Joint Investigation Report

On the Attack Against ROK Ship Cheonan

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Ministry of National Defense
Republic of Korea

Preface

On March 26, 2010, an unprecedented incident in which ROKS Cheonan was sunk by a surprise torpedo attack by a North Korean submarine occurred, resulting in the death of 46 crew members.

The Ministry of National Defense organized the Civilian-Military Joint Investigation Group on March 31 in order to clearly identify the cause of the sinking as well as the entity responsible for the incident. The Civilian-Military Joint Investigation Group proceeded with the investigation with the participation of civilian and foreign experts to ensure objectivity and credibility.

The Civilian-Military Joint Investigation Group conducted its investigation while the whole group was lodging near the incident site in the West Sea facing unfavorable conditions such as harsh climates and currents. Despite these difficulties, its objective and scientific investigation found that ROKS Cheonan was sunk due to a torpedo launched by a North Korean midget submarine. The final investigation results were announced on May 20.

The Civilian-Military Joint Investigation Group reported the investigation results to the UN Security Council on June 14. As a result, UN Security Council Presidential Statement that acknowledges and condemns North Korea's culpability in the incident was unanimously adopted.

Nonetheless, North Korea continues to deny the facts and has heightened its threats of military provocations, claiming that the Republic of Korea fabricated the investigation results. Even within the Republic of Korea, the reality is that there are individuals who raise doubts against the investigation results based on their own interests, and they are taking irresponsible actions such as spreading groundless assertions.

Thus, the Ministry of National Defense has published the *Joint Investigation Report on the Attack Against ROK Ship Cheonan*, which contains the findings of the Civilian-Military Joint Investigation Group and the evidence data in both Korean and English in order to inform Koreans and the international community of the truth, and to resolve unnecessary misunderstandings and suspicions.

The report presents the overview, analysis on possible causes of the sinking, detailed analysis results by team, conclusion, and appendix in order. Detailed contents of the analysis and assessment result are in appendix. The Civilian-Military Joint Investigation Group took into consideration every single possible cause of sinking in order to eliminate any preconception that may exist in finding the actual cause of the sinking. The report encompasses the whole process of the joint investigation and utilizes more than 300 pictures and diagrams to facilitate the readers' understanding.

In particular, a total of 73 experts from 4 different nations, 12 domestic civilian institutions, and military personnel actively participated in investigations on various fields such as scientific investigation, ship structure, explosives, and intelligence analysis. The experts also participated extensively in writing of the report. Every participant and expert concurred with the content, indicating that the report is internationally verified.

This is one of the world's first reports on an investigation of a salvaged hull of a warship that was sunk by a torpedo. The finding of the propulsion motor of a torpedo(the smoking gun) and the detection of explosive components illustrated to the North and the international community that even the most covert of attacks will leave evidence behind. Most importantly, all this entails a solemn warning to the North not to engage in further military provocations.

This report is a pledge that the Republic of Korea will reflect upon this incident and not let the North exercise further military provocations. We are confident that it will contribute to the understanding that the security awareness of the people of the Republic of Korea and the security issues that we face cannot be compromised by any personal and group interests.

Please understand that this report is subject to limitations in release of confidential military information, and since the report focused on the task of demonstrating the findings in a scientific and objective manner, the expression of certain information by using technical terminologies was unavoidable.

It is our sincere hope that *Joint Investigation Report on the Attack Against ROK Ship Cheonan* delivers the truth, and provides grounds to solve the misunderstandings and doubts raised thus far, becoming useful information to interested civilians, domestic and foreign scholars, as well as the press media.

September 2010
Civilian-Military Joint Investigation Group

다국적 민 · 군 합동조사단은 2010년 3월 26일 21:22경 대한민국 백령도 근해에서 발생한 천안함 피격사건의 원인을 조사하였다. 아래 서명자들은 조사에 참여한 각국 조사팀의 대표로서 이 보고서의 내용에 동의하며 아래와 같이 서명하다.

The multinational Civilian-Military Joint Investigation Group examined the cause of the attack against Republic of Korea Ship Cheonan occurred in vicinity of Baekryong Island at 2122, March 26, 2010. The undersigned are the chief representatives of each investigation team, concurring with the contents in this report.

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US Investigation Team Leader RADM(S) Thomas J. Eccles, USN

As Senior US Representative to the Republic of Korea Joint Investigation Group, I concur with the finding and conclusions of this report.

호주 조사팀장 해군중령 안토니 파월
Australian Investigation Team Leader CMDR Anthony R. Powell, RAN

As Senior Australian Representative to the Republic of Korea Joint Investigation Group, I concur with the finding and conclusions of this report.

영국 조사팀장 데이비드 맨리
UK Investigation Team Leader Mr. David W. Manley, RCNC
As the Senior British Representative to the Republic of Korea Joint Investigation Group, I concur with the findings and conclusions of this report.

스웨덴 조사팀장 에그니 위드홀름
Swedish Investigation Team Leader Mr. Agne Widholm

As Senior Swedish Representative in support of the Republic of Korea Joint Investigation Group, I concur with the finding and conclusions of this report relevant to the Swedish team's participation.

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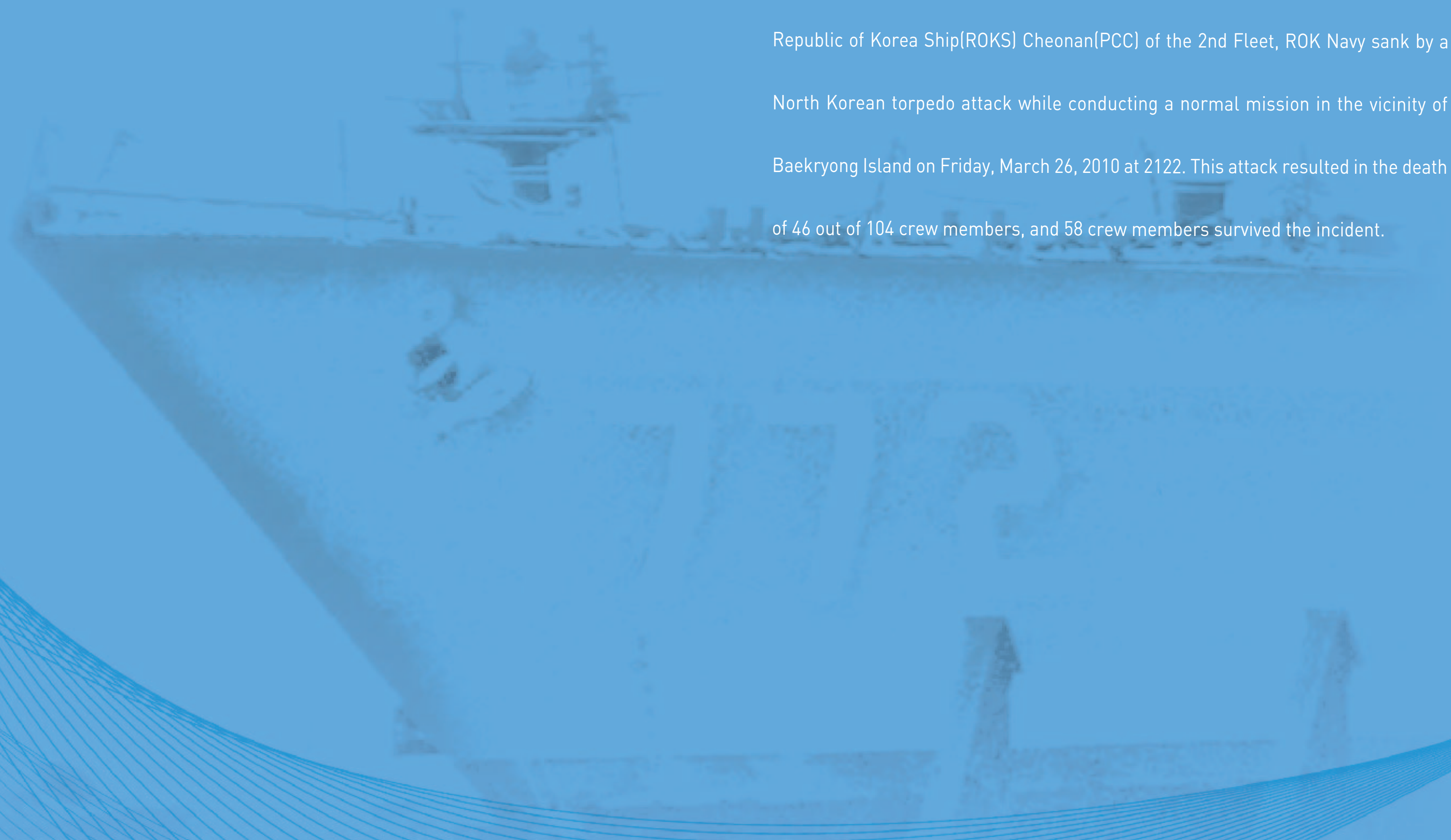
Republic of Korea Ship(ROKS) Cheonan(PCC) of the 2nd Fleet, ROK Navy sank by a North Korean torpedo attack while conducting a normal mission in the vicinity of Baekryong Island on Friday, March 26, 2010 at 2122. This attack resulted in the death of 46 out of 104 crew members, and 58 crew members survived the incident.



1. Overview

In the wake of the sinking of Republic of Korea Ship(ROKS) Cheonan on March 26, 2010, the Ministry of National Defense organized a Civilian-Military Joint Investigation Group(JIG) and commenced an investigation in order to find the cause of the sinking.

In order to ensure the transparency and credibility of the investigation process, the investigation was conducted with 25 experts from 12 Korean civilian agencies, 22 military experts, 3 advisors recommended by the National Assembly, and 24 foreign experts from the United States, Australia, the United Kingdom, and Sweden. The JIG organized the experts into four teams in order to conduct a scientific and systematic investigation. The four teams were as follows: Scientific Investigation Team, Explosive Analysis Team, Ship Structure Team, and Intelligence Analysis Team.

The JIG conducted its investigation in phases with the recovery of the ship as the dividing point. The final investigation results were announced on May 20.

In addition, the Ministry of National Defense operated a “Multinational Combined Intelligence TF” with participations of the United States, Australia, Canada, and the United Kingdom starting from May 4 to verify the perpetrator of this incident.

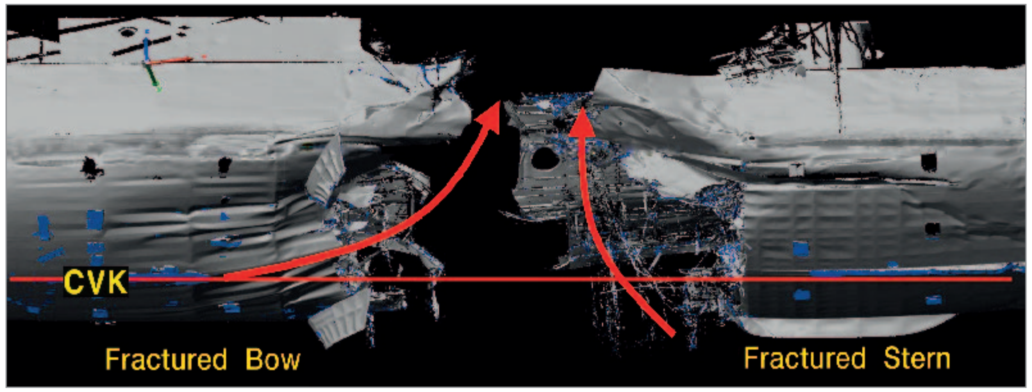
2. Investigation Result on the Cause of the Sinking

Based on the investigation of the collected evidence and the deformed shape of the recovered bow and stern, the JIG assessed that ROKS Cheonan was split and sunk due to a strong underwater explosion(UNDEX) of an influence torpedo manufactured by North Korea(nK).

