranges in Telemark. Barely two months before the end of the war, this ended in tragedy. In a mountain cottage near Møsvatn Lake in Telemark, Tronstad was killed in battle with Norwegian NS members, just weeks before his 42nd birthday.

The post-war period's first Minister of Defence was also a remarkable resistance figure: Milorg leader Jens Christian Hauge became an enthusiastic and important contributor to the establishment of FFI.

The Norwegian Defence Research Establishment was just an idea in Leif Tronstads mind in 1941. Five years later, FFI had become a reality. Thanks to a group of young Norwegian researchers and engineers in the British war laboratories, the road had been paved for the scientific institution of the Norwegian Armed Forces. It would become one of Norway's most important research institutes. In April 1946, the Storting unanimously adopted the historic decision.

FFI was born. ■

LEIF TRONSTAD

Leif Tronstad (1903–1945) was a key figure in planning and organising the Vemork operation. For these efforts, he was bestowed with the Order of the British Empire. He was also part of organising surveillance of German officers in Norway. Among other things, this surveillance provided information regarding the German production of V-1 flying bombs in Peenemünde. This information led to extensive bombing, which set back the production. It offered the British sorely needed breathing room.

Leif Tronstads Plass (place) is found in downtown Sandvika, where King Olav V unveiled a monolith on 8 May 1973. The war hero's name is found in several places: Leif Tronstads veg (road) is located in Trondheim and Professor Tronstads gate (street) is found in Rjukan.

Photo: Norwegian Industrial Workers Museum

THE FIRST FUNDING

Don’t you actually need a million?

A surprise awaited when Fredrik Møller arrived at the Ministry of Defence.

Norway 1946: There was a chronic shortage of everything. There was a shortage of facilities and equipment for Norwegian research. At the Norwegian Institute of Technology (NTH) in Trondheim and in the scientific community in Bergen, resources were scarce. The newly established Norwegian Defence Research Establishment received unexpected start-up aid.

The first budget that was adopted was in the amount of NOK 1 million, with an additional starting grant of 300,000. Allocations in 1946 and 1947 jointly amounted to NOK 1.8 million. This is a large sum when compared to the fact that the well-established NTH was allocated 2.3 million over the same two-year period.

FFI’s first Director General Fredrik Møller personally recounted this situation, explain historians Olav Njølstad and Olav Wicken in Kunnskap som våpen (Knowledge as a weapon).

In the internal newsletter Mikroskopet (The Microscope), Møller wrote about how FFI was allocated its first budget, determined in the Norwegian High Command. Its precursor, the Technical Committee in the Norwegian High Command (FOTU) had boldly requested approximately 600,000 in its first year.

FREDRIK MØLLER

FFIs first Director General 1947–1957

Master of Science in acoustical engineering. Møller had a leading role among the 40 researchers and engineers working in England during the war.
Photo: FFI

In the budget meeting, Major Lindbæk Larsen and Major Pettersen participated on behalf of the Norwegian High Command. Sverre Pettersen would subsequently become FFI’s Assistant Director General.

Møller writes:

”They appear to fully agree on what policies they should have in relation to FFI. The first question was: ‘Tell me, do you not need more?’ To which the response was: ‘Of course, more would be nice’. To which Lindbæk Larsen enquired: ‘Don’t you actually need a million?’ When the answer was given in the affirmative, Major Pettersen interrupted, stating: ‘If you want a million, you will have to ask for one and a half’. And so, we requested one and a half, and to our great surprise we were granted one and a half”. ■

THE CHIEF OF DEFENCE LENDS HIS EAR TO FFI

Chief of Defence Eirik Kristoffersen has no doubts:
FFI plays a big part in what advice I give to the political leadership.

The General was appointed on 17 August 2020. He succeeded Admiral Haakon Bruun-Hanssen, who retired after having served as Chief of Defence in the period 2013 to 2020.

The new Chief of Defence is very familiar with FFI, including from the development of Forward Air Control and Navigation (FACNAV), the digital command and control system created for the Norwegian Armed Forces, and the Black Hornet nano helicopter; a drone that soldiers can use for reconnaissance purposes.

How do you view the lengthy collaboration between the Armed Forces and FFI?
"This collaboration has been very important for the development of the Armed Forces. The result today is that we in Norway have a modern defence. It has managed to continuously adapt. Persistent adaptation based on sound knowledge is crucial in order for the Armed Forces to remain relevant, also in the future".

How important is FFI for the Armed Forces today?
"FFI is important for us. It is first and foremost through research that we are able to further develop our Armed Forces. At the same time, FFI plays a major role in what advice I give to the political leadership, regarding the Armed Forces we should have going forward".

A few years ago, Commander of the Norwegian Defence Staff, Vice Admiral Elisabeth Natvig, said that 'FFI's task is to illuminate the future'. Do you agree?
"Yes, I agree. We are entirely dependent on research-based advice".

From your personal experience: When and how were you first in contact with FFI?
"When I was part of the special forces, a close collaboration with FFI began in earnest. Two specific examples where I was directly involved were the developments of FACNAV and Black Hornet".

What topics and issues will be especially important for Armed Forces and FFI to collaborate on going forward?
"The most important question for me is how the technology can contribute to the Armed Forces having an advantage in peacetime, crisis and war".

Are there any research projects or perspectives from FFI in which you have a particular interest or are curious about?
"In the short term, it is research on how use of our new F-35 combat aircraft can be maximised by the entire Armed Forces. Furthermore, I am very interested in research on technological autonomy, and how this can contribute to better equipping the Armed Forces".

Is there any type of research or projects that the Armed Forced would like to see more of?
"I find that we have close and good dialogue with FFI. Often it is challenging to know something about what is unknown. That is why international

"The collaboration with FFI has been very important. The result today is that we in Norway have a modern defence", says Chief of Defence Eirik Kristoffersen.
Photo: Torbjørn Kjosvold / Norwegian Armed Forces

This collaboration has been very important for the development of the Norwegian Armed Forces.

and national research collaboration is so important. Precisely because it can produce solutions none of us have thought of".

Research on soldiers' lives, health and welfare has always been key to FFI. Is there research in this category that you would like to see more of?

"I would have liked to see more research on the materiel and logistical consequences of the fact that the proportion of women in the Armed Forces is rapidly increasing. My assertion is that much of the equipment we use operationally is first and foremost developed for men, and that we continue to lag behind in the development of equipment adapted for women".

Collaboration between the Norwegian Armed Forces, FFI and Norwegian industry has been an important factor since the 1960s. What are your expectations in this regard for the coming years?

"This triangular collaboration is crucial to achieve quick results. I have personally experienced how good such a collaboration functions, precisely in the development of FACNAV and Black Hornet". ■

Photo: Technical Weekly Magazine

THIS MIX IS MAGICAL

I continue to be fascinated by the myths surrounding the Norwegian Defence Research Establishment – even as the institution is turning 75 years old.

We cannot escape the fact that FFI continues to be shrouded in myth. With a bit of imagination, this myth is easily transferrable to the universe of James Bond, MI6 and Q. New and ground-breaking inventions and weapons that make the battle against the enemy cunning, secretive and, not least, ground-breaking. Cold war, nuclear age, NATO, arms race and associated ingredients can easily make the imagination run wild.

Those seeking to dispel the myths, are not exactly aided by the fact that one of the institute's most important facilitators was resistance figure and Norwegian Labour Party titan Jens Chr. Hauge. The former head of Milorg served as Minister of Defence after the war and was a key figure in Norway joining NATO, and in the Norwegian Armed Forces and Norwegian defence industry developing from nothing to international recognition.

When Hauge finally stepped down as Minister of Defence in early 1952, he handed over the keys to the office to his successor Nils Langhelle. Included with these 'keys' was the code to the Minister's enormous safe behind the office chair. A natural handover of access to classified information. The problem for Langhelle was that the safe was empty. In the book Jens Chr. Hauge – Fullt og helt (Fully explained) (2008), biographer Olav Njølstad writes that Hauge had taken the documents home with him. To this day, we do not know the full extent of their contents. Perhaps secrets are still out there regarding the establishment of FFI?

Hauge cultivated friendships with the two FFI Director Generals, Fredrik Møller and Finn Lied, at the same time as he served as Chairman of the Board for Raufoss Ammunisjonsfabrikker (ammunition factories) and Kongsberg Våpenfabrikk (weapons factory) – and negotiated major contracts regarding defence materiel with allies. This undoubtedly contributed to FFI becoming a significant contributor and force in the development of Norwegian defence industry. We continue to benefit from this position to this day.

The precursor to Technical Weekly Magazine, Polyteknisk Tidsskrift (Polytechnic Journal), was founded in 1854. As the world's oldest polytechnic publication, we have always been interested in the defence industry. To this day, FFI continues to be an important source of news and content. It may seem a bit basic, but it has to be acknowledged: Our readers simply love everything that goes bang, shoots or explodes. One story we have followed from the beginning is the Penguin Project. The cruise missile that, following decades of development, has become NSM and JSM, and that are now unconditional, international success stories.

The institute is exciting for Technical Weekly Magazine's journalists. Not only because of the history and myths, but also because FFI continues to perform important tasks in a small country that needs to stand strong, both independently and together with our allies. We have also been impressed by FFI projects such as RIMFAX, the ground-penetrating radar, that has now arrived on Mars.

FFI is important for Norway. We would argue that the nation has received a lot in return for the resources that have been spent on the institute and its activities. Other nations – many of them much bigger than us – have to allocate far higher expenses to achieve the magical effect and mix to which FFI has contributed in the intersection between research, technology development and industrial growth.

Threats from sea, land and air have changed considerably. Currently, the cyber threat appears to be the most challenging, which presents itself as stealthy, undermining, varied, confusing and potentially paralysing. It is good that we have an FFI that is also able to contribute to mapping digital threats and countermeasures going forward. Therefore, we believe FFI will continue to have its hands full in the next 75 years. This also bodes well for Norwegian business. And for us at Technical Magazine Weekly.

Congratulations on the anniversary!

Jan M. Moberg, Editor-in-Chief and CEO,
Teknisk Ukeblad Media AS (Technical Weekly Magazine)

YOU ARE NAMMO'S TECHNOLOGY SCOUTS

FFI is Nammo's technology scouts in important areas. We have enjoyed an extraordinarily close and good cooperation from the beginning, ever since Minister of Defence Jens Christian Hauge's prioritising of key technological areas in the immediate post-war period. The cooperation has been characterised by both advanced research and practical solutions. Here, we have many good examples of enterprising FFI researchers, who have found incredibly many innovative ways of testing products. The model according to which we work is that FFI's researchers work on basic research and provide specialist expertise in this area, while we have engineers and researchers who look at the use of the technology and how it can be made into new products.

FFI has been a client, driving force and sounding board both for Raufoss Ammunisjonsfabrikker and, later, the entire Nammo system. For instance, in terms of ammunition, we have enjoyed close cooperation with FFI ever since the 60s. The first projects were M72 anti-tank rocket-propelled grenade launchers and multipurpose ammunition. In terms of rocket engines, the roots date back to the 40s, and the very establishment of FFI. This gained momentum in the mid-80s. Since then, we have also collaborated on rocket engine technology, through programmes funded by the Ministry of Defence. Discontinued programmes have often become the start-up of new programmes.

Today, we are an international company that is influenced by the developments on the global market, perhaps especially in the United States. However, FFI continues to be an important partner for us. The collaboration between Raufoss and, subsequently, Nammo and FFI, also celebrates 75 years this year. Such a long-term relationship is not easily replaced.

Morten Brandtzæg, Group CEO at Nammo Raufoss AS

Photo: NAMMO

THE SHORT WAY IS THE BEST WAY

For us here at Kongsberg Defence and Aerospace (KDA), the close collaboration with FFI has been important for the development of our high-tech systems. This particularly applies to missile activity. This began with the anti-submarine weapon system Terne in the 1950s, continued with the anti-ship missiles Penguin and the Naval Strike Missile (NSM), and most recently the Joint Strike Missile (JSM). Terne and Penguin were especially key in transforming KDA from a mechanical weapons manufacturer into a company that is able to face the future with high-tech systems in many new fields. FFI, the Norwegian Armed Forces and the Norwegian Government, often referred to as Team Norway, has been crucial for KDA and others in the Norwegian defence industry on the export market.

Many engineers and researchers have been following the development of FFI and onward to development or manufacturing at KDA. FFI's competence through its employees is what makes the big difference. The institute is undoubtedly a global leader in ground-breaking solutions and innovation. In 1983, we established a department at Kjeller for collaboration and technology exchange, particularly in the area of missile seeker technology.

Our meeting places are what make this collaboration so special. It is unique in an international context. Here, FFI, the industry and the Norwegian Armed Forces can sit and discuss future solutions needed by the Armed Forces. We have taken advantage of the opportunities that are unique for a small nation, with short decision paths, little bureaucracy and a high level of trust. This generates good and productive dialogue. In this manner, we are able to come up with modern and advanced solutions at a low cost.

Eirik Lie, CEO of Kongsberg Defence and Aerospace

Photo: KDA

MARTE S. KALVELAND
(39)

Research Manager

RESIDENCE
Kjeller

EMPLOYED SINCE
2007

FIELD OF EXPERTISE
Astrophysics

DIVISION
Defence Systems

Photo: Espen Wang-Naveen / FFI

LEADERSHIP IS UNDERSTANDING

This was my first job after graduating from university. Now I have been here for 13 years! I was told that FFI is an exciting place, and that there were opportunities to become involved in a lot of different things. This has certainly been true in my case.

My education played an important role: The good thing about astrophysicists is that we are a bit like potatoes; we are versatile. Our profession has a toolbox that contains mathematics, physics and programming. This allows us to work with very different tasks here at FFI, as I have done.

One excellent incentive has been the opportunity to leave my desk now and then. I have been on missions aboard both Skjold-class corvette torpedo boats and Fridtjof Nansen-class frigates. Although much of the work involves experiments and collection of test results, it is exciting to be aboard these modern vessels.

I have also sailed along the entire Norwegian coast and participated in fleet exercises in England. Another useful experience was flying in various types of surveillance aircraft. FFI gives me opportunities I would unlikely have been able to receive elsewhere.

I have always had leadership ambitions. During my studies, I led the Norwegian section of an international organisation for technology students. Now I am one of more than 60 Research Managers at the institute.

Now, as FFI celebrates its 75th anniversary, the organisation is undergoing a period of change. Our Board of Directors would like more young people in leadership roles, which means that some older people need to step aside. At FFI, leaders have traditionally been recruited internally, based on their skills as researchers. However, an interest in leadership is often just as important.

Currently, I am in charge of the research programme Kampstrukturer - luft (Combat Structures - Air), that includes two research projects: Air Force toward 2030, and what we refer to as the tactics project. Combat structures is a new and exciting field of research. It involves utilising knowledge from the entire institute and conveying it to the branches of defence

The good thing about astrophysicists is that we are a bit like potatoes; we are versatile.

Joint operations are essential. The perspective is the Navy, the Air Force and the Army cannot fight each their own war. They must be able to collaborate.

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in a useful and comprehensible manner. Joint operations are essential. The perspective is that the Navy, the Air Force and the Army cannot fight each their own war. They must be able to collaborate. How can we manage this?

One of my most important tasks is to maintain close contact with leaders in the Air Force and meet with them regularly. We must understand the topics they are working on and coordinate research at FFI and issues in the Norwegian Armed Forces. My colleagues are responsible for the same tasks in relation to the Norwegian Navy and Army.

One my fellow students, Sunniva Rose, is a research communicator and blogger who inspires me a great deal. She recently published the book Vi er stjernestøv (We Are Stardust), naturally with a pink book cover. Sunniva writes about everything you did not know you wanted to know about nuclear physics. Like her, I prefer to present results without the use of jargon. My favourite speaking engagements are in front of audiences who are genuinely interested in our results. When speaking with military personnel about tactical calculations, we must make sure not to sidetrack them by presenting all our equations. It is far more important to present the main points.

The Norwegian Armed Forces is an exciting and demanding client. They are accustomed to quick deliveries, with strict deadlines. Therefore, it is perhaps not surprising that they may become impatient. Our presentations must have clear conclusions. It is more time consuming than many might think to go from presenting a PowerPoint to writing down all the results. After the data has been collected, it may take several months to write a complete report.

I make no secret of the fact that researchers enjoy calculating, investigating, evaluating and then re-calculating *ad nauseam*. It is essential that all conditions have been accounted for. As a leader, I must ensure that the results are also comprehensible and relevant for the client, and that they are delivered on time.

My researchers are free to manage their workday as they see fit for the assignments they receive. Most people are driven by intrinsic motivation. It is easy to get researchers to study and think clever thoughts about topics they are genuinely interested in. As a leader, I must follow up, take an interest in their results, and ensure that the research is relevant for the client. One of my most important tasks is to be present and available for both parties.

Changes occur slowly. Our results may not produce any effects for the Norwegian Armed Forces until years after we have handed over our knowledge. I have to show both patience and perseverance. If you ask my family if I'm a patient person, the answer would be no. But I have learned that things take time. ■

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Norway's new F-35 combat aircraft is an integral part of a more coordinated defence at sea, on land and in the air.
Photo: Hedvig A. Halgunset / Norwegian Armed Forces

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Personnel train for scenarios, including in simulators, where forces are operating in the same arena.
Photo: Christian Tandberg / FFI

A damaged part is scanned. In a few hours, an identical component is produced, with 3D technology
Photo: Fieldmade

CAN SPARE PARTS FIT IN YOUR POCKET?

During wartime, faulty materiel must be replaced quickly. It is crucial for all military operations to maintain control over the supply chain. The battle may be lost if it takes too long to obtain spare parts. Ideally, production in the field would replace defective parts. This is why 3D printing is currently being studied in detail by FFI.

For FFI and the Norwegian Armed Forces, 3D printing is about keeping up with technological developments. It is essential to look at the types of use that may arise. FFI's Product Development, Testing and Verification (PTV) is where these methods can be examined.

Rapid, local production would require a new type of logistics. In this case, it would be possible to avoid larger storage of spare parts. Components can be replaced immediately. FFI is collaborating with the Norwegian Armed Forces and suppliers to learn how this would work in practice.

FACTORY QUALITY

Production of a spare part using 3D printing can take anything from a few hours to a day or two, depending on size and material. Technically, it is possible to use polymers or various types of metals, such as aluminium, titanium and stainless steel. It is also easy to produce soft parts, such as gaskets.

These products are just as good as those from traditional factories, and the quality is identical. Our vision is that these microfactories will become so good that they render large storage units superfluous.

'Local' is the key word for spare parts for future defence materials. For Christian Duun Norberg, this was the beginning of something big. With the Fieldmade company, the former officer's goal is to change the digital ecology for everyone who currently requires large storage units and demanding logistics. Not only for the Norwegian Armed Forces, but also for larger companies, such as Equinor.

"The oil industry also requires solutions that can increase operational capability and level of preparedness. We can offer

Christian Duun Norberg's idea behind the company Fieldmade involves more than simply producing spare parts with the aid of 3D printing. The goal is to change the digital ecology for everyone who currently requires large storage units and demanding logistics, including the Norwegian Armed Forces and Equinor.
Photo: Lars Aarønæs / FFI

A worn part can be copied and produced on-site, when needed, within a very short period.
Photo: Fieldmade

on-site production laboratories. Basically, we are able to digitalise clients' spare parts storage. By extension, we can stop talking about 'spare parts'. In a sense, you have your spare parts in your pocket, wherever you are".

A SPECIAL CONTAINER

Top US military personnel showed a strong interest in one special personnel container during the 2018 NATO exercise Trident Juncture. Inside of the container, called Nomad, they were able to see how Fieldmade produced exact copies of damaged materiel. With high quality and in a short amount of time.

"Obtaining spare parts can take several days. Here, a damaged component can be 3D scanned. Missing pieces of the object are recreated. Alternatively, the component can be produced from the same data file as the original. Those who need the part can come and pick it up the next day", says Norberg.

> *Physical storage requires space and localisation, perhaps far away from those who need the delivery.*

During the Trident Juncture exercise, Fieldmade's project stirred great interest among the allied guests, not least among the United States Marine Corp. Photo: Fieldmade

The NTNU graduate and naval special operations commander states as follows:

"During the NATO exercise, we demonstrated the two most important reasons why 3D printing is here to stay: Essential components can be delivered quickly and require less storage. Remember: Physical storage requires space and localisation, perhaps far away from those who need the delivery. Digital storage requires neither of these things".

Fieldmade does not view the company as a microfactory. The future can be bigger than that. Fieldmade is an early representative for what is referred to as additive manufacturing (AM).

"This industry will have an enormous impact on the military supply chain and its operations. This is the near future", says Norberg. So far, there has been little discussion about additive manufacturing factories for defence purposes. But this is now snowballing.

FFI is at the forefront of this technology in Norway. This is why the institute has also established cooperation with academia and research institutions, both nationally and internationally.

FFI WANTS SPIN-OFF INDUSTRIES

Fieldmade is the type of spin-off industry that FFI wants. The company was established at Kjeller. The researchers who participated were among the driving forces. They contributed by sending a project application to the Norwegian Research Council. During this phase, the name Fieldmade was proposed. This is a name that literally describes what it does. PTV at FFI was also key. Christian Duun Norberg recruited people from this group to continue with the work.

"It was essential to collaborate with FFI. Here, I found people with the same interests. Thus, it became an exciting place to work. We were a team of three or four people who volunteered to work on this idea in addition to our actual assigned projects. In a sense, we were educating ourselves. This work materialised into something that would otherwise have simply remained a good idea. Suddenly there were seven of us and the idea became a separate project", says Norberg.

He has no doubts about future prospects. They are bright.

"I have noticed a stronger interest in something that previously was not well understood. The world needs time to mature. The Norwegian Armed Forces has to see the potential. The defence industry is profiting from solutions that are available today. Now we can collaborate on moving forward". ■

The deep snow on the Hardanger Plateau was perfect for testing the Terne missiles. The shells could then be reused.
Photo: FFI

HOW THE PENGUIN LEARNED TO FLY

This is one of Norway's greatest technological accomplishments. How could a small institute get the Penguin anti-ship missile to fly?

It began with an entirely different sea bird. The Terne (Tern) Project was the first major undertaking at the Norwegian Defence Research Establishment. This was a weapon intended for the Navy. Terne weapons systems were developed to attack submarines.

But first, a trip to the mountains. An old black-and-white photo in FFI's archive shows a peculiar situation. The year is 1950. A group of young men are standing in the snow at Hallingskeid, in leisure clothing and sunglasses. It all resembles an Easter ski trip. But the centre of the photo tells an entirely different story. The men are working on a missile. What is actually going on?

This sunny photo is from the tests performed by FFI researchers. They were testing an early version of Terne. The deep snow on the Hardanger Plateau had a clear advantage: It provided missiles without explosives with a soft landing. The shells could therefore be reused. Over and over again. This made the tests cheaper to run.

The Terne anti-submarine weapon system was the first step in a development that made Norway the producing country for some of the world's most advanced missiles.

A BOOST FOR THE INDUSTRY

Terne was the result of work that began the year after FFI was established. Anti-submarine weapons were a very high priority for the Norwegian Armed Forces: In 1947, FFI was granted NOK five million, the equivalent of more than 100 million in 2021, to develop technical expertise in the field.

At the same time, the institute laid the foundation for major changes in Norwegian industry. This project was intended to propel Norway into the space age, no less. In order to produce Terne, Kongsberg Weapons Factory had to undergo some necessary changes. This was the beginning of the high-tech company, Kongsberg. The Terne Project was also important for Raufoss Ammunition Factory, now known as Nammo. This laid the foundation for the company's rocket engine production.

Terne never became a commercial success. There were too few allies who showed an interest, perhaps because sales were not good enough. Nevertheless, the Navy did receive an effective and reliable anti-submarine system.

A NICHE WAS CREATED

The rest of Norwegian missile history, however, has been tinged with success. Following the Terne Project, both FFI and the industry were ready for bigger and more advanced projects. This development is an example of a Norwegian niche, where FFI played a key role for several decades. Terne led to Penguin, which in turn led to the Naval Strike Missile (NSM) and the Joint Strike Missile (JSM). Both systems were purchased by the United States and other allies, as they were considered to be the best missiles for their respective purposes. This contributed to a burden sharing among NATO members and increased operational capacities for the alliance.

