Explorers Club Flag Report 215

MARS the MAGNIFICENT 2014
Imagine, the year of our lord 1564, the 31st day of May, outside a stormy Swedish coastline.
MARS the MAGNIFICENT 2014
- An expedition deep into history, to the time when nations were born, kings ruled supreme and legends were made.

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Expedition Dates: June 27th to July 19th, 2014.

Location: Baltic Sea, Swedish national waters east of Öland.

GPS Coordinates: 56.7454932N - 16.6341766E, depth 250 feet.

TEC Flag#: 215.

Photo 1: Richard Lundgren Fl’12 hovering over the Explorers Club Flag 215 gently placed on top of one of the more than 120 bronze cannons onboard Mars. Photos: Ingemar Lundgren, Ocean Discovery.
Expedition overview

*Mars the Magnificent* was King Erik XIV’s greatest warship, unequaled and unrivaled in the world at its time. The mighty ship was a brutal expression of a king with growing ambitions at a time when city-states developed into nations during the late 16th century. King Erik XIV, true to his Machiavellian inclinations, was convinced that a prince must have no other objective, no other thought, nor take up any profession but that of war, its methods and its discipline, for that is the only art expected of a ruler. This belief gave birth to one of the mightiest and most modern fleets of the world, and drove northern Europe into centuries of war, leading to the Swedish golden era. It also left a legend still alive today: The legend of *Mars the Magnificent*, her might, treasure and the curse.

The legend of *Mars the Magnificent* was revitalized in 2011 when, after an epic, 20-year wreck hunt, a group of divers finally discovered the wreck site. The discovery of Mars is now considered to be one of the most significant of our time and firmly places Mars as one of the most important historical monuments in Europe.

The Mars the Magnificent 2014 expedition sets out to explore the Mars wreck site, its surroundings and to investigate the legend. Some of the scientific questions the expedition sets out to further advance our understanding about are:

- How was Mars was built and constructed?
- What were the living conditions of the men who lived and died on board?
- How was the battle fought?

The scientific goals can be summarized to include:

- Research the historical significance of the Mars wreck site.
- Share discoveries with local, national, and international scientists, scholars and museums.
- Display major discoveries in museums or special exhibitions, while still allowing researchers to work on these discoveries as needed.

The scientific future ambitions include:

- To further develop deep-water scientific diving methods.
- To develop tools and methods for non-intrusive archeology including deep-water photogrammetry.
- Together with partners, complete a documentary that captures the compelling history, the furious naval battle, and the modern adventures of explorations as well
as the state of the art scientific methods.

The Mars the Magnificent 2014 expedition was conducted over a three-week period stretching between June the 27th and July the 19th. During this time more than 65 individuals were involved in the expedition. Eight scientists from different disciplines participated together with professional surveyors, divers, ROV pilots, technicians, boat crew and chefs. In total, 211 man dives were performed, documenting the site using 6k video cameras, still cameras and sonar systems. This produced a tremendous amount of data for the scientists. Close to 100 hours of remotely operated vehicle (ROV) video was also recorded during the expedition.

This report will share some of the findings and give a unique insight into what became one of the world’s largest marine archeological expeditions during 2014. With this report the author also hopes to inspire others to excel in their efforts to explore and discover their surroundings and to never give up on their dreams. The desire to explore is one of the oldest and most important drives of mankind. Without this drive, the world would be static and the future would be repetitious; both dull and predictable.

**Expedition explanation**

In the summer of 2011, after many years of searching, a team of divers from Ocean Discovery discovered the wreck of Swedish King Erik XIV’s legendary flagship Mars. The final resting place of Mars is the focus of the Mars the Magnificent 2014 expedition. Mars sank May 31st 1564 outside the Swedish island Öland, in central Baltic Sea. Sweden, now part of the European

![Figure 1: Sweden is situated in the northern part of Europe.](image-url)
Union, is situated in the northern part of Europe. The wreck site is situated 12 nautical miles southeast of the small fishing harbor Böda, surrounded by the scenic island landscape typical of the region.

Modern Sweden started out of the Kalmar Union, formed in 1397, and by the unification of the country by King Gustav Vasa in the 16th century. Gustav Vasa, father of Erik XIV, is commonly referred to as the historic father of the nation as he instigated the war of liberation, managing to break free from the much-despised union with Denmark. Erik XIV continued his father’s efforts to grow Sweden as a nation, resulting in war with neighboring nation, city-states and kings. In the 17th century, Sweden expanded its territories to form the Swedish empire. Most of these conquered territories had to be given up during the 18th century. In the early 19th century, Finland and the remaining territories outside the Scandinavian Peninsula were lost. After its last war in 1814, Sweden entered into a personal union with Norway, which lasted until 1905. Since 1814, Sweden has been at peace, adopting a non-aligned foreign policy in peacetime and neutrality in wartime.

The Baltic Sea is one of the best places in the world for shipwreck archaeology. One reason for this unique gift is that most of the organisms that would damage wrecks, including the shipworm, *Teredo navalis*, cannot exist in the brackish and cold waters of the Baltic. Another factor is topography, especially along the coasts of Sweden and Finland. The vast archipelagos consist of a plethora of small islands and reefs, which make navigation difficult. Between the islands, the bottom is relatively deep: In this calm, dark, and cold environment, time seems to almost stand still. The absence of a significant tidal period in the Baltic also means that erosion by flowing water, which can break down and wear on shipwrecks, is not a factor. As a result, ship hulls may be preserved intact for hundreds of years; some with masts still standing. There are other places in the world with similar physical conditions for preserving wrecks, such as the Great Lakes in North America or the polar oceans. However, there is another reason the Baltic is so special for maritime archaeological studies. This small, northern European inland sea has, for a long time, been heavily trafficked, and the number of shipwrecks indicates the number of ships that once traveled these waters. Intensive maritime communication, trade, and shipping, as well as naval warfare, can be traced back to prehistoric times. Seafaring is a central part of the region’s history. The Baltic Sea is, in that respect, a northern version of the Mediterranean Sea, which also served an important role in maritime history.

Figure 2: The X marks the final resting place of Mars
The exploration of *Mars the Magnificent* is important for a variety of reasons. The opportunity to study a 450-year-old archeological site is uncommon but several factors make *Mars* unique:

- *Mars* was the largest man-of-war of her time. She was a new design with more bronze cannons than any ship before her.

- *Mars* sank during a furious and brutal two day long naval battle fully, equipped and manned for battle. *Mars* did not sink due to a design flaw or due to navigational mistakes. She was overwhelmed in battle, and fire broke lose, resulting in a tremendous explosion which took more than 600 men with her down to their watery graves.

- *Mars* is a perfect time capsule, undisturbed and protected by 75 meters of dark, cold water with low salinity and oxygen levels.

- The state of preservation is unrivaled. The entire wreck including all the wood, cannons, artifacts and human remains rests on the bottom of the sea.
• *Mars* sank in deep waters, 75m or 250 feet, making it impossible to salvage its treasure and cannons during the time of sinking and many hundred of years after her demise. She rested undisturbed for 450 years, silently guarding her integrity and her legends.

*Mars* presents a rather unique opportunity to study an undisturbed 16th century capital man-of-war. This makes all relevant efforts important; the knowledge accumulated will enhance our current understanding of the ship, shipbuilding, how battles were fought, Swedish society as a whole, as well as culture, life, and death onboard. Finally, investigation into the very origin of human conflicts and how survivors of these horrific events acclimatized back into a normal life as civilians completes a fascinating list of potential research opportunities.

The scientific archaeological study of *Mars* is a part of a multidisciplinary research project at Södertörn University called “Ships at War - Early-Modern Maritime Battlefields in the Baltic.” The study is also a unique collaboration between the Maritime Archaeological Research Institute (MARIS) at Södertörn University, The National Defense College, and the companies Ocean Discovery, Deep Sea Production, and Marin Mätteknik (MMT). An international television documentary has been created to feature the archaeological study.

The capacity for these diverse organizations work together on such a project is uncommon and has gained international interest. Companies and universities are responsible for different specialized knowledge. We are convinced that cooperation between academia and industry can give us new insights and perspectives, both of which may generate new scientific results and contribute to strengthening the company’s abilities and competitiveness. However, regardless of all scientific, practical, and economic benefits of our collaboration, what really links those involved in the Mars the Magnificent 2014 expedition together is that diving, exploration, and solving mysteries is challenging, exciting, engaging and, in a word: fun!

**Permits**

The wreck site of *Mars the Magnificent* and the surrounding area, a 1000-meter radius from the center of the site, is protected by Swedish and international law, 2nd chapter 9§ of the Heritage Conservation Act (KLM). Within this area any underwater activity is strictly forbidden. Even survey activities on the surface are not allowed. No other wreck in the Baltic Sea has the same level of protection. The Swedish Navy and Coast Guard enforce the law using ships, airplanes, radar and hydrophone systems. The county administrative board of Kalmar can issue special permits for scientific expeditions to the site.

On June 17th, 2014, Ocean Discovery and MARIS secured permit #431-4225-14, and were authorized to conduct site surveys and underwater operations on the Mars wreck site between June 23rd and October 30th 2014.
Voluntarism

The *Mars* expedition is a voluntary expedition. All participants chose to commit their time without financial compensation for their expenses. Experienced divers, fully cognizant of the myriad risks involved in such an expedition, performed the underwater exploration.

Priorities

The overruling priority of the expedition was safety. Every stage of the expedition including the dive operation was carefully examined and evaluated. Dive plans involving objectives and operations with an elevated element of risk were either rescheduled or rejected. Acceptable risk involved the chance of divers experiencing manageable and resolvable equipment malfunctions. These are events that potentially could occur, such as loss of navigation, inability to locate or loss of ascent line, team separations and injuries such as DCI. If the diver, the dive team and the surface support had the capacity to manage a potential risk, the risk was defined as acceptable.

The Heritage Conservation Act (1988:950)

*Mars the Magnificent* and the area surrounding the wreck is protected according to the Heritage Conservation Act (KLM). Carelessness or negligence harming or affecting the historical monument will be prosecuted by the state. The expedition participants received a thorough briefing about the implications of this act and how it impacted their activities. A personal copy of the Heritage Conservation Act was distributed before the start of the expedition.

Figure 3: The expedition permit
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Research vessels and dive boats

During the project time period, the *Mars* expedition was comprised of two large research vessels, two dive catamarans, two RIB’s and a crew ship. The survey company Marin Mätteknik (MMT), which can be contacted at www.mmt.se, was a major contributor and supporter of science in general and the *Mars* project in particular. MMT’s contribution did not end with the ships and crew; the company also supplied state of the art ROVs and advanced sonar systems.

IceBeam

IceBeam, the largest research vessel in the expedition, was frequently called upon for ROV operations, geotechnical sampling, geophysical seabed mapping and environmental assignments. During the expedition, IceBeam spent 32 days at sea relentlessly surveying not only the wreck site and the surrounding area but also the entire sector the ships contested during the two-day naval battle. This tremendous effort resulted in the discovery of more than twenty new wrecks, a high-resolution multi beam sonar mosaic of the entire area and close to one hundred hours of ROV video inspecting targets and artifacts.

Photo 3: IceBeam was used to precisely position the 400.000 lumen light rig on the desired areas of the wreck, providing illumination for the video and photogrammetry production teams. Photo: Richard Lundgren, Ocean Discovery.
Photo 4: The research and survey vessel IceBeam is 130 feet in length and capable of performing seabed surveys in water depths of 20 - 1700 feet. IceBeam is equipped with a differential positioning system (DP) allowing her to hold and maintain her position in the sea without having to anchor during dive and ROV operations. The vessel is operated by a crew of six and manned with 4-11 surveyors. Photo: Richard Lundgren, Ocean Discovery.
Askholmen

Askholmen was the main dive vessel for the expedition, from which the video documentation teams worked. She is powered by two Rolls-Royce Kamewa waterjet systems, which provide excellent maneuverability. Her wide hull provides a stable platform. Askholmen is fully equipped for coastal and hydrographic surveys and ROV inspections. She is 70 feet in length and a specialist near-shore vessel for high-resolution hydrographic mapping in water depths of 10 - 850 feet. The vessel is designed with shallow draught and compact dimensions, which enables 12-hour operations in remote areas with shallow water depths. She has the capacity to carry a 20-foot container on deck for shallow water geotechnical operations.