The reasonings behind the assessment are as follows.

First, a precise measurement and analysis of the damaged hull showed that a shockwave and bubble effects caused significant upward bending of the CVK(Center Vertical Keel) compared to its original state. The shell plating was steeply bent, with parts of the ship fragmented. On the main deck, fracture occurred along the large openings used for the maintenance of equipment in the gas turbine room, and the portside was deformed significantly in an upward direction. The bulkhead of the gas turbine room was significantly damaged and deformed.

As seen in 〈Figure Summary-1〉, the upward bending of the bottom of the stern and bow indicates that an underwater explosion took place.



〈Figure Summary-1〉 3D laser scan image of the fractured bow and stern

Second, as seen in 〈Figure Summary-2〉, through a thorough investigation of the interior and exterior of the ship, the JIG had found evidence of extreme pressure on the fin stabilizer, which prevents significant rolling of the ship; traces of high water pressure and bubble effect on the hull bottom; wires cut with no traces of heat; and traces of spherical pressure on the gas turbine room. The above indicate that strong shockwave and bubble effects caused the splitting and sinking of the ship.

〈Figure Summary-2〉 Traces of shockwave and bubble effect

Third, statements made by the survivors were collected, including that they heard a nearly simultaneous explosion once or twice and that water was splashed on the face of the port lookout who fell by the impact. Furthermore, statements made by the coastal sentries on Baekryong Island testified that they saw a 100-meter high pillar of white flash for 2~3 seconds, consistent with the occurrence of a water plume resulting from shockwave and bubble effect. Also, no traces of fragmentation or burn injury were found from the examination of the wounded survivors and the deceased service members, while fractures and lacerations were observed. These observations are consistent with phenomena resulting from shockwave and bubble effect.

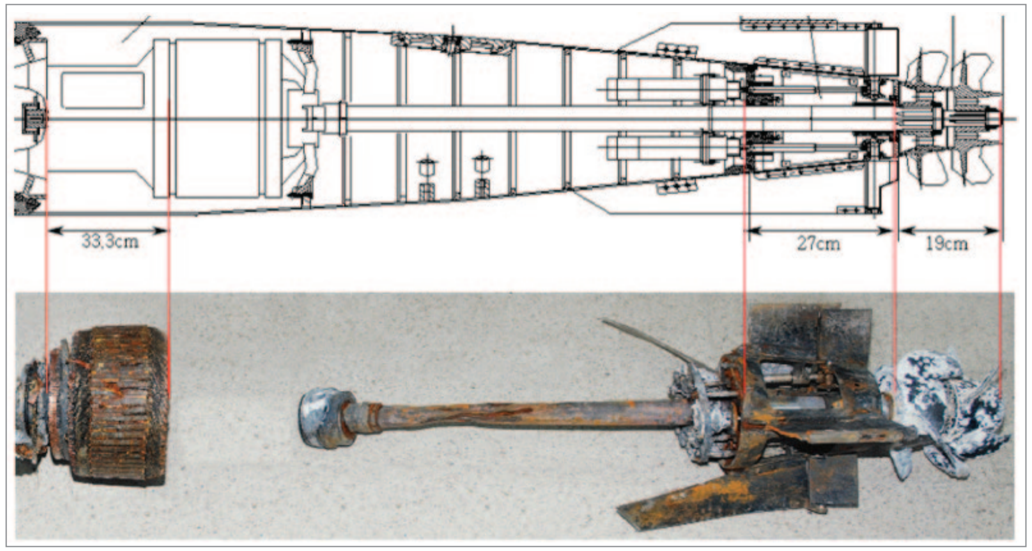
Fourth, the seismic and air acoustic wave analysis conducted by the Korea Institute of Geoscience and Mineral Resources(KIGAM) showed the following. A seismic wave of magnitude 1.5 was detected at 4 stations. Two air acoustic waves with a 1.1 second interval were detected at 11 stations. The analysis of seismic and air acoustic waves verified that they originated from an identical location. All these are consistent with the phenomena that arise from a shockwave and bubble effect produced by an underwater explosion.

Fifth, the 1st analysis result by the US team, from the hull deformation showed that the possible explosion type is an explosion of TNT equivalent of 200~300kg charge size at a point of 3m to the port from the central bottom of gas turbine room, and at a depth of 6~9m. The 2nd analysis result on simulation, by the ROK resulted in the identical location, with TNT equivalent of 250~360kg charge size. The efforts on this were also participated by the UK Investigation Team.

Sixth, based on the analysis of tidal currents in the vicinity of Baekryong Island, the JIG determined that although the currents would not significantly influence the launch of a torpedo, they were strong enough to limit the emplacement of mines.

Seventh, the analysis of the explosive residue found HMX from 28 locations including the stack and fractured surface; RDX from 6 locations including the stack and seabed; and traces of TNT from 2 locations including the fin stabilizer. Based on this analysis, the JIG confirmed the use of an explosive compound containing HMX, RDX, and TNT.

Lastly, on May 15, the JIG recovered the conclusive evidence that confirmed the use of a torpedo during a detailed search in the vicinity of the incident location using special nets. The conclusive evidence was a torpedo propulsion motor system including propellers, a propulsion motor, and steering section. The evidence is consistent with the drawing shown in 〈Figure Summary-3〉 in its size and design. The figure was a part of an introductory brochure produced by North Korea for an export purpose.

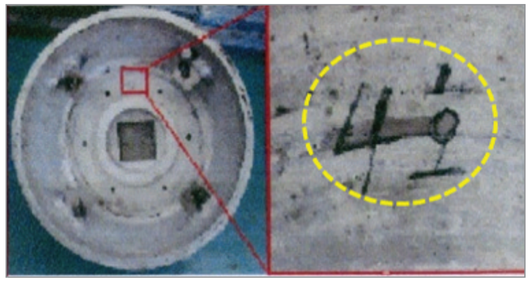


〈Figure Summary-3〉 Schematic of torpedo and recovered rear section of torpedo

A composition analysis of the adhered materials from ROKS Cheonan showed that the materials are consistent with those found on the rear section of the torpedo.

As shown on 〈Figure Summary-4〉 and 〈Figure Summary-5〉, the Korean marking “1번(No. 1 in English)” inside the rear section of the propulsion system is similar to the marking of a North Korean test torpedo obtained in 2003.

〈Figure Summary-4〉 Rear section of torpedo



〈Figure Summary-5〉 Marking on North Korean test torpedo

These evidences confirmed that the recovered torpedo parts were manufactured in North Korea.

In conclusion, after taking the entirety of the analysis results of Korean and foreign experts on the following factors into consideration – the torpedo propulsion system recovered from the incident location, deformation of the hull, statements by related personnel, medical examination of the deceased and wounded service members, seismic and infrasound waves, simulations of underwater explosions, tidal currents in the vicinity of Baekryong Island, analysis of explosive components and recovered torpedo parts – the JIG concluded the following:

ROKS Cheonan was split and sunk due to shockwave and bubble effects generated by the underwater explosion of a torpedo. The detonation location was 3m to the port from the center of the gas turbine room and at a depth of 6~9m. The weapon system used was a CHT-02D torpedo with approximately 250kg of explosives manufactured by North Korea.

3. Identification of Perpetrator

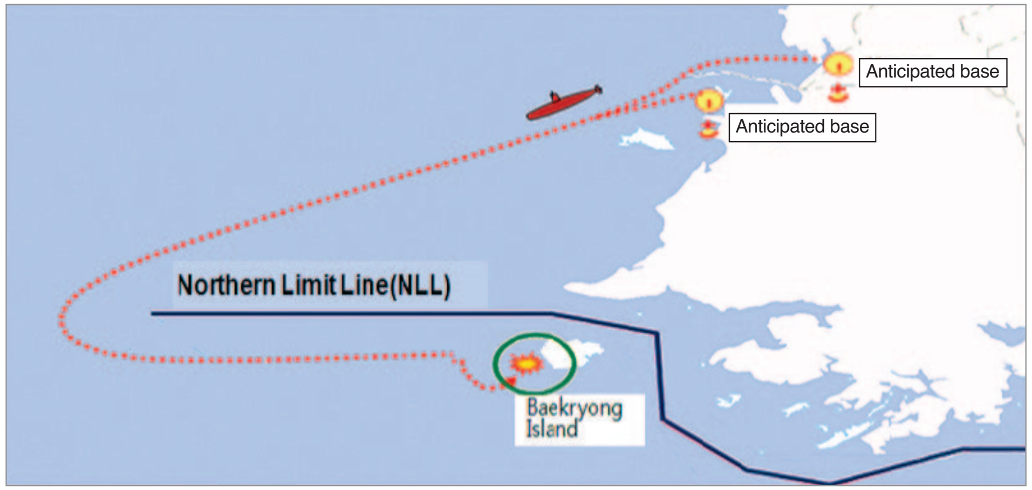
The Multinational Combined Intelligence Task Force(MCITF, and comprised of 5 states including the US, Australia, Canada, and the UK) reached the following conclusion after analyzing relevant intelligence:

The North Korean military possesses about 70 submarines and midget submarines in total, with its submarine fleet consisting of approximately 20 Romeo class submarines, 40 Sango class submarines, and 10 midget submarines including the Yono class. Also, it possesses torpedoes of various capabilities, including straight running, acoustic and wake homing torpedoes.

Moreover, it was confirmed that a few midget submarines from North Korean naval bases in the West Sea left their bases 2~3 days before the day of the incident and returned 2~3 days after the day of the attack.

Furthermore, it was confirmed that all submarines from neighboring countries were either in or near their respective home bases at the time of the incident.

The torpedo parts, recovered at the incident location by bull trawlers on May 15(they include 5-bladed/contra-rotating propellers, propulsion motor and steering section), perfectly match the schematics of the CHT-02D torpedo displayed in the introductory brochure produced by North Korea for export purposes.



〈Figure Summary-6〉 Anticipated infiltration route of North Korean midget submarine

The CHT-02D torpedo manufactured by North Korea utilizes acoustic/wake homing and passive acoustic tracking methods. It is a heavyweight torpedo with a diameter of 21 inches, a weight of 1.7 tons, and a net explosive weight of up to 250kg.