At the time, Terne had to prove that it was possible to achieve good collaboration across FFI's divisions, between the institute's employees, between the professional and operational military – and with the industry. This was successful. The good collaboration made it possible to develop

Researchers Didrik Hveding and Olav Blichner at FFI's supersonic wind tunnel in 1953. There were major forces at work.

This photo from 1963 shows the very first Penguin missile, Enok, on the launch ramp. Its aerodynamic design had been tested in the wind tunnel, but this was the real deal.

In 1968, the Penguin missile guided itself toward the target five kilometres away – and hit it! Researchers Tycho Jæger (left) and Olav Blichner were pleased with its success.

Penguin, a far more advanced anti-ship missile. Work on 'the flying penguins' could begin. Patient research and development was essential: With the Norwegian Navy as the driving force, the project began in earnest in 1961. This work became the largest research and development project in Norway in the 60s and 70s.

PARTS DID NOT EXIST

The Penguin is a guided tactical missile – and the first missile was developed in its entirety at FFI. This project was characterised by bold ideas. It required extensive resources. Researchers had to make use of the latest developments in the area – to the extent suitable technology existed. They often had ideas for solutions requiring components that had not yet been invented.

Penguin was the most advanced missile the world had ever seen. It included innovations such as an infrared detector, laser altimeter and an inertial navigation system. The most important components were created in the detector laboratories of FFI at Kjeller. This was an extensive process. In Norway, only FFI was able to master the required technology.

NORWEGIAN DATA WAS A FRUIT

Diving deeper into history, the conditions needed to arrive at a finished and saleable product become evident. FFI began using calculators early on to make calculations in relation to nuclear physics, missile development, signal processing and operational analyses. This bore new and unexpected fruit. With the development of transistors, FFI began to build its own computers. This was essential, among other things, for processing data from the Penguin tests. As a result, Norsk Data was established by young FFI researchers in 1967.

EIGHT SOLDER WOMEN

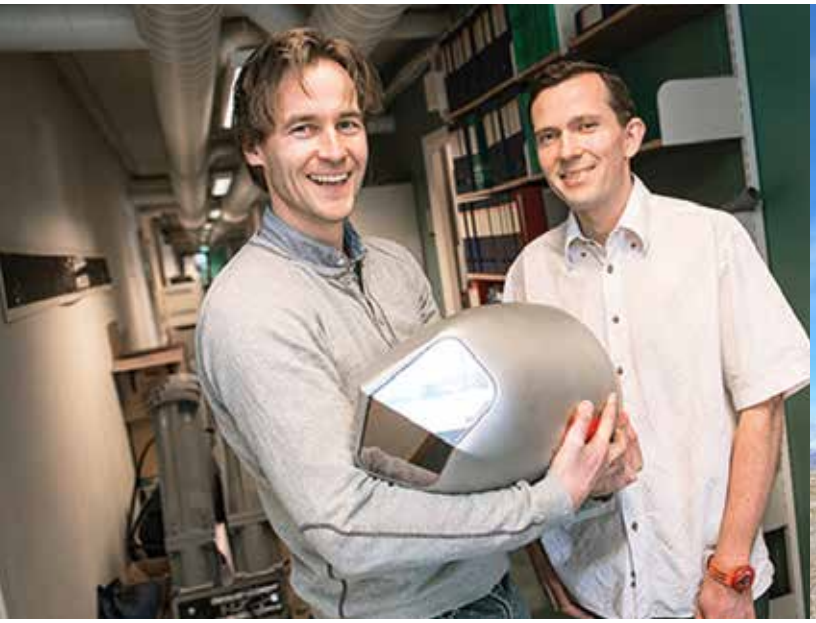
A large number of people were involved. In his book Flygende pingviner (Flying Penguins), author Hans Christian Erlandsen lists the project staff for FFI in March 1965:

- 37 researchers
- 30 designers
- 3 workers
- 8 lab/solder women
- 1 officer
- 16 soldiers

THERMAL RADIATION IN COMMON

In 1973, Kongsberg delivered the first Penguin to the Norwegian Navy. Numerous customers from other countries soon followed. Kongsberg Weapons Factory played an increasingly significant role in the further development of the missile.

> *Penguin was the most advanced missile the world had ever seen.*



Research Managers Øyvind Sjøvik (left) and Lars Trygve Heen hold the head of the anti-ship Naval Strike Missile (NSM), which has the capacity to attack enemy ships at distances far beyond the horizon. *All photos: FFI*

NSM was developed in Norway through a triangular collaboration between the Norwegian Armed Forces, the defence industry and FFI. Photo: FFI Kongsberg Defence and Aerospace

If anyone wondered what an FFI Penguin and the actual penguin bird had in common, this question was answered by Director of Research Karl Holberg, often referred to as the father of the Penguin missile. He stated dryly: "The only similarity is that both navigate with the aid of thermal radiation".

The expertise developed through the work on Penguin became a major advantage for the work on a new anti-ship missile, the Naval Strike Missile (NSM). FFI researchers contributed to this project as well. They developed the concepts for the anti-ship missile in the late 1980s and demonstrated an entirely new imaging missile seeker. Since then, FFI has supported the Norwegian Armed Forces by testing the missile and developing tactics for optimal utilisation. They developed a significant component: target recognition, which is the eye of the missile. If this does not work, the seeker is blind, and nothing will function.

NSM surpasses its predecessor as it has a very low radar signature. The missile manoeuvres even better and has a higher sensor capacity and computing power. NSM can fly low above the surface of the water and would therefore be hidden to enemies nearly all the way to the target.

Many of the ideas from NSM have been included in the Joint Strike Missile (JSM). The Joint Strike Missile, produced by Kongsberg Defence & Aerospace, is currently the only cruise missile adapted to the F-35 weapons bay, and can therefore be carried internally. In this manner, the aircraft can maintain its stealth capabilities, and remain difficult to detect.

LARGE PACKAGES

There is an uninterrupted link from the Terne missile in the snow at Hallingskeid to the missile in the weapons bay of the F-35.

NSM and JSM were both purchased by the United States and other allies because they were the best missiles ever produced in the West. The number of missiles sold to other countries is classified. The same applies to pricing. Typically, the number of missiles will vary between fewer than a hundred for smaller clients to several hundred for bigger clients. One U.S. website has estimated the price of an NSM as approximately USD 2 million. Clients purchase more than just one missile, however. If these are not already adapted to a platform, for instance a vessel, truck or aircraft, it may cost up to several billion Norwegian kroner for these adjustments alone. For this reason, it is best to adapt for certain platforms and weapons, such in the case of the JSM and the F-35.

Clients also need support systems for the missiles, such as computer systems for planning and launching. Most purchase packages that include training, operations, service and maintenance throughout the lifespan of the missile system. This can generate major sales for the industry.

Now in 2021, FFI researchers are ready to take new steps. Their goal is to develop the missiles that will follow NSM and JSM. The work will involve many FFI employees from several professional fields. Triangular collaboration will always form the foundation. The ambition is for Norway to continue to develop and manufacture important missile systems for the Norwegian Armed Forces and its allies, with the objective of significant value creation for Norwegian industry.

AGAINST ALL ODDS

It might not have turned out this way. The final word is from Penguin biographer Hans Christian Erlandsen: "When Norway's first research and development project was launched, it was probably too big an undertaking for such a small country. Yet they were still successful, against all odds". ■

Jan Olav Langseth took us on a tour of FFI's collection of old research artefacts. The sign reads: Belongs to FFI Museum – must not be discarded.
Photo: Lars Aarønæs / FFI

WE HAVE A SECRET TREASURE TROVE

Jan Olav Langseth presents a large, rectangular box made of plywood. As he lifts the lid, he mutters, «I've never seen this before»

Then he exclaims, "There it is! This is what we've been looking for!"

The FFI employee is beside himself with joy. At long last, a historical FFI object has been found.

"We have to exhibit this at the 75th anniversary!"

Langseth lifts up shiny, steel, streamlined parts. They are massively heavy. He needs both hands to lift them. He carefully places the shiny wings onto a camping table that someone has left here.

"This IS the wind tunnel model of the Penguin! But where is the rest of the body?"

THE MUSTY MUSEUM

We are in what is referred to by FFI employees as the Mess. This is a large old German barrack. For many years, this building served as the mess hall for officers of the Norwegian Air Force Materiel Command. For the past ten years, it has been used as a lab for students, for testing drones and other types of flying objects.

At the back of the building there is a door that very few FFI employers are permitted to open. These storage rooms smell like any rarely used rooms: musty. Dust never asks for permission. Langseth sneezes as he picks out a few parts, lifts a couple of cardboard boxes and turns some containers upside down.

We find ourselves in the closest thing to an FFI museum. A large poster placed on top of the cardboard boxes tells us the exact same thing. In 1996, when FFI celebrated its 50th anniversary, many of the objects here were taken out, polished up and exhibited. They were subsequently put back into storage.

ODIN AND THE FISH

A rack of shelves contains the very first Asdic, an echo sounder developed by FFI, that Simonsen Radio later produced under the brand name Simrad. This was the first industrial success based on an FFI invention. The fishing fleet began using this as early as 1948, with far better catches as a result. This apparatus is next to a control console for Odin, a fire support system for artillery from the 1960s. The name is written in Norse typeface.

A gramophone record peeks out on top of a stack of boxes. It has a grey slipcover with a hole in the middle, with a stone plate. This does not consist of an original recording of Jussi Björling or Vera Lynn. Yet it undoubtedly has historical value. The label states that this is a Norwegian Broadcasting recording of the first interview conducted at the newly opened radio link connection between Bergen and Haugesund. It took place on 15 March 1951. This event was a milestone for one of the

In 1951, FFI opened the radio link connection between Bergen and Haugesund, the first in the country. This event was presented by NRK, which also produced an album of the recording. Photo: Lars Aarønæs / FFI

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Blunk was a pocket Geiger counter, in a rounded and handy design, developed by FFI for soldiers in the field.

02
A control console for the Odin artillery system next to what later became Simrad's echo sounder for the fishing fleet.

03
Suddenly, Jan Olav Langseth found the Penguin model tested in the wind tunnel.

Photo: Lars Aarønæs / FFI

> *There is something poetic and reassuring about "1pc shock- and leak-proof shut-off valve for peacetime ventilation".*

biggest and most important FFI projects during the first year of the institute – to ensure better and more secure telephony throughout Norway.

Further down in the box are awards that Director of Research Sture Koch received for his work. It is clear that he has also donated much of this material.

POETRY AT THE PEACE VENTILATION

The contents of the cardboard boxes in this dust chamber varies between the exciting and the unfathomable: Here is a sing-around velocimeter for seawater, dated 1947. In the same box is a summing amplifier for the Tern missile's analogue calculator. A memory card for the Martinus computer lies next to the box for «control box for missile payload».

The list of all the museum objects at FFI is multifarious. There is something poetically reassuring about "1pc shock- and leak-proof shut-off valve for peacetime ventilation". The same does not apply to "autoinjector and antidote for nerve gas poisoning". We note a "handmade core memory from the mid-60s" and "Norway's first self-developed inertial platform, circa 1960". Skogens kamera (Forest camera) is listed, but it mentions neither the model nor the forest area.

Then we learn that it is in fact referring to a person: Erling Skogen was responsible for the history booklets and the internal exhibit displayed by FFI for its 50th anniversary.

"Stagkon and safirkon for Penguin seeker Mk2" sounds exotic. The listed object "Samovar" may be just that. But it is impossible to know for sure: Earlier FFI researchers were known for many imaginative names, such as the radar alert system Forglemmeiei (Forget-Me-Not) and the never-developed aerial torpedo Kråka (Crow) and the proximity fuse Engsmelle (Maiden's tears). Two FFI radiation indicators from around 1950 turn up – a type of pocket-sized Geiger counter. Here, the choice of name was apt: Blunk I (Blink 1).

NEXT THRILLER

When historian Olav Njølstad had finished researching FFI's multifarious past, he found enough inspiration from the archives at Kjeller to write his thriller novel "Mannen med oksehjertet" (The Man with the Heart of a Bull). Anyone lacking a plot for a new thriller from the FFI environment can start with something previously untouched in this room: "1pc. unknown object: Wooden box with German writing".

UNFAIR TREATMENT

Jan Olav Langseth was born in 1962. He has been working at FFI since the late 1980s. As a senior advisor for many years, he was the first person that FFI summer interns met, for instance at a stand at the universities. He is likely the one non-pensioner at the institute who has the broadest overview of all the research and projects at FFI. Therefore, he knows a lot about what lies hidden around the various buildings at Kjeller, and, of course, here. But not everything.

02


03

"Employees at the institute have been dutiful about documenting everything. We have always had photographers, so much of what the researchers have been working on has also been photographed. The physical objects themselves, however, have been somewhat unfairly treated. Much has been thrown out or destroyed. Many of the things that remain are unidentifiable. Many of the older FFI staff members still alive may know. The dream would be to gather some of these people together. Imagine if we could go through all these things", he says enthusiastically.

A RUSTY PIPE

As he continues to talk, Jan Olav Langseth hunts for the rest of the wind tunnel penguin.

"This part is basically just a long pipe. Someone may have tossed it out into a container", he adds.

As I, a reporter for Viten, am about to take some pictures of some of the objects in the room, I have to step over a rusty object on the floor.

This looks like a pipe – but with some strange pieces on it?

"That is the pipe I've been looking for! In here, we can't see the forest for the trees". Now we have a complete Penguin model to display!" ■

"HEY ARMED FORCES! I HAVE AN IDEA".

Now and then, researchers receive letters and questions out of the ordinary. Joakim (9) wondered whether we could help him build a new type of safety equipment for an aircraft. We were so impressed that we invited him to visit.

"Hey, Armed Forces! I have an idea. I hope you like it and that you'll help me create a prototype. I don't think it will cost that much". This is how Joakim (soon 10) begins his letter to FFI. He presents an entirely new idea for how a jet aircraft can land on water. This letter ended up on the table of Principal Scientist and aircraft nerd Stian Betten, who was immediately captivated. Joakim's suggestion is a device that can be hooked onto a jet aircraft. You pull a rope that opens a hatch, and air is pressed into a flexible tube down to inflatable floats on each side of the wheels. This would help the jet aircraft land on water.

"Joakim has created a system. He has drawn a design for how this would work, and he has explained how the problem could be solved, as well as the advantages and how the system could be controlled. This is impressive", says Betten.

"I have checked around. I have never heard the suggestion for using ram air to inflate floats. The only two patents I found that may be somewhat similar are from 1964 and 1970. They were meant to keep satellites afloat in the water after landing. Joakim has never seen this solution on YouTube or online. This is entirely his own idea. It's cool!", says Betten.

A TRIP TO THE SIMULATOR

One Thursday, Joakim was invited to visit FFI together with his father, Tellef, and his grandfather, Bjørn Tore. He was allowed into a workshop where researchers and engineers are creating prototypes and testing various things. They also visited FFI's battle lab, where Joakim got to try the F-35 flight simulator and tested a VR device used by fighter pilots during training.

"I became interested in planes after my dad showed me a cool plane video. And we've gone to airplane shows at Kjeller many times", says Joakim.

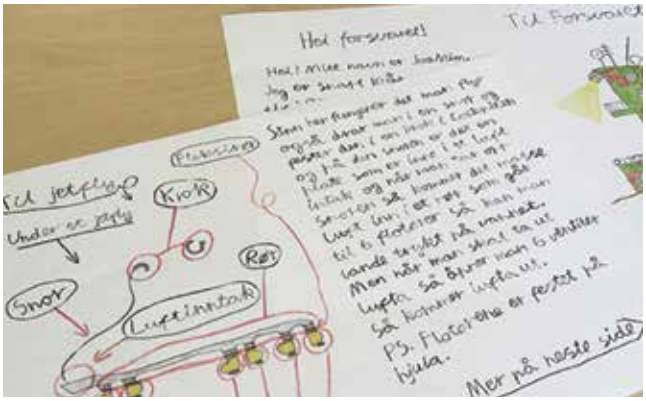
He wants to become a designer or a pilot when he grows up but has not quite made up his mind.

"I wrote the letter for fun, but it was also a little serious. You make a lot of cool stuff, and I'm interested in security", says Joakim.

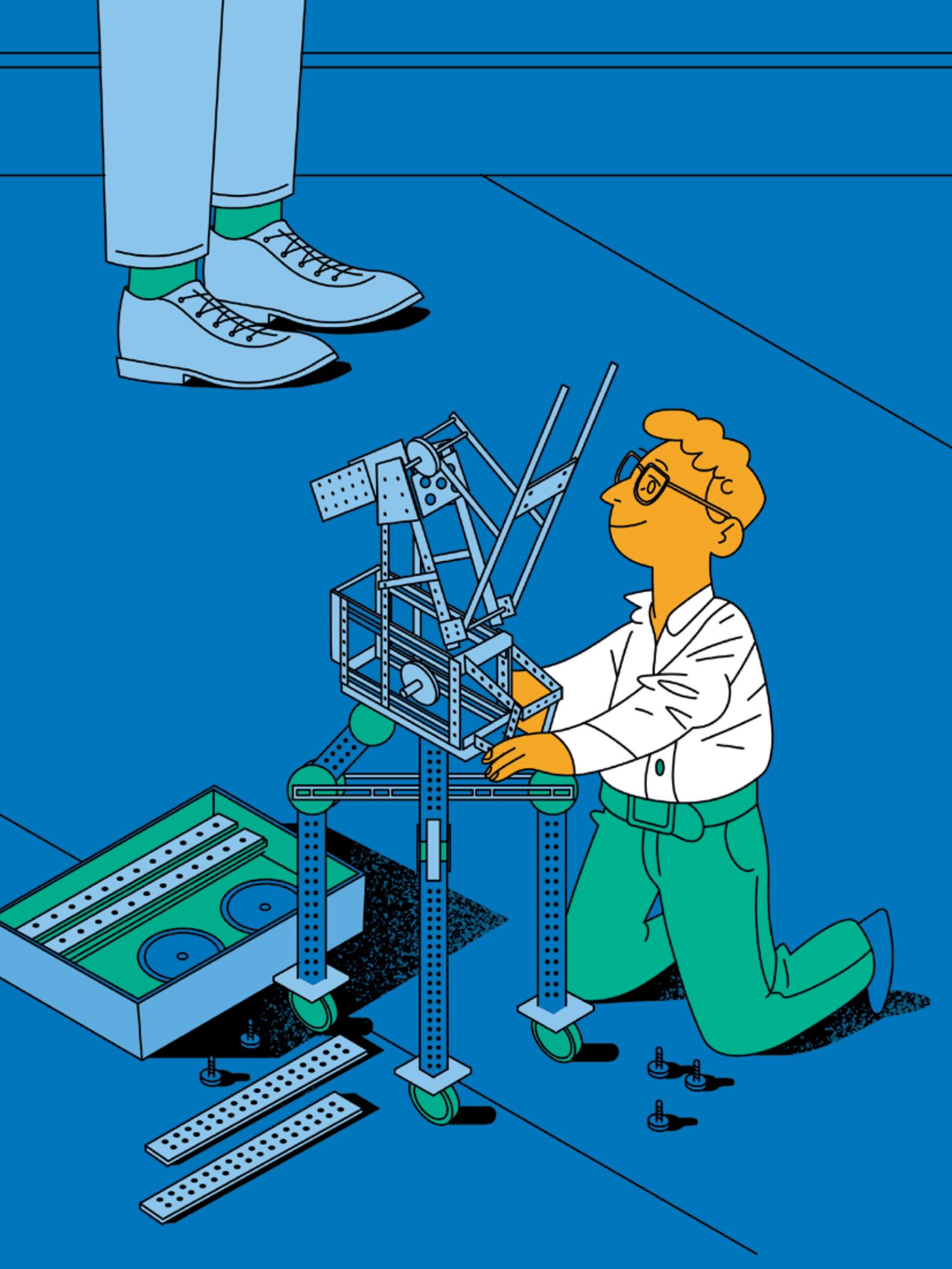
NORWAY NEEDS SMART PEOPLE

The visit was probably just as fun for dad and granddad as for Joakim. Both are engineers. Granddad also got his small aircraft license at Kjeller. Principal Scientist Stian Betten encouraged Joakim to continue drawing, playing and thinking.

"Norway needs bright minds who can come up with smart solutions. We hope Joakim will return as a summer intern in a few years", says Betten. ■



Joakim had the chance to try the «world's coolest video game», a simulator used by pilots while training to fly an F-35. The joystick is a copy of the control lever in the aircraft. This alone costs NOK 25,000. Aircraft researcher Stian Betten was his guide and instructor.
Photo: Christian Tandberg / FFI



Finn was the system builder

Finn Lied led the institute for 26 years, from 1957 to 1983.
No one has had a greater impact on FFI than him.

Finn Lied, age six. The family had moved to Mo i Rana two years earlier. This was before the ironworks period. His parents become good friends with the CEO of the forerunner, New Dunderland Iron Ore Company. His name was Claude Bannatyne, from Scotland.

During the visit, young Finn presented the Meccano crane he built. Meccano, which was the Lego of that time, had beams, wheels, axles, nuts, bolts and screws.

Both the guest and Finn's whole family, including his two older sisters, thought the crane was nice and big. Lied recalls Bannatyne telling him: "You could become a great engineer". But, added the Scotsman, young Lied needed to learn a sense of order! Because the screws were not facing the same direction. They were all supposed to be pointing with the head out on both sides.

"That sentence stuck with me. It taught me a sense of order. From that point on, I started making my bed. People have laughed at me now, fifty years later, as I walked around on Sundays picking up rubbish from the lawns".

FINN LIED

FFIs second Director General 1957–1983

Although he was classified as unfit for active duty, Finn Lied was a soldier involved in life-threatening service during the war. After the war, he became one of the country's national strategists for both FFI and Statoil.
Photo: FFI

Making his bed as a child and picking up rubbish from the lawns at FFI both relate with the same thing for Lien: diligence.

FFI WAS HIS GREATEST JOY

In 2012, the Norwegian Broadcasting Corporation NRK aired a series featuring eight distinct post-war personalities. During the hour-long interview, the host asked: "What has given you the greatest joy in all your life's work?"

The answer was direct:

"Without a doubt, that I managed to reorganise and bring FFI together on large and important projects. This became a pattern for how things could be done. I am happy I was able to be a part of this, together with several hundred motivated employees who showed trust in me. When

When the war ended, we had a very strong sense of duty to rebuild the nation.

the war ended, we had a very strong sense of duty to rebuild the nation".

A NATIONAL STRATEGIST

His directorship coincided with a large share of the Cold War between the Soviet Union and the United States. Norway was the most important NATO nation in the north. Yet it was not a traditional defence perspective that characterised his work. He was a builder of systems.

The research institute became his most important construction. This is something he himself claimed. Lied could have pointed out many other things he managed to accomplish: He was a national strategist. He worked closely with Norwegian Labour Party leaders Trygve Bratteli and Jens Chr. Hauge on major national projects. As a Minister of Industry, he became one of the architects behind Statoil.

When he became Director General for the first time in 1957, the 41-year-old was well acquainted with the research institute. Among other things, he had served as Director of Research for the Telecommunications Division since 1953.

RADIO BUILDER

Finn Lien was born in Fana, south of Bergen, on 12 April 1916. His mother, Astri, was a pharmacist and his father Sigvald was a chemist. His parents had a strong interest in social affairs, and his father was known to have radical left-wing views. During the NRK interview, he mentioned an episode that became a turning point for him.

Before the war, he built his own radios. This was a hobby that he and his father shared.

"I built crystal radio devices and listened to distant stations such as Luxembourg, Hilversum and Daventry".

Thus, he developed an interest in two-way radios:

"I had heard about Diesen, the Telegraph Manager in Narvik. He communicated with people in New Zealand!"

His interest in technology led him to engineering studies in low current engineering at the Norwegian Institute of Technology (NTH) in Trondheim. When Norway became involved in the war in 1940, he was drawn into resistance efforts through the student community in Trondheim. He was forced to flee to Sweden in 1941. In Sweden, Lied was recruited by Norwegian and British intelligence services. His assignment was to smuggle radio transmitters into Trøndelag. The objective was to follow German fleet activity in the Trondheim Fjord, especially around the battleship Tirpitz.

These transmitters and their equipment weighed more than 30 kilos. Lied had to carry them on skis or by foot. He transported the transmitters from Storlien in Sweden to Trondheim or Selbu. He cannot remember whether he was afraid, although the risk was extremely high.

Nor did it seem to bother the young student that he had never been a soldier: Before the war, he was deemed unfit for duty due to tuberculosis. Officers in the Norwegian Armed Forces did not seem to care about this either. Lied was soon appointed captain in the Norwegian Army.

