GETTING MORE
FROM WHAT YOU’VE GOT

Eight technologies that help boost the performance of both current and future systems

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Dear readers,

What is it really that soldiers, marines, sailors and pilots need to do their jobs safely and effectively?

In our opinion the answer is as complex as the question itself, though one thing stands out – as major systems and platforms become more expensive, and the process of replacing them ever more challenging, users need to get more out of what they have already got.

This is the focus of this year’s Nammo BulletIN, where we highlight eight areas where we offer solutions that do just that. They range from futuristic technologies, like ramjet-powered artillery rounds that will allow a standard howitzer to take a completely different role on the battlefield, to a high quality legacy 57 mm round that due to its proven design and affordability offers modern day naval vessels a reliable advantage in the face of any threat.

Indeed, this is what characterizes all of Nammo’s products and services. In every area, from competitive shooting to defense and security to space flight, we work to understand what it is users need the most, and then invest in the necessary technologies to meet those requirements. This includes investing in new manufacturing technologies to ensure we can keep delivering at the cost and quality levels our customers expect.

Together with these technologies, we are also bringing you updates on the development of Nammo, and the efforts to integrate our most recent acquisitions into our growing organization. As we entered 2018, our 20th year as a company, we were present in 14 countries, with manufacturing facilities in nine of them. More than 2 300 dedicated employees working every day to ensure that we do our part in providing the right equipment to those doing an important job.

Nammo is an international aerospace and defense company headquartered in Norway. With more than 2 300 employees in 14 countries, we are among the world’s leading providers of specialty ammunition and rocket engines for both military and civilian customers.

We believe that those doing an important job deserve the right equipment. Our societies look to a small group of dedicated specialists to keep us safe, to help us explore, and to make us proud. Whether defending our security and interests, in space or on the sports field, they accept only the best from themselves and their equipment. These are the people we serve, with products, services and support that provide a truly reliable advantage.

Endre Lunde
SENIOR VICE PRESIDENT
COMMUNICATIONS
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![Image of a satellite and airplane in space]

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Nammo’s programmable ammunition technology makes it possible to fire rounds that are programmed to explode with pinpoint accuracy, either before, above or inside a target, which makes it an effective anti-drone system. The threat of unmanned aircraft systems (UAS) has been on our radar since 2002, when we first began developing programmable ammunition, but the threat has become more pressing in recent years where drones have been increasingly incorporated as weapons on the battlefield in Iraq and recently in Syria.

Nammo’s 40 mm airburst round was designed to maximize its effect within a specific range from the point of detonation, and it’s the star of our video that’s been making the rounds online, in which we show exactly how effective the programmable ammunition is for countering unmanned aerial vehicles. In fact, we brought the obliterated drone to DSEI in London in September where it gathered large amounts of interest from both industry and media.

Another advantage of the 40 mm programmable is its ability to explode in a highly controlled way to avoid damaging surroundings or continuing on its path to hit civilian targets. This is especially important in dense urban environments or in situations where the unmanned aerial vehicle (UAV) is carrying explosives that need disabling or detonating at a safe height.

During the fall of 2017, Nammo, together with Kongsberg, demonstrated the capability to take out moving UAVs at significant ranges. Within a test period of two weeks, we shot down a total of 14 UAVs.

In terms of installation, this is a cost-efficient and simple anti-drone measure to adopt as no modifications or upgrades are
EQUIPPING THE MODERN WARFIGHTER

Nammo started working on airburst 17 years ago. Because it requires an advanced mechanical safety and advanced electronics to be able to air burst, the development of the first airburst round took time, but finally, in 2006, after years of development and extensive testing, the first qualified round, MK 285, was ready for the MK 47 gun. In parallel with this effort, we were working to develop a wireless programming solution, the RF system, which led to the first airburst round with the RF solution being qualified in 2010. This was the C171.

Since then, Nammo has developed several different airburst rounds:

- **MK 285 High Explosive (HE) airburst round** for use in the MK 47 grenade launcher (in service)
- **MK 314 High Explosive Dual Purpose (HEDP) airburst round** for use in the MK 47 grenade launcher
- **C171 HE airburst round with wireless programming** for use in any automatic grenade launcher (in service)
- **NM 264 HEDP airburst round** for use in any automatic grenade launcher (in service)

The airburst principle is simple: you don’t need a direct hit as the ammunition can be set to explode just above or beside targets. Larger calibers can also be set to penetrate a specific distance within a target before detonating.

This versatility and flexibility means one round can be used to take out multiple targets, making it equally suited for targets in the open as behind cover. Other areas where programmable ammunition has proven to be highly effective is in taking out sensors and weapon systems, and against soft skin, light armored and command and control vehicles.

Civilian drones being used in warfare are a relatively new, but real threat to soldiers on the battleground and we believe Nammo’s airburst technology is well equipped to help counter this threat and secure ground forces. The fact that the 40 mm airburst is also versatile enough to take out hidden and moving targets can only strengthen its positioning as the ammunition of choice for the modern warfighter.
In the Arizona desert during June of last year, over 40 representatives from different parts of the US Armed Forces gathered together with members of the Nammo development team and the US Department of Defense (DoD) sponsor, to witness the testing of the M72 E11 Airburst system.

The system did not disappoint, as every single round detonated successfully over a range of 300 to 700+ meters. The demonstration marks a breakthrough in M72 technology, and a major step forward in the development of what is already one of the most advanced unguided shoulder fired systems.

The E11 testing event was integral to securing future funding for 2018 to build the rounds to be entered into the stringent Joint Ordnance Test Procedure (JOTP) qualification, with the aim of fielding them in 2020, or sooner. Funding thus far has come from the DoD sponsor. Already there has been a notable amount of interest from potential end users, due to the fact that the system gives the dismounted soldier a completely new kind of capability, which no other system can offer.