〈Figure Summary-7〉 CHT-02D torpedo manufactured by North Korea

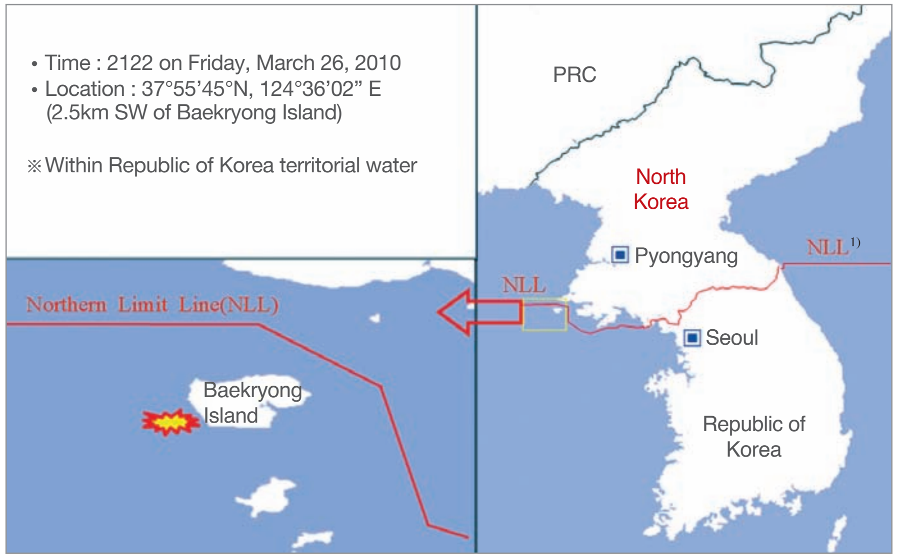
Based on all the relevant facts and analyses of the classified information, the JIG and MCITF reached the following conclusion: **ROKS Cheonan was sunk due to an underwater explosion caused by an attack of a CHT-02D torpedo manufactured and used by North Korea.** The evidence points overwhelmingly to the conclusion that the torpedo was fired by a North Korean submarine. There is no other plausible explanation.

Part I

Overview

1. Situation Overview

Republic of Korea Ship(ROKS) Cheonan(PCC) of the 2nd Fleet, ROK Navy sank by a North Korean torpedo attack while conducting a normal mission in the vicinity of Baekryong Island on Friday, March 26, 2010 at 2122. This attack resulted in the death of 46 out of 104 crew members, and 58 crew members survived the incident.


- Time : 2122 on Friday, March 26, 2010
- Location : 37°55'45"N, 124°36'02" E (2.5km SW of Baekryong Island)

※Within Republic of Korea territorial water

〈Figure Ⅰ-1-1〉 The location of ROKS Cheonan incident

- **ROKS Cheonan's mission**
  - Tuesday, March 16. Left Pyeongtaek, deployed to Western Baekryong Island Patrol Zone.
  - Thursday, March 25. Heavy seas warning activated in the West Sea. Left Western Baekryong Island Patrol Zone. Averted to SE of Daechung Island.
  - Approximately at 0600 on Friday, March 26, started to return back to the patrol zone due to good weather. Arrived at the patrol zone at about 0830 and began normal operations. At 2000, there was a duty shift(29 personnel), with others taking a rest or involved in maintenance.

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1) NLL: The maritime boundary set by UN force immediately after the armistice in 1953.

2. Situation Development

1) Before the Incident

Before the incident, there were 7 personnel on the bridge; 7 personnel at the Combat Situation Center; 2 personnel at the communication cell; 3 personnel at the bow gun R/S; 7 personnel at the machinery control room; 1 at the guiding control room; and 2 personnel at the diesel engine room. A total of 29 personnel were on duty while others were on break or sleeping at the mess hall or their berthing. The Commanding Officer of the ship finished his patrol at about 2105, returned to the CO's cabin and was checking e-mails, message boards and KNTDS[2].

At the time of the incident(2122 on March 26), ROKS Cheonan was in its normal operating conditions.

2) After the Incident

- 2122 ROKS Cheonan began to sink(the time of the incident)
- 2128 Second FLT receives situation report on the sinking of ROKS Cheonan
- 2130 Second FLT orders the immediate departure of 5 PKMs sub-squadrons in Daechung Island to incident location
- 2131 Second FLT instructs ROKS Sokcho to sail to the incident location at full speed
- 2132 Second FLT requests emergency support to Incheon maritime police(ships 501, 1002) and government ships
- 2134 Second FLT activates crisis response element
- 2140 Second FLT activates crisis action team and deploys all operation elements for combat
- 2147 Second FLT orders deployment of LYNX helicopter in Dukjuk Isl. to Baekryong Island
- 2156 Arrival of 3 PKMs, commencement of rescue operations
- 2157 Second FLT declares anti-submarine alert posture
- 2159 Second FLT requests Air Force search and rescue support
- 2207 Second FLT requests Incheon maritime police RIBs[3](501, 1002) support

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2) KNTDS: Korea Naval Tactical Data System.

3) RIB: The bottom section is consisted of glass-fiber stiffened plastic, and the upper section is composed of expandable tube. RIB is light and rigid, allowing for operation in long distance maneuver and high waves in comparison to other small vessels.

- 2210 Additional arrival of 2 PKMs, commencement of rescue operations
- 2228 Rescue of 1 sailor(Operations officer of ROKS Cheonan) by Chamsoori 322
- 2241 Arrival of Maritime Police Ship 501 and 2 RIBs, commencement of rescue operations
- 2250 Commencement of rescue operations by GOV ships(214, 227)
- 2313 Rescue operations completed, 58 survivors rescued
- 2313~0435 March 27 Night search of incident location, transportation of patients

The 58 survivors stated that they heard 'Kwang! Ku-wang' (for 1~2 seconds) sounds as they felt an impact in the rear, and a blackout occurred. The influx of seawater to sections of the ship suddenly tilted the ship to the starboard side by 90 degrees. The impact caused the Commanding Officer to be locked inside the CO's cabin. He strapped a fire hose that 4 or 5 crew members had lowered to his waist and escaped to the portside deck. At this time, about 20 crew members had gathered at the deck.

When the Commanding Officer looked towards the aft side standing from the bow section of the separated ship, the stack and the stern part aft of the stack were not visible (he also sensed a slight smell of fuel). Seeing that the bow side, where the surviving crew members had gathered, was tilted by 90 degrees to starboard, he took necessary measures. The Commanding Officer first instructed the executive officer(LCDR) to rescue the crew members locked inside the ship and the operations officer(LT) to count the number of crew members and check for a suitable disembarking location once the rescue ships arrived and approached the ship. 6 personnel including a LTJG were instructed to help or carry on their backs the injured personnel, including a PO1(lumbar fracture), PO1(fracture of the femoral region), SCPO(bruise on thigh), SCPO(shoulder injury), and SCPO(rib fracture). Following the rescue of all the survivors in the bow, the Commanding Officer confirmed that a total of 58 personnel were present and instructed them to wait for PKMs.

The Commanding Officer had a cell phone conversation with the Squadron Commander, second Fleet between 2232 and 2242. The key points of the conversation included the following: "It seems that we are hit by something," "What do you think it is?" "It seems like a torpedo, the stern is completely invisible," "Stern? From which part of the stern?" "The stack is not visible. Please send PKMs or RIBs quickly," "What about survivors?" "A total of 58 survivors. Many are bleeding. Two of them are severely wounded and not able to stand up."

3) Situation Report and Dissemination

At approximately 2128, the gunnery officer of ROKS Cheonan called the watch officer of second Fleet by his cell phone to request rescue(the communication method within the ship was limited from the power outage). The call was forwarded to the chief of the second Fleet situation cell, who had heard the content of the conversation. He was told that "the ship is tilted to the right, and we need to be rescued." He utilized a text message information network at 2130 to order the PKM sub-squadron at Daechung Island to depart immediately to the incident location.

At approximately 2130, the duty officer at second Fleet situation room received a phone call from the combat intelligence officer of ROKS Cheonan with the information that "ROKS Cheonan 'ran aground' in the vicinity of Baekryong Island and is sinking. Send help immediately." The duty officer reported the situation to the chief of the situation room. Then, he made a phone call to an Inspector, the deputy chief of the Incheon Maritime Police and said, "I got a phone call that a ROK ship ran aground west of Baekryong Island. The situation is urgent. Please send Maritime Police Ships 501 and 1002 to the west of Baekryong Island."[4)]

The deputy chief instantly instructed the 501, which was located south of Daechung Island, and the 1002, which was located south of Sochung Island, to depart for the incident location immediately.

At approximately 2132, the 2nd Fleet liaison officer called the captain of Ship 214, fishery guide ship of Ongjin county, with his cell phone and said, "ROKS Cheonan is sinking west of Baekryong Island. Please send help to support rescue efforts." The captain of the fishery guide ship notified an official at Ongjin county of the incident and set sail at approximately 2150.

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4) Upon the occurrence of the incident, the urgency of the situation led some survivors to use words such as grounding instead of using precise terms.

4) Rescue of Crew Members

All operational elements including ROKN PKMs, maritime police ships, and GOV ships were mobilized to rescue a total of 58 survivors. Around 2156, 3 PKMs from Sub-squadron arrived at the incident location and started personnel recovery accompanied by 2 addtional PKMs at 2210. PKM Sub-squadron connected a wire(3 inches) to ROKS Cheonan. The operation officer of ROKS Cheonan fell into the sea while he was moving between ships and was rescued by PKM.

Considering the possibility that the use of a PKM may increase the rolling of the ship and increase the risk of missteps during the rescue, the Commanding Officer of ROKS Cheonan decided to use maritime police RIBs. Due to the high waves, the wire connected between PKM sub-squadron and ROKS Cheonan was untied around 2238 in order to prevent crew members aboard the bow section of ROKS Cheonan from falling. Two RIBs from Maritime Police Ship 501(500tons) arrived around 2241, approached ROKS Cheonan, and rescued 19 crew members. Ship Incheon 227, a fishery guide ship, rescued 2 wounded crew members and transported them to Baekryong Island around 2308. The remaining 36 survivors were rescued by Maritime Police Ship 501.

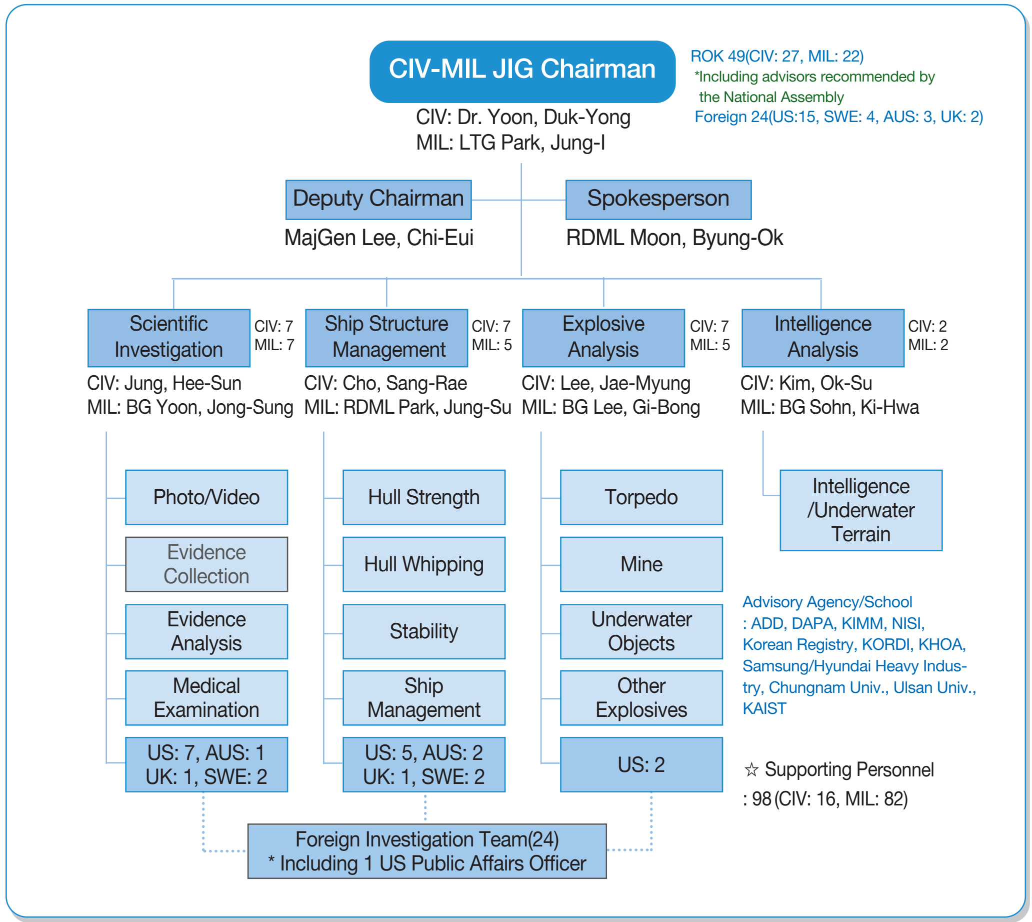
Following the arrival of RIBs, the Commanding Officer of ROKS Cheonan ordered personnel gathered by the aft gun to be transported first and ordered that “the wounded go first and help the severely wounded.” In accordance with the Commanding Officer’s orders, the wounded and seaman apprentices were rescued first and moved to Maritime Police Ship 501 with RIBs and rescue boards. The Commanding Officer, executive officer, and communication officer were the last to leave ROKS Cheonan. Between 2313 March 26 and 0435 March 27, the incident location was searched, and the 51 survivors aboard Maritime Police Ship 501 were transported to PKM Sub-squadrons and then moved to PCC. They arrived at Pyeongtaek port at approximately 1400 March 27.