THE 40 IN ENGLAND

In 1942, he managed to get to England, where he worked for the Norwegian High Command in the communications department. There, he became part of the environment that would ultimately lead to FFI.

"We were 40 Norwegian engineers and scientists", he said in the NRK interview.

"Over time, the group began to discuss the future after the war. In 1942, the Norwegian High Command Technical Committee (FOTU) was established. Its purpose was to assist the British by supplying Norwegian researchers and engineers for their military research. FOTU was also given the task of assessing how Norwegian military research would be structured after the war. This assessment work led to the establishment of the Norwegian Defence Research Establishment, with a core of FOTU researchers and engineers."

Lied continues:
"When the war ended, we had a very strong sense of duty to rebuild the nation.

HAUGE WAS RESPONSIBLE

Finn Lied and Jens Christian Hauge remained in close contact. "Hauge's role at FFI cannot be overstated", says historian of ideas Rune Slagstad:

"With the appointment of Hauge as Minister of Defence in 1945, parts of Milorg's network became linked to the labour party state. This was an enthusiastic group of research engineers, some of whom had experience with intelligence work during the war. Within a short time, by late autumn 1945, Hauge had established the Norwegian Defence Research Establishment. This was a professional body of expertise in Norwegian military industrialism that included Kongsberg Weapons Factory, Raufoss Ammunition Factory and the Navy's Main Shipyard in Horten. Political party colours had little relevance in this environment.

Whether they were named Helmer Dahl, Gunnar Randers, Fredrik Møller or Finn Lied, all were in Hauge's party, regardless of what party they voted for. The main issue was the modernisation of Norway by the knowledge industry". From Slagstad's feature story in Aftenposten, the day before Hauge's 90th birthday, 15 May 2005.

National strategists Finn Lied (left) and Jens Chr. Hauge, photographed in 1974. *Photo: NTB*

This was similar to Christian Michelsen's statements in 1905. He talked about 'the new workday'. We saw what research and development could accomplish during the war.

We wanted to get in on the game. We also saw that the development of defence technology had a dual purpose, with both military and civil applications".

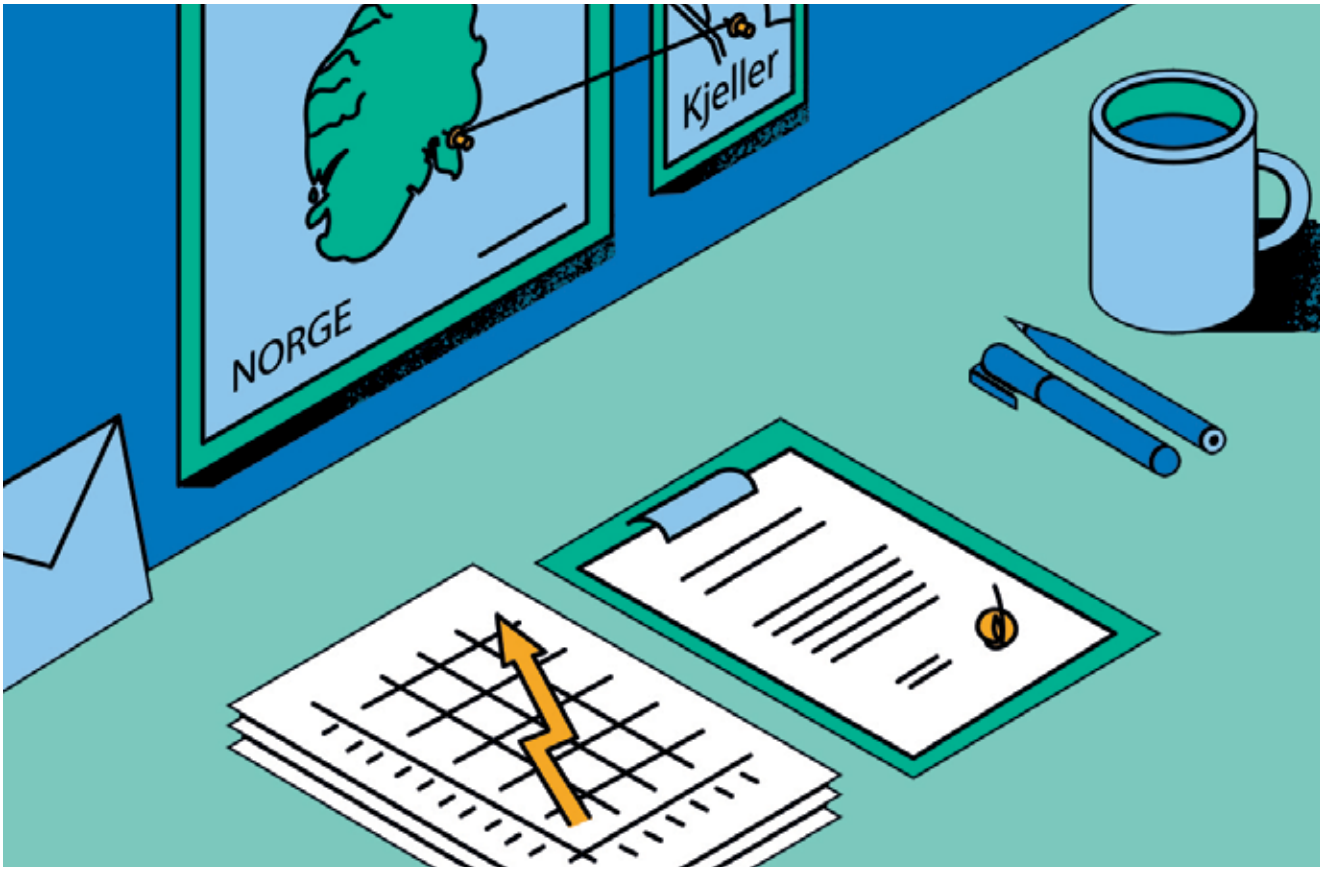
Electrical engineer Fredrik Møller in the London environment and the leader of the resistance movement, Jens Chr. Hauge were at the forefront. At the end of the war, they were still young men. Lied was 29, Hauge was 30 and Møller was 39. "Møller was not a great scientist, but he did have a very dynamic personality. He and Hauge submitted the proposition to the Storting", says Lied.

GATHERED THE NATION AT KJELLER

FFI was founded on 11 April 1946. That same year, Finn Lied graduated with a Master of Science from NTH. He was recruited to FFI. Lied was engaged in research in England in 1946 and 1947.

In May 1946, the first five division directors were appointed. They were spread about the facility: Fredrik Møller with the Asdic Division in Horten, Gunnar Randers with the Physics Division at Blindern in Oslo, Egil Ronæss with the Chemistry Division in Trondheim, Helmer Dahl with the Radar Divison in Bergen, and Leiv Harang with the Telecommunications Division in Bergen.

In 1947, Fredrik Møller was appointed FFI's first Director General. The Director General's office was located in Oslo. It was not until Lied's time in office that FFI was gathered into two locations, Horten and Kjeller. Kjeller had several buildings built by the Germans during the war. There were also five barracks at Kjeller belonging to the Norwegian Air Force. Until this point, FFI's secretariat and headquarters were located in Oslo.



It was said that Lied often ended the meetings in what was known as the Research Directors' Council, by paraphrasing Roman Senator Cato the Elder's famous sentence: "Furthermore, I consider that Carthage must be destroyed". Cato often ended his speeches in the senate in this fashion. Lied's version was more positive: "Furthermore, I consider that FFI should be gathered at Kjeller".

"Møller was not interested in moving. I worked toward gathering an interdisciplinary environment, with a size beyond the critical. I wanted to move out to the countryside, where we could make noise and do things we could not otherwise do in a city or a university environment. It took some time to gain acceptance. When I was offered the position as Director General, these were my conditions: We would move to Kjeller. And the Minister of Defence at the time immediately said yes to construction of the joint administration building", said Lied.

However, he agreed with Møller on one significant point.

"He said we had to be judged on results that could be found in the bottom line of the companies that produced our equipment. The institute should not only be useful, it should also be economical. Møller left behind an image of FFI as something that sustained itself on results. This was a very different perspective than that of the university".

A SMALL INSTITUTE FOR BIG THINGS

Lied expressed his own philosophy in the interview:

"I was enthralled by the thought that we would be a small institute for big things. We would take on tasks that truly meant something and organise the work to ensure a powerful establishment. We had to prevent a stiff, divided and inflexible organisation. We had to move the people to the tasks.

We competed with the best and beat them in many areas.

Akershus Castle was the backdrop for the celebration of FFI's 30th anniversary in 1976. Finn Lied (left) and Minister of Defence Rolf Hansen on either side of King Olav V. *Photo: FFI*

This has been the credo of FFI. An institute that is organised for work, not departments for this and departments for that. FFI was in this sense an extreme and flexible project organisation. We competed with the best and beat them in many areas. For instance, our first proximity fuse."

Lied has not forgotten that politicians in the US Congress noted that the Norwegian FFI had produced proximity fuses for a mortar costing only USD 30,000.

"The Americans had spent millions upon millions trying to do the same thing. But we had some highly skilled engineers. In an unbureaucratic manner, they utilised the new development of solid-state electronics. My good friend and colleague, Christian Holm, went to the US and personally picked out the newest high frequency transistor. This became the core of the mortar fuse. The result was a production of millions of fuses at Kongsberg".

MULTIPLIED GROWTH

Finn Lied's 26 years as Director General was a period of rapid development. The budget grew from well under NOK 10 million to well over 50 million. The number of staff grew from around 300 to more than 600. Kjeller became a technological centre, as the Director General had hoped: FFI's establishment budded into other research institutions. In 1948, the Institute for Nuclear Energy (IFA, and from 1980, IFE, Institute for Energy Technology) was established on the neighbouring lot, with Research Director Gunnar Randers as its first Director General.

Televerket's forskningsinstitutt (Norwegian Telecommunications Administration's Research Institute) was established at Kjeller in 1967, with former FFI employee Nic Knudtzon as its Director General. Norwegian Seismic Array (NORSAR) was established at Kjeller in 1968 and the Norwegian Institute for Air Research (NILU) followed in 1969. The basis for both NORSAR and NILU was the research conducted at FFI, on the monitoring of nuclear weapons testing and studies of chemical weapons, respectively.

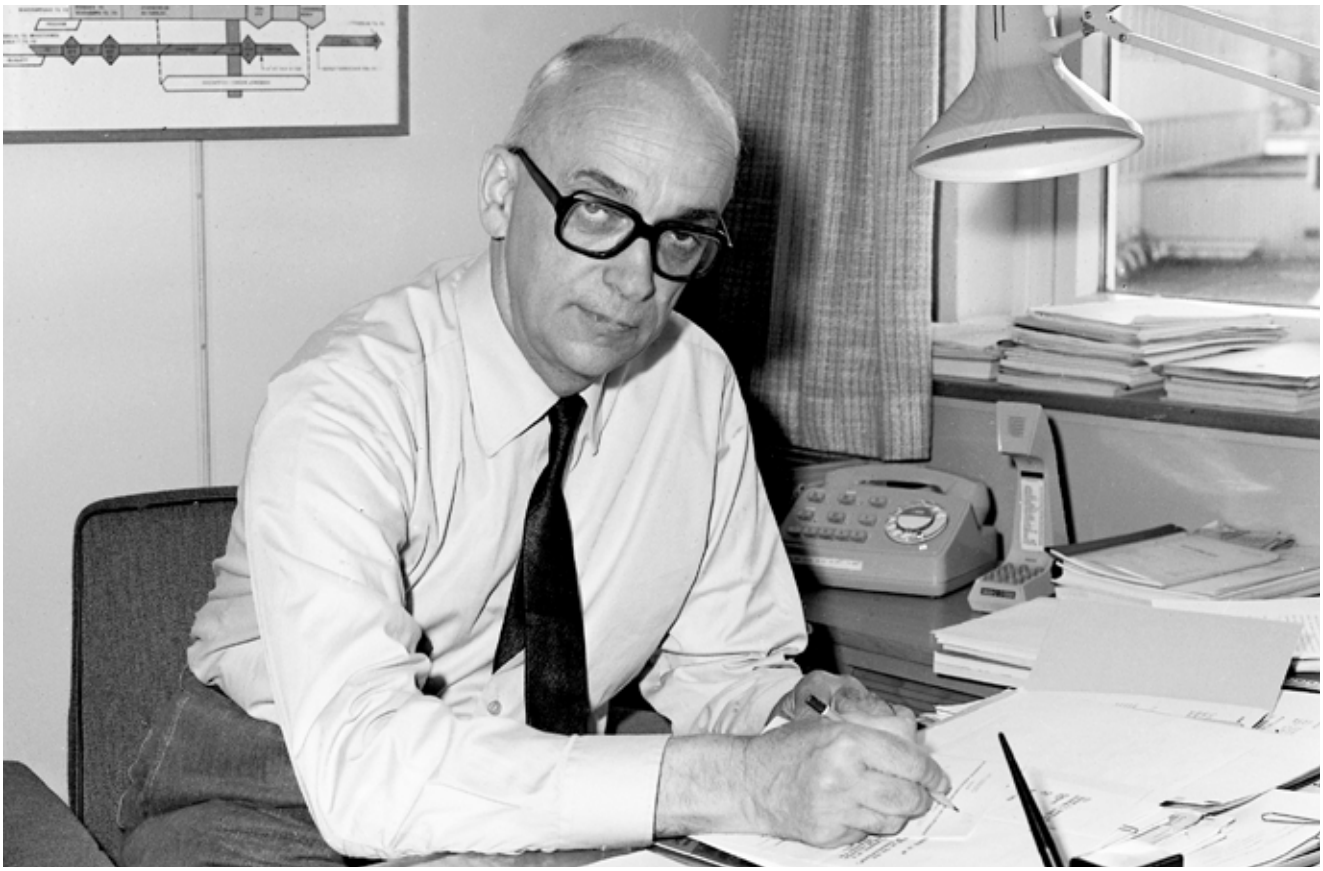
DATA POWER WAS NEEDED

FFI had a key role in a number of different computers in the early 1960s, which in turn led to the founding of Norsk Data and the computer division of Kongsberg Weapons Factory (KV). The first was LYDIA (1962), followed by SAM, SAM2 and SAM3.

Finn Lied's mild-mannered exterior might have fooled some people. But he was part of some strong alliances. Along with Fredrik Møller, who was the head of Noratom from 1957, he provided Jens Chr. Hauge with competent advice and assessments. Frequently, the advice went beyond the usual ideas in the Norwegian Armed Forces and short-term considerations for profit in the defence industry.

EXCESSIVE INFLUENCE?

Although Lied never entirely managed



Finn Lied worked long days and weeks and demanded a lot of his employees.Photo: FFI

They were thankful for peace but not as pleased with the means to obtain peace.

to bring FFI into the Norwegian Armed Forces in the form of a formal position in defence leadership, the institute's influence became so strong, that even he occasionally became concerned. When the important system group at FFI celebrated its 10th anniversary in 1969, he said:

"We are often more afraid that we have too much influence than that we have too little. It could be dangerous if our analyses are used outside the area of their significance".

FFI had many international roles, especially for NATO and the United States. This cooperation could be cumbersome. When Research Director Henrik Nødtvedt was about to take the position as Director of the NATO Undersea Research Centre in Italy, he received the following message from Lied: "You sometimes complain about our bureaucracy. The Americans are much worse, and NATO is ten times as awful. It is futile to try to change it".

KEY IN ALL AREAS

When Finn Lied had an interlude as Minister of Industry in the Bratteli Government from March 1971 to October 1972, he had already been successful in ensuring that FFI was a key actor in security policies, defence policies and industry policies. FFI became a model for similar research institutes in other countries that also wanted to develop national high-tech industries.

Journalist Cathrine Sandnes interviewed Finn Lied for the journal Samtiden in 2006 with the title Those who built the country. The interview began as follows: "Einar Gerhardsen had the people. Haakon Lie led the party. Jens Christian Hauge ensured security. And Finn Lied built the industry".

WORK ADDICT

Lied was a work addict, with seven-day

The Director General in good company with FFI colleagues. Photo: FFI. *Photo: FFI*

ONE OF THE BOYS

Finn Lied had two secretaries who worked in shifts, Elisabeth Garwick and Agnes Michelsen. But FFI photographer Bjørn Fremstad remembers Finn Lied as a down-to-earth Director General. He enjoyed chatting with the boys at the FFI workshops, and often sat with them at lunch. He also liked 'walking meetings' outdoors.

Similar to the walking and talking scenes you often see on TV series. He enjoyed discussing matters with a colleague while out walking.

He was on good terms with foreman Reidar Sørlie at the carpentry workshop. As a hobby carpenter, he also sometimes used workshop tools to build things for his cabin. Sørlie was concerned about Lied working on these things during weekends. The workshop contains planers and powerful saws, and the Director General was often alone in the workshop, without safety supervision.

work weeks. His diligence also made him somewhat of a pedant. He disliked seeing pictures hung crookedly. Lied would stand at the corner of the administration building in the morning to see when people arrived. If he felt that anyone was shirking, they were confronted at the office. For many years, he drove to work from his home at Skedsmokorset in a Volvo Amazon with a vinyl interior roof. That was considered exclusive.

Lied's sanctuaries were his cabins. The first was in Hurdal and the second in Hedalen in Valdres. His neighbours near the cabins noted that his reading material was not the usual crime novels. Instead, he read thick books about Albert Einstein's theory of relativity or literature containing complicated equations. The same neighbours sometimes had to chase away sheep from the cabin areas. They would then discover Finn Lied and his partner Inger Hattrem in the midst of the flock, hand-feeding the sheep.

They also did a fair bit of carpentry. Furniture, patios and stairs were constructed with exact precision, explained cabin neighbour and newspaper editor, Per Brunvand.

MEANS OF PEACE

After he retired from FFI in 1983, Lied continued to work for the Institute for Energy Technology – FFI's closest neighbour at Kjeller – until he was well over 90 years old.

Finn Lied spent the last few months of his life at Sørum nursing home. He died on 10 October 2014, at the age of 98.

In an obituary in Aftenposten, Jonas Gahr Støre, head of the Labour Party, highlighted his career at FFI: "He worked for progress through knowledge and science".

In an NRK interview, Kjell Pihlstrøm asked Lied if he viewed himself as one of the national strategists. The answer was direct:

"Yes, I do. We were only concerned about one thing. Not our salaries, not bonuses, not money. We were focused on strengthening Norway, on building the nation. Einar Gerhardsen listened to the weather report every morning. Why? Because he hoped the farmers would have decent weather for the harvest. When FFI was established, many people believed we were spoiling science by using our knowledge for what they referred to as 'violent purposes'. They were thankful for peace but not as pleased with the means to obtain peace". ■

Fredrik Møller

Director General from 1947 til 1957

Fredrik Christian With Møller (1906–1971) was born in Fredrikstad. The Master of Science graduate with a specialisation in acoustics became FFI's first Director General. He ran his company, A/S Akustik, until war broke out in 1940. He was one of the researchers and engineers that fled to the United Kingdom and worked for the Norwegian Armed Forces. From 1942 to 1945, he was a member of the Norwegian High Command Technical Committee (FOTU). At FFI, he contributed to the development of transducers for echo sounders, intended for Norwegian production. These were finally commercialised by Willy Simonsen at Simrad (1949). Møller served as Director General of the Norwegian Defence Research Establishment from 1947 to 1957.

FFI's first electronic computer, Frederic, one of the most powerful computers of the time, was named after Møller. After FFI, he was in charge of NATO's SHAPE Forward Scatter Branch in Paris. Møller was Chairman of the Board for Kongsberg Weapons Factory, Raufoss Ammunitions Factory and the Navy's Main Shipyard and was also a key member of Jens Christian Hauge's circle. Hauge was eager to use research and technology to create new industry.

Finn Lied

Director General from 1957 til 1983

Finn Lied (1916–2014) grew up in Fana. He spent some of his childhood in Mo i Rana and Trondheim. Lied completed upper secondary school at Trondheim Cathedral School in 1936.

Lied graduated from NTH in 1946 with a Master of Science and he continued his studies in the United Kingdom. He served as Director of Research at the Norwegian Defence Research Establishment (FFI) from 1953, and as Director General from 1957, until he retired in 1983. He was the Minister of Industry during Trygve Bratteli's first government from 1971 to 1972 and was Chairman of the Board at Statoil from 1974 to 1984. He also served as Chairman of the Board of the Institute for Nuclear Energy from 1960 to 1969 and 1978 to 1985.

Among many other posts, he also served as Chairman of the Executive Committee for the Royal Norwegian Council for Scientific and Industrial Research (NTNF) from 1973 to 1979, following his membership in the Executive Committee from 1962 to 1971.

See also page 40.

Erik Klippenberg

Director General from 1983 til 1993

Erik Klippenberg (1926–2018) was a Master of Science graduate from Danmarks Tekniske Højskole (Denmark's Technical University) and was a Visiting Fellow with the Department of Electrical Engineering and Department of Physics at Massachusetts Institute of Technology (MIT) in the United States. He was a fellow and researcher at FFI from 1951 to 1956, after which he was Head of the Operational Research Division at the SHAPE Technical Centre in Haag.

He served as Director of Research at FFI's Operational and Systems Analysis Division from 1959 to 1979, before becoming the Director of SHAPE in 1979. From 1960 to 1967, he was a Chairman and member of the NATO Council for Operations Analysis. In 1983, he became Director General of FFI, a position he held for ten years. He was also a member of the Norwegian Defence Commission from 1974 to 1978.

Nils Holme

Director General from 1993 til 2001

Nils Holme (born in 1936 in Oslo, raised in Trondheim) is a Master of Science graduate from the Norwegian Institute of Technology (1961) with a degree in technical physics and attended the Norwegian Defence University College.

Holme's professional background is primarily from the Norwegian Defence Research Establishment. He was employed by other organisations, including a three-year stint at SHAPE Technical Center in the Netherlands, two years at Norconsult in Saudi Arabia, and two years with the Norwegian Ministry of Foreign Affairs.

He has also been associated with the think tank Civita. Holme was the Chair of the Polytechnic Society (1997–1999) and the NATO Research and Technology Board (2000–2003). He was a member of the Norwegian Academy of Technological Sciences.

In 2021, Holme continues to be active in public debate. In 2013, he wrote the report 'Forsvarspolitikken ved et veiskille' (Defence policy at a crossroads), published by Civita.

Paul Narum

Director General from 2002 til 2012

From 1976, Paul Narum (1951–2017) worked as a researcher, Director of Research and Division Director at FFI. He was also Director General of the Institute for ten years, from 2002. Paul Narum was a Master of Science graduate with a degree in physical electronics from NTH in 1975 and a PhD in technology from NTH in 1989. As a researcher, he participated in the development of an infrared camera for use in the Norwegian Armed Forces, and he conducted studies of countermeasures against electro-optical sensors. This gave him additional insight into military operations.

He became a Director of Research in 1987 and from 1996 to 2001 he was the head of the FFI Electronics Division. He was a driving force in the development and production of the homing device and other critical components for the new naval strike missile in Norway. *(See also page 30)*.

As Director General, Paul Narum restructured the institute, with internal lines of responsibility that more clearly reflected the military branches and the Norwegian Armed Forces' central support bodies.

John-Mikal Størdal

Director General from 2012 til 2021

John-Mikal Størdal (born in 1965) is from Hardanger. He has been working at FFI since 1989. Here, he has worked as a researcher, Director of Research and director of various FFI divisions. John-Mikal Størdal became Director General in 2012. Størdal has a background in professional fields of system architecture, navigation, underwater warfare, and combat and guided fire control systems. Størdal holds a Master of Science in aeronautics and astronautics from the Massachusetts Institute of Technology (MIT) in United States and a Master of Science in cybernetics from the Norwegian Institute of Technology (NTH).

He has also completed the senior executive course at the Norwegian Defence University College. In 2021, Størdal will step down as Director General of FFI. He will then assume the position as Director General of NATO's Collaboration Support Office (CSO), which is part of the defence alliance's Science and Technology Organization. CSO is tasked with strengthening research and development of defence technology in NATO's member states.

WE MUST BE PREPARED

I work with security and emergency preparedness. My colleagues and I work to ensure that FFI is prepared for unwanted incidents here at the institute. What happens if there is an accident at one of our laboratories? How do we act in the event one of our colleagues are kidnapped while travelling? In March 2020, an event arose that resulted in an emergency staff meeting at FFI. Since the end of February, we had seen that the contours of the novel coronavirus could become problematic. The pandemic is an example of a sudden event that can directly affect our work here.