The qualification series concludes with validation of safety, accuracy and the system’s performance against a range of targets. Funding thus far has come from Nammo internal research and development, along with a significant contribution from the US DoD sponsor. Already there has been a notable amount of interest from potential end users, due to the fact that the system gives the dismounted soldier a completely new kind of capability, which no other system can offer.
The M72 E11 Airburst is primarily intended for the dismounted and light-ground or maritime units. It can be employed defensively as suppression against point or area targets as well as offensively for targets in the open, defilade or behind cover. The self-contained munition will dramatically increase squad survivability by providing standoff capability in a single soldier-carried weapon.

**KEY COLLABORATIONS**

This project has been very much a success story, predominantly down to the collaborative effort of the teams in the different Nammo business units.

Each of the below groups have come together in the development project to share expertise in the areas of power generation, sighting and radio frequency signaling to create a product that excels: Nammo MTH provided fuze expertise; AnMa TECH provided expertise on fuzing electronics; and Raufoss provided expertise on the airburst component and the setback generator.

Working in a team from such great distances, along with the cultural and language barriers, is no mean feat, and it is fair to say this collaborative project has required a lot of video conferencing technology. However, face to face is just as important when it comes to breaking the ice, encouraging open discussion and enabling all team members to bring their expertise to the table for honest communication. This has been a true exercise in collaboration, and the result is an advanced system that will revolutionize troops’ capabilities on the battlefield.

In that regard, the project serves as an example of the kind of collaboration Nammo is working to foster across its organization, as it continues to develop as provider of choice for some of the world’s most advanced militaries.
25 years ago, Norway became one of the first European countries to acquire an infantry fighting vehicle with a 30 mm x 173 gun, the CV9030N. At the same time, Raufoss Technology AS, now a part of Nammo, negotiated a contract with the Norwegian Army to develop a new generation of 30 mm ammunition. Today, with 30 mm guns becoming more prominent than ever, the experience gained through this early work has allowed Nammo, through its Strategic Alliance Agreement (SAA) with General Dynamics Ordnance and Tactical Systems (GD-OTS), to become one of the main providers of 30 mm ammunition for the US Armed Forces. Following the recent signature of agreements with the US Army and the US Navy, both services are now adopting Nammo’s 30 mm APFSDS-T MK 258 Mod 1, or “Swimmer”, for use from a multitude of platforms, including the US Army’s latest addition, the Stryker variant known as “Dragoon”.

Ammunition used by vehicles generally falls into three categories – armor piercing (APFSDS), for use against other vehicles; High Explosive Incendiary (HEI), for use against lighter targets and aircraft and target practice (TP) rounds, that allow cost-effective training.

While traditional ammunition is either stopped or deflected when it hits water, Nammo’s 30 mm Swimmer (APFSDS-T MK 258 Mod 1) swims straight through water, thanks to a groundbreaking design on the supercavitating projectile developed in cooperation with the US Navy. Jan Hasslid discusses the implications of this new technology.
The US Navy is adopting Nammo’s 30 mm Swimmer ammunition for use from a multitude of platforms.

Nammo today offers ten different types of 30 mm x 173 ammunition across all three categories, ranging from plastic blank and reduced range anti-armor to multipurpose and explosive rounds, as well as dedicated kinetic energy penetrators.

The Swimmer round falls into the category of sub-caliber kinetic energy penetrators. These can most easily be described as arrows made out of very heavy materials that use the force of the impact rather than explosives to punch through armor. Traveling at speeds of more than 1 km per second, the energy generated by the impact melts the armor of the vehicle into a fluid and the arrow “swims” through the armored side of the vehicle. In the case of the Swimmer, the force of the arrow is sufficient to defeat anything except main battle tanks.

Nammo’s penetrators, both for vehicles and other types of armor piercing ammunition, are made out of a super tough tungsten alloy, also known as wolfram. More than two times as heavy as steel, it has the second highest melting point of any element, making it ideal for use in armor piercing ammunition. For some ammunition types, including the 25 mm APEX for the F-35, tungsten is mixed with carbon, creating what is known as tungsten carbide. This makes the penetrators harder, but also more brittle, allowing them to fragment once they have penetrated the armor, causing added damage inside the target.

What makes the Swimmer unique, however, is the combination of powerful armor penetration and its ability to swim straight through water. This effect has until now been considered impossible to achieve by ammunition fired from air through water. As demonstrated by a number of popular science TV programs, traditional ammunition is either stopped or deflected when it hits water. In a worst case scenario, a projectile could hit the surface, bounce off and hit something else.

Thanks to the design effort for the kinetic energy penetrator originally developed for the Norwegian Army, and perfected by Nammo in combination with US Navy supercavitation concepts, the Swimmer avoids the ricochet in water problem through the use of a supercavitation nose design. This means that the projectile creates a bubble of steam around itself big enough to pass through, substantially reducing the friction that stops traditional ammunition. This enables the Swimmer to be used in defense of either ships or coastal areas against submerged and surface mines, small underwater vehicles, torpedoes and even small fast attack crafts that might be concealed by waves. This is valuable not only for naval vessels, but also for land vehicles defending harbors, bridges or other key locations.