3. Investigation Activities

1) JIG Operations

The CIV-MIL JIG was initially organized on March 31 and included 82 personnel(59 active service members, 17 government personnel, and 6 civilians). It was then reorganized as the Civilian-Military Joint Investigation Group on April 12 and included 73 personnel (49 ROK, 24 Foreign experts), to initiate investigation activities.

The JIG was in operation for a total of 92 days until June 30. During this time, it held press conferences on its investigation activities on four different occasions(April 7, 15, 25,



〈Table I-3-1〉 The organizational structure of the Joint Investigation Group(JIG) and May 20) and also attended a UN Security Council meeting for 9 days from June 9 through June 17 to explain the investigation results.

The objective of the JIG was to find the exact cause of the sinking through a detailed investigation conducted in a scientific and objective manner. The focus was first, to form a civilian and military joint investigation group in order to improve the transparency and credibility of the investigation process; second, to secure international credibility through the participation of foreign experts from the US and other nations; third, to conduct the investigation in phases, with the recovery of the ship as the dividing point; and fourth, to conduct the investigation in a scientific and systematic manner.

2) Activities of Teams

(1) Scientific Investigation Team

The Scientific Investigation Team was composed of 25 research personnel[5] in total(7 military personnel / 7 civilian / 11 foreign experts) from MND Criminal Investigation Command(CIC), ROK Army Investigation Group, National Institute of Scientific Investigation(NISI), Defense Media Agency, and foreign experts. The participating personnel were divided into 4 sub-teams of photo/video analysis, evidence collection, evidence analysis, and medical examination team(responsible for postmortem examination and autopsy). Their investigation was conducted aboard ships(ROKS Dokdo, ROKS Chunghaejin, ROKS Sunginbong, etc.), at Baekryong Island, 2nd Fleet Command, MND, CIC, and NISI.

During a period spanning the occurrence of the incident to the recovery of the stern, the Scientific Investigation Team collected and analyzed statements of the 58 survivors over four periods(1st: March 27, 2nd: March 28, 3rd: March 31, 4th: April 1). Based on these statements, the individuals' locations and status of their injury at the time of the incident were identified and incorporated into a compartmental diagram of ROKS Cheonan, which was then reflected in the investigation for the cause of the sinking.

From April 2 to 5, the JIG clearly identified the circumstances surrounding the incident by confirming that ROKS Cheonan was conducting its normal operation and that the incident occurred at 2122 hours by analyzing the TOD[6] (DVR) recording around incident time, and the cell phone call records of 96 crew members from 1700 to 2400, March 26. This excluded 8 of 104 members who did not possess a cell phone.

The Scientific Investigation Team divided the area in the vicinity of the incident location into section 1(the stern) and section 2(the bow). The photo/video analysis team photographed the entire recovery process beginning from the salvaging of the hull. Together with the evidence collection team, they photographed and analyzed the fractured surfaces, internal and external traces to verify the cause of the incident including factors such as non-explosion, internal explosion, and external explosion. In addition, they conducted digital forensics[7] on the CCTVs.

The evidence collection team divided its efforts into sea evidence collection, bow and stern evidence collection, and seabed evidence collection. During the search and rescue operations, the sea evidence collection team extracted all possible evidence, including the soil at the incident location seabed, metal pieces suspected to be fragments of the incident, and materials that are conducive to the adherence of explosive residue. The bow and stern evidence collection efforts initially focused on the on-site examination of evidence collected every time the bow, stern, and stack aboard the barge ship were salvaged. After the recovered ship was transported to the 2nd Fleet Command at Pyeongtaek, a precise examination was conducted on three occasions for the stern, and on two occasions for the bow. These investigations were focused on the collection of evidences necessary for explosive residue and metallic content analysis.

Lastly, the seabed evidence collection efforts gathered the missing gas turbine protective cover, generator armature and parts, fiber and metallic fragments of the motor. In particular, explosive residue and metallic fragments were collected using a gauze along the hull bottom, mud, and breakplane of the gas turbine room, which had directly received the pressure resulting from the explosion.

In addition, seabed materials collected with the use of a special net were initially sorted out on the deck and moved to a separate site at the Battalion from the 6th Brigade, ROKMC where they were further classified manually and through the use of a mine(metal) detector.

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[5] Total number of ROK investigators was 83(14 ROK military & civilian, and 69 supporting personnel).

[6] TOD(Thermal Observation Device): A device that detects the infrared rays of an object or creature, and converts them into a video imagery. TOD is mainly used for surveillance and reconnaissance purposes.

[7] Digital Forensics: A digital investigation process which analyzes data acquired from electric evidences such as a cell phone, PDA, PC, and server.

The evidence analysis team considered the recovered locations and features of the collected evidence to prioritize its evidence analysis. In case of the chemical analysis, the liquid-chromatography mass analysis method[8] was utilized to detect the explosive components such as HMX, RDX, and TNT.

For the physical analysis, the composition ratios of 3 North Korean test torpedo samples, hull samples from various locations on ROKS Cheonan and various parts of the gas turbine room, which was close to the point of explosion, were contrasted for a comparison analysis.

Afterwards, a composition analysis of collected metals was conducted through the use of an electron microscope and energy dispersion X-ray analysis[9]. By comparing the composition of extracted samples, irrelevant metals were excluded, and further evaluation was conducted on the metals containing aluminum and aluminum alloy, which are metals used in torpedoes.

The medical examination team, comprised jointly of civilian and military forensics personnel, was located aboard the barge ship and ROKS Dokdo. They guided the recovery process of the deceased service members, identified the bodies of the deceased, performed medical examinations, found the causes of death, and analyzed the causes of death in connection with the cause of the sinking.

(2) Ship Structure/Management Team

The Ship Structure/Management Team consisted of personnel from ROK Joint Chiefs of Staff(JCS), ROKN HQ, Defense Acquisition and Procurement Agency(DAPA), academia (Ulsan and Chungnam National University), the ship building industry(Hyundai and Samsung Heavy Industries), research institutes(Agency for Defense Development, Korea Institute of Machinery and Materials and Korean Register of Shipping), and foreign experts. A total of 22 research personnel, including 7 civilian, 5 military and 10 foreign experts as well as 3 additional supporting personnel, was included in the team. The investigation activities of the Ship Structure/Management Team were divided into ship management, basic hull strength analysis, stability analysis, and analysis of the impact on the hull due to an underwater explosion.

In the area of ship management, the team analyzed the possibility of ROKS Cheonan sinking due to non-explosion factors such as fatigue fracture, grounding, and collision by referring to ship maintenance records and the damage seen on ROKS Cheonan.

In the area of basic hull strength analysis, the latest structural analysis methods were used to analyze the stability of ROKS Cheonan in extreme sea conditions(wave height 10.06m) that can occur during 25~30 years of operation.

In the area of stability analysis, the design standard and capability of ROKS Cheonan's stability were analyzed. This analysis confirmed that ROKS Cheonan would not have any issue in stability under normal conditions. Further stability analysis of the fractured bow and stern was conducted.

In the area of analysis on the impact to the hull due to an underwater explosion, experts and measuring devices from the Defense Agency for Technology and Quality(DTaQ) were employed prior to the underwater explosion analysis to precisely measure and analyze the size and shape of the damage seen on the bow and stern. In order to evaluate the nature of the explosion(size of explosive and detonation location), a one-dimensional whipping[10] analysis was conducted on the ship structure. Afterwards, a three-dimensional underwater explosion analysis was conducted for describing the destruction of ROKS Cheonan by using the explosion type that had been deduced by the Explosive Analysis Team.

(3) Explosive Analysis Team

The Explosive Analysis Team consisted of 14 personnel(7 civilian, 5 military, 2 foreign) from ROK JCS, ADD as well as civilian and foreign experts. The Explosive Analysis Team divided its activities into sub-categories of torpedoes, mines, fluid analysis, and other explosives.

In order to analyze the cause of the sinking, a detailed analysis on the possibility of an internal explosion such as a magazine explosion, fuel tank explosion, diesel engine explosion or gas turbine explosion was conducted prior to the recovery of the ship. Following the recovery of the ship, an analysis on the possibility of an explosion on or above the sur-

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[8] An analysis method to confirm the composition of a material by using a device that analyzes the mass of an element after separating everything except vapor by various means such as ion exchange, and high-speed liquidation.

[9] A method of analyzing the content and components of a sample, and the electron's wavelength released after injecting electron into a target sample.

[10] Whipping: A phenomenon where an abrupt bending on the hull (interpreted as the beam) occurs by the effects from the expansion and contraction of the bubble.

face due to a cruise(anti-surface) missile or ballistic missile, as well as an analysis on the possibility of an underwater explosion due to a torpedo, mine, land-controlled mine or improvised explosive device(IED) was conducted. An on-site examination and investigation were conducted in parallel with the above analysis to find the cause of the sinking.

This process allowed the team to narrow down the possible weapon systems to torpedoes and mines. Following the recovery of the ship, it was scientifically proven that ROKS Cheonan was sunk due to a non-contact underwater explosion through analysis of the fractured surface, analysis of adhered materials, and simulations of the splitting of the ship.

In addition, the team came up with the most likely size of the explosive charge and explosion location through various underwater explosion simulations that took into account varying charge sizes and water depths.

(4) Intelligence Analysis Team

The Intelligence Analysis Team consisted of 4 investigation personnel(2 civilian, 2 military) from the Korea Defense Intelligence Agency(KDIA), National Oceanographic Research Institute(NORI), and Korea Ocean Research and Development Institute(KORDI), as well as 12 supporting personnel. The Intelligence Analysis Team was composed of 4 subteams focusing in maritime conditions, North Korea provocation analysis, technical intelligence, and TOD footage analysis.