This escalated during the winter holidays. Many employees at FFI were out travelling. We relied on having people report to us regarding foreign travel and symptoms. Several FFI employees were quarantined. For a while, we held two emergency staff meetings a day. Only a handful of employees tested positive for COVID-19. Fortunately, we were spared a massive outbreak during the acute stage.

We have asked employees to inform us of any questions or issues. If you are employed at FFI, you must be aware that you may be of interest to others. We cannot be blind to suspicious contact or surveillance of our conversations, for instance, when riding the Metro. We also know that several FFI employees have been contacted at seminars and on travels.

FFI has a good security system in place for those who are travelling. Did you know, for instance, that you should never stay below the second floor of a hotel and no higher than the seventh floor? The first is to avoid being directly affected by riots and similar at the ground level and the other is for reasons of possible evacuation, e.g., in the case of fire.

My master's thesis concerned the relationship between risk perception and vulnerability. I came to FFI after working as an advisor for the emergency preparedness staff for the County Governor of Oslo and Akershus. FFI has given me the opportunity to engage in practical work relating to my studies. As part of the defence sector, there are certain requirements for security and emergency preparedness at FFI. We must have underlying plans for the emergency preparedness system for the defence sector and we must conduct and participate in exercises. We must also have plans for emergency preparedness and crisis management. We must also have an overview of the resources we can offer in a situation where there may be a need for FFI's expertise.

We work closely with the rest of the institute. Here, we have access to knowledge that provides useful input for those of us working with security and emergency preparedness. We have some of the country's foremost experts in various aspects of security. For instance, FFI has 24-hour services for emergency services, civil emergency preparedness actors and the Norwegian Armed Forces at FFI's CBRNE emergency preparedness laboratory. They can be contacted in the event of incidents where there is suspicion of toxic chemicals, pathogenic microorganisms, radioactive materials and explosives.

I am now in charge of the project 'Overarching Risk and Vulnerability Analysis for FFI', which will be completed during the first half of 2021. This is an exciting job. The report will tell us something about the required scope of our emergency preparedness moving forward.

When I am not working on interesting challenges at FFI, or enjoying urban life in Oslo, I am most content taking slow trips at sea at home in Southern Norway. For safety's sake, I do this in a refurbished lifeboat. I am not the typical adrenaline junkie. ■

I am not the typical adrenaline junkie.

THEA EIDE HØYESEN
(24)

Security Advisor, Emergency Preparedness

RESIDENCE
Oslo

EMPLOYED SINCE
2018

FIELD OF EXPERTISE
Societal security

DIVISION
Strategic development and corporate governance

Photo: Espen Wang-Naveen / FFI

CAN AN INSTITUTE HAVE SOUL?

This was not what they had been looking for. But perhaps historians Olav Wicken and Olav Njølstad were on the path to find FFI's soul.

It is a thick book. Kunnskap som våpen (Knowledge as a Weapon) is more than five hundred pages in length and delves deep into FFI's history, from its early days in England during the war and up until 1975. The two Olavs cannot recall exactly when they started on the book. However, by the time this work of history was published in 1997, loaded with footnotes, they had spent between two and three years on the process. Neither believe it was a coincidence that they were assigned the project. Both Wicken and Njølstad worked for the Institute for Defence Studies (IFS). They certainly had the professional qualifications.

Both agree that they probably started the project on the day a third Olav, Director General Olav Riste at IFS, popped into their office. He asked if they would consider taking on the task of writing the history of FFI. Someone at Kjeller had mentioned them, although the authors cannot recall whom.

Institution histories were prevalent in the 1990s. There were a rush of publications: Hydro had marked its centennial. The history of the Norwegian Armed Forces was published during the same period. The Norwegian Intelligence Service did the same. The history of Norwegian foreign policy was published during this period, in six volumes.

Another clear trend was the choice of academic historians as authors.

OFFSHOOTS

FFI offshoots such as the Norwegian Telecommunications Administration's Research Institute and the Institute for Energy Technology (IFE) were also given their own history books. It was Njølstad who wrote the latter book: Strålende forskning (Brilliant Research). There is also a great deal of FFI history in the current Norwegian Nobel Institute Director's major biography, Jens Chr. Hauge: fullt og helt (2008). Resistance leader and Labour Party titan Hauge was an exceptionally important individual in the establishment of both FFI and its Kjeller neighbour, IFE.

Olav Njølstad has also written the biography of Leif Tronstad, who could have become FFI's first Director General:

Historians Olav Wicken (left) and Olav Njølstad wrote the book Kunnskap som våpen (Knowledge as a Weapon), the story of how FFI was established and its development up until 1975.
Photo: Lars Aarønæs / FFI

Professor Tronstads krig (Professor Tronstad's War): 9 April 1940 – 11 March 1945. On this day in March, near the end of WWII, he was killed in a clash with Norwegian NS combatants.

We must add that Olav Njølstad's love of writing has not been limited to academic literature. What he saw and found in the archives of FFI and IFE provided him with the material to write his thriller, Mannen med oksehjertet (The Man with the Bull`s Heart). A common thread in the novel is the nuclear threat of the Norwegian post-war period.

The story begins with Doctor Ulla Abildsø from Finnmark, who was affected by radiation. She flies to Oslo, searching for the truth about what actually happened on her father's fishing boat on one fateful October day in the North Sea in 1961. The level of tension and accurate details are every bit as exciting as that found in books by John le Carré and Jon Michelet.

The thriller was published through the book club Krim & Spenning (Crime & Thrillers) in 2002. It is virtually begging to become a film.

NORWAY AS A NUCLEAR POWER

The reality is perhaps just as exciting, according to Kunnskap som våpen: Astrophysicist Gunnar Randers believed that Norway would become a nuclear power and that FFI would be decisive in this achievement. Randers was one of the researchers from the exile community in the United States and England during the war. He was later known in the media as 'Nuclear Randers'. He has been honoured by something that is currently not shared by the other pioneers around FFI: The road to the west of the institute at Kjeller bears his name.

In 1946, Gunnar Randers and Director General Fredrik Møller had begun discussing developing nuclear weapons at FFI. The work itself was never initiated.

The book, Kunnskap som våpen (Knowledge as a Weapon) covers the period from 1946 to 1975, and was published in 1997.

However, Randers made sure that Norway would become a nuclear nation, albeit with a civil purpose. Jens Chr. Hauge was heavily involved and was a good source of information when the early FFI history was being written.

"He was only 30 years old when he took office in 1945. Thus, he became Norway's youngest Minister of Defence. We had many interviews with him. Jens Chr. Hauge was a strong admirer of FFI and very proud that he had contributed to the establishment of the institute."

Can what happened during the initial FFI years be viewed as a combination of strong technological optimism and even stronger personalities?

"It is no longer possible for someone to fill the role these key persons had during the first five post-war years. It was a unique period. Hauge describes Randers as a 'czar'. There was plenty of room for this type of person. Naturally, Hauge was one of them. Many viewed the development of nuclear energy as 'energy problem solved'.

It is still fascinating, that Norway, of all countries, was a pioneer in the field of nuclear energy, with all the hydropower we already had! Equally astounding was how natural it was for some of these people to say that 'here we must simply invest'. Hauge magically produced NOK 5 million for the first nuclear reactor from an entirely different item in the defence budget. In the book, we call it 'Hauge's wedding gift for nuclear research'. The sum was the equivalent of five 1946-budgets for all of FFI. Once it became clear that the work would not involve weapons development, Randers left FFI to develop the Institute for Nuclear Energy (IFA), on the lot neighbouring FFI."

SEARCH OF THE ARCHIVES

The historians spent much of their time at Kjeller.

"It was interesting. The archives were not well organised. There were a lot of things laying around, and it was hard work to find what we needed. Fortunately, we had good help from the Archive Manager, Knut Takla, and the core staff, with Director General Nils Holme at the lead."

The historians were also assisted by former Director Generals Finn Lied and Erik Klippenberg, and retired Director of Research, Karl Holberg.

Much of what is written in the books was clearly confidential material during this period. Nevertheless, Njølstad and Wicken did not encounter any obstacles during their work, although some of the code names in ongoing projects had to be redacted.

Neither of them had a professional military background, nor did they have industry experience. Yet they were able to convey complicated topics from FFI in a highly accessible manner.

For many years, FFI has been researching countermeasures against nerve gas agents. This photo was taken in FFI's Neurobiological Laboratory in 1974. Photo: FFI

The institute forms part of the idea of transforming Norway into a more modern society.

Njølstad did much of the work on the nuclear projects and perspectives on alliances. Wicken concentrated on industry development and the role of the Armed Forces in the industrialisation processes, especially those that involve high tech matters.

THE THREE NEW CONDITIONS

You place a strong emphasis on Finn Lied's role. Why?

"In many ways, he personified FFI's strengths. This was because he was a leader within the research policy and industrial policy establishments. He was even appointed Minister of Industry. He linked these two arenas to defence policy. In doing so, he became an important actor. This has meant a great deal for FFI".

If Lied had not become Director General in 1957 and continued for 26 years, what would FFI have become?

"This takes us into the realm of counterfactual history. FFI would not have been the same, that is for sure. Lied was clearly a person who shaped the institute. But this was not merely about individuals. It was also about an era that allowed for such an institution to be established."

"It is striking how unique the initial post-war period was and how much it differed from the interwar period. Framework conditions for FFI were not in place prior to WWII. After the war, they were extremely apparent."

"These new conditions were built on three different factors. The first was that large parts of the political environment had developed an entirely different attitude toward the Norwegian Armed Forces than before WWII. The second was the experiences of those who had served during the war: They had seen the necessity of having allies. The third factor was the clear importance of military technology for the outcome of World War II".

How did you experience the conversations you had with Finn Lied, who viewed FFI as the most important part of his life work?

"He was one of the most impressive people we have ever met. Not only was he knowledgeable, but he also had deep insight. Lied had perspectives on almost everything. There were also many stories about him and how detail-oriented he could be. We knew, for instance, that he was very displeased when people arrived late for meetings. So, we made sure we arrived on time!"

PART OF SOMETHING BIGGER

FFI is a part of the post-war defence policy. The institute specialises in answering the question: 'How should a modern armed forces act and look?' This also involves a much broader area. FFI is part of a modernisation period. The institute forms part of the idea of transforming Norway into a more modern society.

This research had a bottom-up approach. A great deal happened at the technological level. This model worked well, in many ways. However, the organisation as a whole had no direction.

Politically, there was a strong focus on developing the Norwegian economy after World War II. FFI provided some of the new technologies required to create a more forward-looking industry in Norway. Sweden, the United Kingdom and the United States served as models".

In the book, it is surprising to read FFI's strong, initial emphasis on advising the Norwegian Armed Forces to think less in terms of strategy and more in terms of flexibility. You mention several examples of researchers brimming with ideas outside their actual area of study and many of these ideas were carried forward?
"Before Finn Lied became Director General, FFI was a very open organisation. The environment was a result of what the researchers and management brought from the United Kingdom during the war. FFI had no real senior management. Director General Fredrik Møller was viewed as an equal. Based on this model, research directors determined the course of their own projects. This research had a bottom-up approach. A great deal happened at the technological level. This model worked well, in many ways. However, the organisation as a whole had no direction".

THE GREAT CHANGE

Historians see a significant change at the beginning of the 1960s.

"There was a clear before-and-after picture. FFI had already completed major projects. ASDIC was further developed and put into production through Simonsen Radio (Simrad). This resulted in a major product for the fishing fleet. The microwave project led to the founding of Nera in Bergen. Yet it was the Terne Project that drew the organisation together. This was part of the development of a port defence system. Many processes were initiated."

American funding was important. FFI underwent restructuring. The institute appointed division directors and directors of research. They were part of the hierarchy with a strong core staff. This staff governed the processes based on a top-down approach. Njølstad points out that it was this restructuring process that led to Finn Lied's motto: 'FFI shall be a small institute for big tasks'.

"This had now become possible. During this period, in the late 1950s, FFI received significant economic support from NATO and, not least, the United States. During some of these years, more than half of the budget was financed by external sources. FFI was given new opportunities to concentrate on larger, more demanding projects. This funding offered far greater predictability than a small institute would otherwise have had, in an international context".

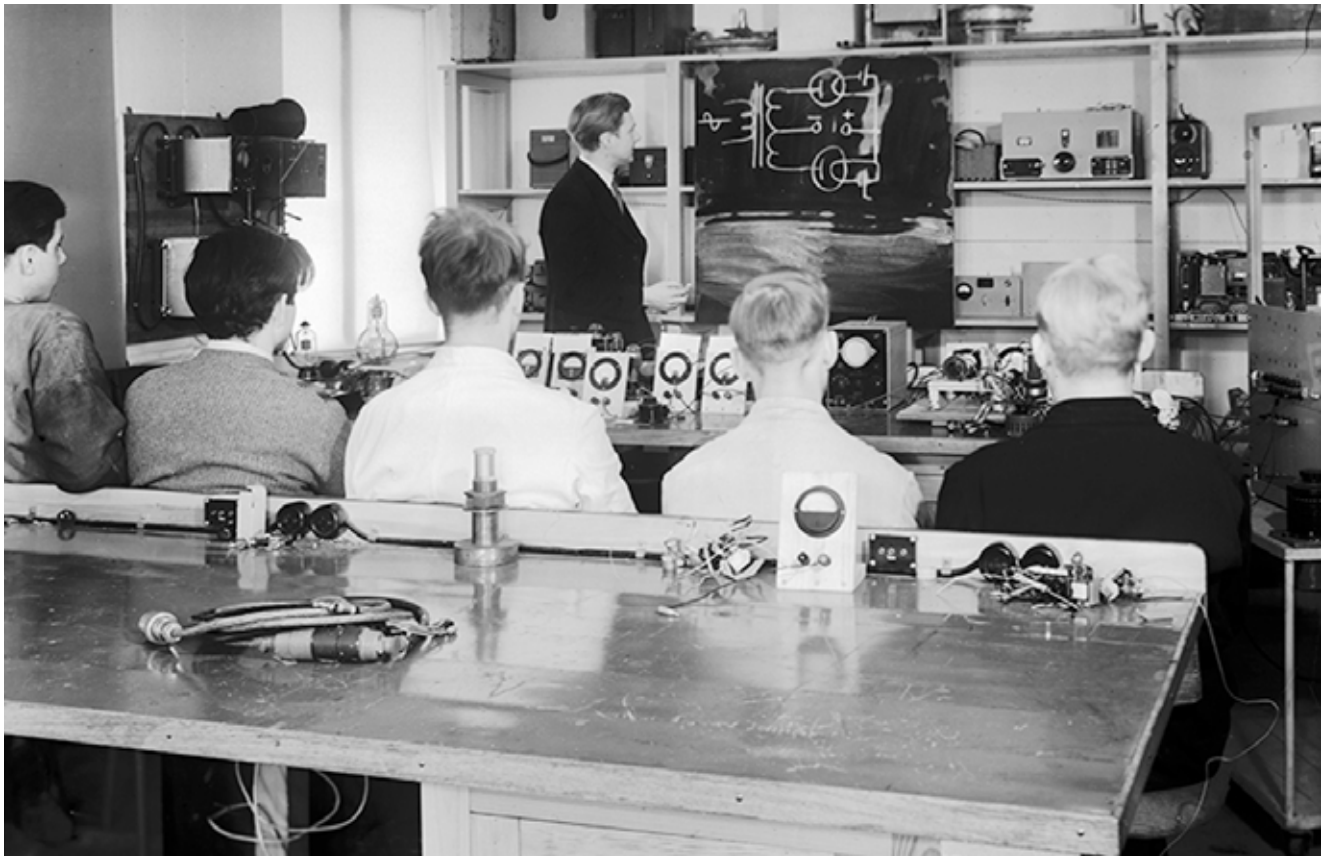
The United States must have appreciated the research delivered by FFI: After all, they were not sending money just to be nice?
"Indeed, they wanted something in return. This was a trade-off. We write about this in the book. You will not receive more than you are able to offer. FFI's Bridge Project is one such example. This related to submarine detection systems and was an interesting part of geopolitics and alliance building".

FFI THE INNOVATOR

The triangular collaboration between FFI, the Norwegian Armed Forces and Norwegian industry is today an important element for all parties. The two historians have studied the background history and its unique aspects.

"High-tech industrial development challenged the old norms. Liberal ideology dictates that there should be a divide between business and public administration: The government should be neutral in relation to special economic interests.

During the Borten Government, a member of Høyre (Norwegian Conservative Party), was appointed Minister of Defence: Otto Grieg Tidemand. It was during his time in office that a procurement policy emerged, which Finn Lied at FFI likely pushed to implement. New regulations



At school in 1946. Researcher Ole Fredrik Harbek instructs engineers in tube theory at the Horten department. Three years later, FFI established a business school, that was in operation for 45 years. *Photo: FFI*

were introduced where the public sector's role was to establish the necessary links. In this manner, an entirely new political economy was formed. It dictated that 'we must work closely together'. This is an entirely different framework and perspective regarding how such processes should ensue.

This triangular collaboration later became part of a larger industrial policy system. FFI had a key role here. When the Thulin Committee in 1980 looked at how research could contribute to industrial development, they obtained expert statements from the British specialist community, the Science Policy Research Unit (SPRU). They were among the first to begin working on innovation research. SPRU realised that if there was one place in Norway where modern innovation policies could be introduced, it was FFI.

It was especially important for personnel from the companies to work at FFI and vice versa: That FFI staff worked at the companies for shorter or longer periods".

WHALE BLUBBER NAPALM WAS A HIT

Wicken and Njølstad are hesitant to comment on FFI's history after 1975, which is the last year included in the book Kunnskap som våpen (Knowledge as a Weapon).

"Other historians should be hired soon to describe the next period of FFI", they say, with a laugh.

However, Norwegian Nobel Institute Director Njølstad has had lecturers from FFI`s research program on terrorism (TERRA) visiting the institute.

"Establishing this programme was a prescient move", he states.

When the book was published in 1997, the year after the 50th anniversary, all employees at FFI received a copy. But it never became a best seller?

"Let us be audacious enough to say that it deserved more readers! However, those who did read the book gave us positive feedback. I remember Aftenposten writing a fairly long article on what we wrote about spermal, napalm based on whale blubber, developed by FFI. Complete with a caricature". ■

Learn more about spermal on page 82.

Photo: Christian Tandberg / FFI

MINESWEEPING WITH HUGIN

How to find and remove mines along the Norwegian coastline? FFI, Kongsberg and the Norwegian Armed Forces are developing an unmanned system for minesweeping.

The crew can run the whole operation at a safe distance.

"Thanks to modern technology, we no longer need to put people in harm's way to perform this work. This is actually a no-brainer", says Research Manager Morten Nakjem at FFI.

He is standing on the deck of the KNM Rauma. The minesweeper is one of three owned by the Norwegian Armed Forces. Such ships do a sweep. The sweep triggers mines to detonate. Soon these ships will be taken out of operation. In their place, unmanned boats and submarines will be clearing mined waters. The crew can run the whole operation at a safe distance.

STARTED IN THE 70S

Keeping the coastline free from mines is vital work, for instance, when accepting assistance from allies during a crisis or war. The system now being developed by Norway will be able to clear larger areas faster than before.

Morten Nakjem is the linchpin of FFI's concept and technology development. Although the idea may be simple, it is often a result of several decades of Norwegian research and technology development.

In the late 1970s, FFI began developing saltwater batteries for small submarines. The first prototypes for the unmanned submarine, Hugin, appeared in the mid-1990s. In the future, Hugin will play a key role in the Norwegian anti-mine concept, by mapping coastal areas and performing minesweeping.

WORKS AUTONOMOUSLY

The sum of more data power, artificial intelligence and new battery technology means that unmanned vessels have become more autonomous and have greater endurance.

Hugin can steer itself when mapping an area. It has advanced algorithms that enables it to automatically recognise mines from photos it takes of the seabed.

If the submarines detect possible mines, one can dispatch an unmanned surface vessel (USV) with disposable weapons to neutralise the mines. If the conditions of the seabed are such that Hugin is unable to detect the mines, a USV with minesweeping capabilities will be used to trigger detonations.

NEW PROBLEMS, NEW SOLUTIONS

The weight of the minesweepers is a challenge. Smaller, unmanned surface vessels are unable to pull the heavy sweeps used by traditional minesweeping vessels. Therefore, Henriksen Mekaniske and FFI have developed a prototype for a new and lighter minesweeper. One variant was tested in the summer of 2020. It was used for the old minesweepers.

The industry, Norwegian Armed Forces and FFI researchers have been collaborating closely.

"This triangular collaboration enables us to find a solution that costs less, works better, and is ready faster", says Research Manager Morten Nakjem at FFI.

THE FUTURE IS MODULAR

The system was built by civil technology. It consists of modules that can be put together as needed. This makes it less expensive and more flexible for the Norwegian Armed Forces.

The Hugin submarines are in use offshore, among other places, to monitor Norwegian pipes on the seabed. In the event of a crisis, it will be possible to requisition them. It is also advantageous to utilise Norwegian industry and create the modules ourselves.

Unmanned mine warfare is a pilot project for autonomous modular systems in several parts of the Norwegian Armed Forces.

"Reconnaissance, situational awareness, communication, target selection, transport and logistics. The utilisation of autonomous modular systems is only limited by the imagination", says Morten Nakjem. ■

HUGIN

Hugin is an Autonomous Underwater Vehicle (AUV) that can operate autonomously at a depth of several thousand metres, without a physical connection to a boat or remote control.

As early as the 1980s, FFI began looking for new power sources for underwater robots. The advanced sonar technology used to search its surroundings is continuously undergoing development.

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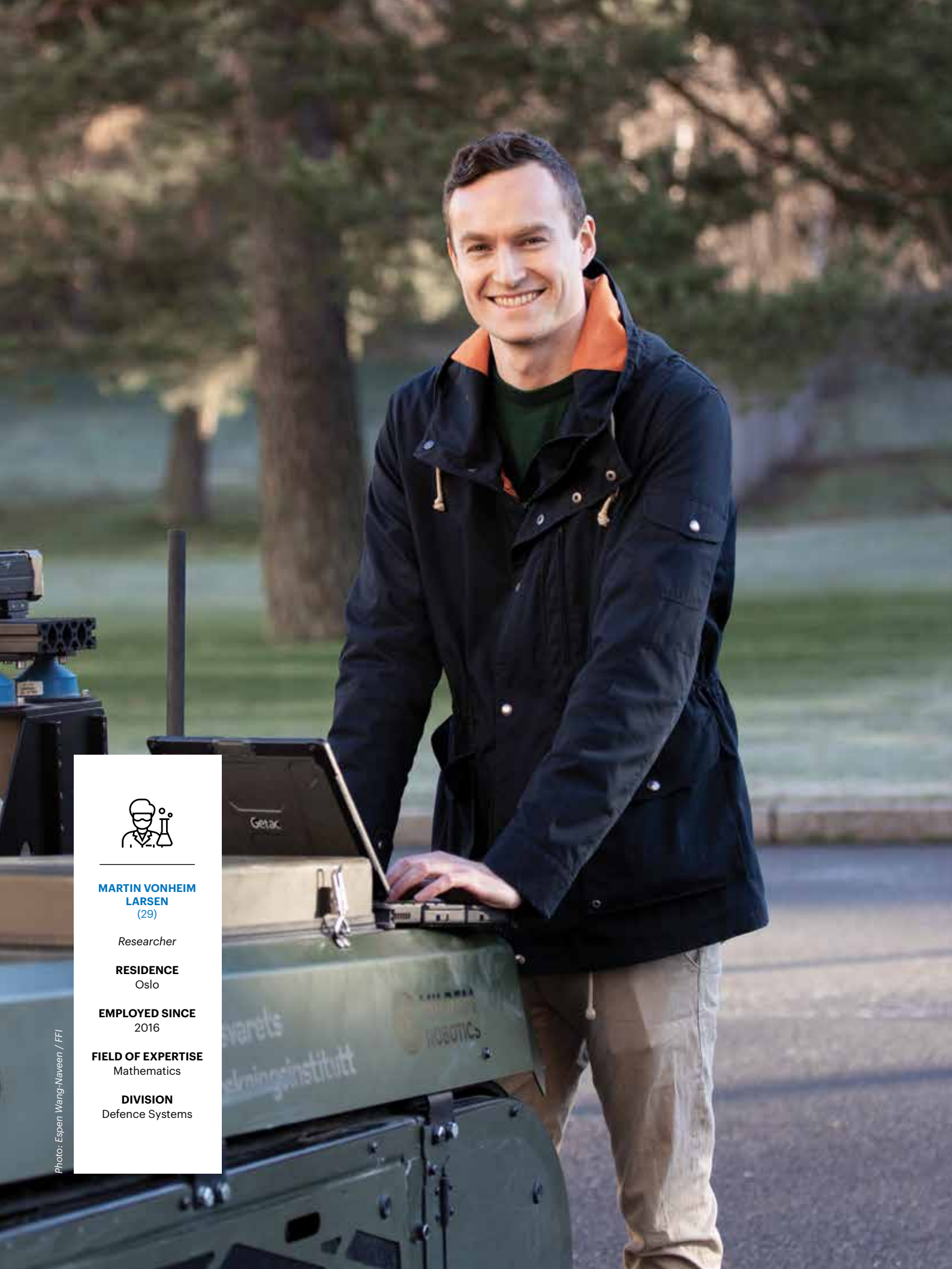
Popular with the kids: An early version of Hugin is displayed at the University Museum of Bergen.
Photo: Lars Aarønæs / FFI

02
From 2028, unmanned surface vessels will begin transporting unmanned submarines out to waters that will be mapped for mines. This photo was taken outside the FFI department in Horten in 2019, during a test of a structure for launching and recovering submarines.
Photo: Christian Tandberg / FFI



MARTIN VONHEIM LARSEN
(29)

Researcher

RESIDENCE
Oslo

EMPLOYED SINCE
2016

FIELD OF EXPERTISE
Mathematics

DIVISION
Defence Systems

Photo: Espen Wang-Naveen / FFI

SENSORS CHARACTERISE THE BATTLEFIELDS OF THE FUTURE

During math class at lower secondary school, we were given a statistics assignment. The assignment was to toss a die 30 times and calculate the average. I ended up creating a program that enabled me to do 20 million tosses of the die. My teacher just said it was 'good'. I don't think she really understood how it worked.