Crimson Tide

Crimson Tide is a 42 feet catamaran, build by Catapult Catamarans in the UK. She is powered with twin 400hp computerized Iveco diesel engines, which give her a 20 knt cruise speed. She is fully fitted out for advanced dive operations and provides a spacious, wide and stable platform for up to ten divers at a time. This vessel was used mainly by the scientific divers during the expedition. Crimson Tide is owned and operated by the global divegear manufacturer SANTI, a company which graciously supports the expedition with equipment and world class photographers.
Dive site

_Mars the Magnificent_ lies on the seabed at a depth of 250 feet. The shallowest point on the hull is 200 feet deep and the average depth for a diver exploring the site is usually 230 feet. It takes a dive team about five minutes to descend down to the wreck: Five short minutes to time-travel back 450 years.

During the descent, one notices very little of the increasing water pressure but the water rapidly gets colder, much colder, and the ambient light disappears gradually, leaving one both chilled and in absolute darkness at depth. The water temperature is stable at depth and rarely warmer than 40°F even though the surface water during the warm summer months can be as high as 70°F.

The visibility at the surface and down to 20 feet is reduced to just a few feet due to algal bloom. Unfortunately, the problems of eutrophication, algal blooms, toxic waste and threatened biodiversity are growing ever greater in the Baltic Sea. Deeper than 70 feet, the visibility improves and at the wreck it can be greater than 40 feet horizontally. In 2014,
descending dive teams could clearly spot other divers working on the wreck when as shallow as 100 feet from the surface.

The wreck is encapsulated in cold, oxygen-poor brackish waters with low salinity levels. Currents at the bottom are uncommon and when currents occur, they tend to be mild. The current is not caused by tidal changes but from water movements in general. These mild and infrequent currents limit the corrosion of the site and help to clear away finer silt and sediments. The seabed composition varies around the wreck site. The bottom the port side is made up of mostly gravel, small stones and clay, while the area outside the starboard side is more porous and composed of silt sediments, which cover objects and artifacts. A careless diver can easily disturb the sediments and seriously reduce the visibility in this area of the wreck.

Although water and sediment samples were taken close to and from the bottom sediments for confirmation, evidence of galvanic corrosion was easily apparent: Aluminum cylinders containing safety gas were left hanging 10 feet off the bottom and all of these cylinders corroded noticeably in less than two weeks. The origins of this powerful galvanic reaction is unclear at this time but a common joke among the divers is that the corrosion is caused by the more than 4000 gold coins said to be hidden among the wreckage.

Photo 7: The Baltic Sea has the largest areas of oxygen-poor seabed in the world. The total area of dead sea bottom has grown ten-fold during the last century, a phenomenon unfortunately attributable to humans. Photo: Tomasz Stachura, Ocean Discovery.
Areas of the seabe are covered with bacterial and microbe growth, suggesting a dead layer of bottom sediments. The white-colored sediment in these areas indicates white sulfur bacteria. The presents of other microbes cannot be ruled out and future samples and studies are recommended.

Dive methodology

The diving methodology and standard operating procedures used during the expedition originate from Global Underwater Explorers (GUE). Global Underwater Explorers emerged out of a shared desire to safely explore and protect the underwater world and to improve the quality of education and research in all things aquatic. Working to redefine the ties binding the average underwater enthusiast to underwater explorers, conservationists and scientific researchers, GUE is committed to the overall goal of promoting the interests of the underwater world and of those who seek to engage it. GUE procedures are used by world-renowned explorers as well as by scientists.

The expedition divers operated a wreck site 250 feet down in the cold ocean. In order to accomplish this dangerous operation with the largest safety margin possible, the divers used rebreathers. Rebreather systems use helium-enriched gas mixtures to eliminate nitrogen narcosis and to reduce the effort of breathing. The density and narcotic level of the respired gas at 250 feet depth are comparable to breathing air at 70 feet. That means the gas is considerably less dense and less narcotic and as a result safer for the divers. The dive teams also used standardized gases. The diluents gas for the rebreather is taken from the same cylinder as the bottom bailout gas, therefore the gas composition is the same: 12% oxygen 65% helium and 23% nitrogen. This gas is commonly referred to as 12/65 trimix and has the favorable breathing characteristics explained earlier. The divers also carry bailout decompression gases, comprised of 50% nitrox and 100% oxygen, in appropriate quantities. Bailout gases are mandatory as the rebreather systems can fail, resulting in reliance on the open circuit scuba system during the ascent.

The rebreather systems used allowed for bottom exposures up to 45 minutes plus decompression time, which resulted in total dive times close to 200 minutes. Typically the decompression stops commenced at 130 feet and ended at 10 feet or, to be pedantically correct, at the surface. During decompression, the pressure reduction between the ambient pressure and the gas dissolved in the body tissues must be reduced slowly in order to prevent the creation of bubbles. Unless decompression is done properly, these bubbles may result in decompression illness (DCI).

As with any deep, cold water dives, the total duration of the expedition dives was restricted by two main factors. The first was the ability to remain reasonably warm during the exposure
The second was the rebreather system’s ability to effectively remove carbon dioxide from the recycled breathing gas. Undergarments made out of 400gr 3M Thinsulate materials were used to maintain warmth during the dives. These undergarments also have electrical heat systems, which increased the comfort around the chest and abdominal area as well as the hands, where the circulation is reduced. Hypothermia was a real danger during the dives, and something seemingly as trivial as cold fingers might have significantly compromised safety. During the 2012 expedition the author of this report suffered an equipment failure, leaving his drysuit full of 40°F cold water at maximum exposure: 40 minutes bottom time at 230 feet. The author had to suffer through 180 minutes of frigid decompression before being able to break the surface and slowly warm up again.

Video documentation

One of the 2014 expedition goals was to complete the video documentation initiated during the 2012 project. This video material will be used in a TV production that will air internationally through the main broadcasters during 2015. The documentary film is being made as a cooperative effort between Ocean Discovery and Deep Sea Productions, in conjunction with the German ZDF and Terra X networks. Future partners may include National Geographic TV, NOVA, ARTE, SVT, NRK and DR among others. The challenge is to bring the legendary ship back to life and to illustrate the compelling history of Mars, as well as the fascinating details of the wreck site itself.

Shooting cinematic video underwater is challenging in the best of circumstances, and the dark and cold conditions of the Baltic Sea make it more difficult still. The biggest obstacle is sufficient light for studio-quality illumination. As there is no ambient light at depth: the video team relies on handheld lights and occasionally a 400,000 lumen light rig lowered down to the site from a surface vessel. One concern with handheld lights or lights mounted on the camera housing is backscatter. Backscatter occurs when light beams reflect back into the lens when they hit particles in the water. The result is images that look as if they have been shot in a snowstorm. This can be avoided entirely if the light source is moved further away from the camera lens. To achieve this the camera housing is equipped with two dimmable lights on long arms. These camera lights are used to carefully illuminate some the foreground and the object or model. Powerful hand-held lights are used to illuminate the area behind the object being recorded. This avoids backscatter and provides depth to the images. The hand-held lights can also be used to provide back light effects creating a halo around objects and artifacts. The hand-held lights are never used to illuminate the foreground or the front of the object or model. A weaker hand-held light can be used as key light if the foreground or object needs light from a different angle to create or remove shadows or create artistic illumination effects. The model can use a weak light to provide a face light during a shot. This technique is common when shooting extreme close-ups of a diver’s face or eyes as it allows the light source to remain concealed out of the shot.
During the expedition, the video production was meticulously planned and rehearsed on land before the dive, to ensure that the entire team understood and retained the planned shots. Typically no more than four scenes were planned at a time, in order to avoid confusion underwater. The cinematographer, Eric Börjesson, and the director, Martin Widman, were an integral part of this process.

The production team settled on using the Red Epic and Red Dragon cameras after careful evaluations and tests. These 5k and 6k cameras provided unparalleled image resolution, light sensitivity and dynamic range favorable for the harsh conditions of the Baltic Sea.

Photography and photogrammetry

Still images were important to gather for future exhibitions, as they will help to present Mars for the public. However, just as with the video work, photography at 250 feet depth without natural light was challenging.

Moreover, when divers and not remotely operated vehicles were involved, the divers were also subject to the limited bottom times, and the total darkness in which the wreck rests. At depth on Mars, the flashes on the camera reached a maximum ten feet and had to be placed on long arms to avoid backscatter. The divers were required to carefully swim over the wreck to avoid stirring up silt sediments. Still image photography was used to document the interesting objects and artifacts and will also be used to create 3-D models using photogrammetry techniques. The 3-D models created provide precise measurements. This allows scientists to study objects on the surface rather than at great depth underwater.

Ingemar Lundgren, Carl Douglas, Tomasz Stachura and Jonas Dahm were the expedition underwater photographers. Ingemar Lundgren used a Nikon D800 camera with a 16-24 mm VR lens. The Nikon D800 provided an extremely high resolution of 36 megapixels, allowing ample opportunity for detailed studies. This camera is preferred for photogrammetry. Jonas Dahm and Carl Douglas used Canon 5D MK2 cameras. Carl Douglas focused on macro photography, the art of taking extreme close-ups of small objects.

As part of the development of a 3-D model for the television production and for a non-intrusive archeology project, Ingemar Lundgren, assisted by his team, performed stereoscopic photogrammetry photography with remarkable result. Due to this work, the entire wreck site with its numerous cannons, timbers and artifacts will be able to be recreated in an exact 3-D model with photographic texture retained. Worldwide, this is the first 3-D production of such tremendous scale and complexity.
Tomas Stachura used a Nikon D700 camera with a 14-24 mm lens, which provided reduced distortion, and allowed him to create a photo mosaic over the entire wreckage. Tomasz used large aperture, F5.6 and ISO 2500 for strobes, to penetrate as far as possible. A spirit level and a depth gauge was placed on the UV housing to assist the photographer maintain the correct perspective and scale. The port hull side of the wreck is more or less intact, which gave the photographer navigational reference points. The starboard side is more complex and challenging to navigate, which forced the photographer to use strobes and guidelines. The finished mosaic is breathtaking and is a result of 640 images stitched together. We believe the Mars mosaic to be unique in both detail and complexity. The accomplishment becomes even greater considering the severe production conditions.
Expedition target

Imagine, the year of our lord 1564, the 31st day of May, outside a stormy Swedish coastline.

The smoke from the fires is thick; heat and poisonous fumes from gunpowder are mixed with screams of terror and agony. The sound of blades hitting steel, continuous musket fire and bursting cannon balls is deafening. A cannon ball screams by closely and smashes with devastating force into the railing. Wood and metal splinters cut down gun crews toiling at their weapons on the gun deck. The decks are awash in the blood of the injured crew, making footing treacherous as the youngest members of the crew, the 12 year old deck-hands, pour sand on the deck to help the gun crews fight on. On the top deck of Mars, the remaining Swedish soldiers are fighting courageously and repel wave after wave of boarders. The situation is
desperate, the ship is on fire, and it’s only a matter of time before the fire will reach the magazines. To surrender, and lower the flag, is unthinkable. This is far from a gentleman’s battle: To be captured equals being put to death in the most gruesome way, as vivid deterrence to others. Only those few of noble blood can hope to be held for ransom. The Danish-Lübeck soldiers are driven by a frightening urgency to capture Mars, claim her and thus get a share of the ship’s bounty. This goal is far more important to the commoner than the royal ambitions of noble lords and Kings. Cannon balls from Mars and her attacker continue to cross the short distance between the ships, locked together rail-to-rail by grappling lines, weaving a deadly spider web of smoking destruction. Forty-pound cannon balls hit with the force of a thousand jackhammers, shattering bridge timbers and turning the interior spaces of the enemy ships into abattoirs. Cries of pain are mixed with howls of aggression and anger from the battling soldiers. Suddenly, a powerful explosion shakes Mars, forcing the deck to lift upwards and throwing the battling combatants to the deck. Mars struggles in what is clearly the last moment of her life, her eventual demise now a foregone conclusion. This is the end for Mars: the once glorious battleship is sinking. Swedes and Danish-Lübeck alike desperately try to abandon the sinking ship while the heat from the burning Mars causes the water around her to boil like the devil’s own cauldron. An enormous cloud of steam rises, like a ghost, out of the ocean. Mars the Magnificent is nowhere to be seen.