In order to determine the cause of the sinking, the Intelligence Analysis Team analyzed the underwater obstacles(reefs) and characteristics of currents in the vicinity of Baekryong Island. The analysis of the underwater terrain was conducted in 5 phases for sequential verification. The analysis of the tidal current was done through analysis and verification using the tidal movement and current forecast system for military operations. A detailed analysis of the TOD imagery before and after the incident was conducted. For types of possible North Korean provocations, an analysis was conducted through categorization by types of infiltration assets and armaments. The technical intelligence analysis focused on supporting the Scientific Investigation Team with evidence collection in an attempt to identify the cause of the sinking.

3) Investigation Activities

(1) Prior to the Recovery of the Ship: March 31~April 14

Prior to the recovery of the ship, each team of the JIG closely reviewed the operational timeline and actions of ROKS Cheonan. The JIG recruited personnel from the private sector and concurrently held discussions with relevant experts. Internal and external factors were both considered as a possible cause of the sinking. As for internal factors of the sinking, the analysis conducted by the ADD indicated that fatigue fracture was highly unlikely. The summary of the maintenance records also indicated that the possibility of maintenance failure causing the sinking was highly unlikely as well. In addition, a fuel tank explosion was assessed to be highly unlikely, because such an explosion would not satisfy the necessary conditions for the splitting of the ship.

As for the external factors of the sinking, the possibility of friendly mines was found to be limited according to the expert opinions and assessment by the JIG. An explosion of North Korean torpedoes and mines, on the other hand, was assessed to be possible by experts. There were no reefs on the sea charts of the incident location, and according to expert opinions, chopping waves would be highly unlikely to cause the sinking. In addition, radar records and TOD imagery of the incident location vicinity showed no other ships, indicating that sinking by a collision is highly unlikely as well.

An examination of key materials such as the clothing and recovered items resulted in no explosive residue being detected from the clothes of the survivors(9 itmes including service uniforms). The recovered items(3 items including MCR floor plate) from the surface and coast of Baekryong Island also showed no trace of fire.

(2) After the Recovery of the Stern: April 15 ~ April 23

During the recovery of the stern, the JIG organized an on-site investigation team of 57 personnel, which was deployed to ROKS Dokdo on April 14. The stern was recovered on April 15, and the on-site investigation results following the recovery of the stern were announced on April 16.

The preliminary on-site investigation led to the assessment that an internal explosion causing the sinking was highly unlikely. This assessment was based on the lack of burn damage on the interior structure, the good condition of the wires, and the upward deformation of the hull bottom plating.

Grounding was also assessed to be highly unlikely given that the hull bottom was found in relatively good condition and that the fractured surface on the bottom of the stern was bent in an upward direction.

Fatigue fracture was assessed to be highly unlikely given that the fractured surface of the hull bottom was bent upward with an 80° angle and that the stiffeners located at the aft bulkhead of the gas turbine room were rolled up.

Therefore, it was assessed that an external explosion was the most likely possibility given that the hull fracture occurred from the port bottom toward the starboard side in an upward direction; no trace of fragments was found at the fractured surface; the bending of the hull was caused by external pressure; and the wires were cut and not melted by heat. An examination of the collected evidence from the scene, which consisted of 10 samples including interior materials from the fractured surface, was conducted to detect explosive residue and aluminum components.

A detailed examination of the stern was conducted on April 18. At this time, 147 samples of 29 types were collected. A 3-dimensional laser scan of the fractured stern was performed on April 21. The DTaQ took precise measurements of the damaged parts of the stern and conducted an investigation of the damaged locations and deformations. The on-site investigation during the recovery of the stern, and the detailed investigation following the recovery of the stern, which was conducted from April 15 to 25, led to the assessment that an external explosion was more likely than an internal explosion.

(3) After the Recovery of the Bow: April 24 ~ May 19

The JIG sent an on-site investigation team of 50 personnel to Baekryong Island on April 23 for investigative activities following the recovery of the bow. The bow was recovered on April 24, and the investigation results following the recovery of the bow were announced on April 25. The second on-site investigation led to the assessment that the possibility of an internal explosion was highly unlikely given the intact magazines and fuel tanks, inward bending of the hull at the fractured surface, upward rolling of ribs and upward bending of the CVK.

A grounding was confirmed to be highly unlikely given that the hull bottom was found in good condition and the sonar dome[11] located at the hull bottom did not show any damage. Fatigue fracture was confirmed to be highly unlikely given the nature of the deformation: the fractured surface was significantly deformed in an upward direction due to external pressure, and complicated damage was delivered to ROKS Cheonan.

Among the factors of an external explosion, a contact explosion was assessed to be unlikely given the lack of soot within and outside the hull. Furthermore, there were no holes or traces of melting due to heat on the wires and interior materials at the fractured surface.

Therefore, the possibility of a non-contact external explosion was assessed to be highly likely based on the severe inward bending and severance of the hull due to shockwave and bubble effect generated by an underwater explosion.

The on-site investigation results indicated that the explosion occurred at the port of the gas turbine room centerline with pressure being exerted upward toward the starboard side. The size of the explosive charge was estimated through a simulation that took into account the size and shape of the damage seen.

A three-dimensional laser scanning was conducted on the fractured surface of the bow. A discussion on an underwater explosion hull whipping analysis by the US team was conducted on April 26. The on-site investigation during the recovery of the bow and the detailed investigation following the recovery of the bow, which was conducted from April 23 to May 19, led to the assessment that an underwater explosion occurred and that a non-contact explosion was more likely than a contact explosion.

(4) The Recovery of the Torpedo Propulsion Motor: May 15

The propulsion motor and propellers of a torpedo propulsion system were recovered on May 15, during a detailed search of the seabed using a special net that began on May 10.

An analysis of the torpedo propulsion section confirmed that the recovered evidence was identical in size and shape to the schematics of a North Korean torpedo. Furthermore, the JIG was able to confirm through composition analysis that the adhered materials found on the torpedo propulsion section and ROKS Cheonan were identical. In addition, the Korean alphabet inscription in the rear of the propulsion section (“1번”, Number 1 in English) is similar in style with the Korean alphabet inscription method on a North Korean torpedo (“4호”, unit 4 in English) obtained in 2003 near waters in the vicinity of Pohang.

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[11] Sonar dome: The cover for the sonar, and consists of special material to allow the transmission of the sound waves

(5) Press Conference on Investigation Result: May 20

During a press conference at the MND conference room with members of the local and foreign press corps in presence, Dr. Yoon Duk Yong(Civilian Co-chairman) announced the investigation result.

After taking the entirety of the analysis results of Korean and foreign experts on the following factors into consideration – the torpedo propulsion system recovered from the incident location, deformation of the hull, statements by related personnel, medical examination of the deceased and wounded service members, seismic and air acoustic waves, simulations of underwater explosions, tidal currents in the vicinity of Baekryong Island, and analysis of explosive components – the JIG confirmed the following:

ROKS Cheonan was split and sunk due to shockwave and bubble effect generated by the underwater explosion of a torpedo. The detonation location was 3m to the port from the center of the gas turbine room and at a depth of 6~9m. The weapon system used was a CHT-02D torpedo with roughly 250kg of explosives made by North Korea.

4. Overall Shape and Structures of ROKS Cheonan

ROKS Cheonan was constructed by Korea TACOMA Marine Ind.(merged with Hanjin Heavy Ind. & Construction Holdings co. in 1999), and after its acquisition to ROK Navy in 1988, it had been in operation for approximately 22 years before the incident.

ROKS Cheonan consisted of O-1 deck and O-2 deck above the main deck, and of 1st Platform and 2nd Platform below the main deck. On the main deck, from the bow-side to stern-side there were a ward room, officers' berthing, CPOs' mess, machinery control room and crew's mess. The CO's cabin, Combat Information Center, communication room, demist[12], and stack[13] are located on the O-1 deck. The bridge and mast[14] are located on the O-2 deck. On the bow-side of the 1st Platform, there are a deck admin room, sail/gunnery/operation crews' berthing, and CPOs' berthing. The machinery crews' berthing, CPOs' lounge, aft head, decontamination room, machinery storage, stern gun R/S, and steering gear room are located on the stern-side. On the 2nd Platform, firearms admin room, elec. maintenance room, and gyro room are located on the bow-side, and the gas turbine room and diesel engine room are on the stern-side. On the ship bottom, a sonar dome, fin stabilizer, and bilge keel[15] are located.

〈Figure I-4-1〉 Overall shape and structures of ROKS Cheonan

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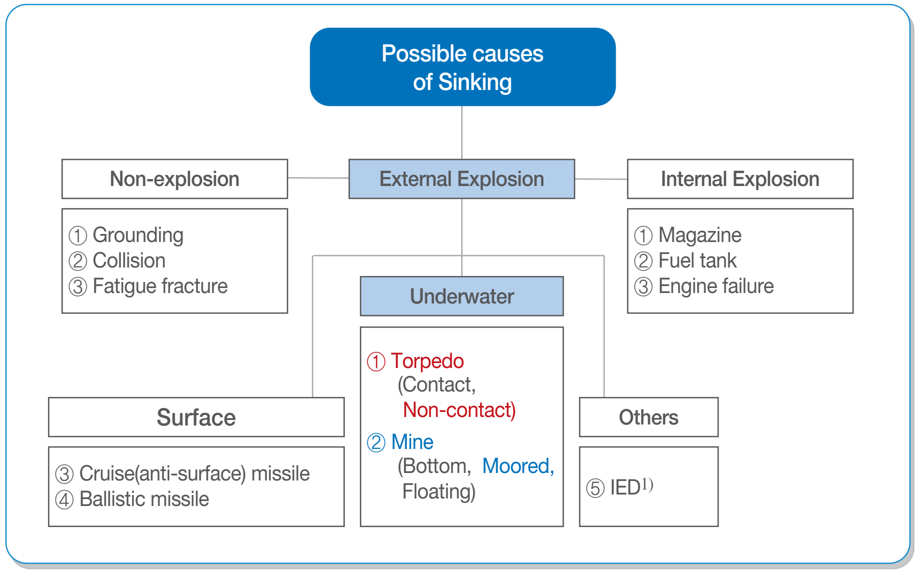
[12] A demist is a device which inhales air that the engine needs and excludes moisture and dust.
[13] A stack is a chimney which acts as an exhaust part of an engine.
[14] A mast is located at the center of a ship.

[15] A bilge keel is located on the left and right side of a ship bottom mitigating blurring of a ship.

Part II

Analysis on Possible Causes of the Sinking



All possible causes of the sinking were analyzed after defining these factors in 3 categories: non-explosion, external explosion, and internal explosion. The evaluations were conducted under the review standards employed by IMO(International Maritime Organization) to assess the likelihood of each possible cause to the incident.

1. Non-explosion

1) Grounding

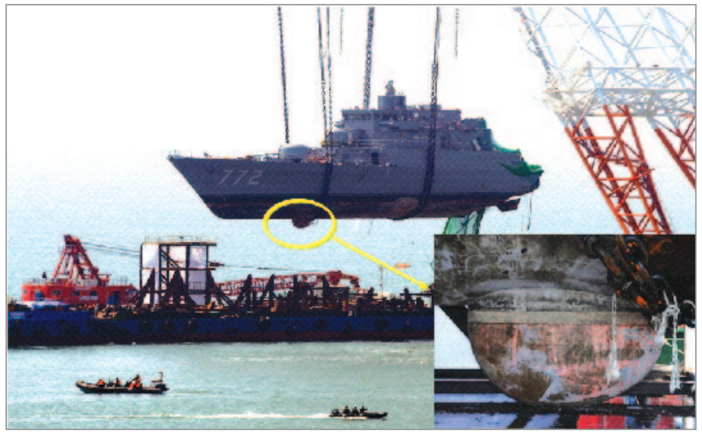
A damage inflicted on a ship by a grounding would typically result in lengthwise cutting on the bottom of the hull. Especially for vessels with a sonar dome on the bow(such as ROKS Cheonan), normally the sonar dome would be damaged prior to the hull in case of a grounding.