In my job at FFI, I have plenty of opportunities for fun things like this. Ever since the age of eleven, I have had a strong interest in programming. If unmanned drones, boats and other systems are to function properly, they must be programmed to take full advantage of the hardware. Even though my profession is mostly theoretical, it is easy to spot the end results. Especially when things don't turn out the way they were supposed to.

The word 'tracking' turns up repeatedly in much of what my research group is currently doing. We look at how we can use sensors, for instance on a self-driving vehicle, to detect objects that are moving in the immediate area. These tools help us detect things that are difficult to spot with the naked eye. We also do research on things that can trigger false alarms and confuse operators. Testing in the field is an important part of the job. We spend a lot of time in the areas around the Rena military base, looking at autonomous vessels and work on self-driving boats in Horten.

Thanks to new technology, combined with strong computing power, the physical world has become more transparent. We are only studying a fraction of this military technological revolution.

Over the past five years, a lot has happened in the field of deep learning. What we call artificial intelligence is now enabling machines to interpret images in real time.

The same applies to data from all types of sensors, such as radar and sonar. Traditionally, these tasks have been both difficult and time consuming.

It is much harder today to hide a tank in the woods, since it is far too easy to

> *Cheap sensors and energy-efficient calculating power has many implications.*

An unmanned vehicle with radar and pan-tilt-zoom camera is used to give the operator a better overview. *Photo: Espen Wang-Naveen / FFI*

detect. The development of cheap sensors and energy-efficient calculating power has many implications. One of them is that it takes far less effort to discover what the enemy is doing. A simple drone or a camera can capture images that previously required dispatching a team of soldiers to the woods to locate.

In military terms, this would involve materiel, terrain and movement. My master's thesis concerned automatic terrain analysis for the positioning of combat vehicles. I have now commenced work on my PhD. The title itself is a mouthful: Wide Area Long Range Multisensor Object Detection and Tracking.

One challenge is to know how far certain other nations have come. It is easy to fall behind. Some of the most important ways FFI can contribute is to establish Norway as a world leader in these technologies. This is essential if we are to become an attractive collaborative partner; a nation that is recognised by NATO and the EU.

In order to stay ahead in technology, you have to be best at research. You have to contribute to the international research communities. In conjunction with my PhD, I looked at the ethics of defence research. I noticed something about the letters of allocation that apply to FFI.

From 2017, they were worded differently. Earlier, there was no mentioned of contributing to international research. Now, this is being emphasised. This is an important antipole to the operational departments of the Norwegian Armed Forces, which prefer to acquire things they can use immediately. I am proud that we can manage to balance these needs and that the interest in long-term research has been clearly worded.

My dialogue with the Norwegian Armed Forces in my research field has been excellent. Only a few years ago, many were naturally sceptical, since automatic processing of sensor data was difficult. Now, I feel that they are pushing to test how well things work and what can be done to fool these systems. We are talking about who is best, and who can fool whom.

Our job includes enabling others to understand how enemy systems work. If you are able to disrupt a network or fool the enemy's sensors, you are in a good position. Such technologies may determine outcomes on future battlefields. ■

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Researchers have been working to develop a system that enables the Kongsberg Remote Weapon Station to detect, track and down drones. This system was presented in the winter of 2020.

02
Martin Vonheim Larsen and Sigmund Rolfsjord (left) study the results of the tests on the shooting range.

03
This is how a drone looks after it is hit by a 40 mm airburst grenade.

Photo: Espen Wang-Naveen / FFI

THE TERRORISM RESEARCHERS

How does a terrorist think? What is the driving force for a foreign fighter? Since 1999, a small group of FFI researchers have been asking themselves these questions. Their work is world renowned in studies of terrorism and asymmetrical threats.

This series of research projects is referred to as TERRA. Among other topics, the researchers study Jihadism and how it may threaten Norwegian and international security.

AN ABRUPT TRANSITION

TERRA was a small research community, in a country located far away from the topics it studied. However, in Madrid, on 11 March 2004, it happened. Ten bombs exploded on four urban trains during rush hour. 193 people were killed, and nearly 2000 injured.

The Project Manager at the time, Brynjar Lia, recalls a document he had read just before Christmas the previous year. It concerned al-Qaida's strategy to get Spain to withdraw from Iraq. He and his colleague, Thomas Hegghammer, found it and translated the most relevant pages.

The media took an immediate interest. The BBC was among the news outlets that quickly had more of the document translated. The news that Norwegian researchers had found a possible link between al-Qaida and the Madrid bombings spread like wildfire. They abruptly became aware that the entire world was interested in their work.

The press was surprised that crucial expertise in this area could be found in Norway, of all places. Journalists from all over the world came to Kjeller. The researchers participated in a live interview via satellite outside the FFI premises. This was broadcast in Australia, the United Kingdom and the United States.

11 SEPTEMBER 2001

Research on asymmetric warfare began with a forward-thinking Research Manager Ragnvald H. Solstrand (1942–2018). He saw the need to take a closer look at international terrorism and radical Islam. Young people with relevant backgrounds were recruited to the institute.

One of them was Hegghammer. He had just completed his master's degree in Middle East Studies. He had no idea of what to do next, other than to work with something related to this region. In the summer of 2001, he obtained an internship at FFI. Here, he was tasked with writing a report on terrorism. This was his first contact with the phenomenon of al-Qaida and Osama Bin Laden. Then came the 9/11 terrorist attacks.

"It was pretty banal, really. I was here because I needed a job and then 9/11 happened happened. I became very motivated and interested in the topic. I wanted to find out what this was and why it happened", says the researcher.

AZZAM THE IDEOLOGIST

Curiosity made him dig deeper to learn the reasons for the acts of terrorism. In 2020, Thomas Hegghammer was bestowed the FFI award for excellent research communication for his book The Caravan: Abdallah Azzam and the Rise of Global Jihad.

The outline of Azzam's life included his birth in Palestine in 1941 and his death by car bomb in Pakistan in 1989. The books describes how he became one of the most influential ideologists in Jihadism. He was a key figure in the mobilisation of Arab foreign fighters in Afghanistan in the 1980s. Azzam was also the first religious scholar who argued that becoming a foreign fighter was an individual, religious duty. Subsequently,

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01
The Madrid train bombings in March 2004 left 193 people dead and injured thousands.
Photo: Paul White / TT Nyhetsbyrån / NTB

02
Thomas Hegghammer in 2004, with an al-Qaida document that indicates Spain as a potential terrorist target.
Photo: Espen Rasmussen / VG / NTB

02

both moderate and radical wings of the Jihadist movement have employed this doctrine to support their views.

Hegghammer spent many years on this book. The search for sources led him to places where Azzam had lived. The content is not simply a dry statement of facts. Many have praised his vivid narration. The book was published by Cambridge University Press.

PLACES, LIVES AND SMELLS

Hegghammer and his colleagues have done fieldwork in countries including Afghanistan, Pakistan, Saudi Arabia and Jordan.

"You can't just sit online and gather propaganda. If you don't know where these groups are, how they look, how they smell, and how they live, you will never truly understand the texts", says Hegghammer.

There were never any face-to-face meetings with active Jihadists.

"That actually became impossible from around 2000. In the past, they needed researchers and journalists to communicate their messages. With the arrival of the Internet, we became a bit superfluous. Then they could start killing us. You could probably go to Syria and make contact with a few smaller radical groups, like Ahrar al-Sham. A white, non-Muslim researcher would never be allowed into IS as an observer. So, we have to speak with former Jihadists instead".

UNAFRAID OF DEATH THREATS

You are active in public debates and often interviewed. Do you get a lot of unwanted attention?

"Not really. There have been a few death threats and such, but who hasn't received a death threat these days? If you are covered on Facebook, in politics or in some other fashion, you encounter a lot of strange people. I have never had major, important people come after me. Had the Norwegian Jihadist community continued to grow, so that we lost control over it, I might have become a bit anxious. There are instances of people from these communities having shot at people's houses. But it is very rare for researchers to become targets for this type of thing. Disliked politicians and journalists are higher up on the list". ■

OPEN SOURCES PROVIDE KNOWLEDGE

The books, reports and articles from the TERRA community have been widely read and have won multiple awards.

The researchers emphasise that they work with open sources. They want to know more about the actors behind acts of terrorism. They are particularly interested in the emergence, recruitment, radicalisation, ideology, strategies and tactics of these groups. The research team includes historians and political scientists that speak relevant languages and who know the culture of the areas they study.

TERRA researchers' publications include Peter Nesser's book Islamist Terrorism in Europe (2015) and Anne Stenersen's al-Qaida in Afghanistan.

Physicist and computer scientist
Pål Spilling had fun at work.
He was one of the Internet pioneers.
Photo: Terje Heiestad

FROM THE UNITED STATES TO FFI

Kjeller was first online

On 15 June 1973, Kjeller became the first place outside the United States to go online. Pål Spilling at FFI pressed the necessary keys.

The outcome was the result of defence matters, old friendships, a little luck and an impressive effort by FFI. These factors helped enable Norway to become the first international member of the Arpanet (ARPA – Defence Advanced Research Projects Agency). The Arpanet was the precursor to what is now known as the Internet.

Spilling, age 39 at the time, was the assistant of FFI researcher Yngvar Lundh. FFI's journalist Øystein Hagen interviewed Spilling 30 years later. In the interview, the researcher stated that he saw two reasons for Kjeller to become the first node outside the United States: The first was that it already had a good relationship with ARPA via the Norwegian Seismic Array (Norsar), where Norway had a strategically important position.

The other reason was the American Lawrence Roberts, or Larry, as he was known among friends. In the early 1970s, Roberts led ARPA's Department of Communication. Larry completed his PhD work at the Massachusetts Institute of Technology (MIT). FFI's Yngvar Lundh worked in the same laboratory.

FFI ONLINE

1973

Pål Spilling was a nuclear physicist, not a computer expert. This is exactly why it was only natural that he was the person to establish the first connection between the US Arpanet to FFI on 15 June 1973.

ARPA AGAINST NUCLEAR BOMBS

Pål Spilling was not a computer expert. He was a nuclear physicist. Yet there was still a connection: Arpanet had direct connections to nuclear threats.

The man that pressed the keys of the very first TIP (Terminal Interface Processor) outside the United States, at the Norsar premises on this day in June 1973, realised how important this could become.

Spilling knew pretty much all there was to know about nuclear bombs and underground nuclear weapons testing. The Cold War lasted from the end of World War II until the fall of the Berlin Wall in 1989. NATO and the Warsaw Pact were rivals for 44 years. The conflict involved the balance of terror and the arms race. It also related to who had the most powerful and highest number of nuclear weapons. The parties had entered into a mutual agreement to halt testing. Neither party believed that the other would uphold

The idea behind Arpanet was to prevent communications in the United States defence from failing in the event of a comprehensive Soviet nuclear attack. The fear of Russian capabilities was justified: In 1961, the largest nuclear weapon ever, the Tsar Bomba, was detonated over Novaya Zemlya. This was a thousand times more powerful than the Hiroshima bomb.
Photo: Reuters / Rosatom / NTB

their end of the agreement. At least not if they could get away with it unpunished. Thus, Norsar at Kjeller was established, as a branch of FFI.

Norsar used geophones to detect ground vibrations in the strategically important northern regions. Such detection instruments can be compared to putting your ear to the ground. Both larger and smaller vibrations could have natural explanations. At the same time, they could also serve as a warning that the Soviet Union was conducting unlawful underground nuclear weapons testing.

Norsar produced daily reports. These were sent through a regular line to the Swedish satellite station in Tanum. From there, they continued via satellite to the United States.

BALANCE OF TERROR DISRUPTED

Both NATO and the Warsaw Pact realised the following: In order to win a nuclear war, the attacking party had to annihilate its enemy. With one strike. Both knew that if the enemy had the opportunity to respond to the attack, all life on earth would be threatened. Only the party that triggered a nuclear war could win.

The use of packet switching via Arpanet significantly reduced this threat. Packet switching split this communication data into small segments referred to as packets. The packets had information in the address field that could reorder the information back into a single file. This was possible, although sometimes an information packet or two went missing. Parts of the communication data took different paths through the network. They were then put back together at their destination.

A massive nuclear attack could not stop the information others needed to retaliate. Someone would then be able to immediately respond to a nuclear attack. This could be done from an entirely different place in the United States. Or from the rest of the world.

Packet switching changed the rules of the game. The very logic of the balance of terror took a hit. It was no longer possible to view things the same way. I.e., if a military base were destroyed by a nuclear attack, the attack would also make it impossible to retaliate simultaneously. The balance of terror had become a game that was impossible to win.

Arpanet had therefore contributed to the ending of the Cold War. Norway was a strategically important NATO outpost. A great deal of communication and information was sent via Kjeller. This site was therefore vulnerable. It had never been more dangerous to work at Kjeller than during the days of the Cold War.

FFI VISITED WASHINGTON

Larry Roberts and his second-in-command, Bob Kahn, visited Kjeller in the summer of 1972. They proposed a collaboration on the data network via satellite. Yngvar Lundh convinced FFI Director of Research Finn Lied and Research Director Karl Holberg to go along with the idea.

They were invited to Washington, partly to see the Arpanet. Here, some technical problems were resolved. A technological

It had never been more dangerous to work at Kjeller than during the days of the Cold War.

strategy for Norway's connection with Arpanet was devised.

How would this develop? Neither Lundh, Pål Spilling nor Finn-Are Aagesen had any idea. Aagesen was the third key Norwegian in the Arpanet efforts. Pål Spilling also took a business trip to their network friends at University College of London (UCL) and later to Stanford University in the United States. At Stanford, he also met several of the key participants in the Stanford University Network, later known as SUN.

Internationally, the Arpanet network became operational on 15 June 1973. Signals were transmitted via satellite stations in Tanum, Sweden and Etam, West Virginia in the United States. INTERNET, in capital letters, became the designation that included both the Arpanet and the international nodes. The Internet, as we know it today, was given its name in 1983. At that point, the network was shared between a military (with the suffix .mil) and a civil research network (with the suffix .edu).

A SANDBOX FOR EVERYONE

The research groups that Kjeller researchers joined met frequently. Between meetings, they did something that the world was not yet aware of. They sent one another emails. Discussions, network measurements, program codes and ideas were all sent back and forth.

New solutions were tested, tried, corrected, debugged, and tested again in record time. Often, such things occurred over the course of a day or two. All important information was documented in RFCs (Request for Comments). This was made available to everyone. In other words: Arpanet became a distributed laboratory for researchers and students.

In this sandbox, they generously shared everything they learned and received even more. Researchers at FFI played an important role in the development of packet switching in the network. They continued to develop the technology into the 1980s, through the SATNET project. Up until the end of the decade, the exchange of ideas continued between elite universities in the United States, UCL in London and FFI.

FFI CONTRIBUTED TO THE PROTOCOLS

The institute participated in the highly active network of nine different researcher groups. This commenced in 1972 and continued for ten years. This collaboration resulted in the protocols TCP/IP.

Thus, the standard for packet switched satellite channels, CPODA, was established. Over time, FFI's neighbour and offshoot, Televerket's forskningsinstitutt (Norwegian Telecommunications Administration's Research Institute), or TF, took over, encouraged by Pål Spilling. He wanted more extensive work on the Internet. But he was not heard. TF was embedded in the government telecommunications monopoly. The institute made the same priorities as most government telecommunications monopolies.

ANARCHISTS WERE BOUND

The same applied to other European telecommunications agencies. They took control in the 1980s. These were old and often cumbersome organisations. All research collaboration became more formally organised, more structured and slower. The X400 standard for communication of messages became essential. The network via this protocol was the foundation. It was also required in order to be granted research funding. Researchers almost secretly retained what they could, their @ address. This enabled them to maintain network contact with their American colleagues.

"More hierarchical, less anarchic – a duller and less dynamic working method", said Spilling. He compared this to the rivalry between Microsoft and UNIX. The latter continued the tradition where everyone has access to a source code and anyone who had something significant to contribute would be heard.

20-YEAR ICE AGE

This became a sort of ice age for Norwegian Internet involvement on the research front. It lasted until the Internet was commercialised in 1993. This was nearly 20 years after Pål Spilling established the first connection with the Arpanet.

It should be noted that Norway and Kjeller were not alone in this new connection for very long. Their lead, on this day in June 1973, lasted only 20 minutes. The University College of London (UCL) were then given the opportunity to connect, right behind Norway.

The idea behind the US defence network was about to become a public domain. Thus, the contributions of FFI researchers were an important step on the path toward the Internet. A network no one can imagine being without anymore. ■

Photo: Lars Aarønæs / FFI

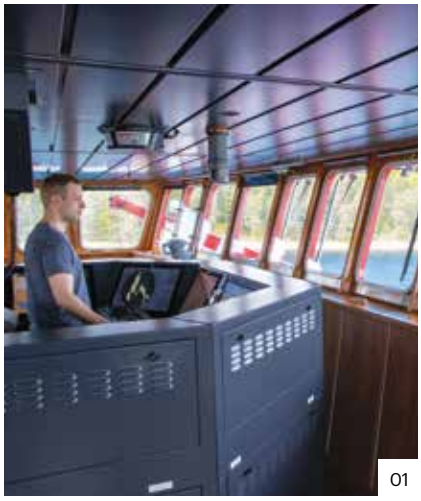
HOW SVERDRUP UNCOVERS THE DEEP SEA

How do different whales react to noise in the sea? How many shipwrecks are there along the Norwegian coastline and where are they located? What is the condition of chemical ammunitions dumped into the Skagerrak Strait?

H.U. SVERDRUP II

Launched: Flekkefjord in 1990
Length: 55 metres
Crew: 7

The ship is FFI's third research ship, after the Tustna (1946) and the H.U. Sverdrup I (1960).



01

02

Since 1990, the H.U. Sverdrup II has combed Norwegian waters, searching for answers to these questions. Mapping is carried out year-round. This is FFI's own vessel. The red and white ship is in principle a floating measuring device, 55 metres in length.

The equipment on board can provide many answers. What is down there? What does the seabed look like? How hard or rough is it? What type of sediment can be found? What type of power is required? Are there unknown shipwrecks down there?

EXTREME ECHO SOUNDING

Most refer to FFI's third research ship simply as Sverdrup. Sverdrup is equipped with a Norwegian-manufactured echo sounder that surpasses all others on the market. The EM 712 Multibeam echo sounder from Kongsberg Maritime enables mapping of the seabed down to 3400 metres, if the conditions are otherwise good. Each time the echo sounder 'pings', it captures an enormous amount of data from the seabed. Each of these measurements captures a field on the seabed. These surfaces are referred to as footprints. At a depth of 40 metres, the echo sounder registers an enormous row of these. Details the size of a newspaper page will be clearly visible.

HORTEN IS THE HOME PORT

It is not possible to simply go aboard. The gangway is blocked. In 2020, the year of the coronavirus, not even management were admitted until everything was thoroughly checked. Able Seaman Arne must measure Research Manager Torgeir Svolsbru's temperature.

INSPECTING THE SEABED

Svolsbru is in charge of the numerous expeditions with the Sverdrup. He has no doubts that the ship has an important mission for the Norwegian Armed Forces. The topography of the seabed has an impact on the use of sonar, which is the vessel's most important instrument for orientation in the depths of the ocean. Knowledge of the ocean depths and the landscape of the seabed can potentially be an advantage during submarine operations.

Among Norway's many research ships, Sverdrup is one of the smallest.

"We don't want the ship to be much bigger than this. We often operate out in the fjords. And we are often close to land. Larger vessels would be an impediment", says Svolsbru.

A SEPARATE COMMUNITY

There are seven crew members. One of them is Ann from Kristiansund. She is a catering assistant for the upcoming expedition. Right now, she is serving lunch. "They used to call people like us 'mess girls'. While at sea, we become our own little community. Although the composition of researchers varies from time to time, there are so many who return for new expeditions that I know the names of their spouses, kids and dogs", she says.

SVERDRUP UNIT

On the wall of the common room is a picture of the man the ship is named after. Renowned Norwegian oceanographer and meteorologist Harald Ulrik Sverdrup (1888–1957) led the scientific studies during Roald Amundsen's expedition on the Maud from 1917 to 1924. He became the first director of the Norwegian Polar Institute, founded in 1948. He is considered one of the leading researchers in the field of oceanography. His work was so widely recognised that he had his own unit of measurement named after him, which measured the ocean

03

04

01
The view is wide from the bridge of the Sverdrup.
Photo: Lars Aarønæs / FFI

02
Corona check is mandatory. Able seaman Arne measures Torgeir Svolsbru's temperature before he can get on board.
Photo: Lars Aarønæs / FFI

03
A lot of research is done by placing out buoys and measuring instruments.
Photo: Christian Tandberg / FFI

04
Ann from Kristiansund makes sure researchers and crew get what they need from the galley.
Photo: Lars Aarønæs / FFI

currents. A Sverdrup is one cubic kilometre per second.

A LAB IS VITAL

The ship's most important room is the Lab. Here, the windows have been replaced with light from computer screens. Information is often sent directly to clients on land. There are also clients other than the Norwegian Armed Forces. One good example is the Mareano Project. The Institute of Marine Research, the Geological Survey of Norway, and the Norwegian Mapping Authority are all involved, with the Norwegian Environment Agency as the highest authority. The purpose of the Mareano Project is to map the ocean depths and assess seabed conditions, biodiversity, natural habitats and the chemistry of the sediment in Norwegian coastal and marine areas.

On the Sverdrup, researchers are able to study everything from hagfish to old shipwrecks and dumped mustard gas.

Researchers are permitted to load the deck with containers that contain special devices for measurement and, for instance, Hugin, the FFI-developed autonomous underwater vehicle that has become an essential export product for Kongsberg.

Sverdrup has been used as a mother ship for Hugin, when examining the environment around old drilling holes. The vessel has been equipped with methane detectors, to check where methane gas bubbles up from the seabed. Hugin's side-scan sonar provides an image of an object on the seabed, with a one-centimetre resolution. This has been used in the Skagerrak Strait to study many of the shipwrecks with dumped ammunition. The Norwegian Armed Forces use Hugin for minesweeping.

HOW DOES THE WHALE REACT?

The Sverdrup has also been a tool for researchers who have studied the reactions of different types of whales to military sonar. Researchers have utilised the Sverdrup's rapid light craft and equipment that allow them to attach sonars to whales who come up for air. These sensors are approximately the size of a mobile phone. They are attached to whales with a suction cup and remain in place for about 24 hours. During this period, researchers are able to collect data on the whale's movements, before the sensor floats up and is collected by the ship.