Swedish war of liberation

A fragile peace was all that remained after the signing of the treaty 1524 when Sweden broke out of the union with Denmark and Norway. The hatred among the Swedish nobility towards the Danish King Christian the Tyrant did not fade, and the memories of the horrors and humiliation of the Stockholm bloodbath were still fresh in the minds of the people. The mind of the Swedish King Erik XIV was focused on the goal of revenge, the dream of finally breaking free of oppression and the birth of a nation, unchained. The whole situation is reminiscent of the American War of Independence only hundreds of years earlier, and much more brutal.

War and heroism

_Mars_ sank on the 31st of May 1564, after a brutal two-day naval battle involving more than 60 man-of-war ships. Despite this ultimate defeat, _Mars_ succeeded with something extraordinary, something that had previously never happened in history: She sank one of the enemy’s admiralships with her cannons alone. Despite a desperate defense and heroic actions, during the dramatic finale of the battle, _Mars_ finally succumbed, and was abandoned by the Swedish fleet. The ship was boarded and fire spread, leading to a tremendous explosion that sent the fore mast into the sky like a shooting missile. _Mars_ sank below the surface, still burning, while water boiled and steam rose around her. Mars was lost but in so doing she gave birth to a legend that survived for 447 years.
This masterpiece painting captures the intensity of the furious naval battle that raged outside the Swedish island Öland in 1564. Mars the Magnificent is shown as desperately outnumbered, surrounded by enemy ships. The artist, Pieter Cornelisz van Soest (born ca. 1600–1620, flourished ca. 1640–67), was a Dutch marine artist, especially prolific in battle pieces.
The discovery

The sensational discovery of the legendary ship *Mars the Magnificent* made headlines around the world in 2011. After a 20-year search, a group of divers finally discovered what proved to be an undisturbed wreck site and battlefield. It was clear from the beginning that the discovery of *Mars* and her preserved wreck site was a sensation with no equal anywhere in the world. *Mars* was probably the largest and most capable warship of her time and she was considerably larger than *Vasa*. *Mars* was outfitted with 121 bronze cannons, compared with “only” 72 cannons onboard *Vasa*. *Mars* is truly one of the most magnificent archeological discoveries of our time.

The discovery was only made after an epic 20-year wreck hunt involving the survey of millions of square meters of cold seas. The account of the discovery includes the efforts of a small group determined to carry on a childhood dream of adventure and discoveries. It is a story of adventures at sea and drama on land as two unevenly funded teams competed to make the discovery of a lifetime. At its heart, it is a true underdog story, where the most determined team succeeded, and at the same time managed to heal lost friendships, bring two teams back together and create triumph for all.

The wreck site

The *Mars* wreck site is large and complicated. The wreckage is spread out over 500 meters and it is actually possible to follow the final hours of the battle, step-by-step from the traces it has left on the sea bottom. Cannon balls, parts of the rigging and masts as well as personal artifacts and parts of bones are evidence of the brutality of war. The main wreckage itself, including both hull sides, is relatively intact in the middle of this area. Cannons of different dimensions and calibers litter the seafloor in unprecedented numbers. Everything that was onboard during the time of sinking is still there, resting in the dark, including the legendary war treasure that King Erik XIV entrusted to Admiral Jacob Bagge.
Figure 4: The Mars wreck site illustrated by Alexander Rauscher.
Photo 10: A magnificent wreck. Mars was built to be an unsinkable fortress, but no wooden ship is safe from fire. A burner ship from the Danish/Lübeck fleet sneaked up on Mars during her first major battle, on May 31, 1564 just north of Öland in the Baltic Sea. During the ensuing fire, hundreds of enemy soldiers boarded the admiralty ship to loot it, but an explosion in the forecastle brought down the whole ship together with an estimated 600 men.

After decades of searching, the wreck was found by Ocean Discovery in 2011. An easily identifiable bronze cannon confirmed the identity of the ship. Because of the explosion, the hull has collapsed, but large sections of the ship are still intact. The wreck site contains guns and other artifacts of immeasurable value – not least as evidence of a crucial epoch in European history.

This photo is actually a photo mosaic: 640 individual images have been carefully stitched together to complete the mosaic. The mosaic of Mars is uniquely detailed as every image contains 36 megapixel data, pushing the resolution to 6144x4912 pixels. Another impressive aspect of this mosaic is that it was competed in total darkness at 250 feet. Photo: Tomasz Stachura, Ocean Discovery.
The treasure and the curse

The legend speaks of a large treasure that followed Mars to her watery grave. Historical documents reveal that that King Eric XIV indeed loaded a war treasure on Mars. The intended use of the treasure was to purchase a mercenary army. The treasure consisted of 220 thousand silver and 4000 gold coins, making it by far the largest in the Baltic Sea. During 2012 the dive team discovered the treasure and the legend came alive! Coins have since then been recovered and preserved for museum exhibition.

Many of the bronze cannons onboard Mars was casted using bronze. About 20 % of the bronze came from melted churs bells confiscated from Chatolic chureses by King Gustav Vasa during the reformation. This gave birth to the legend that the Kings ship was cursed and also offered a convinient excuse and explanation to why the mightiest of ships could be defeeted

Documentary

Ocean Discovery, in cooperation with Deep Sea Production, is producing a documentary TV series focusing on sea battles. The story of Mars is the starting point of this series, which will
feature science, dramatizations and reenactments. Computer animations will allow the viewer a chance to experience how naval battles were fought and how mighty warships like Mars the Magnificent once ruled the seas. Production has already commenced and will follow the divers and scientists progression during the following years. Cameras with five times the resolution of high definition TV, along with advanced light riggings will allow the dramatic wreck site to be captured in all its glory. Books, articles and scientific reports are also in production.

Exhibition

For 447 years Mars has rested undisturbed on the bottom of the Baltic Sea. In that time the crown jewel of the Swedish fleet, once a brutal expression of a newly formed state’s growing ambitions, has been transformed into a shipwreck. Centuries have passed and time has taken its toll but the brackish waters of the Baltic have preserved the ship well and it can now be viewed as a priceless time capsule. The discovery of Mars unleashes amazing new insights and knowledge about life during the 16th century, this eventful period of shipbuilding and the evolution of naval battle tactics. Mars the Magnificent is now exhibited at the Västervik Museum. During 2013, the exhibition expanded and some of the unique silver coins that were recovered during 2012 were displayed. Future plans include the addition of cannons and other objects to the exhibition, making it truly unique.
Assisted by high-tech sonar equipment, the wreck site continues to be surveyed and mapped with great accuracy. A 3-D model has been created in order to digitally rebuild the ship in all its might and splendor. This 3-D image gives a fantastic overview of the entire wreck site, something crucial for battlefield archeology and equally important for visitors at exhibitions and museums. A variety of science projects focused on many different aspects of Mars are also in progress. Life onboard a 16th century warship during battle, ship building techniques, metallurgy studies of cannons, and the role of warships in the society are but a few examples of these ongoing scientific projects. Mars sank with more than 800 combatants and sailors on board. They have left numerous remains and artifacts that enable scientists to create and describe life on board and also offer a glimpse of 16th century life. Mars is incredibly unique, a closed and undisturbed time capsule, waiting to provide answers to a steadily growing number of questions.
Photo 14: Using photogrammetry, areas, in fact the entire wreck, can be 3D scanned and exact models created. Photo: Ingemar Lundgren, Ocean Discovery.
Expedition results

The *Mars* expedition: Deus dat cui vult. *A legend comes true.*

By Richard Lundgren, FI’12, Ocean Discovery

During 2012, one of the greater surprises of the expedition came about by mere chance. A small shape caught the attention of a diver; something glistened in the corner of his vision. A film team working a complicated back light shoot at the starboard side of the wreckage was fortunate enough to notice something reflecting in the powerful video lights, just where two cannons protrude through the hull. Little did they know, they were about to revitalize a 450-year-old legend.

Upon inspecting the source of the light reflection, the divers, Fredrik Skogh and Richard Lundgren, discovered a large silver coin, estimated 1.2 inches diameter, darkened by the years of oxidation and embedded in the deck timber. It appeared the coin had been forced into the massive oak timber: Could the explosion have been so powerful as to cause this result? This is speculation at this point, of course, but future investigations may provide an answer. Upon careful inspection, the area yielded several other coins, some with different shapes and dimensions. Most of the coins lay scattered on top of and underneath the deck timbers covered by only a thin layer of silt.

Ever since the loss of *Mars*, the legend that the mighty ship sunk with more than cannons and a great loss of human life has prevailed. Legend tells that *Mars* also brought the entire Swedish war treasure with her, down to her watery grave. The myth speaks of a silver treasure that would make even Marcus Licinius Crassus weep of envy. These legends indeed find support in the historical records. *Mars* did carry a considerable amount of coins onboard. The records indicates that 200,000 silver dalers and 4000 gold coins were secured onboard the admiral ship *Mars*. The present day value of this “war treasure” is hard to estimate but can be estimated to 140 million SEK or 22 milion USD for the silver dalers alone. Today the Erix XIV silver daler minted 1563 is extremely rare, making the numismatic value considerable higher. The purpose of this fabulous treasure was to hire a mercenary army in the northern part of what is now Germany and thus have the capacity to invade Denmark from the south. It was a cunning plan, but it met an abrupt ending on May 31st 1564.

Upon the discovery in 2012, the County Board of Kalmar promptly issued a permit allowing for protective recovery of three silver coins, a task that was gladly taken on by the team who made the discovery. The dive team prepared a plastic box with a sealing lid and Ziplock flexible plastic bags to protect the coins during the recovery process. Before the recovery, the coin site was photo and video documented and each individual coin was geo-referenced. The recovery was successful and the coins were brought back to the surface. These coins were the first *Mars*
objects to return to the surface, 450 years after the sinking. After a brief study and documentation at the site the coins were transported to the Vasa Museum in Stockholm for conservation. Two of the recovered coins were circular in shape, typical of silver daler of this time. The third coin was smaller in size compared to the daler and had a square shape typical of a klipping. The coins were scaled in the field, revealing their individual weights. The silver dalers’ individual weights were 30 g respective 24 g and the klipping 18 g. The coins were in a remarkable state of preservation and on the silver dalers, parts of the inscriptions and image could be studied immediately, without any cleaning. The image of King Erik XIV with regalia, crown, scepter, sword and orb adorn the coin motif on the obverse of the silver dalers. The King’s device circles the coin legend and reads “Deus dat cui Vult” meaning “God gives to whom He wishes.” King Erik XIV is not remembered through history as a humble man. The Swedish coat of arms adorn the reverse side of the coin, with the legend “Guds nåde och Svea Goter och Venders Konung” meaning “Godsend and the King of Swedes, Gots and Venders.” Or in latin, “Dei gratia Sueorum, Gothorum et Vandalorum Rex.”

During the 2014 expedition, additional coins were discovered in other areas of the wreckage, indicating that they are spread out widely over the site. All individual coin findings were carefully geo-referenced in order to provide context and to answers the questions of when, how and where the coins were located at the time of sinking. Were they secured in a
compartment below deck or were they being looted, carried in chests up onto the deck when the ship explored and sank?

[Image: Photo 16: Eric XIV Daler 1562]
The Mars expedition: Background and historical context to the coins

By Kenneth Jonsson, Stockholm University

From studies that have been previously made of warship wrecks, it is clear that the coins were present in large number on board. The most famous are the Vasa (1628), with more than 4200 coins and the Crown (1676), with about 17000 coins. The Vasa was not fully equipped when she sank and coin finds consist almost entirely of copper and therefore reflects the coins used by individuals from the lower social ranks. The Crown has findings that reflect all social ranks of the 17th century society, but above all, the results can be linked to the admiral on board, Lorentz Creutz, i.e. the top layer of society.