(1) Damage Indicators

Damage patterns	Investigation result
• Cutting effect in longitudinal direction on the bottom hull	None
• Scratch marks in longitudinal direction	None
• Damage on sonar dome and propellers	None
• Damage condition indicating grounding (damage caused by large plastic deformation[2])	None
• Possibility of grounding by depth and unknown reef	None
• Indications, warnings, and testimonies	None

(2) Visual Inspection

No scratch or cutting consistent with a grounding was found on ROKS Cheonan on the bottom of the hull along the longitudinal direction. In addition, the sonar dome, and propellers located on the very bottom of the ship, were observed with no grounding damages as displayed in 〈Figure II-1-1〉 and 〈Figure II-1-2〉. Furthermore, two types of hull deformations, impossible to occur in a grounding event, were observed.



〈Figure II-1-1〉 The sonar dome at the time of bow salvage

First, severe dishing(concave deformation of outer panels between stiffeners) was present on the bottom shell plates of the forward and aft sections of the gas turbine room

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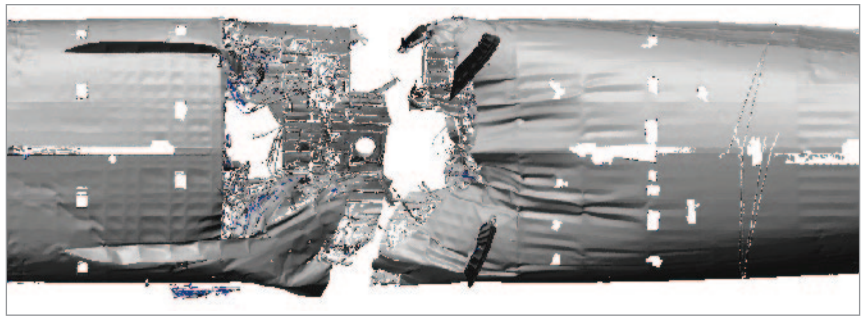
1) IED: Improvised Explosive Device.

2) Plastic deformation: Permanent deformation by the force exceeding elastic limit of a material.

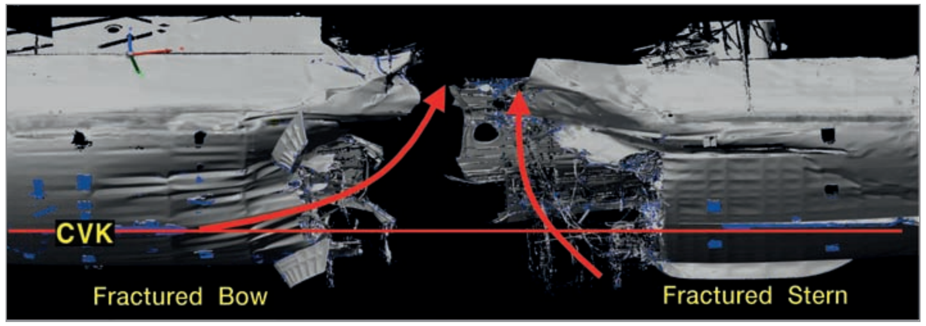
〈Figure II-1-2〉 ROKS Cheonan propellers upon the recovery of the stern

(See 〈Figure II-1-3〉). This is a result of extreme pressure impacting broadly on the shell plates due to shockwave and bubble effect, and cannot be explained with grounding as a cause.



〈Figure II-1-3〉 Dishing on the shell plating panels on the bottom of the hull

Secondly, shell plates on the bottom of the fractured area bent significantly inward. On the stern side of the fractured areas, shell plates were deformed in an upward direction, from the bottom of the hull to the main deck level(See 〈Figure II-1-4〉). The shell plates on the bow portside of the fractured areas also suffered an equivalent level of inward deformation. The shell plates on the portside of the bow were deformed in concave curvature with the center located outside of the ship. The CVK below the gas turbine room, as shown in 〈Figure II-1-5〉, had also been severely deformed in an arc-shape by spherical pressure. These cannot occur in case of a grounding.



〈Figure II-1-4〉 3D laser scanning images on breakplanes of bow and stern

〈Figure II-1-5〉 Shell plates of ROKS Cheonan gas turbine room

On the other hand, the damage characterization of the fractured surface did not reveal traces of large plastic deformation caused by loss of longitudinal strength[3] after a grounding, but shearing fracture[4], which results from instantaneous pressure on shell plating along the direction of plating thickness, and brittle fracture[5] by a rapid deformation(See 〈Figure II-1-6〉).

Also, after examining the deformation of the starboard propellers, it was assessed that

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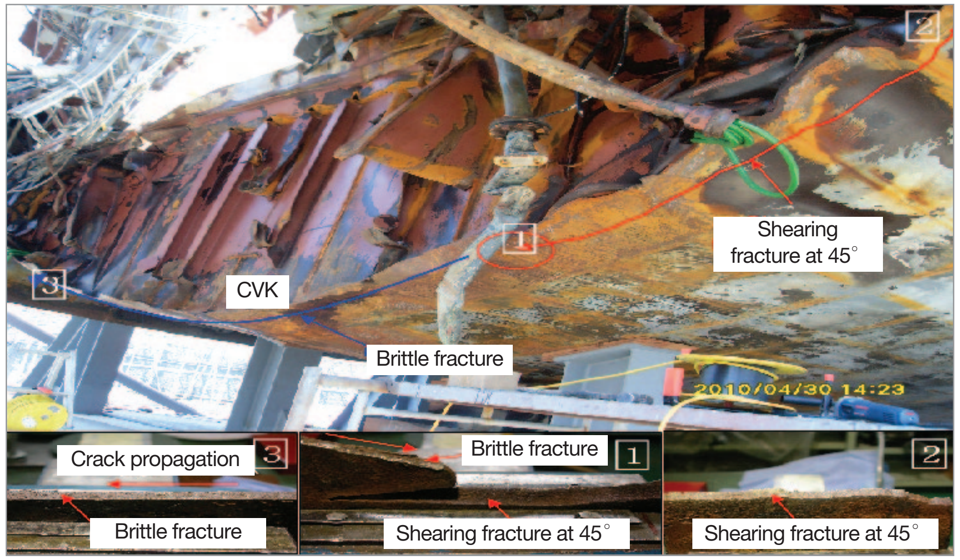
[3] Longitudinal strength: The strength to endure the loading or any other pressure on the longitudinal direction of the hull.
[4] Shear fracture: Instantaneous force severs an object plane in shear direction.
[5] Brittle fracture: An object fractured by external force without expansion in size(length, width, etc.).



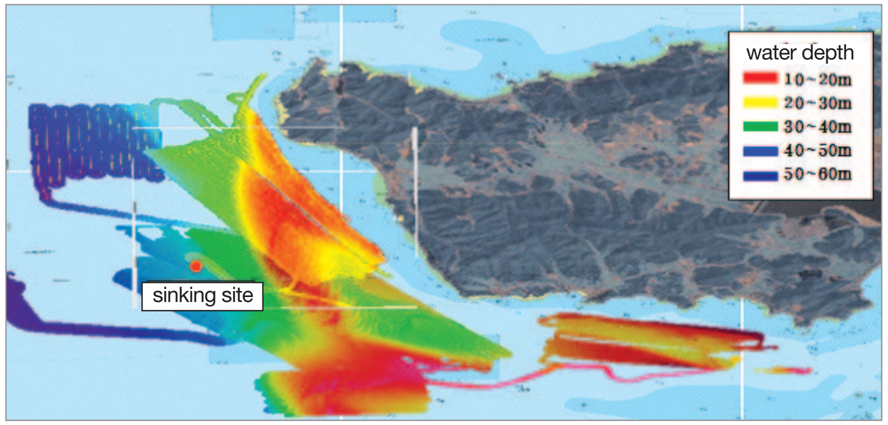
〈Figure II-1-6〉 Analysis result on the damage characteristics of the fractured surface seen on ROKS Cheonan

the break of the blades or global scratch marks were absent, which would have occurred in case of grounding, but no such traces were found. Instead, 5 blades were bent toward the bow side in a symmetric manner(See 〈Figure II-1-7〉). The Swedish Investigation Team assessed that this type of deformation cannot occur due to a grounding event, and concluded the possible cause as the mass force of inertia, which was created from the sudden halt of the propeller rotation, and propulsion shaft being pushed severely.

〈Figure II-1-7〉 The deformation of starboard propellers

(3) Environmental Conditions

According to the data of ROKS Cheonan, the draft of the ship is 2.88m. Judging from the growth of seaweed remaining on the hull, operational draft is estimated to be an average of less than 3.1m. The water depth of the incident site is 47m. It is known that the depth at the shallowest point around the operational area is 8.6m, thus leaving no possibility for ROKS Cheonan to make contact with the seabed. In addition, there were no obstacles identified in the water after thorough probing on the incident site from March 28 to May 8 with 4 Navy mine sweeping vessels and 2 investigation vessels from KORDI(See 〈Figure II-1-8〉). It was also discovered that artificial reefs were placed at depths of around 17~34m. This also leaves no possibility of contact with the seafloor. These facts were verified by the Australian Investigation Team.



〈Figure II-1-8〉 Probing result of seafloor geography in incident site

(4) Modeling and Simulation(M&S)

M&S were not conducted due to no possibility of a grounding with little practical significance expected.

(5) Indication and Warning

There were no indication and warning that can support a grounding as the cause of the sinking of ROKS Cheonan.

(6) Statement from Relevant Personnel

There is no statement that can support a grounding.

(7) Conclusion: No Possibility

The damage conditions that would be present in case of a grounding such as longitudinal cutting effects, hull scratch, sonar dome and propeller damage(located under hull bottom), and others were not present. In addition, it is confirmed that there are no known reefs in the incident sea area. Furthermore, since dishing effect(normally generated from underwater explosion) was apparent on the bottom shell plating, the possibility of damage from reefs or other grounding events was rejected.

2) Collision

When an incoming ship collides into a victim ship during navigation, the side shell plates of the victim ship are torn apart, and the fracture shape normally appears in a form almost identical to the head of the incoming ship.

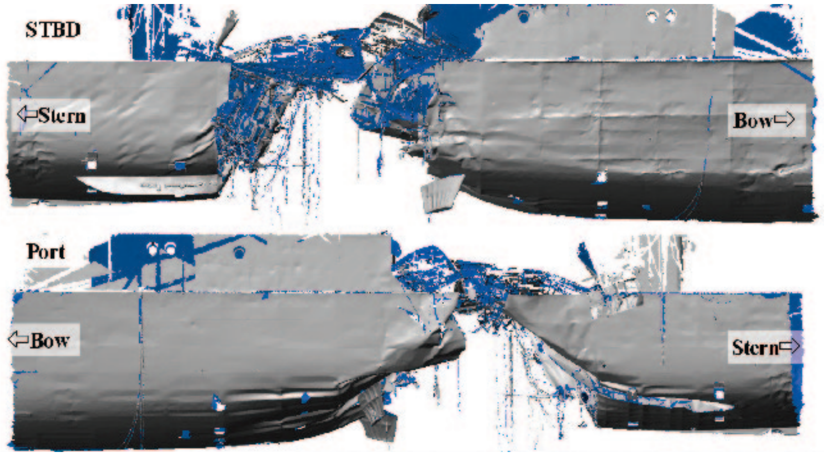
Additionally, the trace of an incoming vessel such as paint will remain at the collided(victim) vessel.