THE ORDER BOOK IS FULL

Torgeir Svolsbru has determined that FFI's order book for research vessels is now full. "We have up to 320 expeditions per year", he explains.

"As we have a large variety of assignments, very few people grow tired of participating, which is also the case for the researchers who are frequently aboard. We can all agree on the biggest frustration: Sitting in thick fog that often surrounds the waters around Svalbard". ■

FROM INDUSTRIAL MECHANICS TO CIVIL PROTECTION

My entry point to research has been a bit unusual. Ever since I was little, I have been fascinated by technical gadgets. This was not that unusual for a coutry boy from Tysnes. I was also very interested in space and space travel. For a long time, I considered becoming a watchmaker, until I realised that this would be a very narrow future. However, since I really enjoyed fidgeting with things, I started my career in the field of industrial mechanics. I obtained my trade certificate at a refinery in Mongstad, north of Bergen. This led to an interest in becoming an engineer. Along the way, I found university studies so enjoyable that I kept going, this time at Blindern, University of Oslo. I usually say that I went from industrial mechanics to quantum mechanics.

My PhD was in physical chemistry and concerned the decomposition of greenhouse gases in the atmosphere. After my PhD, I started worked for Sintef Energy in Trondheim for two years. I also did a research fellowship at Sandia National Laboratories in California. After that, I was a post-doctoral fellow at Blindern for a period. The job I applied for at FFI in 2009 was in the Protection Division. I am still with this division but now it is called Total Defence. I have been working on i sues relating to chemical weapons for ten years.

One of the most exciting assignments I have been involved in was in the waters outside Syria from 2013 to 2014. The Norwegian Navy asked FFI to join them in retrieving compounds for chemical weapons. This operation was called RECSYR. It involved about a thousand tonnes of chemicals. These were part of the chemical warfare agents of President Bashar al-Assad. The containers were to be transported out of the port city of Latakia, and the contents were to be destroyed. I was aboard the cargo ship MV Taiko for three months as an advisor, hired for this particular assignment. To protect us against attacks, we were escorted by the frigate KNM Helge Ingstad. But the operation went well.

I was also the Research Manager of the Total Defence Division for four years. Until 2016, I led a research programme regarding protection against chemical weapons. Then, I decided I wanted to return to research.

Now, I am working on civil protection in an entirely different field. We are looking at future challenges for agencies under the Ministry of Justice and Public Security. This is part of the long-term plans for the police, Norwegian Police Security Service (PST) and the Norwegian prosecuting authorities. This work is an extension of an FFI report on civil protection. Along with the operation RECSYR, this is one of the most meaningful assignments I have had.

Some might say that I, as a chemist, have now become a criminologist. I have not. However, I have learned a great deal about threats to national security. The point is that you can continue to develop your expertise here at FFI. What is most important for a researcher to learn is to be inquisitive and have a methodical approach to a problem.

The Total Defence Division has various projects, which means we can follow Norwegian society closely over many years. Personally, I am now just as familiar with civil agencies as I am with the various branches of the Norwegian Armed Forces. Perhaps more.

FFI is in a good position to assess complex threats to society. We know what combinations make us vulnerable. By spring 2021, we will be publishing three reports for the judicial sector. These reports concern future challenges for the police, Norwegian Police Security Service (PST) and Norwegian prosecuting authorities. One of the reports is unclassified. Classified studies are important for the client, although these are unlikely to have a significant impact on public debate. Some aspects of research involving social development may be highly classified and therefore relatively unknown. For me and FFI, it is important to try to do both. It is always useful to have part of the research open to the public, as this allows for external critique. ■

It is always useful to keep part of the research open.

STIG RUNE SELLEVÅG
(45)

Principal Scientist

RESIDENCE
Jessheim

EMPLOYED SINCE
2009

FIELD OF EXPERTISE
Originally chemistry

DIVISION
Total Defence

Photo: Espen Wang-Naveen / FFI

NEW TRENDS MAY CHANGE EVERYTHING

The way we think about war and defence may change in just 20 years and be entirely different from today. Artificial intelligence, sensors and 3D printing will become more integrated and unified. These changes may force the Norwegian Armed Forces to change the way it thinks.

Researchers see many trends that could change the Norwegian Armed Forces itself. Technological convergence will become essential. Why? Because the sum of all solutions could become far greater than each individual innovation. In recent years, certain innovations have matured, such as autonomy technology, artificial intelligence, 3D printing, and new, advanced materials. The overall impact could be enormous.

DISTINCTIONS WILL BE BLURRED

These technological convergences are certain to open new areas of use, reduce the time it takes to achieve the desired effect and meet far more needs.

The government or authority that manages to see and utilise such opportunities before their enemies do, will have a strong advantage in a conflict or war. Utilising convergences is a recipe for success.

FFI expects this development to gradually erase the distinctions between different domains of warfare and branches of service. Researchers have a strong focus on trends that may affect the military operations of the Norwegian Armed Forces.

NEW CHALLENGES

NATO has defined several technologies under the umbrella of Emerging Disruptive Technologies – EDT. These EDTs will be followed closely by the alliance. Disruptive technologies displace existing solutions. In civil society, typical examples of actors that have based themselves on new technological opportunities include Amazon, Netflix and Norwegian mobile payment application Vipps. In this manner, they have displaced their competitors, and to a certain extent, they have created entirely new arenas.

In a military context, the following combinations are considered especially important:

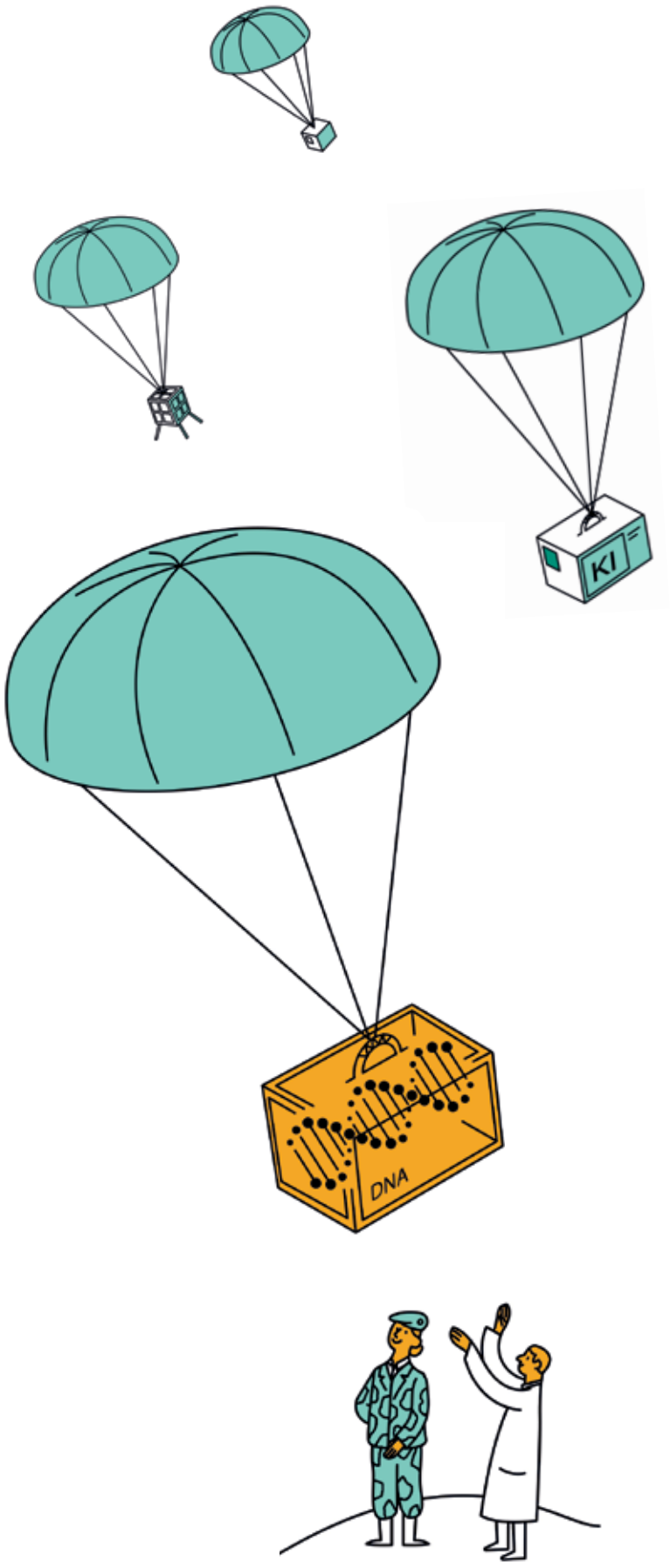
Autonomous technology. A combination of autonomy, big data and artificial intelligence. It uses smart, inexpensive and distributed sensors in its network, together with autonomous units. They will force new methods that offer military-strategic and operational advantages.

Biotechnology. Artificial intelligence combined with big data makes it possible to design new medicines and useful genetic modifications. It will also be possible to manipulate biochemical reactions in the body. Living sensors may then be created.

Material technology. It will be possible to design new materials with unique physical qualities. This would be especially important for the development and use of 2D materials. These are materials that consist of a single layer of atoms. Two-dimensional materials could be used in solar cells, among other things.

Quantum technology. Over the next twenty years, quantum technology will increase the opportunity to collect, process and use data from command, control, communications, computers, intelligence, surveillance and reconnaissance. This is known as C4ISR solutions. This will be possible, as quantum technology will provide more secure communication, improved computational power and increased sensor capacity.

Space technology. Space-based quantum sensors and communication with quantum key distribution will give us an entirely new group of sensors. These can be placed in satellites. Space-based low energy sensors will be utilised. These



will become part of a network activated by quantum sensors and can become an essential part of military intelligence, surveillance and reconnaissance.

Hypersonic technology. New materials, miniaturisation, more effective energy storage, new production methods and new propulsion systems will be essential for utilising opportunities in space and what NATO refers to as hypersonic environments. This development will reduce prices, increase reliability, improve performance and enable the production of tailored systems where necessary.

WHEN WILL THIS HAPPEN?

When will these changes occur? It is difficult to know when such technologies will change the way the Norwegian Armed Forces operates. Perhaps some new solutions will arrive earlier than expected, while others will encounter obstacles that delay their implementation for decades. Rival states and their defence industries prefer to play their cards close to their chests. The development of new weapons and systems and how far researchers have come, is rarely divulged openly.

TRENDS ARE EXAMINED

All these new trends involve technology. All are based on opportunities to alter warfare and the balance of power between states. Trend studies are therefore an essential part of the work at FFI. The goal is to analyse the broad consequences of technology for Norwegian military operations. This is necessary for planning the road ahead of the Norwegian Armed Forces. ■

HIGHLIGHTS FROM THE PAST 75 YEARS

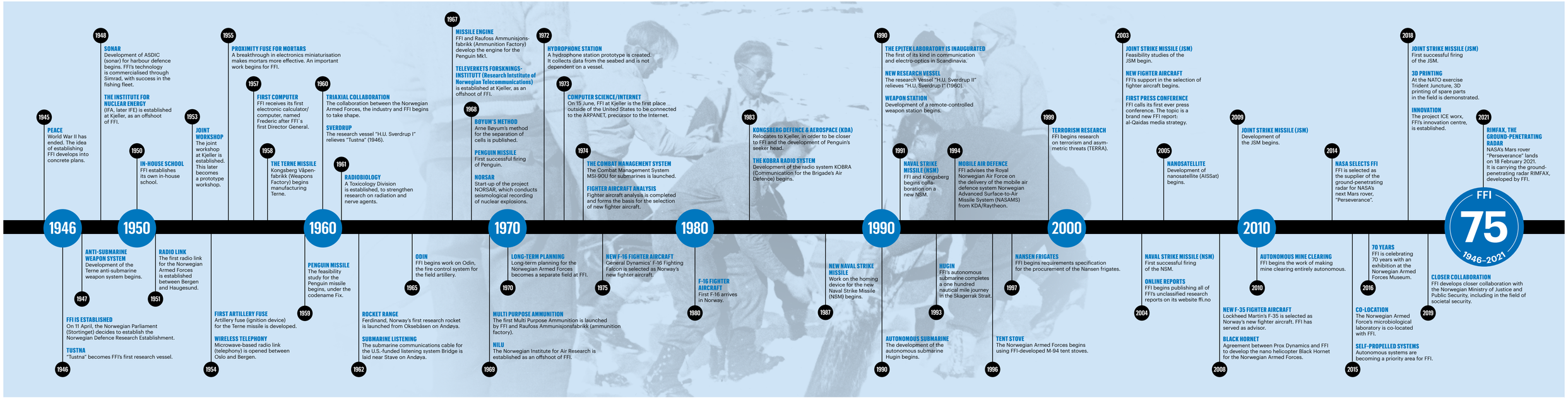
The history of FFI is full of events. Many have had an impact on the Norwegian Armed Forces, while some have also affected society in general. Here are a few of the most important milestones.

The common thread through the Norwegian Defence Research Establishment's 75-year history is innovation. Researchers have invented, improved and altered everything from equipment and devices that make soldiers' lives a little better, to self-driving underwater vehicles, advanced homing devices for missiles, micro-helicopters and satellites.

Many of the innovations from FFI have become successful for Norwegian industry. The first research on submarine defence in the late 1940s is a good example of a spin-off. ASDIC research led to echo sounding devices from Simrad, which changed the everyday lives for Norwegian fisheries. The anti-submarine weapon system Terne led to Penguin, Norway's major research and development project in the 1960s and 70s. The next step has been the NSM and JSM missiles.

FFI was involved in the establishment of Norsk Data and the Internet. Notable companies such as IFE, Nilu and Norsar are all offshoots of the institute. Researchers have assisted the Norwegian Armed Forces in the selection of aircraft, frigates and insight into future combat scenarios.

The list is extensive. Unfold and read about some of the highlights since the start-up in 1946.



1946 FFI IS BORN

On 11 April, the Norwegian Parliament (Stortinget) decides to establish FFI. Fredrik Møller becomes the first Director General in 1947. FFI starts out with 40 employees.

1954 WIRELESS TELEPHONY

Microwave-based radio link is opened between Oslo and Bergen. The radio link provided telephony based on relaytransmission, instead of traditional and expensive telephone lines.

1957 COMPUTER INITIATIVES

Research on missiles, in particular, requires computing power. Harald Keilhau sits at FFI's first electronic computer, Frederic; the fastest in Europe. Norsk Data and Kongsberg Våpenfabrikk's (Weapons Factory) computer division are among the fruits from FFI's computer initiatives.

1967 FFI PRODUCES OFFSHOOTS

Televerkets forskningsinstitutt (Research Institute of Norwegian Telecommunications) is established at Kjeller in 1967, Norwegian Seismic Array (NORSAR) in 1968 and the Norwegian Institute for Air Research (NILU) followed in 1969.

1978 BEFORE YR (NORWEGIAN WEATHER SERVICE)

FFI has its own, local weather radar long before services like Yr become commonplace. The radar is developed for the field artillery. Here, Georg W. Rosenberg is busy with its operation.

1957-83 RAPID DEVELOPMENT

Finn Lied's 26 years as Director General was a period of rapid development. The budget grows from under NOK 7 million to well over 50 million. The number of staff grows from around 300 to more than 600. Kjeller becomes a technological hub.

1985 AMBITIOUS RADIO

Hanne Hunges with the weapon terminal for the radio system KOBRA, which is to prevent eavesdropping and disruptions and is an important step toward the development of the industrial product Multi Role Radio (MRR).

1990 THE EPITEK LAB

The Epitek laboratory is inaugurated; the first of its kind in Scandinavia. Here, it is possible to "customise" semiconductors and develop new materialsand components in the fields of communication and electro-optics.

2008 AFGHANISTAN

FFI sends the first operations analyst to the Norwegian-led stabilisation force in Maymana, Afghanistan.

2015 A DRONE IN HAND

Those working with unmanned aerial vehicles, known as drones, research many models during the course of the 2000s.

2021 CORONAVIRUS RESEARCH

FFI's experiences with, among other things, biological agents is employed to trace the virus during the coronavirus pandemic. This work provides knowledge on the use of methods for future events.

7
FFI SUCCESS STORIES

The Norwegian Defence Research Establishment is behind thousands of innovations, big and small. Here are the top seven success stories selected by FFI's own employees.

Bøyum's method

NORWAY'S MOST CITED SCIENTIFIC WORK

Arne Bøyum worked on, among other things, the consequences of human exposure to radiation. In his doctoral thesis, he described a technique for isolating a special sub-group of white blood cells from the blood.

The World Health Organization (WHO) has made Bøyum's method the standard for how to isolate blood cells.

1968
PROJECT START

Arne Bøyum
Researcher and Research Director at FFI

BØYUM'S METHOD IS A STANDARD AT LABORATORIES WORLDWIDE

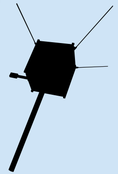
Arne Bøyum's article from 1968 was ranked number 67 in scientific journal Nature's list of the world 100 most cited research articles (2014). He was the only Norwegian on the list.

Nanosatellites

A NEARLY IMPOSSIBLE TASK

The success story of Norwegian nanosatellites began with a collaboration between FFI, the Norwegian Space Agency and Kongsberg Seatex AS.

An ordinary satellite often weighs over several hundred kilos and is priced in the billions of Norwegian kroner. FFI's nanosatellites perform their tasks so efficiently and at such low costs that they have received international attention.



2005
PROJECT START

6 kg
The cube-like nanosatellites measure only 20 centimetres

THE OBJECTIVE WAS TO CREATE SATELLITES THAT WERE ABLE TO MONITOR SHIPPING

FFI developed the first AISSat-1, which was launched in 2010. Since then, a series of small satellites have been developed and launched. NorSat-3 to be launched in 2021.

RIMFAX

EXPLORATION OF ANOTHER PLANET

RIMFAX is the ground-penetrating radar that will explore Mars. The radar will look under the surface of Mars and provide new insight into the geology of the Red Planet.

The ground-penetrating radar is developed and delivered on assignment from NASA. RIMFAX is one of seven scientific instruments placed on the NASA rover "Perseverance", which was sent to Mars in 2020 and which landed on 18 February 2021.

Developing technology that will be sent to another planet places considerable demands on the researchers, and for meticulous testing and documentation.

2014
PROJECT START

RIMFAX
Radar Imager for Mars' subsurface experiment

The Penguin missile

THE FLYING PENGUIN

The Penguin Project entailed new and in part, immature technologies in heat-sensitive detector materials, laser and inertial navigation. The continued development occurred in close collaboration with the industry and the Norwegian Armed Forces.

The new missiles NSM and JSM are the successors of Penguin. The development of missiles and rockets has been an uninterrupted FFI activity since its establishment in 1947, with the anti-submarine missile Terne as its first initiative.

1961
PROJECT START

PENGUIN WAS ONE OF THE WORLD'S FIRST HOMING MISSILES

Hugin, the mini AUV

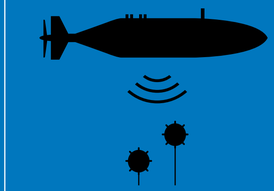
A RESEARCH AND INDUSTRIAL ADVENTURE

Hugin is an Autonomous Underwater Vehicle (AUV). It can operate autonomously at a depth of several thousand metres, without a physical connection to a boat or remote control from the surface.

In the 1990s, a collaboration began with Kongsberg Maritime and Statoil on the development of AUVs for seafloor mapping in the oil industry. The result was a prototype that was self-supplied with energy, navigated precisely and executed assignments automatically.

The international breakthrough occurred in 2000, when Hugin became the first of its kind to be sold on the international market. FFI's navigation system tipped the balance. In 2017, the Royal Norwegian Navy ordered four complete vehicles to commence the transition to autonomous systems for mine countermeasures

Hugin is continuously being developed and is among the most advanced underwater robots in the world. Kongsberg Maritime is currently the biggest on the market for such AUVs. FFI continues to conduct research on the improvement of sonar technology, autonomy, navigation and power supply.



ONE OF THE WORLD'S MOST ADVANCED UNDERWATER ROBOTS

1993
PROJECT START

AUV
Autonomous Underwater Vehicle

Computer technology

DEVELOPMENT OF THE INTERNET

1972
PROJECT START

DARPA
Defence Advanced Research Projects Agency

In the 1960s, it was merely a dream that computer equipment could communicate with each other. A network could be better utilised if messages were divided into packages, sent and reassembled at the recipient. This is referred to as "packet switching".

This was demonstrated for the first time between four computers in the United States, which was the beginning of the ARPANET. Behind it was ARPA – Defence Advanced Research Projects Agency.

FFI began its own development of computers in the 1960s. In 1972, FFI researcher Yngvar Lundh received an ARPANET demonstration in the United States. He commenced a project on computer network technology. As a result of this work, an ARPANET node was established at Kjeller in 1973. It was through this node that the first email message was sent; from the United States to London.

Terrorism research

A SMALL, BUT WORLD-CLASS, COMMUNITY

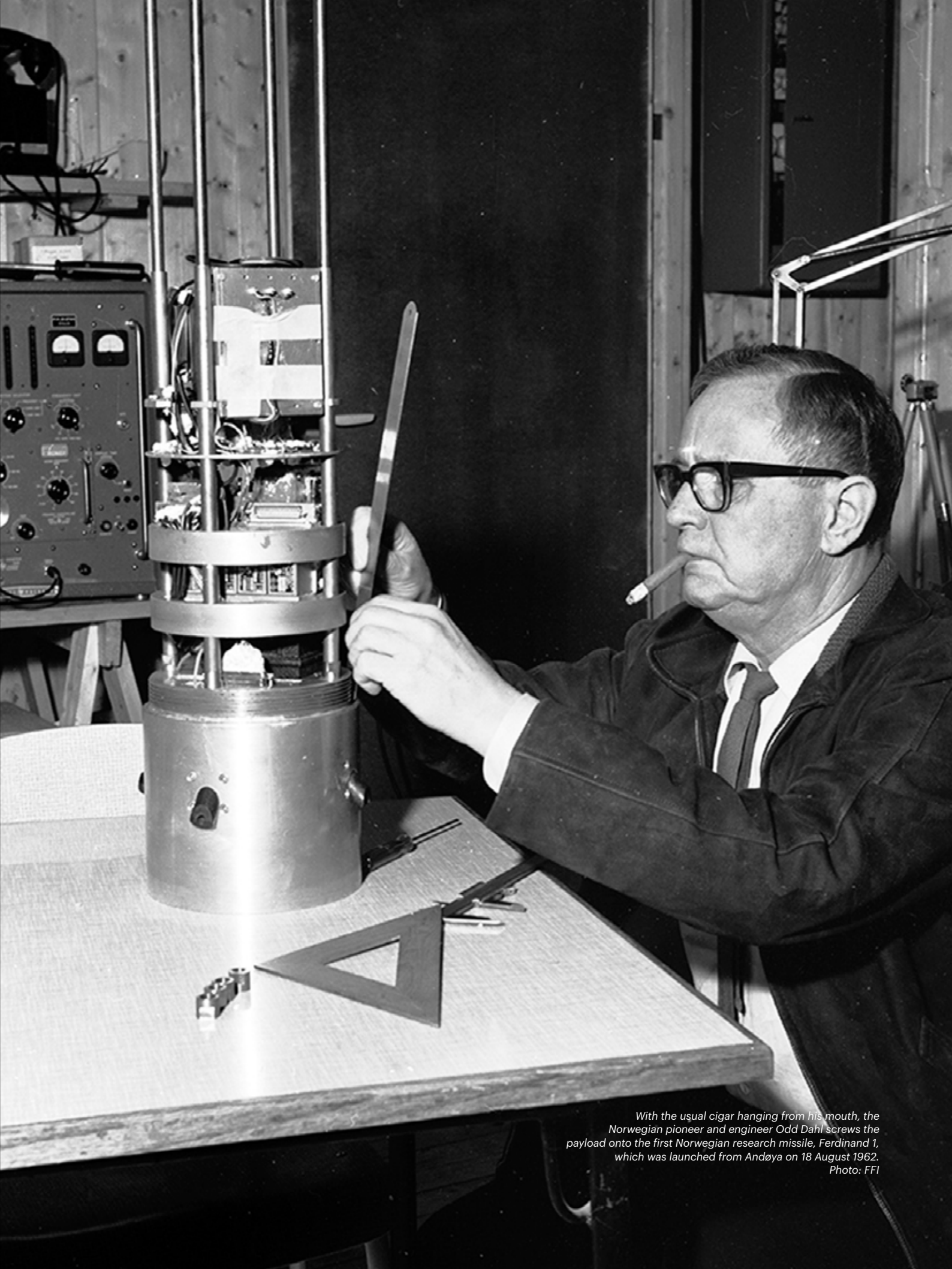
A foresighted leader at FFI, Ragnvald Solstrand, established a research project at FFI on asymmetric warfare. This took place in the late 1990s. In 2001, it developed into TERRA, which, in particular, studies international terrorism and militant Islamism.