When Mars sank in 1563 silver coins were minted in Sweden in a variety of domestic mark and öre denominations, as well as the silver daler, an international trade coin with a high face value. The domestic denominations were minted annually, but the silver daler, which was first minted in 1534, was minted more regularly during the reign of Erik XIV. In addition, there were foreign gold and silver coins. The latter were almost exclusively foreign counterparts to daler (taler, Daalder, etc.). The findings from Mars might therefore be expected to give an interesting insight into the coins brought on board the Navy's largest warship of the mid-1500s.

The investigation of Mars found three coins on the deck and they give an indication of the findings that can be done in future studies. All three are Swedish coins of high denomination from Eric XIV. Two silver dalers are from 1563 i.e. the highest valued coin minted in Sweden and the third coin must be, judging from the size and shape, to be 16 öre (klipping).

The silver dalers have the King image on the obverse and large Swedish coat of arms on the reverse side. The klipping coin has a crowned ER (Ericus Rex - King Eric) on the obverse and the small Swedish coat of arms (three crowns) on the reverse side. The daler edition, number of minted coins in 1563 was 35,496 or more, which was a very high number of that particular year. The silver daler consisted of about 90% of silver and the 16 öre klipping had between 37% and 48% silver by the year 1563. During the Nordic Seven Years War, the klipping was likely primarily used for hiring foreign mercenaries. Two other discoveries of Erik XIV silver dalers, both from the Varberg region, further indicate that the daler shared the same function as the klipping during this time. Varberg was occupied alternately by the Swedish and Danish troops during the war. The silver daler design followed the continental engraving: The image of the Master of Mint, commonly the King, with regalia made the coins easily identified internationally. This is important as the coins lack a denomination stamp. They also served to introduce and legitimize the King of Sweden abroad.
The coins so far discovered on Mars, therefore, reflect very well a war-like environment. They also confirmed that foreign soldiers or crew served in the Swedish navy at this time. A considerable expansion of the fleet during Erik XIV domain created a need for foreign personnel on board. Future coin finds on Mars may provide a unique opportunity to study the issues.

Photo 17: Professor Johan Rönnby and project leader Richard Lundgren, TEC international fellow, studies recovered coins. Photo: Ingemar Lundgren, Ocean Discovery.
The Mars expedition: Maritime archaeological investigations of a legendary ship
By Johan Rönnby, Ph.D.

A Baltic wreck

In the summer of 2011, after many years of searching, a team of divers from Ocean Discovery discovered the wreck of Swedish King Erik XIV's legendary flagship Mars. It rested at 75 meters depth, approximately 12 nautical miles southeast of the island of Öland in the central Baltic.

The Baltic Sea is one of the best places in the world for shipwreck archaeology. One reason is that most of the organisms, including the shipworm, Teredo navalis, cannot exist in the brackish and cold waters of the Baltic. Another factor is topography, especially along the coasts of Sweden and Finland. The vast archipelagos consist of a plethora of small islands and reefs, which make navigation difficult. Between the islands, the bottom is relatively deep. In this calm, dark, and cold environment, time seems to almost stand still. Ship hulls may be preserved intact for hundreds of years; some with masts still standing. The absence of a significant tidal period in the Baltic also means that erosion by flowing water, which can break down and wear on shipwrecks, is not a factor.

There are other places in the world with similar physical conditions for preserving wrecks, such as the Great Lakes in North America or the polar oceans. However, there is another reason the Baltic is so special for maritime archaeological studies. This small, northern European inland sea has, for a long time, been heavily trafficked, and the number of shipwrecks indicates the number of ships that once traveled these waters. Intensive maritime communication, trade, and shipping, as well as naval warfare, can be traced back to prehistoric times. Seafaring is a central part of the region’s history. The Baltic Sea is, in that respect, a northern version of the Mediterranean Sea, which also served an important role in maritime history.

The King’s new ship

The giant Swedish warship Mars (sometimes also called “Miraculous”) was larger than any other contemporary or past vessel on the Baltic when it was built in 1563. She went down practically brand new on May 31, 1564, after a fierce battle against a fleet from Denmark and Lübeck.

The historical background is complex and dramatic. In the early 16th century, Denmark and Sweden were still unified under the same king. However, in 1523, the Swedish nobleman
Gustav Vasa led a successful uprising, and was crowned the new Swedish King. During his reign, he established a “modern” Swedish state government, in which a new tax system and a modern army and navy were important components. King Gustav died in 1560 and was succeeded by his eldest son, Erik. To underscore his authority, Erik chose to call himself “King Erik the Fourteenth,” asserting that he had thirteen mighty Viking royal ancestors.

King Gustav was a largely self-educated man who ruled his new country, Sweden, as a landlord administers his farm. His son Erik was different; he received a solid education, spoke Latin and several other languages, played music, and studied European politics. He was, however, also hot-tempered; though friendly and melancholic at times, he would suddenly turn angry and dangerous. He was very much the kind of Renaissance ruler described by Machiavelli in “The Prince.”

King Erik was very ambitious. For instance, he tried, without success, to convince Queen Elizabeth of England to marry him. As a new regent he also expanded Swedish territory to include areas on the eastern side of the Baltic Sea, and introduced harsh taxes on foreign ships. In 1563, he built a powerful new flagship, which he named after the Roman war god Mars. The new ship was, in a way, an alter ego for the king and his ambition.
King Erik’s ruthless policies and his claim for dominion over the Baltic Sea challenged the trade interests of both Denmark and the Hanseatic city of Lübeck. As a result, in 1563, the Nordic Seven Years War broke out. It was a hard and cruel war, and the civilian population suffered tremendously. When the war ended in 1570, there was no clear “winner;” instead, this conflict initiated a protracted period of battling in Northern Europe, which included Sweden up until 1720.

The battle

The Battle of Northern Öland in 1564 was one of many bloody clashes fought on land and at sea during the Nordic Seven Years War. The Mars, under the command of Admiral Jacob Bagge, was the largest vessel in the Swedish navy, which consisted of 38 ships of various sizes. The 1500s were a period of transition for naval warfare. Boarding tactics, where warring ships latched together to enable man-to-man fighting, were being replaced by regular artillery battles, where ships fired on each other from a distance. The events outside Öland in the summer of 1564 are illustrative of this transition.
The Battle of Northern Öland lasted for two days. On the first, *Mars* sunk the Lybckian ship *Länge Barken* using heavy artillery. After disengaging and resting during the night, the fleets resumed hostilities the following morning. The enemy ships approached and fired on the *Mars*, while their crews threw burning fireballs made of grease. Eventually, a fire ignited onboard the Swedish flagship. In the ensuing chaos, two German ships—the *Der Engeln* and *Der Fux*—maneuvered alongside the *Mars*, allowing a couple hundred enemy soldiers to board her. As the *Mars* burned, vicious man-to-man combat endured. Suddenly, there was an explosion amidships, followed by an even worse explosion in the stern. *Mars* the Miraculous sank quickly, taking more than 800 men down with her.

The result of this dramatic event on May 31st, 1564, is today a sunken, well-preserved marine battlefield on the Baltic seabed, complete with burnt timber, cannons, and associated maritime relics.

![Photo 18: A heavy section of top-timber from the hull is lifted onboard RV Triad. Photo: Ingemar Lundgren, Ocean Discovery.](image-url)
The investigation

The first archaeological investigation of the Mars wreck was conducted in the summer of 2012; the work continued in July 2013. This exploration of Mars has been one of the largest marine archaeological projects in the world; five survey vessels and more than 40 people have been involved in the field work. The work has been carried out with the help of technical divers, but also with underwater robots and multibeam sonars. A 3D scan of the wreck was initiated using a BlueView scanner with the goal of combining this data with the detailed photomosaic constructed in 2012. To brighten up the Baltic Sea’s darkness at 70 meters, a light rig was hung ten feet above the wreck, strong enough to light up a small sports field.

An important scientific objective for 2013 was to reconstruct a cross-section of the “battle space.” As part of this goal, ship timbers were salvaged for detailed examination on the surface. These timbers provided vital information regarding the construction of the hull and the high stern castle of Mars. As expected, all timbers were heavily blackened by fire.
In addition to timbers, two of Mars’ approximately 120 bronze guns were salvaged; a unique, small—roughly 150 kg—rail gun known as a falkon, and the front and rear of a shattered 3-meter long cannon known as a fältslanga. Many of Mars’ guns are in a similar state as the fältslanga, probably the result of the intense heat engulfing the vessel before she went down. On the rear of the recovered cannon is the coat of arms of King Erik XIV, complete with the double Vasa sheath. The discovery and salvage of the long-range fältslanga, a crucial tool during the battle, can be used to reconstruct the history of the fight. Finally, a gun carriage was also salvaged. It has large spoke wheels and a rough protruding axle. The gun carriages of Mars are of a completely different and older style than those found on later wrecks, including Vasa (1628) and Kronan (1676).

In terms of history, Mars is linked to a dynamic period in European history during which Renaissance princes like Eric XIV were vying to construct new states and consolidate new dynastic positions of power. Ships and fleets were a vital part of this process, especially in the Baltic region. How these massive, first-generation warships were constructed at the end of the medieval period and beginning of the modern period is almost completely unknown. Examining the Mars on the bottom of the Baltic Sea and studying the salvaged artifacts provides singular access into maritime history, particularly in this region.

The wreck of Mars, however, is not just the remains of a ship; it is also a well-preserved maritime battlefield. Further research here will provide fresh insight into unknown issues related to practical solutions in naval battles during early modern times. But the scope for research is more extensive than this. The opportunity to study the battlefield space also invites discussions and reflections regarding mental and psychological aspects associated with warfare in general, and human behavior in such situations and environments.

**Biography**

Johan Rönnby, PhD, Professor of Maritime Archaeology at Södertörn University and professional diver. Head of the Maritime Archaeological Research Institute, MARIS at Södertörn University. PhD from Stockholm University 1995. Senior curator/marine archaeologist at the National Heritage Board, Stockholm, 1994-97. Teacher and researcher at Södertörn University since 1997. STINT fellow and visiting professor at Skidmore College, USA, 2005. External examiner at Southampton University 2001-2005. Associate Professor (docent) in maritime archeology at Helsinki University since 2008. His research and publications has focused on shipwrecks in the Baltic Sea, but has also covered Viking Age lake dwellings, harbors and submerged prehistoric landscapes, coastal landscapes and man's cultural and social interaction with water.
Guns on Mars

By Ingvar Sjöblom, lecturer National Defense College

Imagine more than hundred guns scattered all over the wreck site. It is nearly impossible to describe how unique this is. It is like the discovery of hundred “new” paintings and drawings made by Leonardo Da Vinci - even better than every other piece we previously knew were made by his hand. Together with the historical sources, we can almost sense the tide of history. Everybody knows about the fantastic Baltic Sea were the lack of saltwater clams (Terredo Navilis) provides the perfect conditions for a “Tintin wreck” to be found. Also the Swedish Archives provides a unique possibility to investigate the historical context of ordnance artifacts. The combination of analyzing (comparing) historical sources on one hand and marine archeological artifacts on the other hand, is vital and one of the core methods for the Mars research team. In the contemporary Ordnance Accounts from the Military Archives, we know in detail the amount of guns, ammunition and even every single powder ladle expected to be found in further investigations.

Down to the nitty gritty. Mars was altogether armed with 122 guns in different sizes. Previous research has estimated the amount of guns between 106 to 200 guns. The amount of armament on Mars has been a tricky question and been discussed a lot in out of dated research. The span relies on different sources from the involving countries (i.e. Lübeck and Denmark). 3 It is easy to follow the miscalculations if you go to the original accountings. It is just common sense, not even historical source criticism. The Danish and Lubeckian sources were based on intelligence reports and the interrogation of the Swedish prisoners. Of course, the quality differs even if they were contemporary. Therefore, the actual primary sources from the early Swedish royal administration are more reliable. Brazz guns was very expensive to produce, therefore they also are very well documented. We actually can follow the brazz guns, step by step, the copper ore from the mines in Falun, to the gun-founder, the Royal Ordnance and ending up on Mars. It’s really amazing.