(1) Damage Indicators

Damage patterns	Investigation result
• Damage condition indicating collision(head shape of incoming ship)	None
• Traces and debris left by incoming ship on victim ship	None
• Vessels operated in nearby area at the time of incident	None
• Indications, warnings, and testimonies	None

(2) Visual Inspection

When observing the fracture shape of ROKS Cheonan on the sides(See 〈Figure II-1-9〉), there are no apparent fractures and debris that resemble a bow of an incoming ship. Furthermore, the overall fracture status indicates a massive upward force originated from the bottom. Additionally, the dishing effect apparent on the bottom plate of the ship, shown in 〈Figure II-1-3〉, is a deformation that cannot occur through a collision but can be seen as a result of intense shock pressure from underwater.



〈Figure II-1-9〉 Fractured areas of ROKS Cheonan

(3) Environmental Condition

There is no possibility of a collision since KNTDS(Korea Naval Tactics Data System) and AIS(Automatic Identification System) data confirmed that there were no vessels within 5.5 miles of ROKS Cheonan at the time of the incident. Furthermore, no vessels were confirmed to be operating near ROKS Cheonan on the TOD imagery.

(4) Modeling and Simulation

Since there is no possibility of a collision, M&S were not conducted with little practical significance expected.

(5) Indication and Warning

At the time of the incident, there were no indication and warning relating to a collision.

(6) Statement from Relevant Personnel

There was no testimony made by the survivors and the rescuers relating to a collision, and rescue operation footage captured no vessels involved in a collision.

(7) Conclusion: No Possibility

The damage status that correlates to a collision, such as the shape of a bow of an incoming ship, traces, debris indicating a collision, and nearby vessels in the area at the time of the incident were not present. Additionally, there are no survivor testimonies related to a collision. Furthermore, since dishing effect, which can occur through a non-contact underwater explosion, was apparent on the bottom plate, the possibility of a collision was disregarded.

3) Fatigue Fracture

Fatigue fracture, where fracture occurs at a lower level of stress[6] than the yield stress of the material, can take place when a structure is exposed to a repeated load. The crack (which begins when the stress cycle reaches limit) gradually expands and may result in unstable breakdown if it reaches the critical size, and it usually initiates from the surface rather than in the interior. At the initiating phase of a crack, a complete destruction of the hull is almost impossible.

If repeated load is applied to the crack, it expands and propagates. Generally, this phase also does not develop rapidly, and is detected and repaired through a periodic inspection. These minute cracks are kept at a level that can only create local damage on structural members[7], so it is nearly impossible for them to result in a catastrophic accident such as the hull breaking down in half.

The fractured surfaces due to fatigue fracture would leave beach marks as a trace. Also, the clean cut split on each surface would allow the exact match between the fractured surfaces when fitted together.

(1) Damage Indicators

Damage patterns	Investigation result
• Crack in the hull	None
• Damage cutting indicating fatigue fracture (beach mark on fractured surface, clean-cut fractured surface)	None
• Hull aging	Insufficient to fail
• Indications, warnings, and testimonies	None

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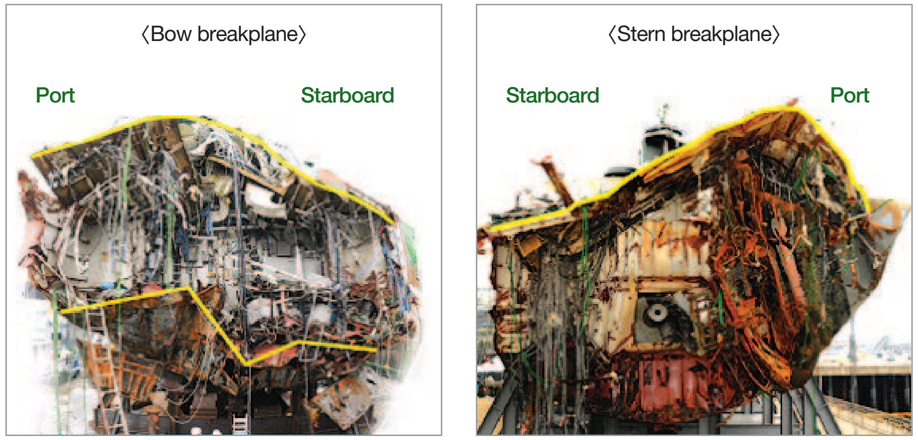
[6] Stress: The counter force created within an object as a reaction when the object is affected with the external force.
[7] Structural members: The materials consisting the ship.

(2) Visual Inspection

A close inspection on the breakplane of ROKS Cheonan reveals that the bottom of the bow was bent upward, while the stern portside bottom was deformed extremely upward to the main deck level, to the point that it is almost not recognizable(See ⟨Figure II-1-10⟩). The fractured surface on the bottom of the stern is cut clean at in front of the transverse bulkhead.



⟨Figure II-1-10⟩ Breakplane of the bow and stern

After examining the damages seen in ⟨Figure II-1-6⟩, it was verified that an enormous force exerted in an upward direction from the bottom resulted in instantaneous shearing around bulkheads and external breakdown accompanied by a large plastic deformation. Also, the rigid foundation of the gas turbine and the side structure of the starboard side were fallen apart, and the bottom of starboard side of the bow breakplane has also been torn out because of intense tensile force.

(3) Environmental Conditions

ROKS Cheonan had been in service for 22 years since its commission and had not reached the end of its service life(25 years). For the last 5 years, ROKS Cheonan had been under maintenance for a total of 14 times over 69 weeks. Extensive maintenance in the fleet was conducted a total of 5 times over 9 weeks with safety maintenance done on the hull such as anti-fouling coating and ultrasonic tests. Especially, no cracks or indicative evidences were discovered in the previous maintenance.

Also, after the hull was recovered, ultrasonic tests were conducted on April 30, 2010 to check the condition of the hull. Since the average hull thickness reduction(See 〈Table II-1-1〉) was 3.22%, significantly below the reserve thickness reduction of 20%, the condition of the hull was confirmed to be sufficient(for the design standard) to render no possibility of fatigue damage.

CAT	Port (avg. thickness: mm)			Starboard (avg. thickness: mm)			Overall
	Initial thickness	Measured thickness	Avg. corrosion(%)	Initial thickness	Measured thickness	Avg. corrosion(%)	Avg. corrosion(%)
Diesel engine room	9	8.75	2.77	9	8.67	3.66	3.215
	11	10.59	3.72	11	10.63	3.36	3.54
	11	10.68	2.90	11	10.55	4.09	3.495
	15	14.59	2.73	15	14.61	2.60	2.665
			3.03			3.42	3.22

〈Table II-1-1〉 Ultrasonic test results on the hull(April 30, 2010)

(4) Modeling and Simulation

M&S were not conducted because there is no possibility of fatigue fracture with little practical significance expected.

(5) Indication and Warning

There were no indication and warning of hull cracking or fatigue fracture.

(6) Statement from Relevant Personnel

After interviewing one of the survivors responsible for maintenance and repair of the ship, he reiterated that there were no cracks throughout ROKS Cheonan. There were no other testimonies that could support the possibility of fatigue fracture.

(7) Conclusion: No Possibility

No hull cracking was discovered in ROKS Cheonan prior to the incident. Also, beach marks which are normally found in fatigue fractures, were not present on the structures and fractured surface of the hull. The ultrasonic tests also revealed the thickness reduction of the hull plates at 3.22% on average, which indicates a good condition for operation. Additionally, the dishing effect on the shell plates and observed damage shapes were consistent with the effects of a non-contact underwater explosion. Thus, the JIG rejected the possibility of fatigue fracture as a cause of the incident.

2. Internal Explosion

1) Magazine Explosion

ROKS Cheonan mostly conducts patrol missions with an installment of 40 and 76mm naval guns, anti-surface Harpoon missiles, anti-submarine depth charges, and other various types of explosives.

(1) Damage Indicators

Damage patterns	Investigation result
• Completely broken apart or damaged bulkhead of magazine and upper deck from the center of detonation	None
• Outward bending of deck and sideshells	None
• Trace of fire / soot	None
• Fragment marks and damage holes created by fragments on the bulkhead and upper deck of magazine	None
• Damage on the gun in case of R/S room explosion	None
• Internal damage in magazine and damaged ammo inside	None
• Numerous burn injuries from heat and hearing damage	None

(2) Visual Inspection

TOD footage showed that ROKS Cheonan was sunk and broken in half. It was confirmed following the recovery of the ship that it had been split up in the middle.

〈Figure II-2-1〉 Shape of damage on ROKS Cheonan

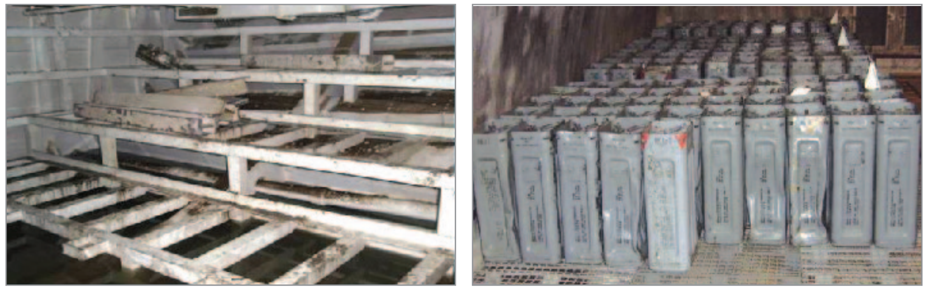
〈Figure II-2-2〉 Conditions of the bottom of bow and stern

Investigation on the exterior of the stern and the bow, where 40 and 76mm magazines are located, showed that no upper iron plates of the waterline had undergone bending effects. In addition, the magazines showed no trace of internal damages, and there was no deformation in an outwardly direction on the magazine bulkhead and no damages resulting from fragments. Furthermore, no leftover fragments were found.

In addition, the salvaged ammunition cases were only bent as a result of the water pressure without traces of an explosion(See 〈Figure II-2-3〉).

76mm magazine

76mm ammunition box after off load maintenance



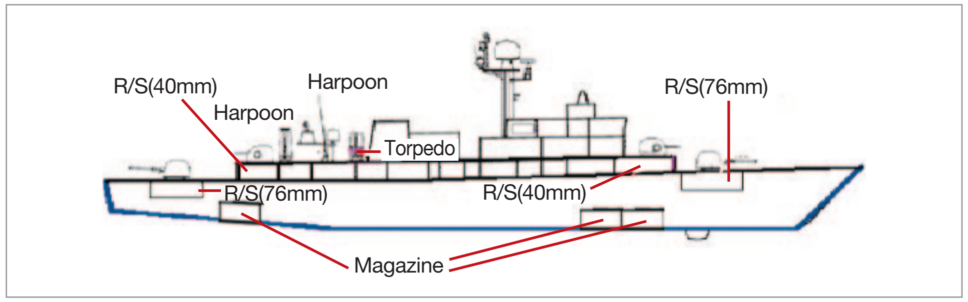
40mm magazine

40mm ammunition box after off load maintenance

〈Figure II-2-3〉 Conditions of magazines after the hull recovery

(3) Environmental Condition

〈Figure II-2-4〉 below depicts specific locations of the major ammunition storage area(excluding small arms, etc.). Harpoon missiles, Mistral missiles, torpedoes, depth charges, and small depth charges are located on board and 40 and 76mm ammunitions are stored inside the ship.