This small community has developed world class terrorism research. They have continuously produced doctoral theses, books, articles and op-eds.

1999
PROJECT START

TERRA
A series of research projects

FFI RESEARCHERS ARE USED AS EXPERTS BY THE INTERNATIONAL MEDIA



With the usual cigar hanging from his mouth, the Norwegian pioneer and engineer Odd Dahl screws the payload onto the first Norwegian research missile, Ferdinand 1, which was launched from Andøya on 18 August 1962.
Photo: FFI

BURNING JELLY

Spermal was Norwegian napalm

A biproduct of the whaling industry piqued the interest of researchers.

We know napalm as a horrific weapon from the Vietnam War. This has become ingrained in our culture, due to the image of the naked children running from the Vietnamese village in 1972. In the film Apocalypse Now (1979), Lieutenant Colonel Kilgore states the most chilling line in the film: "I love the smell of napalm in the morning".

Napalm is a flammable gelling agent. Firebombs containing napalm were first used during the invasion of Normandy and later by the United States during the Korean War and in Vietnam. Many countries still employ such weapons, despite the controversy regarding their use.

FFI developed a Norwegian variant of napalm, called 'spermal'. This is how the story goes: In Norway, military materiel were often exposed cold temperatures. In the early 1950s, researchers were asked to develop a thickening agent for gasoline that could withstand cold temperatures. Napalm is just that – thick, gelled gasoline.

American napalm was based on coconut oil – thus the wordplay on 'palm'. However, napalm stiffened and became insoluble in gasoline when temperatures dropped below 15°C. Therefore, the material would largely be unusable in the Norwegian climate.

WHALE OIL WITHSTOOD THE COLD

At this point in time, whaling was a major industry. Chemists at FFI discovered that they could use one of the raw materials from whale oil – spermaceti. This acidic substance was superior to napalm. It could be dissolved in gasoline in temperatures down to 0°C. It could also be stored for up to one and a half year, while napalm deteriorated after just six months. This new, acid-based gasoline thickening agent was given the name 'spermal'.

After many trials of flamethrowers and aerial bombs, FFI built a factory for experiments. There, 100 tonnes of spermal was subsequently produced. The ambition was to export the product, then under the name 'Northick'.

Norwegian napalm was used during exercises, to simulate nuclear explosions and for the Penguin trials. Spermal provided the heat source for missiles to locate and steer toward. Despite a great deal of marketing directed at Norway's allies, there was no interest in the product. The entire inventory of what had become 'Northick II' was left to the Norwegian Civil Defence in 1960.

DORMITORY ON FIRE

One incident in FFI's history showed that experimentation with spermal could go very wrong. The first shot during a flamethrower experiment at Kjeller in 1954 went awry. The material set fire to the gable of FFI's own dormitory. The next shot went through the trees next to it. It hit the wall of the aircraft factory's materials building, which was under construction. ■

Here we see a successful test of a flamethrower. This time the dormitory was spared.
Photo: FFI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10011 11010
00111 10011

WHERE IS FFI HEADING?

What tasks are awaiting FFI in the coming decades? Where should researchers be looking?

Unfortunately, there is no crystal ball to show the most crucial tasks for the Norwegian Armed Forces. There are far too many challenges. Nevertheless, there are a few notable developments. We have taken a closer look at four areas of significance for FFI in the years to come.

Long-term planning. Future threats are not only technological in nature. They may also deal with the Norwegian Armed Forces' capacity to maintain a balance between means and ends. Therefore, FFI has focused on long-term planning based on solid knowledge and a good foundation for decision making: What solutions can actually be realised in the years to come?

Cyber domain. Many states are now investing heavily in the field of offensive and defensive cyber operations. There is no doubt that this is a top global priority. Activity in this area has already become substantial. FFI researchers are carefully studying what states' data breaches entail and how they can be addressed.

Innovation. How quickly would industry and defence forces be able to develop new innovations? The new ICE worx can become an important part of the answer.

Sensors. Theoretically, the Norwegian Armed Forces can have eyes and ears everywhere. This frenetic development of all types of sensors may also be highly challenging for the people who will be monitoring them all. There could be too much data. Researchers are working on systems and solutions to make this job easier, with more efficient surveillance. The biggest tasks ahead for researchers are in the field of artificial intelligence.

Turn the page and learn more. ➔

LONG-TERM PLANNING IS A WEAPON

One research area with an extensive past at FFI is also an area that has a very promising future. The purpose of supporting the defence sector's long-term planning is to find solutions that can actually be realised and that are flexible and cost effective.

Such planning requires the ability to envision various scenarios. Operations analysts, economists, experts in security policy and officers all sit down together. They then typically discuss the possible effects of a conflict or war on various aspects of the Norwegian Armed Forces. What are the weaknesses? What must be rectified?

Analysts at FFI are in close and frequent contact with leaders in the Norwegian Armed Forces, including both politicians and military professionals. In 2021, this community will continue to work together, including on a project that will assist the Norwegian Armed Forces in its strategic development. While this type of research is common for the defence sector, it is almost absent elsewhere in the government apparatus. Nor is the police and justice system accustomed to long-term planning as a regular discipline. This situation may change in the years to come. The idea of a total defence system, with different types of preparedness for crisis management in society will require more long-term perspectives. At the beginning of 2020, FFI began a limited collaboration with the judicial sector. There may be more in the future.

One set of circumstances for long-term planning are described in an FFI report from 2020: "Societal security towards 2030 - trendst". In this report, 13 FFI researchers discussed the following major questions: How will the world and Norway continue to develop towards 2030? How might this development impact societal security?

The researchers' point is that critical societal functions are becoming increasingly complex and mutually dependent. New perspectives and a holistic approach will therefore be necessary in the areas of regional planning and security.

The report was commissioned by the Ministry of Justice and Public Security. The researchers have reviewed a number of key development features that may have implications for societal security including security policies, social and economic conditions, climate and technological developments. In the report, FFI has also looked at potential positive features: What are the opportunities and challenges of certain technological megatrends for societal security.

Digital cloud services, the Internet of Things (IoT), artificial intelligence (KI), 5G and robotisation are all important technological areas. They all contribute to the digital transformation of society. FFI expects new technology to have implications for police work. Such technologies may also result in increased value creation for businesses and improved public services.

It may take some time before long-term planning becomes a regular part of the budget in sectors other than the Norwegian Armed Forces. This means that researchers will continue to rely on support from individual projects. Nevertheless, FFI sees that the tools and methods used by the planning community can be implemented in other areas. In the coming decades, long-term planning may become one of Norway's most important weapons. ■

THE DIRECTOR OF RESEARCH WHO THOUGHT AHEAD

Former Director of Research Ragnvald H. Solstrand was the 'father' of long-term planning at FFI. In his summarised report from 2010, he wrote: "A planning system can best be judged based on the contributions it makes to good decision making". For him, it was just as important to simulate budgets as defence combat. The threat of an imbalance between means and ends in the Norwegian Armed Forces was always present.

Long-term planning has been a separate discipline at the institute since the 1970s. The need arose when the Norwegian Armed Forces faced planning and management problems once the United States stopped providing financing for weapons systems. The Norwegian Armed Forces had to learn to be self-sufficient. This led to a community that had the capacity to sit down and explore problems that were perhaps not topical for the Norwegian Armed Forces, but that could become important for emergency preparedness and the economy over time.

HIGH STAKES IN CYBERSPACE

Put simply, cyberspace is the 'space' created by the world's information and communication technology (ICT). Much of this space is accessible to everyone, simply by going online. There, we visit computers that offer us services for online banking and shopping and of course entertainment. They may be located thousands of kilometres away, but ICT can bring you there at a phenomenal speed. We are surrounded by cyberspace. Much of what takes place on computers is interlinked.

Cyber operations involve states' data breaches, or the handling of imminent or detected data breaches. This is typically carried out by intelligence and security services, or by military forces. NATO distinguishes between offensive and defensive cyber operations.

Offensive cyber operations are conducted primarily to obtain information considered to be of value for international politics or military operations. One well-known example is the data breach of the Norwegian Parliament's email systems. In autumn 2020, the Ministry of Foreign Affairs stated publicly that Russia was likely behind this breach.

Offensive cyber operations may also be conducted for financial gain. These cyber-attacks may be carried out to alter or destroy data and to sabotage physical processes run by computers. The sabotage of the Ukrainian power grid and the Iranian uranium enrichment site are known examples. Offensive cyber operations occur all over the world. They are also carried out in a very large scope.

Defensive cyber operations entails defence against cyber-attacks. This may resemble the handling of data breaches by civil undertakings. It involves the safeguarding and protection of political and military targets. Sabotage may make it more difficult for the Norwegian Armed Forces to do its job, perhaps at the most crucial time. If the Armed Forces are subjected to cyber-attacks during an armed conflict, it may necessitate changes in ICT and the way the Armed Forces engages in combat. Defensive cyber operations therefore require an understanding of the relationship between the technology and military operations. Combat could then continue despite the enemy's attempt to harm us through cyberspace.

In the years ahead, it will be important for the Norwegian Armed Forces to recruit and develop at the same pace. Research must contribute with technology and ideas on how cyber operations will fit with the Norwegian Armed Forces' other use of force. Research must also contribute by enabling long-term planning for cyber capabilities, in the same manner as new tanks or vessels. Among other things, FFI researchers have studied how security incidents in civil networks have been managed. This occurred in connection with a case where unauthorised persons hacked into the networks of the South-Easter Norway Regional Health Authority and County Governor offices.

Cyberspace is also used in influence campaigns. FFI has initiated a project called Cyber-Social Propaganda and Influence. This is occurring in collaboration with the Ministry of Defence and the Ministry of Justice and Public Security. ■

ICE WORX SOLVES PROBLEMS FASTER

The Norwegian Armed Forces need equipment that addresses new operational needs. Much of this equipment can be developed with the use of existing civil technology. This is the starting point for ICE worx.

Ice worx is FFI's innovation centre for the defence sector. 'ICE' is an acronym for the Centre for Innovation, Concept development and Experimentation. The centre is based on the Norwegian triaxial model, where the Norwegian Armed Forces, the industry and FFI all collaborate closely.

ICE worx is a meeting place. Those who have needs can meet those who have possible solutions. Personnel at the centre manage innovation projects with several participants: FFI researchers and engineers from the industry work together with soldiers from the Norwegian Armed Forces. Together, they can build systems that are functional in demanding Norwegian conditions.

Norway is NATO in the North. Military operations in the northern regions have special requirements for equipment and personnel. Suitable solutions are not always available on the open market. Norway must therefore develop some of this materiel on its own. The ICE worx acronym reflects the arctic region. The centre's ambition is to improve Norway's ability to develop technology near its users. This involves technology that is adapted to demanding climate and topographic conditions.

That path from needs to solutions that offer a better operational effect will be shortened. This will take place through the rapid development of prototypes, experimentation together with end users and recurring development processes. One important principle for ICE worx is that the goal for a new invention or technology is never attained until the solution is actually implemented and benefitting users in the Norwegian Armed Forces.

The key to good results is to work closely with the military. Testing and seeing the new solutions utilised in a familiar environment is an advantage, preferably under demanding conditions, such as those of a combat environment. The shorter the development time, the better. A high level of trust is essential, with few formal barriers between the participants of the triangular collaboration. Experimentation is necessary in order for projects to proceed quickly. Such experiments may occur with existing technical solutions, or solutions that are nearly ready. These will then be adapted for use in military operations. This is why ICE worx uses several systems, both those created by FFI, and systems and technology offered by Norwegian industrial companies.

One of the goals is to test frequently and a lot. ICE worx has therefore established arenas for innovation near military sites. In these arenas, all preparations have been made. Everything will be in place for researchers and engineers. This means that ICE worx makes it easier for users to participate in innovation and development. ■

HOW TO FILTER IMPRESSIONS?

How can soldiers and officers gain the best possible overview of what is happening?

Imagine if you had eyes and ears everywhere, in every town and village across the country. You would have access to an incredible amount of information. In fact, you would have so much information, it would be impossible to keep track of it all.

In Norway, the Armed Forces has a formidable task of monitoring and tracking everything happening at sea and throughout our vast country. In order to manage this task, we need technological solutions to enable personnel to manage vast areas through remote-controlled sensors. Just as the Norwegian Public Roads Administration uses cameras to monitor our roads, the Norwegian Armed Forces uses its systems to monitor the sea and land. There is no point in having thousands of cameras if we need thousands of people doing the monitoring to form a comprehensive picture. This would become far too expensive. Cameras and sensors must instead be connected in networks. They have to be 'smart', so that they alert us to anything out of the ordinary.

In this way, just a few soldiers can efficiently operate many sensors. FFI collaborates with several industry companies with the aim of creating good solutions for these interactions. In order to protect the nation, the Norwegian Armed Forces must also work together with other agencies that contribute to societal security. This may mean, for instance, that the police, Norwegian Customs and the Norwegian Coastal Administration work together with the Norwegian Armed Forces and that they share their sensors and incidents with one another. ■

THE PROBLEM WITH DRONES

During a demonstration at the Rena base in 2020, FFI researchers demonstrated how an operation with many types of sensors may look in practice. Data from different cameras, radars, microphones and other sensors were linked together, with the aim of providing personnel with a good understanding of the situation.

This exercise allowed researchers to show how several drones and unmanned vehicles could be used as advanced sensors for a combat vehicle. In the control room, operators had a 3D map of the landscape. On the screen, the forest and moors fused together as though it was a colourful computer game. This was not accidental. The game Starcraft was the inspiration for FFI researcher Aleksander Simonsen, when programming the user interface.

During this demonstration, a smaller swarm of drones was used to carry thermal cameras. This type of equipment can detect heat waves from vehicles and people. The cameras do not rely on good lighting. In theory, drones can also be equipped with sensors that detect radio signals, radar waves and other electromagnetic signals from things that happen on the ground.

The problem that researchers must solve is to get such sensors to cooperate and 'talk' with each other. In this way, they can gain a better understanding of the situation, based on the information from all single sensors. The goal is to block out noise for operators, while also gaining useful information.

This field of research is called sensor fusion. It is one of the major unsolved problems in the field of artificial intelligence. Sensor fusion is what Tesla and others struggle with in their self-driving cars. The key word is speed. It involves finding a way to present sensor information, such that the system or operators are quickly able to understand what is happening – and then react appropriately to the potential threat. This entails finding a way to present sensor information in a manner that enables the system or operators to quickly understand what is happening – and then to react appropriately to a potential threat.

The Mars rover Perseverance was assembled at NASA's Jet Propulsion Laboratory in California. At the top of the photo is the rocket module that transported the rover across the last stretch down to the surface of Mars.
Photo: NASA / JPL-Caltech

SPACE SCOUTS

The secrets of space will soon be fewer. FFI instruments are already circling Saturn. In 2021, the ground-penetrating radar RIMFAX is investigating the subsurface of Mars. An equally important task is to detect ships hiding in Norwegian waters.

How is it possible to monitor shipping – including vessels that do not want to be monitored? NorSat-3 will be launched in the spring of 2021. This small satellite is equipped with a radar detector. FFI has developed a technology that in principle makes it possible to see and follow all ships with their radar switched on. No one will be able to sail unseen when manoeuvring through the two million square kilometre area of Norwegian territorial waters.

NorSat-3 won't win any beauty contests. However, it's what is inside that matters. This satellite is yet another advanced surveillance instrument from a research community that specialises in these.

Norway's first microsatellite was the AIS-Sat-1. It was launched in 2010, with an Automatic Identification System receiver (AIS) on board. The receiver detects anti-collision signals from ships. The aim is to improve safety at sea. In this case, larger ships exchange data regarding position, course and speed. However, not all vessels are willing to share their movements. Technical issues and deliberate deception may both be involved: AIS transmitters can be turned off. Fortunately, other signals from ships can provide a more complete picture, for instance, the ship's own radar, which the NorSat-3 can track.

POLAR ORBIT

The overview of shipping in Norwegian waters, around Svalbard and the rest of the Arctic, including the Northeast Passage, is better than it has ever been.

Norwegian microsatellite orbits are unique. They do not circle at the equator, but rather around the North Pole. These pass near the North Pole 15 times a day, at a height of 600 kilometres. Once they are within range of Vardø or Svalbard, new data is downloaded to these stations. In the 1990s, FFI showed how ships and oil spills could be detected from space. The institute was a driving force for the utilisation of this technology. It was not too difficult to argue in favour of this: One of the first satellite images showed more than 40 foreign trawlers fishing in the 'Loophole' in the Barents Sea, close to the borders of Norwegian zones. Even with a hundred coastguard vessels, these would not have had the same monitoring capacity as this little device in space, hundreds of kilometres above fishing poachers and government actors.

These positive experiences with AIS-Sat-1 led to the construction of its twin, the AISSat-2. It was launched on 8 July 2014. A third satellite, the AISSat-3 was lost during a failed launch from Russia in November 2017.

When a satellite is sent up into orbit and is hopefully useful for many years, it is essential that it carries several tools: NorSat-1 has a Swiss solar instrument and Norwegian Langmuir probes for studying the Northern Lights. NorSat-2 is testing VDES – a new international standard for testing two-way communication at sea. Both were launched in the summer of 2017.

FERDINAND INITIATED NORWEGIAN SPACE AGE

The Norwegian space age began long before. On 18 August 1962, the civil research rocket Ferdinand 1 was launched from Andenes on Andøya. The launch took place from the newly established rocket range at Oksebåsen (Bull Base), hence

Is there life on Mars? sings David Bowie. RIMFAX may help answer that question.

the name of the rocket. The work on the rocket range began in 1960, just three years after the Soviet Union launched Sputnik. FFI and the Royal Norwegian Council for Scientific and Industrial Research took the initiative jointly.

Andøya still has the northernmost permanent rocket range in the world, on the 69th parallel north. There were many good reasons for choosing this site: The island is located in a zone with the most frequent appearance of Northern Lights. The sea around the island never freezes and provides an enormous catchment area for the rockets. Researchers can therefore choose many different rocket trajectories. It is also easy for both Norwegian and international research communities to access the site.

FROM ANDØYA TO SATURN

Ferdinand was part of FFI's ionosphere research, a field that FFI began studying as early as 1946. The ionosphere is the part of the atmosphere that has electrically charged particles, from 80 kilometres above the planet's surface.

Over time, the 'ionosphere' group changed its name to the more descriptive 'space physics' group. Researchers here were involved in a large share of the well over 100 research rockets that were launched from Oksebåsen. FFI was behind the very first lidar instrument on a rocket. Lidar is an optic, remote sensing method based on lasers.

Gradually, researchers have moved further out into space. FFI researchers were involved in the major Cassini/Huygens Mission. This brought the institute's work all the way to Saturn.

The dates alone describe the adventure of the Saturn journey. The launch took place in October 1997. In 2004, the probe arrived at the solar system's sixth and second largest planet. There, it began orbiting the planet, after passing close to Venus, Earth and Jupiter, to increase its speed toward its target. The satellite sends data on the complex magnetosphere around Saturn and its many moons, of which 82 have so far been discovered.

The Huygens probe had a spectacular landing on the moon of Titan, with a video recorded on its descent. Although the FFI group did not have instruments on the Huygens, they were involved in the planning of the probe. This included planning of the instruments on board that would study the waves and turbulence in the atmosphere around Titan. An electron spectrometer, developed in part by FFI, went along on the journey. This was built on another instrument that was developed into the ESA Cluster mission: Four satellites in coordinated orbits that studied the interactions between the solar wind and the Earth's magnetosphere. This included a device that allowed researchers to experiment with unwanted electrical charges of the spacecraft. This improved measurements by the electron spectrometer and other plasma instruments.

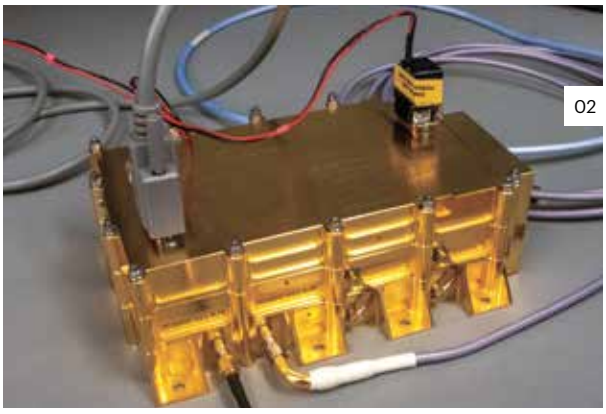
BOWIE SINGS, RIMFAX SEARCHES

FFI's list of space projects and partners grows longer each year. At the top of the list during the 2021 anniversary year is the ground-penetrating radar, RIMFAX. The name stands for Radar Imager for Mars' Subsurface Experiment. It is also a word play on Norse mythology: Rimfakse is the horse that the night rides across the sky. Morning dew is what drips from Rimfakse's bit. The name can be translated as "frost from the muzzle".

01

01
The FFI-developed radar detector for NorSat-3 will provide an even better overview of the shipping in Norwegian waters – including traffic that does not want to be detected.
Photo: Norsk Romsenter / UTIAS / AdobeStock

02
The ground penetrating radar RIMFAX is comprised of an antenna and a gold-plated box. The box contains the technology that enables it to 'see' what is hiding beneath the surface of Mars. Photo: Lars Aarønæs / FFI



02

"The bestselling show: Is there life on Mars?" sings David Bowie. RIMFAX may help answer that question. The antenna and the anonymous, gold-plated box is one of seven instruments mounted on NASA's Mars rover, Perseverance. The rover landed in February 2021, after a journey that began in summer 2020. As soon as the instruments were ready, RIMFAX began sending data – not from Earth, but from Mars. Earlier studies of the planet have identified minerals that can only be formed in water. An important goal is to find sedimentary layers that might have supported past life. RIMFAX enables researchers to get an idea of the basic conditions of the ground under the rover. This will provide important information on areas of interest for further study.

RIMFAX is a Ground Penetrating Radar (GPR). It takes pictures of Mars geology several metres below the surface. This is done by sending electromagnetic radio waves. The radar then reads the reflected signals. GPR is often used on our own planet in order to study layers of soil and ice and to locate groundwater.

FFI developed ground-penetrating radars of this type to enable the Norwegian Armed Forces to 'see' through walls and beneath the ground. Areas of use include the detection of buried mines. The same type of technology is used in archaeology, and to study avalanches. FFI has also studied the use of this type of ultra-broadband radars for medical purposes, for instance, in providing images of the heart.

BROAD COLLABORATION, NEW QUESTIONS

RIMFAX is typical of FFI's work on space research, as it is a broad-reaching project: FFI has collaborated with the Norwegian Space Agency, Kongsberg Norspace AS, Bitvis AS and Comrod AS on the construction of this instrument.

FFI has made many visits to space since 1962. The institute has many more invitations. This results in fewer secrets, while research also leads to new and bigger questions. ■

THE EARTH'S SENTRIES

The word 'satellite' comes from the Latin word 'satelles', meaning 'attendant'. Satellites come in many sizes. The largest has a mass of more than one tonne. It is common to categorise them by weight. The category 'small satellite' has a mass of less than 500 kilos. Minisatellites have a mass less than 250 kilos, microsatellites are less than 50 kilos, and nanosatellite are less than 10 kilos. The Soviet Sputnik was the first satellite. Among the 9000 satellites that have since been launched, around 2000 are still in operation. The remaining satellites have either fallen back to Earth or they are in orbit around the Earth as space debris.

Photo: Espen Wang-Naveen / FFI

THE VIRUS HUNT

How do viruses spread? Researchers Kari Bøifot and Jostein Gohli collect and measure air particles at Oslo Airport, Gardermoen. This biological material is brought back to the lab for analysis.

01

01
Filter particles from air are collected and placed in test tubes.

02
Surface samples are registered with metadata such as the date, time, temperature, air moisture, the object from which the sample was taken and surface material.