Going forward, Nammo expects that most armored vehicles armed with medium caliber guns such as the 30 mm will carry one armor piercing round, and one multi-role round capable of acting as either a traditional high-explosive or an airburst round. With the Swimmer established as a leading armor piercing round, Nammo is now turning its attention towards developing a new type of programmable 30 mm ammunition that can be used against the kind of targets where the Swimmer is less effective. Based on the same technology as the 40 mm grenades that have been demonstrated against drones, this would allow fighting vehicles to program their ammunition to explode either in the air, or at a specific point inside a target. This would allow future combat vehicles to address the full range with only two ammunition types, and hence be ready for any mission, at any time.
Nammo Raufoss has become a competitive and favored system developer in space rocket propulsion, thanks to its green propulsion technology. Jan-Erik Ronningen, Technical Manager RACS, updates us on the VEGA-C RACS project.

Imagine a rocket with a start weight of 210 tons with a two ton, $200 million satellite on top. The customer wants the satellite placed in a precise orbit around Earth, 700 km up. In order to reach that orbit, the speed of the rocket needs to be almost 10 times that of a rifle bullet. We are talking about achieving a speed of close to 29 000 km/h – that’s 8 km per second. This is the right job for the European rocket launcher VEGA-C.

The VEGA rocket is no fantasy; it has already been flying in a smaller version since November 2011. Up until November 2017, a total of 11 flights have successfully been accomplished without any incidents, and 11 more flights are planned before the launcher will be retired in favor of the larger and more powerful VEGA-C, which is due to take to the air in early 2019.

The VEGA-C rocket is a four stage rocket launcher, meaning a stack of rocket engines placed on top of each other, reaching a total height of 35 meters. The fourth stage, called the AVUM, holds a liquid rocket engine and a reaction control system. On top of the AVUM the satellite is placed on a payload adapter protected by the nose fairing. Part of the AVUM propulsion system is what is known as a reaction control system, consisting of six reaction engines currently using the liquid hydrazine as propellant, a highly toxic and costly chemical.

The reaction control system used on VEGA-C is named RACS and is the abbreviation for Roll and
Attitude Control System. Simply put, RACS is used by the on-board flight computer to maintain correct flight heading (“nose up”) and orientation during the entire flight, from take-off to end of life. By end of life we mean a controlled reentry into the Earth’s atmosphere, burning up the remaining stage after the satellite has been placed in correct orbit. The reentry maneuver ensures that no leftover material from the rocket is allowed to become “space junk” orbiting the Earth.

Working on VEGA-C may become the golden key for Nammo to unlock other future possibilities.

The prime company behind the VEGA is AVIO, an Italian company with a long and proud heritage in space and launcher business that became interested in Nammo’s green and clean rocket propulsion technology based on the liquid propellant hydrogen peroxide. Nammo has been working on hydrogen peroxide for as long as the VEGA launcher has been flying. It is an attractive propellant since it promises a substantially lower cost than the present hydrazine-based RACS system while also providing a non-toxic solution. Nammo Raufoss and Nammo Ireland are currently engaged in a pre-stage development program with AVIO which is set to end in June 2018. Nammo Raufoss is system lead, while Nammo Ireland provides valve products for the system.

The full development program will take three years and will involve more than 40 people, making it the biggest space program Nammo has ever embarked upon and a true test of Raufoss’ expertise and capabilities – a challenge we are well equipped to meet. Still, throughout 2017, Nammo worked to expand the staff at Raufoss in order to ensure we have the people we need for full scale RACS development.

The overall RACS program is a system development program consisting of 11 sub-programs to be developed and woven together into a high-precision, reliable propulsion system. The plan is for three to four propulsion systems to be delivered each year starting from 2021, with the first flight with a hydrogen peroxide based RACS planned for late 2021.

Working on VEGA-C may become the “golden key” for Nammo to help us unlock other future possibilities for our new propulsion technology. AVIO is already in discussions with Nammo on using a similar system for other platforms like the Space Rider and VEGA-E. Space Rider is a small spaceplane based on the successful IXV plane that flew in 2015, though Space Rider will be larger and will fly on missions with durations lasting up to six months. Also, following the VEGA-C, the VEGA-E rocket launcher will enter into service from 2025. It, too, will need a reliable RACS system.

As always, Nammo stands ready to support, and looks forward to providing our advanced technologies to future European space initiatives.
The 57 mm High Explosive Point Detonating (HEPD) rounds may have been in production since Bofors first introduced its 57 mm MK 1 gun in 1966, but they are showing no sign of falling out of favor as naval defense weapons.

There are two main reasons for the continued popularity of this product. First of all, Bofors, and later BAE Systems, have done extensive work to improve and modernize the 57 mm weapon system, enabling it to defend against attacks from land, sea and air. The second reason is the quality of the ammunition, which even today meets the highest quality standards.

The most recent proof of this is that Nammo has negotiated a new contract for qualification of both the 57 mm L/70 IM HEPD and Target Practice (TP) versions for the US Navy. It is a deal that speaks volumes about the quality of the products. Both rounds are now under qualification, with serial production expected to begin in 2019.

IN THE BEGINNING

The 57 mm ammunition was originally designed by Bofors, and the rights passed to Nammo when the ammunition section of Bofors became part of the new Nordic ammunition company in 1998. Today, 20 years later, Nammo and BAE Systems Bofors continue to be the only qualified providers of ammunition for the Bofors 57 mm L/70 guns.

The 57 mm ammunition of today is a highly sophisticated version of that original product – one that uses top-grade suppliers for every component: propellant, explosives and mechanical elements. The result is a product that is both extremely robust and accurate. More recently, the introduction of insensitive munitions (IM) characteristics, which lessen the risks associated with transporting and storing it, has helped broaden the ammunition’s appeal even further.

For a system with this kind of history, it is still relevant to a wide market: as well as being compatible with Bofors MK 1 and MK 2 naval guns, it is also compatible with the newer BAE Systems Bofors 57 mm MK 110 – the deck gun chosen for the US Coast Guard’s National Security Cutter and Offshore Patrol Cutter classes of ships, in addition to the US Navy’s Littoral Combat Ships (LCS).