Mars was built in Björkenäs shipyard near Kalmar 1561-1563. In the sixteenth century Sweden (including Finland), there were shipyards in all the big cities (Stockholm, Kalmar, Åbo, Älvsborg). When finished, the ship was sent to Stockholm shipyard for equipment and armament. Just the for transport from Kalmar to Stockholm, she got a minimum armament of three larger muzzle loaded brazz guns (one demi culverin and two falcons, “dubbla falkonetter”), twelve smaller iron guns (skeppshakar) and 50 spears. 4 Even the expert on

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2 This is an article within the project Ships at War, at Södertörn University. A longer version of the article is also going to be published in Mariners Mirror.
3 The most sited source (173 guns) is from the Danish admiral Herluf Trolle, in Wad, G. L. (1893), Breve till og fra Herluf Trolle og Birgitta Gjøe. Køpenhamn. Brev nr 61. Juni? 1564 p. 148-149. Maybe the amount comes from the interrogation with Swedish admiral and prisoner Jacob Bagge? Even older Swedish research relies on this Danish source, but it has been corrected (107 guns) in Jan Glete, Swedish Naval Administration. Brill, 2010., p. 534. Glete has not calculated the guns, equipped in Kalmar.
4 Military Archives (Krigsarkivet, KrA) Artillery countings (Arkliräkenskaper, Ar) vol 9 1563.
Swedish marine history Jan Glete, did not calculate the guns from Kalmar together with the loaded guns in Stockholm. There is no evidence that the Kalmar guns were unloaded in Stockholm. It is easy to understand why they have not been included with the summary of all the loaded guns. The list of the loaded guns in Stockholm was also used as the list over the lost guns in the administrative reports.

*Mars* got her full armament in Stockholm. In April and May 1564 were 103 metal guns loaded on board outside of the old castle three crowns. Another four guns was contributed from other warships. Altogether Mars got her fully armament of 122 guns! Not all of them were on the Warship, some of the small ones, armed the longboat (esping). *Mars* longboat had ten small caliber brazz falconets “falkon” (0,5 pounder). Somehow the longboat was changed with the longboat belonging to the “smaller” warship *Elephant* (1200 ton displacement), which was armed with two falconets and two “skeppshakar”. This boat must have been connected to *Mars* (1800 ton displacement), due to it was marked in the source as lost when *Mars* sank. To summarize, we are expected to find 112 guns, near or in the wreck site and four smaller guns on the *Elephants* longboat.

The lion’s share of the guns was made of brazz (a metallurgic mix of circa 95 % copper and 5 % tin). Copper was expensive and worth its weight in money. Therefore the weight was marked into the gun in roman digits. These digits are like a license plate to a car. For the larger ones, the weight of each gun, are rare and unique, because the gun maker used different amount of copper ore due to the copper quality to make a stable gun. It makes large guns with the same caliber, but with different (and unique) weight. This was the preconditions when a research team together with the explorers, went on a first research expedition with the aim to try to finally determine that this is the *Mars* wreck. Many artefacts made it clear that this could be *Mars*, but backbiters always wants to see the ship bell and the ships name to be fully satisfied. I don’t think they even know that the ship bell was not introduced back then.

Two guns can fully and without any question, identify the wreck as *Mars*. These were the cannon and the long culverin (notslanga). This was the heaviest gun (almost 5 tons) and the longest gun (over 5 meters). In November 2011, I was called to join the research team as historical expert on the Swedish 16th century navy and ordnance. I brought with me, copies from the original sources from the archives. I can hardly describe the feeling on board the research vessel, when the explorers told me that they found markings on one of the guns. Roman digits came visible when filmed with the ROV (robot videocamera). What could it be? I knew immediately what it was. It read “XXIII : IX : XVIII” which tells us that it without any doubt was from the 16th century. Even the Swedish king Erik XIV spelled his name Ericus XIII as the 14th king with the name Erik. The digits 24:9:18 marked the weight in “skeppund, lispund and

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5 Glete 2010 p. 534 note 49.
6 KrA Ar vol 11 1564.
7 KrA Ar vol 11 1564.
8 KrA Ar vol 11 1564.
markpund”. Translated to kilograms, the gun weight was circa 3 300 kilograms. According to my copies, it was the long culverin, made in Stockholm by the gun-founder Thomas Matsson! We were all stunned and the research expeditions aim to finally identify Mars was fulfilled almost immediately. A key moment followed by celebration in coffee and cookies. During the sixteenth century, the gun caliber was measured by the weight of the shots they fired. Later, during the seventeenth century, the guns was classified by the bore diameter and recalculated to weight of shots they fired. It means that a cannon was classified as 40 pounder during the sixteenth century and 48 pounds during the seventeenth century. The long culverin was classified as a 20 pounder (or 24 pounder). During the Mars expedition 2013, I identified one of the two cannons on Mars, also by the weight inscription. The gun-founder Gillius Packet, casted the large gun in Stockholm in mid April 1564. A notice in the acknowledgement tells us that the gun was supposed to be delivered to Mars. 9 The gun master Esbjörn Staffansson, receipted the cannon and finally it ended up on Mars. 10 Through photographs and documentary film and for the second time (hardly visible) weight markings were discovered on a gun inside the wreck. The markings: ”XXXV : XVI : VIII” means that the gun weights almost 5 tons (4875 kilogram). 11 It was an amazing feeling when the largest gun in the wreck site finally was identified.

According to my calculations, Mars had 24 heavy brazz guns in the main gun deck, 36 guns on the upper gun deck and 62 small caliber guns in the castle deck, fighting top and the long boat. The heaviest guns were placed on the main gun deck. They were all casted and muzzle loaded brazz guns between 1,5 to 5 tons of weight and 3 to 5 meters long. According to the administration sources was it 24 guns (two cannon, two demi cannon, seven half cannon, two long culverin, ten whole culverin and probably one demi culverin). 12 On the upper gun deck most of the guns, 32 of them were made of brazz, but there were also four cannon perier, i. e. so called “stone guns”, large breech loaded wrought iron guns equivalent to cannons. Except for the cannon perier, the “middle sized” brazz guns differed between 0,35 to 1 tons and between 2,5 to 3,5 meters long (four demi culverin, 20 half culverin/saker and 8 falcon). Needless to say, they were also of a large size compared to seventeenth century guns. In the castles, fighting top and in the long boat, the 48 (or 50) small caliber brazz falconets and twelve iron “skeppshakar” were placed. 13 Soldiers managed this smaller artillery and at least the “skeppshakar” could almost be compared to a heavier variant of muskets in later centuries.

It should be pointed out that this is based on calculations from the primary sources. This is our best hypothesis of what to be expected to find 70 meters down under the surface. A gun in a gun port was a question about supply and demand. Often there were not enough guns to fill all of the ships gun ports. There is a high probability that Mars got “full” armament due to that she

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9 KrA AR 1564 vol 13.
10 KrA AR 1564 vol 12.
11 Calculations is based on: ”skepppund”: 136 kg, “lisipund”: 7 kg and and “markpund”: 0,343 kg. See Jakobsson 1937, appendix 1 s 410. It gives us the calculations in kilogram 4760 + 112 + 2,744 = 4874. 744 kg, rounded off to 4 875 kilogram.
12 One demi culverin has been counted as being on the main gun deck due to get equable numbers.
13 The list over receipted guns shows 50 falconets and the list over the lost falconets accounts 48 falconets. See KrA Ar vol 11 1564.
got so many newly casted guns in a row. But we cannot be sure until we have studied the wreck in detail. This jigsaw puzzle of comparing historical sources and archeological artifacts makes the research suggestive and challenging.

One mystery left to be solved is the exploded cannon perier. According to the Swedish admiral Jakob Bagge, the fire on Mars started during the close combat and was caused by the explosion of a cannon perier called the apostle. Eight or nine people were killed and the explosion also made the cow bridge above the stone gun to raise 30 centimeter. When Mars was in flames, the officers took the decision to give up the ship. A hundred Swedish crewmembers was captured and brought to the Lubeckian admiral ship the Angel (der Engel) and Henning Kragens warship. Hundreds of Lubeckian soldiers and sailors gushed in trying to take their rightful part of the captured ship. At the same time the fire reached the powder chamber in the bow. The gigantic explosion was so powerful that the fore mast went up like an arrow in the air. The ship broke into pieces and sank with six hundred swedes and hundreds of Lubeckian conquerors.14

Is it possible to find the mystery cannon perier that caused the fire? Is it a true story? Apostle was the name of the largest 10 inch cannon perier. The gun shot stones of 25 centimeters size. According to the administrative sources, Mars did not have apostle cannon periers - “only” two 8 inch, one 7 inch and finally one 5 inch stone gun. Maybe the admiral mistook an 8 inch for a 10 inch cannon perier? Bagge was not an expert and apostles were common on the largest ships. For instance, the Elephant that admiral Bagge commanded the previous year had four apostle cannon perier and Saint Eric had two.15

One of the cannon periers was found immediately when the divers started to explore the wreck. This evidence together with ship design and loads of brazz guns was originally a strong hypothesis that this could be Mars. Today have we discovered three, maybe four cannon perier. One is still in its place and still sticking out from a midship gun port, on the upper gun deck of the starboard side. It has been measured to circa tree meters and is probably the 7 or 5 inch stone gun. During the research expedition 2013, one of the 8 inch cannon perier was measured to four meters long. These two cannon perier are visible in their whole length. We have found the remaining two wrought iron guns. At least parts of them are visible. Could this be two stone guns or two pieces of the same stone gun? We still don’t know if these gun artefacts will support or falsify Jakob Bagges story. Time will tell due to our continuing research.

The guns on Mars are the real treachery. For 450 years ago, the brazz guns lasted for over hundred years in use. The carvel built warship lasted for 20 to 30 years in service. The guns value often superseded the value of the ship. Hundreds of brazz guns more than 450 years old were found in one place. Two of them were salvaged (one whole culverin and one small caliber falconet). Take the opportunity to go to the museum in the explorer’s home town Västervik. Sense the tide of history. Amazing!

15 KrA Ar vol 11 1564.
The Mars expedition: Reconstructing the hull

By Niklas Eriksson

Information detailing the architecture of 16th-century ships is scarce. Besides King Henry VIII’s ship, the Mary Rose, which sank in 1545, the number of archaeologically investigated wrecks from this time period is negligible. With the discovery of Mars, we are suddenly faced with another nearly complete ship from that era. But even if a significant portion of this ship has survived, piecing the wreck together is quite a task; a challenge compounded by the fact that the remains rest 75 meters from the sea surface. However, the task of surveying and reconstructing the Mars is, of course, a very stimulating one, not least because the initial work has revealed many unusual and surprising construction features that are not found onboard post-16th century ships of war.

Figure 5: Pieter Bruegel, (1525-1569) engraving of a large heavily armed warship. Note the high stern castle the four masts with arsenals of spars ready to be thrown against enemies. Mars would have looked something like this, but larger! Artist: Landstrom 1980.
From boarding to artillery, from medieval to modern

Medieval naval warfare is sometimes described as field-battles that had gone to sea. Merchant vessels were outfitted into warships and used to transport fighters to enemy warships. The primary at-sea battle tactic was for these merchant vessels to come alongside enemy warships to allow their soldiers to aboard. The enemy warship then became the battlefield where armed combatants fought face-to-face.

When warfare-specific vessels were introduced, they were equipped with high fore and stern castles intended to deter an enemy from embarking. Height was of tactical importance, as it allowed a fighter to shoot down onto the deck of the enemy vessel with longbows, crossbows, spears, and later in history, lob hand-grenades.