03
Researchers have cleared customs in the arrival hall and will now be heading to the security area at Oslo Airport.

Photo: Espen Wang-Naveen / FFI

Is there corona here? Jostein Gohli is one of FFI's specialists in environmental monitoring. The senior researcher became the head of the NorCov2 project in 2020, after the outbreak of the COVID-19 pandemic.

In their research on COVID-19, he and his colleagues have collected samples from the Metro station and Metro cars and from Oslo Airport, Gardermoen. The researchers have also collected samples from various types of surfaces. They have also collected many samples from hospitals, including patient rooms. The goal has been to examine environmental exposure for healthcare workers. Results of the project will be published in scientific journals and communicated to participants.

"Our follow-up work will show how effective our monitoring has been in Metro stations and airport environments. We will be obtaining information from hospitals on the amount of virus particles in the air, as a function of the distance to the patient. We will also be looking at certain treatment methods at hospitals and how these affect the amount of viral particles in the air", says Gohli.

Researchers use a particle counter that measures aerosol concentration, or the number of particles of different sizes in the air. They also use an air sampler. Air particles are collected and brought back to the laboratory for study. At the outpatient test clinic for COVID-19 at Ullevål Hospital, air samples are collected in distances of one metre, two metres and aerosol distance from patients diagnosed with COVID-19. Aerosol distance is so far away from the patient that droplet transmission is not possible. The study involves potential virus particles that hover in the air over a longer period.

"Aerosol transmission of SARS-CoV-2 is a highly debated topic that we wish to highlight. The work in the outpatient test clinic can provide important answers in this debate", says the FFI researcher.

This research will also be useful in a potential war situation, where a virus or biological weapons may conceivably be disseminated during the conflict or as an act of terrorism.

Gohli concludes:

"It is important for us to harness this opportunity. Not only to contribute to the knowledge base around SARS-CoV-2 but also to understand the limitations and benefits of technologies used for monitoring biological threats in general". ■

02

03

NEW VIRUSES AHEAD

The coronavirus pandemic that arose in 2020 will not be the last of its sort. Research performed on COVID-19 is also important to learn how to deal with future outbreaks of infectious diseases.

All experts agree that there will be new viral pandemics. The only question is when. An important part of FFI's research project is to develop testing methods for detecting viruses in environments where people congregate, in order to prepare for future pandemics and outbreaks.

PHOTO WALK

MOMENTS OF HISTORY

At the beginning, the research institute consisted of only a few dozen researchers, distributed across many different sites. Already then, some people were keen on photographing the activities at FFI. Join us on this photo walk!

Photo: FFI

1947

The researchers move in

FFI was established by Parliamentary resolution on 11 April 1946. A year later, researchers and engineers moved into the buildings abandoned by the Germans, on what were farmlands at Kjeller. Luftwaffe had their combat medical training here. The building in the photo still houses many FFI researchers, and the field behind it is still being ploughed today.

Photo: FFI

1952

FF

At first, the institute was only known as FF, as depicted here on the gate post. Today, the abbreviation is FFI. The colocation at Kjeller in Lillestrøm was initiated when the institute, in 1947, took over two buildings that had been used by the Kjeller Aircraft Factory as a storage area after the war had ended. The Physics Division was the first to move in. From 1949, the main portion of FFI's research was gathered at Kjeller, although its secretariat remained in Oslo.

Photo: FFI

1954

Hello?

Haakon Sørbye is testing FFI's microwave links between several Norwegian cities. Building good telecommunications was a priority. Industrial production and export followed in the aftermath. On the right is Director of Research Sture Koch. The man to the left is unknown.

Photo: FFI

1954

Gardening

Personnel, wearing white lab coats, find time for a little gardening on FFI's arable land. In the mid-1950s, FFI's budgets were relatively small, although the number of employees had increased to nearly 300 by 1955. In 1962, there were 400 employees and by 1968, the number had surpassed 500.

Photo: FFI

1958

Digital Frederic

Harald Keilhau in front of FFI's first digital computer, with 2000 vacuum tubes and 20kW heat loss. Ferranti Rapid Electronic Defence Research Institute Computer (Frederic) represented a breakthrough in researchers' ability to solve complex mathematical problems. They had previously used electromechanical machines. Frederic was Europe's most advanced computer. It was smuggled in as diplomatic mail to avoid additional fees.

Photo: Bjørn Braaten / FFI

1962

Hipp, hipp!

Egil Eriksen 'test rides' a Nike Cajun rocket. The rocket was then given an instrument section at the front and became Norway's first research rocket, Ferdinand 1. It was launched from Oksebåsen rocket range on Andøya, that FFI had worked to establish.

Photo: Oddvar Smith / FFI

1963

Photographs from the new premises

FFI has always focused on ensuring visual documentation of its research, including high-speed recordings of rocket launches and gallery photos of technical devices. These photographs were placed in a new photo laboratory in 1963. On the left is Teddy Larsen, Bjørn Braaten and Bjørn Fremstad, who was then a photo assistant in training. Learn more about Bjørn on page 118.

Photo: Bjørn Braaten / FFI

1967

Glass blower

The small detector element in the Penguin missile, that registers heat waves, had to be kept cool to avoid internal noise. The solution was to place the element in a small glass thermos. A vacuum in the thermos was necessary to avoid condensation upon cooling. Liquid nitrogen (-196°C) was used to cool the detector element. Jan Knudsen was FFI's in-house glassblower. He created the small thermoses and solved many difficult problems.

Photo: Bjørn Fremstad / FFI

1978

Before Yr (Norwegian weather service)

FFI had its own local weather radar long before weather services such as Yr became a public service. This radar was developed for field artillery. Here, Georg W. Rosenberg is busy with its operation. The attire was appropriate for the era but perhaps not for the cold north wind that often blew at Kjeller.

Photo: Bjørn Braaten / FFI

1980

Calculating machine with unheard of performance

The multiprocessor, Martinus, had 30 single processors and a miniature machine from Norsk Data that operated everything. This fast-calculating machine was intended to perform highly advanced signal processing and was placed at a site in Northern Norway. Both the hardware and software elements exceeded the system's boundaries.

Photo: Bjørn Fremstad / FFI

1991

Protection from the cold for wounded in the field

For many years, FFI worked on charcoal-based stoves and heaters. One example is the patient warmer, which together with the patient bag were to prevent a wounded person from developing complicated frostbite on their arms and legs. This little incinerator had a fan that effectively supplied plastic hoses with warm air.

Photo: Bjørn Fremstad / FFI

1998

Runways are repaired

FFI has constructed a special vehicle: A repurposed Moxy dumper clears and repairs runways. The vehicle has a prototype for a remote-controlled Vinghøg weapons station and an armoured clearing plough that was developed and built at FFI. Later, this plough was mass-produced at Gjerstad Mekaniske Verksted.

Photo: FFI

2006

Power nap

During a field test on Andøya, FFI researchers direct instrumented infrared missile seekers at planes and helicopters. The plane shoots out flares resembling fireworks to try to trick the missile seekers to steer toward them instead of the plane. Researchers check their instruments to see whether or not the missile seekers have been tricked. This was an early test and not much of the equipment they had constructed was functioning as it should. Therefore, they worked day and night to make things work. Everyone was tired and engineer Egil Bernt Austrheim uses this opportunity to take a power nap, while a P-3 Orion aircraft makes a low pass above him.

Photo: Christian Tandberg / FFI

2012

Optic sensors

Researcher Daniela Heinrich uses optic sensors to test the properties of a new camouflage smoke screens. This was one component of the testing of a new type of smoke grenade. Military smoke grenades are manufactured for various purposes: To create signal smoke, mark targets or landing zones, or to provide a smoke screen when moving.

Photo: Jan Olav Langseth / FFI

2014

The music stops

Researcher Tor Holmboe turns off the torch and the music stops! At the Oslo Science Expo at Universitetsplassen, FFI shows how it is possible to send music through the light from a torch. Children have the chance to make their own torches. Through the Oslo Science Expo, FFI seeks to stimulate curiosity among children and youth for natural sciences, technology and research.

Photo: Wenche Gerhardsen / FFI

2014

Old gas

When the AGA gas company needed help to find out what type of old gas they had received, FFI was there to assist. Together with Oslo Fire and Rescue Service (OBRE), four FFI researchers studied the contents of the last tanks from a shipment of unidentified gas tanks that were to be destroyed. FFI researcher Fatima Ibsen checks the results of the first tests while OBRE waits to assist the researchers with the next test sample.

Photo: Grethe Skaugvoll / FFI

2015

Radar to Mars

Researcher Mats Øyan tests a prototype of the Ground-penetrating Radar Imager for Mars Subsurface Experiment (RIMFAX) on Svalbard. RIMFAX is installed on the Perseverance rover, which landed on Mars in February 2021. Mars is a cold and dry planet and Svalbard is well-suited for this type of test, due to its glaciers. RIMFAX searches underground to help determine the type of geology it traverses. This may enable it to find sites on Mars where there may have been water.

Photo: Tina Hay Iversen / FFI

2018

Haakon and Olav

Haakon, Crown Prince of Norway examines FFI's autonomous vehicle Olav (Offroad Light Autonomus Vehicle). This visit is part of a tour arranged by Kjeller Innovation. The environment in and around FFI has contributed to the start-up and development of many companies.

Photo: Espen Hofoss / FFI

2021

Sensor Wolf

Headless Freke is named after one of Odin's two wolves. This four-legged robot from Boston Dynamics is part of the research conducted by FFI on drones and unmanned vehicles. Can Freke become part of a flock dispatched to provide soldiers with vital information about their environment? Could he ride in an unmanned tank and then move into buildings and environments that others are unable to access? This is what Tønnes Frostad Nygaard (photo) and his research colleagues want to know. Autonomy combined with advanced sensors is becoming increasingly important for the Norwegian Armed Forces.

PHOTOGRAPHER

The images I will never forget

Bjørn Fremstad began as a trainee photographer with FFI at Kjeller in 1960, 15 years old. Many hundreds of thousands of photos later, he has become a part of its history himself.

One photograph shows him hanging in a harness out of the door of a Bell military helicopter. It is flying a hundred metres above the ground at Hjerkinn. The helicopter is hovering in place. Grenades are exploding beneath them. Bjørn Fremstad's job is to film the grenade fragments from above.

"If we were afraid of being hit? No, they had clearly aimed correctly. We knew that the grenades would be shot low, or I wouldn't be sitting here today. It was fun to get out of the office", says the photographer dryly.

BORN IN THE YEAR OF PEACE

The man who was born in the year of peace, 1945, has been involved in a lot of war-like activities. In one of the other photos in FFI's massive archives, he snapped a picture of a Penguin missile in flight, just one millisecond before it blew a discarded military vehicle to shreds.

BJØRN FREMSTAD

FFI photograph from 1960

Born in 1945. Still working at FFI in 2021, on pensioner terms, with the digitalisation and cataloguing of photos and videos from his career. Enjoys sailing, shooting and fly fishing. Occasionally spotted with an accordion.

"It was all prepared in advance and I was far away. The challenge with such assignments was that you might become really seasick. I was lowered by helicopter to rig my photo equipment in the discarded vehicle that was going to be shot. This was outside Andøya and there are usually some strong winds. When I got aboard, we were moving so much that I was scarcely able to manage it".

Bjørn Fremstad looks back on his career as a continuous learning period, from the technical 4 x 5-inch cameras, to his mechanical Rolleiflex, Leica and Hasselblad, up until his use of digital equipment.

SPECIAL EQUIPMENT

A lot of equipment had to be specially constructed at FFI, or he had to play detective on the global market. In Australia, he found six specially built high-speed cameras with fisheye lenses for filming target vessels. These were well-suited for the missile tests.

Neil Armstrong (left), the first man on the Moon, together with FFI researcher Olav Blichner at Spåtind. The photographer received an autograph. *Photo: Bjørn Fremstad / FFI*

> *The story behind the photo is usually more important to me than the photo itself.*

No photo assignment was impossible. Some of them just had to be improvised. In collaboration with the Norwegian Air Force he was able to repurpose a fuel tank for the F-5. This became a platform for photo and telemetry, installed under the belly of an F-16. Behind the windows of this tank, they placed several high-speed cameras. They took up to 3000 pictures per second. There was room for two more cameras on the wings, one on each side:

"Researcher Asbjørn Oddan, who mostly worked with chemistry and explosives, was a technical genius. He had an idea, which the Fellesverksted (Common workshop) decided to employ: They created new 'camera noses' for the Sidewinder missiles on the wingtips. Power for the equipment was sourced from the navigation lights. Pilots were given a special control panel and it was triggered at exactly the right moment. This was crucial, as the film rolls lasted only four seconds. Thus, the researchers could see precisely when the Penguin rockets were launched", says Fremstad.

TWO MEN AT SPÅTIND

His photo of two men walking toward the camera was taken in quieter surroundings.

"One of the men is Neil Armstrong, the first man on the Moon. The other is his good friend Olav Blichner, one of FFI's experts in aerodynamics and an important researcher on the Penguin Project. I shot a photo of them at the Spåtind Mountain Hotel in 1973, four years after the Moon landing. Norway was hosting a NATO meeting specifically regarding space research. I don't think any of the media outlets knew who was visiting. Armstrong was a quiet, pleasant man. I must admit, I did ask for his autograph. He wrote it on the back of a Spåtind postcard".

Have you ever forgotten to put film in your camera?

"Only once, fortunately".

What is the best photo you have ever captured?

"Impossible to say. There have been so many great images. The story behind the photo is usually more important to me than the photo itself". ■

01

02

03

01
FFI's photographer and Captain Rudolf Holm at Rygge airbase have prepared their high-speed cameras, both in the tank below the body and on the wingtips of the F-16 aircraft. This will capture the launch of the white Penguin MK3 missile. *Photo: Norwegian Armed Forces*

02
The wide-angle camera is properly rigged. It will capture an image of the missile one millisecond before it hits the target vessel. *Photo: Bjørn Fremstad / FFI*

03
Waves splash against the hull of the MTB P990 Skarv, photographed from the logistics vessel Valkyrien on a sunny day in Vestfjorden in 2001. *Photo: Bjørn Fremstad / FFI*

04
Fashionable: Bjørn Fremstad films at Hjerkinn in the 1980s. *Photo: Norwegian Armed Forces*

05
Always ready for a flight: Bjørn Fremstad in front of the Armed Forces' Saab training aircraft at Kjeller. Photo: Norwegian Armed Forces

04

05

THE SURPRISE

A radioactive researcher in the corridor

Was there something wrong with the measuring instrument?
Or was there some other reason why a desk at Kjeller began clicking?

During the Cold War, the nuclear bomb was a key topic. Soviet nuclear testing in the atmosphere was closely monitored by Norway.

The detonation of the Tsar Bomba over Novaya Zemlya in October 1961 was a dark event. This hydrogen bomb was the most powerful bomb ever detonated, with a thousand times the energy than the bomb that destroyed Hiroshima. (See page 68).

Radioactive fallout was a real threat. FFI was strongly involved in the measurement of fallout and alerts. Norway developed expertise in this area.

FFI researcher Godtfred Barstad was one of the people with the most expertise. He spent a great deal of time developing reliable and practical measurement devices. This made it possible for soldiers in the field to check local radioactivity.

The most well-known patent was for the small, handheld Blunk from 1950. This device was a type of pocket-sized Geiger counter. Both the Norwegian Armed Forces and the Norwegian Civil Defence purchased many of the three models that were manufactured.

This is related to a story about Barstad's experience with radiation sources: One researcher had a Blunk laying around – or possibly a Geiger counter – on his desk at Kjeller. Suddenly, it began clicking. It was apparently just about to detect something radioactive nearby his office. Then the signal stopped. What was this? Could there be something wrong with the measurement device?

No, it started clicking once more. The researcher tore open the office door. In the corridor, he spotted none other than Godtfred Barstad, now on his way back from an errand in another part of the building. He had nonchalantly placed a radioactive isotope in the pocket of his lab coat. ■

HOW TO AVOID AN EXPLOSION?

I have always been fond of the natural sciences. I attended Roald Amundsen Upper Secondary School in Oppegård, south of Oslo. We had a physics teacher who was very interested in what they were doing at NTNU. I didn't know why, until I saw it with my own eyes: NTNU invited us to an event in Trondheim, including hotel, events and lectures. They called it Girl's Day. There were probably a hundred of us. I went and fell in love with the programme and all the opportunities they showed us.

I chose to study industrial chemistry and biotechnology. I like the theoretical aspects better than lab work. That is why I chose to specialise in applied theoretical chemistry.

I learned about the summer internships at FFI several years ago. A post-doctoral fellow here at NTNU had worked there. Earlier, I had a more industrial summer internship with Hydro. The first time I applied to FFI, I didn't get in. There was a lot of competition for places. I was accepted the second time.

The application deadline was in November and I was offered the position in December. The only condition was that I had to have a security clearance. During the Christmas holidays, I sat and tried to fill out the form, which was nine pages long. It was very strict. Not a single dot out of place. After a few months, I was told that I had made a mistake. I had to fill out everything all over again. The message from FFI was clear: 'If the clearance is not ready by your start date, we will, unfortunately, have no position for you'. Luckily, I made it through!

The reception by the group that works on energetic materials was great. Everyone was so helpful. In this department, they study the effect of rocket fuel and explosives. One question is how much force an explosive can deliver. Another question is how sensitive it is. If this material takes a hit, or if there is a spark, how much would it take before it explodes? It is important to be able to answer these questions when transporting weapons or storing them over time. We don't want anything bad to happen. We would like to have a good theoretical model for better predictions. The testing methods used today are inadequate.

I never shot or exploded anything while I was at FFI, though. It all involves molecular calculations. Those are done on a screen.

Much of what takes place at FFI is top secret. You feel kind of special when you get to know things not everyone knows. But my report from my summer internship is not classified, fortunately. This is why I had the chance to make a chart that indicates sensitivity of energetic materials. I was asked to present this chart to the Norwegian Chemical Society's group for quantum chemistry and modelling at their annual meeting. That was exciting.

Now, I'm in my fifth and final year as a student at NTNU. New challenges await. My experiences from the summer internship at FFI will be useful. Last I checked, there were no available positions I would be suited for at the instituted. Still, I feel my stay at Kjeller was very positive. So, I keep checking. ■

You feel kind of special when you get to know things not everyone knows.

KRISTINE WIIK
(24)

Summer intern at FFI in 2020

RESIDENCE
Trondheim

FIELD OF STUDY
Chemistry

STUDYING AT
NTNU

Photo: Lars-Erik Berg

SUMMER INTERNSHIPS ARE AWESOME

The summer internship programme has been offered by FFI for several years. Despite the coronavirus situation, 75 students worked here in 2020, on nearly just as many projects.

Director General John-Mikal Størdal emphasises that it is perhaps FFI's own researchers who are the most satisfied. "Students are given the chance to work with the researchers on many of our regular projects. When anyone suggests that this programme should be less extensive, there have been immediate objections. The idea is that student internships provide a resource. Therefore, this is something we will continue to offer".

Students who apply to FFI are young academics who need the experience and a summer job.

"Here, they can utilise their strong academic skills", says Senior Advisor Jan Olav Langseth, who has worked closely with the students during the hectic weeks of their internships.

Historically, many interns have later become employees at FFI. This makes summer internships an important arena for recruitment.

The institute often enables students to do their master's theses at the institute and work on projects part-time. Universum Professionals Survey 2020 asked young, working graduates in the fields of natural sciences and technology who their dream employer would be. FFI came in 10th place.

"We are in good company. Above us are names such as Google, Equinor, Kongsberg Gruppen, Norconsult – and Sintef. I am proud that we are in the top 10 in this survey for the first time. It is extremely important for us to be an attractive workplace for young people", says John-Mikal Størdal. ■

Historically, many interns have later become employees at FFI. This makes summer internships an important arena for recruitment.

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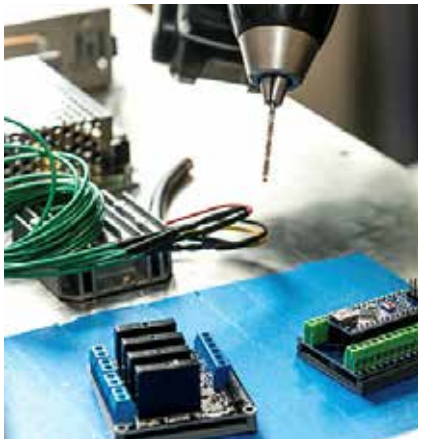


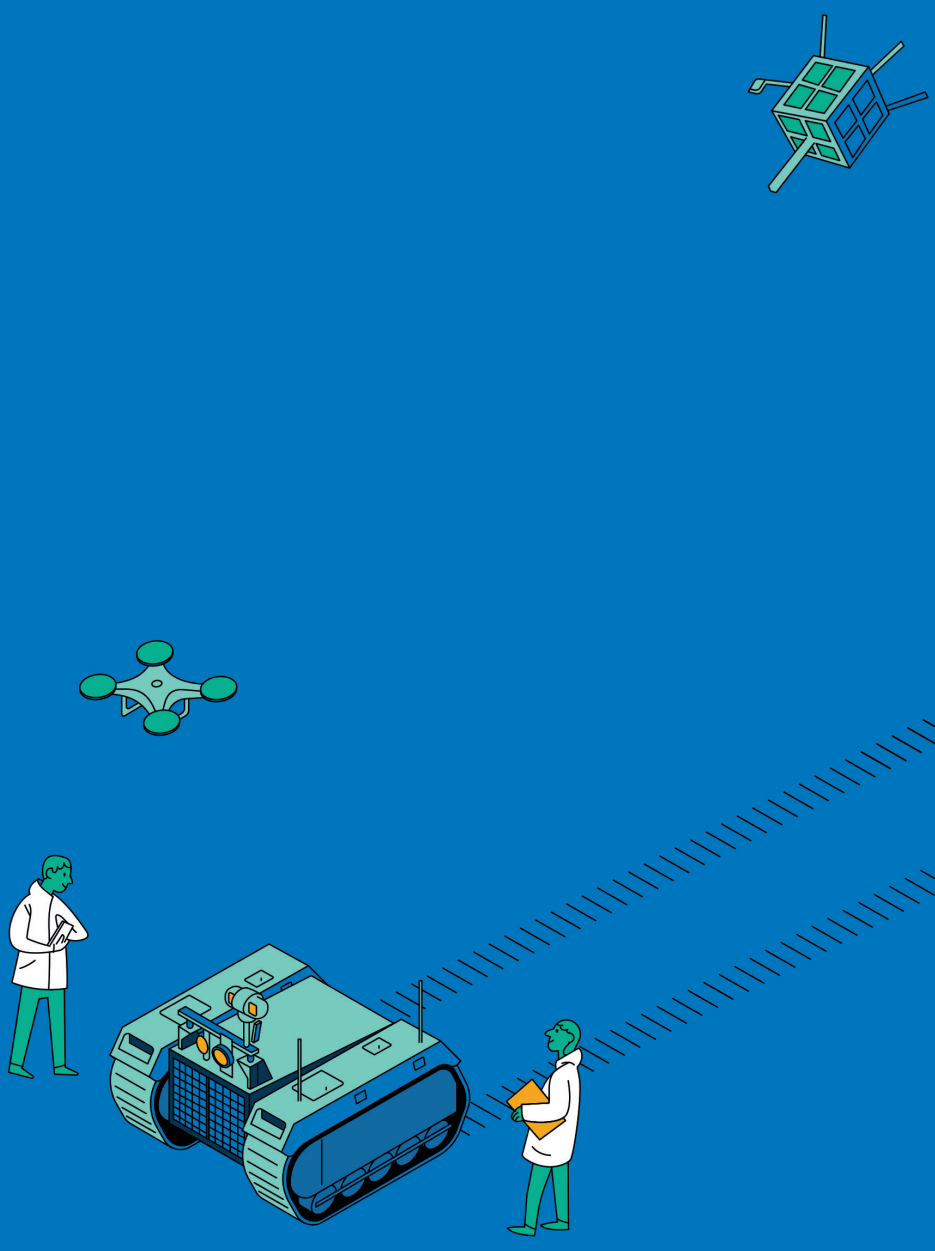

Photo: FFI

READ, SEE AND HEAR MORE ABOUT FFI

We will be celebrating our 75th anniversary throughout 2021.

You can find more stories on our web pages. See photos and videos and listen to podcasts about our research.

ffi.no/en/75



FFI Norwegian Defence Research Establishment