The ammunition is also relevant to less modern systems, including 57 mm weapon systems that date from as far back as the 1960s, which are still used in some countries today. This is in contrast to other munition types, such as the BAE Systems Bofors 3P which requires a programming device integrated into the weapon platform to function.

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MEETING CHANGING DEMANDS – AT THE RIGHT PRICE

In Nammo we believe that those doing an important job deserve the right equipment, and that the “right equipment” isn’t always that which is newest, and most advanced. This is why we continue to offer a wide range of products and systems in order to meet the user’s needs, including both conventional and next generation technologies.

For a system with this kind of history, it is still relevant to a wide market.

In 1998 BAE Systems Bofors introduced the 57 mm MK 3 gun with programming capability, along with the 57 mm MK 295 3P-HE programmable round, often known just as “3P”. Programmable ammunition provides several tactical advantages, and is a type of technology that Nammo also pursues in other areas (see pages 4 and 5). However, any added capability must always be weighed against the cost associated with it and, in the case of the 57 mm, Nammo’s conventional products are able to handle targets just as well as the 3P, but have a significantly lower price point.

In the case of the 57 mm, we are particularly conscious of the
need for cost-effective training. Regular training on dummy targets is vital for crews in order to maintain high weapon skills, but live ammunition, even in the case of the Nammo IM HEPD, can pose a strain on budgets. The 57 mm Target Practice round has been developed as a budget-friendly product that meets the ballistic envelope of the live HE and programmable ammunition. As an added benefit, the TP round can also be used for more than training, for instance in conflict scenarios where a graded or scalable effect is desired for warning and show-of-force purposes.

In our view, this is essential in the current environment of tight budgetary restrictions. Defense forces are frequently faced with the dilemma of maintaining a high level of proficiency and readiness, while also saving money. Nammo therefore considers its conventional 57 mm HE or TP ammunition as a potential solution that helps its customers balance both operational and budgetary requirements.
Nammo is playing a key role in extending the range, and thereby the role of traditional tube artillery on the battlefield, says Thomas Danbolt.

Nammo began working on base bleed technology in the 1980s. Simply put, base bleed is a technology used to increase range without affecting the accuracy of a projectile. We initially worked as a sub-supplier for other manufacturers, before developing our own solutions.

Base bleed works by utilizing a propellant grain that is attached to the bottom of the shell. This grain ignites upon launch and burns during the first part of the ballistic trajectory, releasing gas behind it which smooths out the airflow, which in turn reduces the drag. This means that while a regular artillery shell can be fired from a modern L52 gun system and reach 30 km, the same shell with base bleed technology can reach 40 km or more from the same gun system, purely down to the reduction of drag. It is a huge increase.

Since the 1990s we have been constantly advancing the technology, with chemists and engineers working closely together to optimize grain type, composition, shape and size to create the precise amount of constant gas flow over a set period of time to give a shell as much range as possible. Of course, each piece of technology needs to be tailored to each specific shell to maximize the range potential.

WE HAVE STARTED WORKING ON A NEW PROJECTILE THAT HAS A RANGE OF UP TO 100 KM
In 2009 we decided to move beyond delivering only the base bleeds, and started a technology program aimed at delivering a complete shell design that could be fired over 40 km. This program led us into developing a new family of what we call Extended Range ammunition – 155 mm non-propulsive, drag reduction systems for artillery range extension components. In 2016 the first new Nammo round was successfully fired over 40 km, proving that the optimized base bleed design and its associated shell is truly state-of-the-art.

**COLLABORATION AND INNOVATION**

Over the years, Nammo has come to be recognized as a world-leader in base bleed technology. The best proof of this is that we are the base bleed supplier on three of the most advanced artillery munition programs in the world: the Nexter 155 mm BONUS, an anti-armor artillery munition; Raytheon’s Excalibur, a long-range guided shell that can reach over 50 km; and the US Army’s in-development High Explosive Extended Range XM1128.

In addition, we are also working with the US Army on the XM1113, a slightly different project in that it is a rocket-assisted shell. The grain is larger and more energetic, meaning that it is powerful enough to help the shell maintain its speed, rather than just reducing the drag. All of these programs are significant for Nammo as they solidify our position as a leading provider, while also allowing us to develop new designs and technologies.

**REVOLUTION IN ARTILLERY RANGE**

What could be even more significant for Nammo is the work that is now underway to develop a completely new projectile with a range of up to 100 km when fired from a standard L52 tube gun. It forms part of our Extreme Range concept, which utilizes ramjet technology – a type of air breathing system where the shell has an internal rocket engine that takes in oxygen through the nose of the projectile and in turn uses it to burn the propellant, thus generating thrust. You can read more about this innovative technology on page 16.

We have called this technology HE-ExR™ (High Explosive Extreme Range) and it is integral to our goal of creating ammunition with extreme range that does not add any additional load to the gun. Considering that the current maximum range of regular shells is around 40 km, this new technology with a range of up to 100 km will be a huge improvement. Compared to other systems with that kind of range, the shell will provide high-precision capability at a competitive price point.

**MOVING ON THE MARKET**

At Nammo we believe the Extreme Range concept will form part of a new market segment, providing artillery that has a multi-domain capability – a true force multiplier. In Norway, for example, we have a very long coastline. With our technology, future armies will be able to use land-based artillery to strike naval vessels. Instead of supplying several different products to our customers for each scenario, we will instead be able to provide something that makes what they already have more flexible, covering a wider spectrum of requirements.