In time, fighting ships became more like sailing artillery platforms, an evolution that was dictated by the advancement of artillery. As guns became more efficient, innovations in shipbuilding became vital. In Northern Europe, the perhaps most visible change was the introduction of carvel construction by the end of the 15th and beginning of the 16th centuries. On a carvel-built hull, the strakes of planking are laid side by side and the strength of the hull comes from internal reinforcing frames. This is in contrast to the clinker technique, in which the strake of planking overlap and the strength comes from the shell of the hull. Most notably, the introduction of carvel construction facilitated the ability to cut gun-ports in the hull side. Large guns could thus be installed low down in the ship, keeping the center of gravity low, which helped stabilize the vessel. Another important aspect was that the new technique enabled the construction of much larger ships. During the 16th century the size of naval ships increased rapidly as they grew into colossal entities.
Ship design in the 16th century was done informally by copying and modifying previous designs; construction drawings were not widely used until approximately 100 years after the construction of the Mars. Even so, images exist that help to reveal something of the appearance of Mars. In fact, several 16th-century artworks portray gigantic warships with high fore and stern castles. Among these, the engravings of the Flemish Renaissance artist Pieter Bruegel the Elder (1525-1569) are especially noteworthy. Bruegel’s representations depict a number of offloading fortresses with up to four masts and an impressive array of guns, from large, high-caliber muzzles pointing out from the gun ports along the sides of the hull to smaller guns that appear on all four sides of the box-like fore and stern castles (Figs. 1 and 2). But a careful inspection of these images reveals that these floating fortresses even carried guns up in the masts. The small round platforms in the masts—or “fighting tops”—supported small swivel guns. Firearms, however, were not the only weapons used in the rig of these ships. In the fighting top, an arsenal of spears appears alongside guns, and the end of the spears are equipped with sharpened grappling hooks that would tear an enemy rig apart if it were to sail too close.

The ships in Bruegel’s engravings appear to be grotesque mechanical monsters. The question that arises is how accurate are his outlandish representations. Were warships so monstrous in the 16th century, or are these images just an expression of artistic license? The wreck of Mars
provides us with the opportunity to finally see for ourselves what one of these large warships really looked like.

Site formation

According to witnesses from the battle in 1564, when the powder storage area exploded, Mars’ foremast flew straight up in the air like a crossbow bolt. The remains of the ship on the seabed further underscore the extent of this violent detonation and the course of events that followed. Today, the ship's forward portion is nearly annihilated, and what remains of the heavily-framed hull is broken up into three more or less coherent parts. Survey results so far suggest that the ship broke up into these three pieces while it was still on the surface. The keel, over 50 centimeters thick and made of oak, is cracked like a match, and loose parts of the stern have been found over 60 meters from the portside.

When the hull made contact with the seabed it listed to starboard. Looking at the plan (Fig. 3), its portside area is perhaps its most identifiable section, whereas the rest of the site appears as a chaotic, unstructured jumble of burnt and eroded materials. However, there is certain logic to this stack of ship timbers, bronze cannons, bricks, cordage, human remains, and other materials, and it will be possible to reconstruct quite a lot of the ship’s interior.

In contrast to the dramatic foundering, the past four hundred years appear to have been remarkably uneventful down in the deep. Over time, the wood has softened and iron corroded, but overall, King Erik XIV’s ship is remarkably well-preserved. Large hull structures with cannon ports, deck knees, and rigging details are still detectable and indicate clear traces of fire and bombardment. Even the metal in the bronze cannons, bearing the Vasa dynasty’s coat of arms, reflect the diver’s lights under thin layers of sediment.

Initial surveys have revealed that Mars had two gun decks running from stem to stern. These decks are easily distinguishable from the gun ports in the preserved portside. In the stern castle, Mars also had a quarterdeck that ran from the main-mast to the stern, onto which lighter ordnance was placed. In the aftermost part of the stern castle, the ship also had a poop-deck. Underneath the two gun decks was the orlop deck, which served as a dry storage area for gunpowder, personal effects, cordage, spare sails, carpenters stores, and so on. Below the orlop deck was the hold used for the storage of provisions. In all, Mars was comparable to a five-story building with the number of decks it supported. When the hull disintegrated, these levels collapsed and now rest comfortably on top of each other. Naturally, it is difficult to sort out and determine the original location of the loose deck beams and other timbers that lie scattered underneath or just above the conspicuous port-side. But it is not impossible!
The components of the different deck levels have been measured in relation to the stress that guns or cargo would have exerted on them. The dimensions of the deck beams may thus be used to establish their original location. In the same way, notches and abutment surfaces in the
different beams, frames, knees, and similar timbers can be used as clues to piece together the wreck into a ship.

Much of the information that is required for this reconstruction may be gathered using ROV’s. For a nautical archaeologist, this is an unusually comfortable way of doing fieldwork; sitting in front of a TV screen with a cup of coffee, watching the source material come into view. But even if it is possible to do much of the assessment of the different artifacts from the comfort of the air-conditioned and dry ROV booth, it is complicated to take measurements with an ROV. The size of different object scan be estimated by scale reference using laser-pointers oriented parallel to each other. As described by Joakim Holmlund in this issue, the shape, dimensions, and proportions of large structures can also be recorded using multibeam sonar and Blueview laser.

Besides recording measurements of the wreck at the seabed, a few timbers have been raised to the surface. These specific wreck components were intentionally selected because they were informative in regards to the shape of the hull, the dimensions of deck-levels, the height between the decks, and the methods used when the ship was built (Fig. 4). The aim has been to reconstruct a cross-section of Mars in order to highlight the distinctiveness of a 16th century ship. As mentioned above, this was a period of transition, from boarding tactics to artillery fights. Mars was built in the very middle of this transition, and this is evident when examining the ship in cross section. While the lower hull consists of heavy frames and large dimensions to carry the load of the modern, heavy bronze guns, the upper structures are much more lightweight. Mars’ stern castle is reminiscent of the high structures on medieval ships, meant to discourage the enemy from boarding. This stern castle would never be able to withstand bombardment from the guns she carried on the lower gun-deck. The situation corresponds well with for instance the written accounts concerning the Spanish Armada that attacked England in 1588. A witness observed that “the upper work (...) was of a thickness and strength sufficient to bear off musket shot. The lower work and the timbers thereof were out of measure strong, being framed to planks and ribs four or five foot in thickness, insomuch that no bullets could pierce them.”

In the 17th century, the lightly built upper works of fighting ships decreased to a few strakes of clinker-laid planks along the bulwark instead of large quadratic castles in the bow and stern. On Mars, the lower parts of the hull are heavily built, perhaps so that “no bullets could pierce.” Several marks from round shots reveal that the wooden walls withstood gunfire quite well. In fact, Mars was lavishly built. All the frames and other curved construction elements are made out of so-called compass timbers, or naturally curved pieces of wood. This is an extremely expensive way of building ships, even if the result is a very strong hull. One hundred years after Mars was launched, it was impossible to build a ship in this manner. The supply of compass timber was short and the construction of large carvel-built hulls had been updated so that their hulls could be built with less demand on high quality wood.
Figure 9: Cross section of the hull. Artist: Niklas Eriksson.
How large was Mars?

*Mars* may be regarded as the prototype of the large fighting ship. One hundred years later the sailing artillery platform template had reached its final form, with three masts and muzzle-loaded guns in ports along the hull side. This construction continued until the mid-19th century, when it was replaced by ironclads, rotating gun-turrets, steam engines, and so on. During the 16th century, Sweden, Denmark, and Lübeck were struggling to learn how to build even larger ships. The arms race around the Baltic Sea may be regarded as an experimental workshop for the construction of fighting ships and naval warfare.

The foundering of the enormous *Mars* was a great triumph for the allied forces. Needless to say, they were not slow to use the Swedish defeat for propaganda purposes. Pamphlets describing the victory over the enormous Swedish warship were soon in print. However, no contemporary documents exist that provide a clear indication of how large *Mars* really was. Over the past 400 years there has therefore been much speculation on the ship’s impressive dimensions. According to a contemporary chronicle, the ship was “ten feet longer than the cathedral in Lübeck.” Another measure of a ship's size is by the number of guns present, and there are many conflicting reports and calculations based on this. Some state that the ship should have had just over a hundred guns while others indicate as many as 172.

From the initial surveys of the *Mars* wreck site, we have learned a lot about how a 16th century warship was built and how it was used. However, the material from the two field expeditions still requires further processing and analysis. It is when fieldwork ends that real archaeological reconstruction begins. Reviewing the material so far, things look promising, and eventually, in a not so very distant future, we will have a quite clear picture of what *Mars* used to look like. But there is still a lot of work to do before we get there.

**Biography**

Niklas Eriksson is a diving archaeologist. He was formerly employed as a Curator at the Swedish National Maritime Museum in Stockholm and is currently a doctoral researcher at Södertörn University. He is specialized in the technologies of shipping and in recording and visualization of historic wrecks. His current research interests focus on the use of space on board ships and maritime processes of urbanism in the Early Modern period. Alongside this he is working on recently discovered wrecks in deeper water, including the Ghost ship, Mars and Sword.
The Mars expedition: Non-destructive archeology - Proof of concept.
By Richard Lundgren, FI’12, Ocean Discovery

Introduction

Archaeological research involves the discovery and recovery of objects and artifacts, and the study of their locations and context. Ocean Discovery together with MARIS develops methods allowing rigorous scientific studies of objects and locations in a non-destructive and non-invasive manner.

Problem description

During an archeological project, precise survey and documentation of objects and artifacts is of fundamental importance for the study and understanding of context. This is implemented today with lasers and advanced measuring instruments on land. Marine archaeological studies underwater today rely mostly on tapes and drawings. To be able to study an entire site in detail, its artifacts, objects and context and be able to convey the data digitally for secondary opinion prior to further action would be a important step forward with regard to quality assurance and efficiency.

During land archeology, objects and artifacts are usually covered and protected by layers of earth. The object is normally dug out, careful documented and surveyed before lifted from its original site. This leaves the site damaged in an irreversible manner. The object is removed from its original setting and the context is broken and lost.

During marine archaeological surveys, objects are often found exposed, enabling studies without sediment removal. The underwater environment often limits these studies, nor just scientific divers in particular but also remotely operated vehicles (ROV’s). Divers are limited by exposure time, amount of gas, cold and visibility while robots are hampered by weather conditions, operational cost and time. When objects are uncovered or brought to the surface, the site and context is again destroyed and lost forever.

All salvage of artifacts and objects involves additional challenges. The place and the object can easily be damaged during the operation. The recovery operation and subsequent preservation are expensive. The actual cost of salvage and preservation for a medium sized cannon from the Mars wreck site is estimated to exceed 2 million SEK.

Method development

Ocean Discovery and MARIS has developed methods that will result in:
Capacity to survey and distribute information on locations and objects, early in the process and with exceptional accuracy, so analysis can be made before further interventions occur.

Ability for scientists to study places and objects without the stress or the influence of external factors.

Reproduction of objects in high detail, without having the subject raised or salvaged, thereby avoiding irreversible damage of the location, object and context.

The study of the objects without the requirement of conservation concerns.

Objects that can be conveyed without the need for conservation.

Significant cost savings for research, as recovery operations and conservation costs can be avoided entirely.

Method description

The method incorporates the following three steps:

1. Data collection.
2. Data processing.
3. Distribution.

Data collection

Four principal means of collecting data are utilized:

2. Acoustic survey.
3. Laser survey.
4. Photogrammetry.

These methods can be combined to achieve even greater accuracy and quality assurance.

Manual survey

During manual surveys, locations and objects are surveyed manually using measuring sticks and measuring bands. This method provides accurate measurements and surveys. However, the method is time consuming and expertise is needed to ensure
quality and accuracy. Inaccurate measurements yield a corrupt survey.

The quality and accuracy of object and site illustrations depend heavily on the skill and technique of the artist. It is hard to rival the work of a true artist but mediocre performance is on the other hand often less useful.

Manual survey data needs to be converted to digital form in order to be distributed efficiently.

_Acoustic survey_

During acoustic surveys locations and objects are surveyed using acoustic instruments or sonar system. Sound waves are transmitted through the water and when they hit an object, the sound waves are reflected back to the transducer. The time it takes the sound waves to return enables an image based on a point cloud to be generated. The amount of and frequency of sound waves determine the image resolution and density of the point cloud. Generally the higher
frequency and number of sound waves the better the resolution gets. However, the effective range of high frequency sonar systems is limited in some cases down to less than 30 feet. A correctly performed sonar survey gives centimeter accuracy and is not limited by water clarity. The post processing needed of the surveyed data can be substantial and time consuming before a finished illustrated report can be distributed.