This technology will transform the battlefield for some armies, especially smaller forces without access to large air assets for deeper strikes. In these cases this ammunition will introduce a completely new capability.

Our firm belief is that if successful, our Extreme Range technology will secure Nammo a central position in the future market for large caliber ammunition.
Nammo Aerospace Propulsion (AP) has initiated a technology program on extended range for missile propulsion systems. The background for looking into this is highly connected to the focus areas in the “new long term plan” for the Norwegian Armed Forces, which is focusing on missiles with significantly longer range and higher velocity towards the target. The work connected to increasing range and velocity is also in line with NATO and the Western international need. The required range and velocity improvements according to the “new long term plan” are well outside of what is possible using standard Solid Rocket Motors (SRM).

BACKGROUND

The propellant fuel grain of a traditional SRM includes both the fuel and oxidizer utilized for the combustion; the oxidizer fraction is typically ~80 percent of the total propellant mass. In addition, this type of motor has been optimized for decades and large performance improvements are difficult to achieve. Significantly higher performance can be achieved using air breathing propulsion systems, where the oxidizer utilized for combustion is collected from the external ambient air. The propulsion performance with respect to specific impulse is many times higher than for a standard SRM.

TECHNOLOGY WORK

Nammo has a long history of working together with Forsvarets Forskningsinstitutt (Norwegian Defense Research Establishment, FFI) on technology improvements for missile propulsion systems. Through FFI, Nammo has participated in several Data Exchange Agreements (DEAs) with different US governmental labs. A Coalition Warfare Program (CWP) between the United States and Norway was initiated through one of these DEAs and the goal will be to demonstrate an Advanced Solid Fuel Ramjet (ASFRJ).

A ramjet, a flying aero-thermodynamic duct, is a form of air breathing engine that uses the forward velocity to compress incoming air without using a separate compressor. Because ramjets cannot produce thrust at zero or low air speed, they cannot propel the missile (or vehicle) from standstill or low velocity. Therefore, a ramjet-powered vehicle will require a booster, like a rocket assist, to accelerate it to a speed where the ramjet begins to produce thrust. Ramjets work most efficiently at supersonic speeds around Mach 3. To achieve the ramjet operational speed a traditional ejectable SRM booster or an integral SRM booster can be used.
Testing a ramjet motor requires a test facility that simulates the engine’s forward velocity, i.e. the compression and heat-up of the incoming air, at the flight condition in Mach (velocity) and altitude.

Nammo has invested in a test facility to support the CWP work and other possible air breathing activities. This facility can be operated in manual mode or in computer controlled flight mode, and was fully defined, designed and assembled in-house in order to have maximum process control during tests. The test facility was established in record time – slightly above one year from initial decision to first test firings.

The facility can simulate operation from low velocity to approximately Mach 5 and from sea level to approximately 50-60 000 feet.

To heat the ambient air to the required temperature after the inlet, a heater with a maximum effect around 10-12 MW is required. Nammo has the ability to test air breathing propulsion systems both for missiles and for ammunition in this facility. It is capable of simulating the ramjet transition phase, i.e. transition from rocket assisted boost to ramjet operation. The representative diameter size of the propulsion systems can typically be 70-250 mm. Nammo is presently doing tests on a 100 mm test motor and has successfully performed more than 50 tests so far.

The energy required to heat the ambient air during testing corresponds to running 1 000 3-burner BBQ grills at the same time.

Future potential

The air breathing technology work initiated at Nammo on ramjets will fulfill the Norwegian need for missiles with longer range and higher velocity towards the target. The technology can be utilized for air and ground launched applications. It is a technology which can be implemented into the new F-35, as well as the Norwegian frigates and possible future ground based air defense launchers. In addition, the technology can also be applied to gun-launched ramjet powered projectiles for range extension.

A ramjet is a form of air breathing engine that uses the forward velocity to compress incoming air.
November 2017 was a significant month in the Nammo APEX calendar as it saw the delivery of the first F-35 combat aircraft to Norway’s Ørland Air Force Station. The event was surrounded by much ceremony and celebration, attended by prominent guests including the King of Norway, the Prime Minister and other government ministers, and covered live on Norwegian TV. It was particularly momentous for Nammo, who has developed a completely new type of 25 mm ammunition to support the multi-role functions of the jet, the Armor Piercing with Explosive ammunition or, as it is more commonly known, APEX.

With deliveries of the F-35 accelerating, Nammo Raufoss is now pushing on with the full industrialization process for APEX.

So far the production volumes for APEX have been relatively small, with a limited number manufactured for testing and integration purposes. With preparations for serial production underway, this will change, but just as APEX represents a step forward in terms of capability, it will also mark a significant advancement in production technologies.

Until today, the pressing and assembly of medium caliber ammunition has depended on a number of highly skilled operators with excellent craftsmanship.

As part of the industrialization of APEX, Nammo is investing in new autonomous production lines, improving the speed, the quality and the costs associated with the round.

The team was able to take proven technology already in use in Nammo production lines and put it together in a new and even more efficient way. Building a number of controls into the process to monitor torque, glue application, product heights and markings means Nammo can now produce even complex products with extreme accuracy and precision.

In August 2017, the first part of the fully automated projectile assembly line passed the Site Acceptance Test (SAT) confirming that the assembly line is ready for production with the ability to produce 300 projectiles per hour, and during the winter of 2017/18 construction of a new dedicated facility to house the pressing and assembly line commenced.

Until now, almost all of the fuze components were supplied by Dezamet in Poland. As production
ramps up, however, the supply chain needs to develop as well, with component production switching to Nammo MTH in Switzerland. This will allow Dezamet to focus on assembling and subsequently delivering the complete fuzes.