Laser survey

During laser surveys, locations and objects are surveyed using laser instruments. Laser beams are transmitted through the water and when they hit an object, the laser beams are reflected back to the transducer. The time it takes the sound waves to return enables an image based on a point cloud to be generated. The amount of and frequency of laser beams determine the image resolution and density of the point cloud. The laser systems effective range is not practically limited on land, assuming a clear field of view, but underwater the levels of particles in the water limits the range dramatically. During conditions where the water is turbid with lots of particles, laser surveys are not practical. Even if the laser system is calibrated to the water properties, the operative is commonly less than 50 feet.

The survey speed is one of the more compelling arguments for laser surveys. Lasers are much faster compared to any other form of surveying techniques and under ideal conditions also more accurate.

The post processing needed of the surveyed data can be substantial and time consuming before a finished illustrated report can be distributed.

Photogrammetry

During photogrammetry surveys, locations and objects are surveyed using high-resolution digital still cameras. Photogrammetry is the science of making measurements from photographs. The output of photogrammetry is typically, map, drawing, measurement, or a 3-D model of some real-world object or scene. Photogrammetry can be classified a number of ways but one standard method is to split the field based on camera location during photography. On this basis we have area photogrammetry and object photogrammetry.

- Area photogrammetry. In area photogrammetry the camera is usually pointed vertically towards the seabed or wreckage. Multiple overlapping photos of the seabed or wreckage are taken as the divers swims along a planned path. Remotely operated vehicles (ROV) can be utilized as well. An entire wreck site or debris field
can be surveyed using this method.

- Object photogrammetry. In object photogrammetry the camera is close to the subject and is typically hand-held but can be on an ROV as well. Usually this type of photogrammetry is non-topographic - that is, the output is not topographic products like terrain models or topographic maps, but instead drawings, 3-D models, measurements and point clouds.

High-resolution cameras with distortion-free lenses are used to model and measure archaeological artifacts, objects and entire wreck sites.

The most compelling advantage of photogrammetry is that the surveyed site, object or artifact retains its photorealistic textures. The finished model looks like the real thing! If performed correctly the measurements are accurate to the millimeter. However compelling photogrammetry is as a survey method, its success relies on favorable conditions and good water visibility.

As with other methods, the post-processing required before a finished illustrated report of the survey data can be distributed is substantial and time consuming.

Data processing

When survey data is collected digitally, different software programs are used to create maps and models. This following chapter describes how photogrammetry survey data of a 16th century bronze cannon collected during the Mars the Magnificent 2014 expedition is processed.

1. The photographs taken of the subject are imported to the software (Agisoft Photo Scan). In this case 74 individual overlapping photos, each with 36 megapixel resolution taken during a previous dive. The software aligns the photos and determines the unique camera angles.

2. The software processes the imported photographs, converting them to a point cloud.

3. Now the subject, in this case a 16th century cannon, can be distinguished in the dense point cloud. All of the points, tens of thousands of them, must now be linked and converted into a mesh.

4. The dense point cloud and mesh have now been linked together into a coherent model. The model can now be cleaned from erroneous points and holes can be filled.
5. The time has come to generate and apply a photorealistic texture to the model. This step completes the process and a photorealistic 3-D model of a 16th century cannon with millimeter accuracy has been created.

Distribution

3-D printing is today more than just prototype creation. The advantages and possibilities with today’s systems are overwhelming. Today photorealistic scale models of archeological artifacts can be recreated completing the vision of non-destructive archeology. Today, after the discovery of a specific subject, we can conduct a photogrammetry survey that can be processed into a 3-D model and then recreated at the surface using a 3-D printer.

The possibilities and advantages are numerous. No longer do we need to recover objects and spend considerable amount of money and time on conservation and the associated bureaucracy. No longer do we have to travel far to be able to examine the artifact. No longer do we need to schedule or apply for access to the artifact. With a simple email artifacts can be shared and distributed around the world to scholars, students and scientist who can at their own leisure recreate the artifact at their facility. This vital step completes Ocean Discovery’s vision of what non-destructive or non-intrusive archeology really means and the vast potentials that come with it.

3-D printers use a variety of different types of additive manufacturing technologies, but they all share one core thing in common: they create a three dimensional object by building it layer by successive layer, until the entire object is complete. It’s much like printing in two dimensions on a sheet of paper, but with an added third dimension: “Up,” or “Z-axis.” Each of these printed layers is a thinly sliced, horizontal cross-section of the eventual object. There are also various types of additive manufacturing. These range from FDM printing, where a material is melted and extruded in layers, one upon the other, to SLS printing, where a bed of powder material such as nylon or titanium is “sintered” (hardened) layer upon thin layer within it until a model is pulled out of it.

This process begins with a digital file of generated through photogrammetry. The model is then sent to the 3-D printer. Along the way, software slices the design into thousands of horizontal layers, which are printed one atop the other until the 3-D object is constructed.

Results

During the Mars expedition in 2013, data was collected on one of the many 16th century bronze cannons using photogrammetry survey methods. The data was processed into a photorealistic scale model. On December 23rd the first photo realistic scale model of an object, the cannon, was successfully 3-D printed. The 3-D printed cannon, the first of its kind, serves as proof of
concept. During the Mars 2014 expedition most of the wreck site was surveyed using the photogrammetry survey method. The survey data is still being processed: Expect to be amazed!

Biography

Richard Lundgren has worked as a professional diver around the world for more than 20 years. He has been fortunate to participate in many sensational exploration projects such as HMHS Britannic, sister ship of the RMS Titanic, and the discovery of the mighty admiralship Mars the Magnificent, sunk during the Nordic seven-year war in 1564. Lundgren is a founding member of the exploration organization, Global Underwater Explorers (GUE) and serves on the board of directors. Richard is a fellow member of The Explorers Club, member of the Board of Scientific Divers and president of Ocean Discovery. He is an accomplished photographer and cinematographer with a contagious passion for discovery and exploration. Lundgren also served as the deep cameraman on National Geographic, PBS and NOVA production – First Face of America.

Awards:
Discovery Award 2014 - For outstanding contribution or significant research that has resulted in a discovery that has advanced the field of technical diving - TEK DiveUSA
DIVER of The Year 2011 - Global Underwater Explorers
Citizen of the Year 2012 - Västervik, Sweden
Diver of the Conference - 2012 Eurotek
The Spirit of Independent Award - Fort Lauderdale Film Festival
Film award – 2010 Zagreb International Film Festival

Photo 20: A 3D printed scale model of a bronze cannon from the Mars wreck. Photo: Ingemar Lundgren, Ocean Discovery.
The Mars expedition: Developing tools for non-intrusive electronic marine archaeological wreck excavation

By Joakim Holmlund, Ph.D.

Exploring archaeological sites in the Baltic Sea varies significantly from similar work in other parts of the world. Low biological activity and the lack of wood worms and oxygen in deeper waters keep structures of old wrecks intact; sometimes even whole ships can be found structurally whole. This, in turn, allows for detailed investigations of ships that are several hundred years old. Even so, due to the depths at which they are often located, it takes a long time to execute a comprehensive archaeological investigation of these undisturbed wreck sites.

For several years now, the marine survey company Marin Mätteknik (MMT) has worked with Södertörn University’s Maritime Archaeological Research Institute (MARIS) to develop new tools for deep water archaeologists (Dixelius et al., 2011). As a member of the survey industry, MMT works with clients who demand high-resolution survey systems to ensure precision in cable and pipeline installation. While in years past these precision instruments were carried by ships, they are now carried by ROVs and AUVs, delivering 3D multibeam echo sound (MBES), film, photomosaics, side scan sonar (SSS), and other geophysical information. As one can imagine, the data made available by this sophisticated technology is very useful to archaeologists, laying the foundation for developing tools for non-intrusive archaeology or, in essence, electronic excavation.

At the Mars wreck site, several of these sophisticated data collection devices were used. The wreck was discovered with high-resolution SSS, and the site and the surrounding area were thoroughly mapped by state-of-the-art MBES. This data helped create a large-scale 3D image of the seafloor, and helped locate unknown debris near the wreck site. Thus far, four MMT vessels have been used in the project; the MV Icebeam, MV Triad, MV Askholmen, and Mama Duck. Each serves a distinct purpose and each carries different equipment.

Multibeam systems have been the primary instrument for mapping the site. The first was the Kongsberg EM3002 on the vessel MV Askholmen which undertook a complete survey of the wreck site and surrounding area. From this survey, information regarding where to best position the mooring blocks was gleaned. Furthermore, the 3D data yielded by the Askholmen also provided the Triad, equipped with the higher resolution Kongsberg EM2040, with a template for a future survey pass. The 3D map created by the data collected by the Askholmen was also used for navigational purposes in dive operations, for example, in the precise placement of the down line (less than a meter off).
Simply put, MBES resolution is divided into range resolution and spatial resolution; range resolution depends on bandwidth while spatial resolution depends on the opening angles. While a higher bandwidth (frequency) yields better range resolution, its range is shorter because water absorbs energy. The opening angles of each beam provide a footprint, which increases with the distance from the detected target; hence, it’s best to be as close to the target as possible. Figure 2 shows a typical MBES setup on a vessel. This includes two sensors and receiver heads that transmit and receive ultrasonic pressure waves; these sensors/receivers collect information in a fan shaped profile while the vessel transits. Data collection can be described as several hundred beams measuring simultaneously, perhaps 10 to 30 times a second depending on the sea bottom’s depth. Figure 3 shows that it is possible to get a decent overview of the wreck site and surrounding area; however, the footprint of each beam at 75 meters deep is quite large.

These efforts are now augmented by constantly evolving technologies for mapping above and below the sea surface. Once gathered, 3D photo imagery can be presented in Google Earth. Lidar, a remote sensing technology, previously used from airplanes and unmanned helicopters to obtain detailed 3D imagery of infrastructures at a centimeter resolution, have now made
their way beneath the sea surface and there are now lidar scanners for UV applications. A lidar displays high-resolution images that are an order of magnitude better than using traditional ultrasound survey techniques (cf. http://www.2grobots.com/).

Using HD cameras to produce mosaics of several hundred high-resolution images yields high resolution imaging information. However, these are 2D captures, and though one can build a 3D image from these captures, the scale of objects at varying distances in the mosaic gets problematic. Hence, the best way to build a correct 3D model of an object is to use a scanner or MBES, though the major drawback will be the use of light as a source of illumination given the rate of its absorption. Typically, Baltic Sea visibility is limited to just a few meters, so any scanning method that relies on light as a source of illumination will be hindered in function.

The footprint of the Kongsberg EM2040 at a depth of 75 meters is too big to yield detailed information; one might detect single planking of less than 0.5 meters width, but no detailed information about construction details. So, researchers must be closer to the wreck. Though MMT still uses ROVs and AUVs carrying MBES (Dixelius et al.), and will use similar tools in the future on Mars, during the 2013 summer expedition, MMT and MARIS tried (with very good results) a new high resolution MBES system: a so-called mechanical scanning multibeam system, a Blueview BV 5000 3D scanner.

The Blueview 3D scanner was mounted on a tripod together with a 360-degree scanner and launched from the Triad which was stationed above the wreck in a six-point mooring position. The tripod was equipped with a mechanical scanner that could be controlled from the surface. The elevation and azimuth could be adjusted to create a 3D image of the surroundings. The maximum range of the BV5000 1.35MHz is approximately 30 meters; however, the longer the range, the larger the footprint. During the Mars wreck site scans, the range was kept to less than 15 meters to maintain high resolution.

A scan plan was formulated to encompass the wreck site from all directions, which required positioning the Blueview on top of the port side of the wreck. Divers dropped down sticks on the sides and on top of the wreck to serve as reference points (cf. Figure 5). We used a small ROV (Ocean Modules V8) to move the tripod with the scanner and ultimately managed to cover roughly half the wreck site. Unfortunately, the current increased which made it impossible to move the tripod with this ROV. Divers could have moved the tripod; however, there were too many positions still to be scanned, and because a scan could take about 20 minutes at depth before the tripod had to be moved, it was an inefficient use of the divers’ short bottom time.