Interestingly, Nammo MTH’s Swiss sub-suppliers are all from the watch-making industry, sourced for their expertise in the field of high-precision, micro-mechanical parts with complex geometries. The switch also demonstrates Nammo’s commitment to having full control over the whole production process, which includes only working with companies that comply with the highest European and international standards.

A NEW TRAINING ROUND

Work is also ongoing on a 25 mm Target Practice Reduced Ricochet Risk (TP RRR) training round. First conceptualized in 2009, the plan is to complete qualification in autumn 2018.

What makes the Reduced Ricochet Risk round special is how it performs just like the APEX in every way up to the point when it hits the target. Standard training ammunition will typically ricochet when fired at soft ground surfaces like sand, and this represents a potential hazard to the aircraft. The RRR round is designed to break up on ground impact, even when impacting soft surfaces at shallow angles. The disintegrated projectile pieces have low mass and high drag, and will therefore not ricochet far.

The design is challenging to develop as it must be strong enough to withstand the launch forces, while still fragile enough to break up on impact. For the 25 mm TP RRR Nammo has developed a new design concept that does not compromise on either; the projectile is as strong as the regular APEX ammunition when launched.

ONE TECHNOLOGY, MANY PLATFORMS

An added challenge given to the development team for the assembly and pressing lines is to make sure they are flexible enough to work with other caliber ammunitions. Work has already begun making the 25 mm APEX assembly line compatible with the assembly of 20 mm and 30 mm projectiles, enabling Nammo to transfer the same efficiency and quality to other products as well.

The 25 mm APEX is a state-of-the-art ammunition due to its penetration capability, detonation-inside-target ability and graze impact function. Nammo is also looking to share this technology in other calibers of ammunition used by other platforms, starting with the 27 mm round used on several European combat aircraft designs.
The unique collaboration between the Nammo teams in Ireland and Norway has brought tremendous advances in aerospace propulsion technology in the company, explains Business Development Manager Derek Harris.

**IT STARTED WITH AER LINGUS**

What is now Nammo Ireland was initially set up in 1982 as a subsidiary of Aer Lingus. It was called Devtec Limited and its mission was to provide research and development services to Irish industry, and to support the airline with professional engineering and manufacturing skills.

During the Devtec years we had many interesting programs, beginning with civilian air transport, before later transitioning into the space sector. One of the first projects was a 737 Overhaul Docking System, for which Devtec designed and manufactured a series of platforms used to service and overhaul aircraft at Dublin Airport. Later, the company also provided a cargo handling system, along with several systems to allow for the conveyance and storage of aircraft igloos.

**FLYING HIGHER**

We made our first ventures into the space sector with the Hipparcos spacecraft ground test equipment. Contracted by Contraves in Switzerland, we designed and built a vibration test adaptor, a thermal test adaptor and the assembly test stands. This was a fantastic program that gave us the motivation to pursue more business in the space market.

Our space efforts really took off, however, with the Vulcain engine supports. In 1988 Devtec started working with the Société Européenne de Propulsion (SEP) in Vernon, France, on the structural supports for the Ariane 5 main cryogenic engine, known as Vulcain. This was a huge undertaking for the company and we needed to learn a lot along the way.
As our space expertise grew, we also had our first change in ownership. The first buyer was Marotta Controls. The Marotta purchase came out of our collaboration with them and BPD on a tethered satellite system, where we delivered a thruster pack intended to test if a tether could generate enough power for a satellite to survive on. The tether was propelled from the cargo bay of the space shuttle, and was a success for the Marotta team. BPD is today known as Avio, and our paths crossed again in 2017. Under the Marotta flag, we started working on three-way two-position solenoid-controlled valves for ground applications and became Marotta’s production facility for this product. Building on that, our first venture in space valves was a monumental challenge, developing a latch valve and mechanical pressure regulator for the electric propulsion system on the Alphabus platform. These developments reached the critical design review stage. However, by this time, the valve and regulator schedules were no longer aligned with the Alphabus launch window, so the programs were stopped.

Building on the new skills in the field of valve development, together with the European Space Agency (ESA) and the Nammo Westcott site we have developed a solenoid-operated flow control valve for the 400 N bipropellant apogee engine. This thruster flow control valve is now used on the Nammo Raufoss hydrogen peroxide Roll and Attitude Control System (RACS) for Vega. Read more about this on page 10.

Work today continues on Vulcain, and Vinci for Ariane 6. We are currently working on the structural hardware for two engines on the Ariane 6 launcher. The Vulcain engine is currently in its third evolution, and the new upper stage Vinci engine will see its first flight on Ariane 6 in 2020.

**NAMMO IRELAND TODAY, AND TOMORROW**

At Nammo Ireland today we are working on the final production activities for the Ariane 5 Vulcain supports and the development activities on the Vinci engine supports. Our final Ariane 5 delivery will be in 2020. We are also preparing for the contract discussions on the Ariane 6 engine supports production. Nammo Ireland will make the first Ariane 6 hardware delivery in January 2019.

Just over three years ago we met some interesting people from Nammo Raufoss, who were looking at a totally green propulsion system using hydrogen peroxide. The management team in Dublin liked their enthusiasm and we decided to lend them a valve for a series of demonstration tests for a launcher application they were developing. The valve is still in Raufoss, but we plan to let it go to our product museum one day – it has served us all well.

Elsewhere, Nammo Ireland is supporting University College Dublin’s (UCD) MSc in Space Science and Technology by providing professional lectures on space program management, requirements generation and setting writing proposals to students. Nammo has also supported UCD in consultancy roles for a study on the feasibility of a space science and engineering center, and on a Nanosat program. The latter has cumulated in the EIRSAT-1 project – Ireland’s first satellite.

We have also developed a good relationship with key staff at ESA’s European Space Research and Technology Centre (ESTEC) in the Netherlands, and they are ready to support our next space valve developments.

Looking forward, we are confident that we fit well with the culture and philosophy in Nammo Raufoss, and we will have a long and successful future together.
La fábrica de armas means much more than a factory to the city of Palencia. It represents the result of decades of hard work, loyalty and dedication of generations of Palencia citizens; grandparents, parents, brothers, sisters, sons, daughters and, surely, grandchildren of the current Nammo Palencia employees used to and will work here. To many of them, the factory has become deeply embedded into their family history, hearts and minds.

During its 78 years of existence, the factory has held a major role in the social and industrial evolution of Palencia. It was the first significant industrial site in Palencia’s history, and has helped build and leverage the Spanish city’s industrial expertise to transform it into what it is today, an industrial hub.

Even decades before the acquisition, Nammo recognized the commitment of Palencia’s employees to their factory and the potential the site held, both in terms of its work ethics and the high quality products that were being produced for customers worldwide. In fact, Nammo Raufoss was a long-standing customer and used to procure medium caliber steel cases which would later be assembled in Norway with Nammo’s high performance projectiles. The two companies also cooperated closely to deliver medium caliber ammunition to the Spanish Armed Forces.

Four years have passed since Nammo acquired the Palencia factory. Luis Asensio explains the significance of the factory to its local community and how a quick integration has led to Nammo Palencia delivering the best results in its 78 years of history.
NAMMO PALENCIA IS BORN

On 16 October 2013, the long-term relationship between Nammo and Palencia was cemented as Nammo reached an agreement for the purchase of the factory and assumed Palencia’s existing workforce, assets, operations and production lines, therein assuring the future stability of the factory’s workers.

Nammo’s intentions were always to continue and further develop the Palencia operation as a competitive ammunition supplier to the Spanish Armed Forces as well as to international customers, supported by the Nammo group’s operations and capabilities. Not only were the Palencia products an important supplement to Nammo’s current portfolio of specialty ammunitions within the small and medium caliber product range, but the factory also shared similar values and a devotion to quality and service.

It was a good match on all counts, and an important acquisition for Nammo’s strategic growth plans. In a market where the supply chain is one of the most challenging matters to deal with, Nammo assured the production of a key component, the cartridge cases, and gained access to new customers and market areas where Palencia had a strong foothold. This customer portfolio created the base of the factory’s recent growth, supplemented by commercial opportunities from across the group.

A SUCCESSFUL INTEGRATION

Since Nammo Palencia was founded in 2013, the factory has retained 100 percent of its customers and successfully entered into markets that were previously out of reach. The integration process into Nammo was conducted in phases, where the first year focused on bringing IT, finance and management in line with the rest of the group, as well as initial commercial integration which was fully achieved in the second year. By the third year, the integration of small and medium caliber products was also completed, thanks in part to intense communications between the factory and the different departments involved.

One important factor in this success is the engagement of the local workforce – a good mix of wise, experienced and determined professionals who are eager to take the factory to the next level. From the very beginning, Nammo has supported Palencia by bringing in investments, orders, technology, strategy etc. and involved the team in all developments, forums and procedures, a proof of confidence that has been definitive in engaging and getting the best out of them. The Nammo Palencia team has corresponded by going the extra mile to implement new procedures and become fully integrated into the “One Nammo” family.

After only four years of joint history, Nammo and Palencia is a successful match. The quick and well-executed integration has brought an increase in revenue and significant cost improvements, and this success is reflected in Nammo Palencia’s initial performance figures: the site is already delivering beyond expectations and the best is yet to come.
Since Capstone Precision Group was formed last year, following the Berger Bullets acquisition, there has been a flurry of activity in Arizona and Missouri as our new distribution and production facilities have been established. As of 1 January 2018, the new distribution model for Lapua, Vihtavuori and SK in the United States is officially in place and Berger production is back in operation.

Bill Gravatt, President of Capstone Precision Group, reflects on the challenges, early milestones and future opportunities for Nammo’s commercial brands in the United States.

All of Nammo’s commercial ammunition products are now distributed within the United States from our new centralized distribution facility in Sedalia, Missouri, giving us greater control of our products, growth and destiny. With the addition of the Berger brand, and its established footprint in the United States, Nammo now has a stronger presence in North America and has the infrastructure to respond quickly to new opportunities in this growing market.

The Challenges
Capstone Precision Group was created with three primary missions: to produce and distribute Berger bullets, to produce and distribute Berger branded ammunition, and to import and grow the distribution of Lapua products, Vihtavuori powders and SK Rimfire products in the United States.

To achieve these goals, there has been a lot of work behind the scenes. Within the space of a few months, we have successfully replaced the old distribution model, upgraded systems and processes to best practices, built new facilities and teams, migrated our ERP systems, and we have relocated bullet production from California to Arizona.

A project of this massive scale is not without its challenges. The production team dismantled our equipment, moved it 379 miles to the Nammo campus in Mesa, Arizona, and brought it back into production within an extremely compressed time period, which is an astounding accomplishment in itself.
To complement the key Berger employees that moved to Arizona with the machinery, we have been fortunate to locate talented individuals from the Mesa/Greater Phoenix area, and together they form a focused, committed and success driven Capstone team that we are confident will help us achieve our production goals.

At the same time in Missouri, we took an existing structure and converted it into a centralized distribution/marketing center for all Capstone products and have staffed it with experienced employees from the local area. This facility began receiving Nammo products in December 2017.