Overall, the 3D data captured by the Blueview yielded invaluable information for mapping the wreck site. From the scans, archaeologists could use the 3D data to take measurements and get curvatures. One of the next phases of the Mars project entails combining the high-resolution HD photo mosaic of the wreck and the accurate 3D MBES data from the ROV and Blueview on a
tripod. It is not difficult to understand why archaeologists have high hopes for this technology that can allow them to create an accurate mosaic of high-resolution images to help analyze shipwrecks. In addition the Blueview data will be very important to both verify and correct future 3D-Photogrammetry work on Mars and other archaeological sites. The combination of the high resolution from photo and the accuracy and range of MBES makes a very useful tool for archaeologists to post examine the wreck site after the completed field work. Figure 7 shows the stern made up by 4 Blueview scan positions. The mage also shows all the debris that are scattered below the stern and the archaeologist can in post examination measure different planking and their positions relative to the wreck site.

From the perspective of MMT, participation in this project has been interesting. There have been many maritime enthusiasts who have been involved in this project in some capacity on each of the vessels that have been used in this non-profit venture. MMT’s owner, Carl Douglas, who sanctioned his company’s involvement in this project, has a genuine interest in the maritime history of the Baltic Sea. In cooperation with MARIS, this project has presented a great opportunity for marine archaeology education, which comes in handy for MMT when working on large infrastructures underwater.

Regarding the software for processing I have so far been evaluating two packages. Leica Cyclone Register is the traditional package used for processing of these point clouds, however it requires some training before one can use the full extent of the package and retrieve good results registering the different point clouds together. The other software used is EIVA Navimodel, EIVA has been very accommodating in this project and developed new tools in for the processing in Navimodel that simplified the processing a lot. Navimodel is easy to start with to register point clouds without too much basic training in the package.

So far in the project without being finished with the 3D mapping I like to thank some people at Teledyne and EIVA for excellent support, especially Ed Cheesman, Nick Lesnikowski and Jon Robertsson from Teledyne as well as Mikkel Bak Vester and Jesper Knudsen from EIVA.

Biography

Joakim Holmlund has been diving wrecks since the beginning of the 80s, most of which have been north of Norway and, as of late, in the Baltic Sea. However, Joakim has also participated in several excavations in the South China Sea together with, among others, the National Museum of Negara in Malaysia. After earning his Ph.D. in Physics at Chalmers University of Technology and a few years of research, Joakim transitioned to offshore business with the survey company MMT. His work at MMT involves developing and using the most current UV technology and infrastructure to map the seafloor. Recently, Joakim has also worked with the Maris Institute of Archaeology at Södertörn University to upgrade archaeological tools. His focus has been to find and evaluate tools that are usable in deeper waters that are not accessible to conventional diving.
The Mars expedition: Mars the Magnificent & the Swedish maritime history of the 16th century – an exhibition project

By Veronica Palm, exhibition project leader, Västerviks Museum

In the summer of 2011 the Västervik-based dive team Ocean Discovery located a large wreck at a depth of 75 meters, just east of the Swedish island Öland in the Baltic Sea. The wreck was identified as Mars the Magnificent - one of todays most stunning archaeological finds!

The wreck site – a time capsule

The discovery of the Mars (1563) was the start of a major new research project, which enables fantastic opportunities for new knowledge of the naval history of the 16th century, an eventful era in the development of new large warships and warfare in the Baltic Sea. There are also possibilities to gradually document how officers, crew and soldiers lived on board the ship and the tools, equipment and personal effects they used. A combination of old and new weapons technology was used and the Mars was armed with more than 120 cannons. The wreck site constitutes the biggest source of knowledge about 16th century cannons known today.

The first archaeological surveys on the wreck were carried out 2012 and 2013, but the research team, under the direction of PhD Johan Rönnby, Professor of maritime archaeology at Södertörn University/MARIS, has only begun uncovering the true facts about the Mars. The conditions for preservation of organic materials and the absence of the shipworm, terredo navalis, in the Baltic Sea are unique and the Mars wreck is extremely well preserved. Since she settled down on the ocean floor 450 years ago, it is almost as if time has stood still. The
hull is in good condition and both sides of the ship are quite intact. Timbers and several artifacts show traces of the raging fire on board before the ship sunk, but one can still see cannons in the gun ports, cannon balls, pieces of rope, pots in the galley as well as personal belongings scattered on the wreck site. Broken timber, cannons broken in half and human remains reveal the inferno and brutality of the events surrounding the sinking of the *Mars*. Over time we will learn more about the battle of Öland, the *Mars* and life on board. The archaeological documentations have only begun.

An exhibition project

The discovery made headlines in the national and international press and has generated a large and legitimate interest in the scientific community. An important aim is also to make the research results accessible for the public.

The finding of the *Mars* has not only lifted the city of Västervik as a base of an internationally renowned dive team but has also highlighted a very exciting and important part of the region’s history. During the 16th and 17th centuries Västervik was one of the most significant naval and commercial shipyards in Sweden, in which many of the great ships of the era were built. In 2012 Västerviks Museum was therefore entrusted with developing an exhibition project focusing on 16th century naval history with the *Mars* as the basic story. Västerviks Museum is now the principal arena for mediation of new results that emerge in the *Mars* project.
Through generous contributions from the local foundation Sparbanksstiftelsen Tjustbygden as well as the scientists from the MARIS - maritime archaeology research institute - of Södertörn University, the Swedish National Defense College, the Swedish Maritime Museum, Ocean Discovery and several marine companies and divers the first exhibition opened in 2012. Since then the exhibition has expanded to the museum's main exhibition hall, covering about 300 square meters.

The exhibition *Mars the Magnificent & the Swedish maritime history of the 16th century* focus on the development from armed merchant ships to large specially built and heavily armed warships, the importance of the Kings shipyards, were Västervik was one of them, as well as maritime archeology as a science. Based on the current research the story about the Nordic seven years’ war and the battle of Öland are told. In the exhibition the *Mars* is presented together with previously known and excavated wrecks from the same era, such as the merchant ship *Ringaren* (1530) which sank just north of Västervik and the Kings warships *Kraveln* (1525) and *Elefanten* (1563), the latter a sister ship of the *Mars*. The partnership with the National Maritime Museum has enabled us to show almost all of the items that have been recovered from Swedish 16th century wrecks so far. The exhibition is in its current form, alongside the artifacts, based on text and image banners and dispersed in the exhibition are several screens where underwater film and photos from the expeditions are shown. Exclusively for the exhibition a 25 minutes long documentary has been produced, shown in a new film studio and included in the visit in the museum. The documentary is also a popular feature for group tours, then often shown on a wide screen in the exhibition hall.
Methodological development and new technology for documentation & visualization

The documentation of the wreck is complicated due to the great depth of 75 m and requires great expertise in diving and the maneuvering of ROV’s and other instruments. In order to document the wreck the archaeologists and divers therefore need to use new and revolutionary technologies. One of the projects main objectives is to develop and use non-intrusive archaeological documentation methods to gather information and data from the Mars without affecting or change the wreck site. These results then need to be processed on land and methods for visualization has to be developed. The latter also has great potential in terms of exhibitions and public events.

The team has already developed methods for digital film and photo documentation on large depts. Under the light of a new especially built light rig deployed over the wreck site the divers, equipped with high tech cameras, have already spent hundreds of hours documenting the wreck. For example over 600 still images, shot by the underwater photographer Tomasz Stachura, have been merged into a single photo mosaic where you can see the wreck site in its entirety. This mosaic is unique and is now a central part of the exhibition at Västerviks Museum, printed on a 10 by 5 meter large screen complemented with facts and photos in a digital application for iPad. An application for smart phones is being developed as we speak.

In the exhibition visitors can see the first salvaged items from the Mars, supplemented with additional items and timber from contemporary wrecks from the 16th century. In 2013 the research team salvaged three ship timbers, two cannons and a gun carriage for examination on the surface, with the intention to reconstruct a cross-section of the hull. The objects are placed in a specially built water filled tank in the exhibition hall. To be able to show these objects in parallel with the ongoing research is somewhat unique. Often it can take years before salvaged items can be displayed for the public.

Photo 25: Photogrammetry in the making! Ingemar Lundgren are processing the photogrammetry data from the documentation of a salvaged cannon. Photo: Veronica Palm, Västerviks museum.
Just recently the objects has been photographed with high-resolution camera to test photogrammetry as a method for documentation and 3D visualization. This method for under water documentation, tested and developed by Ocean Discovery’s high tech diver Ingemar Lundgren, has now been proven to be an excellent tool for documentation, even at the bottom of the sea, and the tests carried out at the wreck site in 2013 shows that it can be used for 3D projections, reconstructions and animations as well as for model printing using a 3D printer. It then becomes an important tool for non-intrusive archaeological documentation, scientific work and public visualization, since it enables surveys of artifacts and wreck sites “over the surface”. 3D projections and even actual models in different scales are under production for the exhibition. The museums aim is to, alongside the research project, develop the shipwreck exhibition, for example with more digital components. A future plan discussed is to display 3D projections and underwater film in a dome theater. Visitors will be able to “visit” the Mars wreck, on land, in a near future!

The past and the future

Västervik has historically been a major and important shipbuilding region. The reconstruction of the city in the 1540s was primarily due to the establishment of the shipyard and dry dock initiated by the Swedish King Gustav Vasa (1523-1560). Several ships in his fleet was built here, but it was under the reign of his son, King Erik XIV (1560-1568), that Västervik became one of the leading naval yards in the kingdom. In the 1560s three of the Swedish navy’s largest ships were built at the shipyard – St Christopher, Tanthejen and Mars’ successor
Neptunus, later renamed Röde Draken (the Red Dragon). The building trend continued into the 1570s when the Swedish navy launched another large ship – Smålands Lejon (Smalands Lion) estimated to 1 100 tons. The ship building tradition in Västervik carried on in to the late 1800s. Even though the Mars was not built in Västervik, she was built in Björkenäs 140 kilometers further south along the coast and launched in 1563, this magnificent ship and the town of Västervik are parts of the same important and very interesting story - the emergence of the Swedish naval fleet and the art of shipbuilding during the 16th century.

Västerviks Museum, in collaboration with MARIS, Ocean Discovery och the Visualization Centre in Norrköping are now working on a pilot study regarding development of methods of non-destructive archeology and visualization. Our common ambition is, with the Mars project as a base, to develop new methods for the presentation of research results. The study will be the start of a major development project for alternative research methods instead of, or as a complement to, excavations and salvage that lead to expensive conservation costs for museums and cultural heritage institutions, as well as creating new opportunities for public experience through development of visualization technologies for exhibitions. The methods are also of interest for various institutions and companies working with underwater documentation.

With Västerviks background in the maritime history it’s an excellent location to build a base for maritime field archaeology under water documentation and adequate facilities for dissemination of research results in collaboration with MARIS and Ocean Discovery. The research results from the Mars project will be presented through various channels to researchers, students and professionals as well as to schoolchildren and the general public. In an extended and modern visual museum the field of maritime archaeology and the 16th century maritime history can be presented as a complement to existing museums exhibiting ships from the 17th century, such as the Vasa Museum in Stockholm and the Kronan in Kalmar County Museum, and for example the National Maritime Museum and The Naval Museum with focus on late maritime history.

During this summer new dives are planned at the wreck site and the Mars will then be documented further through film, photos and measurements. At the same time research are progressing in the archives. The wrecks potential as a source of knowledge is immense and in time we will learn more about the Mars and life on board one of the largest warships in the 16th century. The exhibition Mars the Magnificent & the Swedish maritime history of the 16th century is an ongoing project that will evolve as the research is progressing. We are looking forward to many exciting developments during the upcoming years.

Biography

Veronica Palm is employed as an archaeologist and deputy director of Västerviks Museum. Västerviks Museum has been entrusted with developing an exhibition project on Mars, acting as the principal arena for mediation of new research findings that emerge in connection with the Mars project over the coming years. Veronica is the project leader of the exhibition project called Mars the Magnificent – naval history of the 16th century.

References

Painting 1: http://en.wikipedia.org/wiki/Pieter_Cornelisz_van_Soest