**EARLY MILESTONES**

While production is now fully operational in Arizona and we are set to make millions of bullets here in the future that will ship all over the world, there was a very special moment on the production floor at 11:02 am on 31 October 2017, when our very first bullet was produced in the new facility. It was produced by Bullet Machine Technician Jason Bird on Bullet Machine #801, but in the true spirit of “One Nammo”, that first bullet was a combined result of the hard work and sheer determination of the entire Capstone team along with support and best practices from fellow team members within Nammo from around the world, and signaled the start of our new era.

We reached another significant milestone already on 27 September 2017, when the first Berger bullet jackets were produced on Jacket Press #4. Without these quality jackets, our entire production operation would come to a standstill, so it is just as important a milestone as the first bullet and absolutely critical to our success.

These early milestones may seem inconsequential, but they represented a significant step in establishing Capstone as an important entity in the shooting industry in the United States.

**FUTURE OPPORTUNITIES**

Now that everything has been put in place and set up for optimal business performance, we have started looking ahead at the opportunities present in the United States for Capstone and, in turn, Nammo. Our new distribution model will help us gain greater exposure for the commercial ammunition brands, as well as give us better control of the customer-facing side to ensure we uphold Nammo’s reputation for quality and precision throughout distribution and beyond.

We have already started exploring new partnering opportunities and refining our position within the market, and believe Capstone is perfectly positioned to help achieve Nammo’s strategic goals for North America. The team we have built has already accomplished so much and we look ahead to our future prospects.
BAKELITTTFABRIKKEN
A HISTORY OF INNOVATION

Nammo Raufoss, Aurskog, (previously Nammo Bakelittfabrikken AS) is a long-standing producer of plastic training ammunition and plastic components. We look back on the factory’s rich history of innovation with Trond Bergerud

AN EARLY PIONEER

Established in Oslo in 1946, Bakelittfabrikken was moved to Aurskog in 1955 and has been an important establishment in this small society ever since, but the factory has also played a significant role in the defense industry on a national and international level.

In the early 1950s, the Norwegian Army was using brass cased blank rounds with a wooden bullet. However, after many accidents involving soldiers being hit by fragments of the wood projectiles, the Army was looking for safer ammunition to use for target practice. Around the same time, Bakelittfabrikken introduced thermoplastics into its production and in 1953 invented the world’s first plastic blank ammunition.

Bakelittfabrikken’s solution was a blank round made of plastics, and the first contract with the Norwegian Army for delivery of the 7.62 x 63 mm plastic blank round was awarded in 1954. Continuing its groundbreaking developments, Bakelittfabrikken then introduced a plastic short range round in the late 1950s which enabled soldiers to conduct live firing and training even within limited space and safety zones.

Over the years, both the plastic blank and the plastic short range rounds have been developed in many different calibers and for many different weapons, from 4.6 mm up to 40 mm. In parallel with the development of the plastic ammunition, Bakelittfabrikken, in collaboration with weapon manufacturers and customers, was also crucial in the development of blank firing attachments and training bolts for different weapons.

DEVELOPING CIVILIAN PRODUCTS WITH A DIFFERENCE

Since that early contract was awarded, the Norwegian Army has been one of the factory’s most important customers, taking delivery of millions of plastic blanks and plastic short range rounds through the decades. However, Bakelittfabrikken was also deeply involved in the development and production of several innovative civilian products.

One civilian product of note was the plastic boat Pioner, which has been designed and produced in Norway since 1959, and is today exported across Scandinavia and Europe and highly regarded as a tough, maintenance-free boat for any conditions.
There was also the electric two-seat micro car, Think, which was originally produced with a plastic chassis. Designed and produced in Aurskog, it was one of the first modern electric cars to take to the road and was used during the 1994 Olympics in Lillehammer.

Although these products were originally developed at the Aurskog site, they were later split into separate companies, and when Nammo in 2005 bought Bakelittfabrikken, it only acquired the ammunition production side. This subsequently became Nammo Bakelittfabrikken AS, a legal entity owned by Nammo Raufoss AS.

**BECOMING PART OF NAMMO**

As the first company in the world to produce plastic blank and plastic short range ammunition, the acquisition of Bakelittfabrikken was a natural expansion of Nammo’s product portfolio and expertise, as well as a good match in terms of company values and a shared drive towards innovation.

The full range of plastic ammunition was integrated into Nammo’s marketing activities – presentations, exhibitions, promotional materials etc. – and an extensive internal process began to establish best practices and close cooperation with the Nammo group.

Then, in 2016, the group decided to merge Nammo Bakelittfabrikken AS with Nammo Raufoss AS to make the plastic training ammunition more competitive on the international market. The formal date for the merge was set to 1 July 2017, after which Nammo Bakelittfabrikken AS officially became a part of the legal entity Nammo Raufoss AS.

Six working groups were established with the sole purpose of harmonizing processes across all vital operational areas. While the majority of this work has now been fulfilled, some processes are naturally more complex and will continue for a while before they become fully integrated with the Nammo Raufoss processes.

This merger represents a significant organizational change that will help us better utilize synergies and streamline our processes to create a more efficient and cost-effective production. However, one core aspect remains unchanged: the production of high quality plastic training ammunition shall continue at Aurskog long into the future.

**BAKELITTFABRIKKEN INVENTED THE WORLD’S FIRST PLASTIC BLANK AMMUNITION IN 1953**
Nammo's vision: Securing the future

- We will protect our national and allied forces with high-quality defense products
- We will secure the future development of eco-friendly products, processes and services
- We will secure our continued growth based on a strong financial performance
- We will develop and secure a long-term, sustainable business for our customers and employees
- Our future development depends on a secure and safe working environment

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