〈Figure II-2-4〉 Ammunitions layout on ROKS Cheonan

(4) Indication and Warning

There were no unusual indication and warning regarding an ammunition explosion prior to the incident.

(5) Modeling and Simulation

No magazine explosion modeling and simulation were performed due to no possibility of a magazine explosion with little practical significance expected.

(6) Statement from Relevant Personnel

Most survivors heard one explosion noise but one heard a “wham” and a “bang” noise(another crew heard “gwang”, “gwa~ang”). At the time of the incident, hull and crew members’ bodies were lifted up to the air approximately 30~100cm and dropped back onto the surface. All crew members testified that they did not witness any fire or smell explosives.

(7) Conclusion: No Possibility

After the hull recovery, counting of the installed ammunitions from ROKS Cheonan showed that a few 5.56mm ammunitions, small depth charge fuses, and R-BOC[8] were lost.

All the munitions stored in the upper deck were installed with full consideration of their safety. Regarding the operation mechanisms of these munitions, there is no possibility of a self-detonation. In case of the self-detonation, these munitions would have only caused local damages; the self-detonation of these ammunition can not cause a comprehensive damage to the hull. The gun rounds stored in the bottom of the ship could have caused a significant damage to the hull given their net explosive weight. However, since these ammunitions are stored at the bow and stern, they cannot cause the splitting of the ship's center.

Additionally, there were no traces of an explosion in the bottom of the ship and magazines. Also, the entirety of 76 and 40mm ammunition was recovered further proving that the magazine explosion did not occur.

2) Fuel Tank Explosion

(1) Damage Indicators

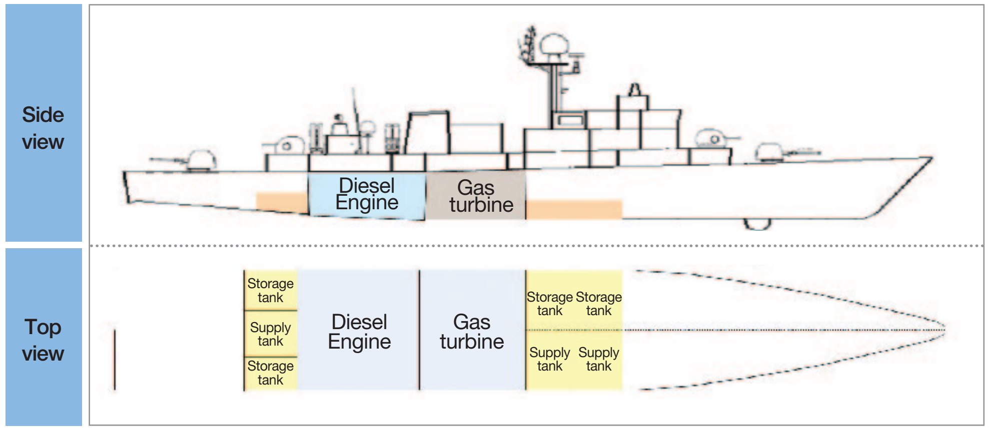
Damage patterns	Investigation result
• Broken apart or damaged bulkhead of fuel tank and upper deck from the center of detonation	None
• Outward bending of side plating of fuel tank	None
• Trace of fire occurrence, and soot from fuel vapor	None
• Damaged fuel pipe	None
• Weakened fuel tank material due to explosion	None
• Outward bending of hull shell plating	None
• Damaged fuel tank in the bow and stern	None

(2) Visual Inspection

Damage on the hull is not at the fuel tank and is not consistent with that of a fuel tank explosion. After recovering the hull, it was confirmed that the two fuel tanks behind the diesel engine room and in front of the gas turbine room were not damaged. The fuel, mixed with seawater, remained in a relatively good condition and was recovered and disposed of. The side plating and bottom hull were intact. In other words, there was no trace of a fuel tank explosion.

(3) Environmental Condition

〈Figure II-2-5〉 illustrates the fuel tank locations of ROKS Cheonan. No damaged conditions were found after the inspection on these tanks, the remaining fuel was preserved, with no traces of fire or an explosion observed.



〈Figure II-2-5〉 Location of fuel tank of ROKS Cheonan

(4) Modeling and Simulation

No fuel tank explosion modeling and simulation were performed due to no possibility of a fuel tank explosion with little practical significance expected.

(5) Indication and Warning

There were no unusual indication and warning regarding a fuel tank explosion prior to the incident.

(6) Statements from Relevant Personnel

There were no relevant statements to support that a fuel tank explosion was the cause of the sinking.

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[8] A device that spreads aluminum pieces near the enemy's guided missile in order to induce the missile towards another direction.

(7) Conclusion: No possibility

Although there was an ambiguity of statements from the survivors, there were no crews that witnessed fire, or fire column. After recovering ROKS Cheonan, no traces of fire, soot or an internal explosion of the fuel tank were found. The stern fuel tank was in a good condition and with the exception of 2 bow supply tanks, which had moved upwards, there were no significant changes in structure. Therefore, the assessment is that a fuel explosion did not occur. The investigation of the fuel tanks showed that the 2 bow storage tanks were not damaged, and 2 supply tanks were moved upwards due to the damage to the gas turbine room. The 3 tanks in the stern were in a good condition. In conclusion, it was confirmed that ROKS Cheonan did not sink due to a fuel tank explosion.

3) Diesel Engine Defect

There were two MTU 12V 956 TB 82 diesel engines on ROKS Cheonan, with each engine connected to the right and left shaft respectively. Normally, both engines are used during the ship's maneuver.

(1) Damage Indicators

Damage patterns	Investigation result
• Broken apart or ripped apart bulkhead of diesel engine room and upper deck from the center of detonation	None
• Outward bending of side shell plate of diesel engine room above waterline	None
• Trace of fire occurrence and soot	None
• Damage holes due to fragmentation from an explosion	None
• Damaged diesel engine room	None
• Outward bending of hull shell plating	None

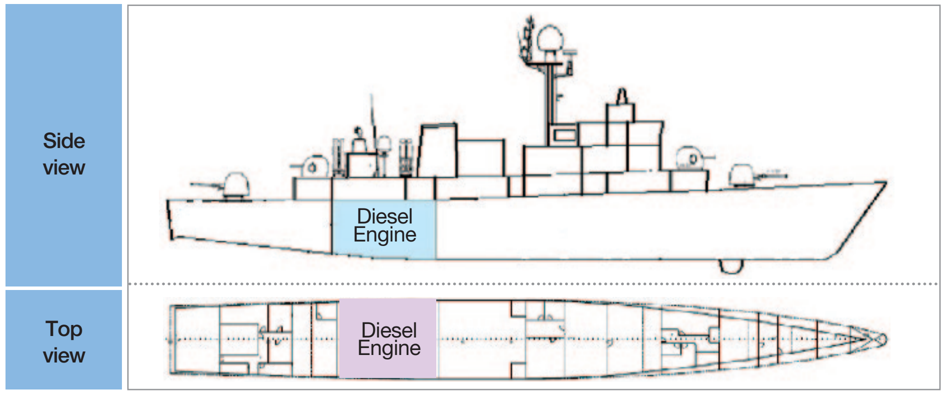
(2) Visual Inspection

The front bulkhead of diesel engine room was damaged towards the stern direction. The gear box and shafts were found bent upwards and toward the starboard, with the starboard shaft bent more than the port. The two diesel engines did not show any damage that would result from an internal explosion and remained in a relatively good condition.

(3) Environmental condition

① Location of the Diesel Engine

The location of the diesel engine is in the stern side on the bottom of the ship as shown in 〈Figure II-2-6〉.



〈Figure II-2-6〉 Location of the diesel engine room of ROKS Cheonan

② Possibility and Checklist for the Possibility of Diesel Engine Explosion

The following 〈Table II-2-1〉 lists the result of the analysis on the possibility of a diesel engine explosion. The analysis referred to an up-to-date investigation and analysis, documents regarding the maintenance and operation of ROKS Cheonan and inspection following the recovery of the ship.

Category		Check-list	Analysis Result
Related Documents		• Engine records and operation records(life cycle, etc.) • Anything special during "operations" • Check on regular maintenance schedule and implementation	Although the life cycle was over, regular maintenance was done and no problem was found with operation
Survivor statements	Explosion sound	• Check on sound of engine	None Heard
		• Sound of metal breaking, internal shock sound	None Heard
		• Check on fire alarm in engine room	Not activated
Condition During Recovery	Engine	• Damage of exhaust such as engine cylinder. • Damage (pressure, temperature) to engine gauges	No damage No trace of explosive
	Engine Room	• Leaking of fuel or lubricants in the engine room • Are there any secondary damages due to engine explosion • Equipment damage in engine area, fire, soot • Damage to the ENG' BED, etc.	No signs of fire and soot in engine room. Engine was in proper spot
	Engine Room Wall	• Hole, scratch to the side bulkhead of engine room • Soot on side bulkhead and ceiling of the engine room	No signs of hole to bulkheads or scratches

〈Table II-2-1〉 Analysis result on the possibility of diesel engine explosion

After checking the maintenance and operations records of ROKS Cheonan with the ROK Navy maintenance information system at ROK 2nd Fleet N4, it was found that the diesel engine has been in operation since 1988. Although this exceeds the life cycle(2008), regular maintenance was conducted internally and through outsourcing. The summary of maintenance records for total operated hours is shown in〈Table II-2-2〉. As displayed, the maintenance period for both internal and outsourcing were never reached at the time of the incident.

Category	First operated	Maintenance		Total operated hours since maintenance	
		W-5 maint.	W-6 maint.	W-5 maint.	W-6 maint.
No.1 D/E	'88. 12. 29	'07. 4. 30 '09. 5. 13	'08. 2. 22	2,288	5,434
No.2 D/E	'88. 12. 29	'07. 4. 30 '09. 5. 13	'08. 2. 22	2,288	5,434
Maintenance cycle	• Life cycle(years) : 20 years • W-5 (internal maintenance) : Operates 3,000 hours • W-6 (outsourced maintenance) : Operates 9,000 hours				

〈Table II-2-2〉 Diesel engine operation & maintenance records

The summary of the maintenance record in the ROK Navy maintenance information system for the past 3 years is listed in 〈Table II-2-3〉 below(detailed information can be accessed in Navy Maintenance Information System).

Year	Maintenance record
2007	• Cylinder head inspection and repair etc. 28 cases
2008	• Circulation pump motor repair etc. 15 cases
2009	• Air isolation equipment repair etc. 50 cases

〈Table II-2-3〉 Diesel engine maintenance records for past 3 years

In addition, after checking with national agencies, manufacturers, and Navy engine operators for manuals and technical materials, it was found that the diesel engine explosion is highly unlikely. Even in case of an explosion, it will be limited to the engine components, and given the size of the diesel engine room(10m × 10m), any form of an explosion would not result in the fracture of the hull. In theory, an explosion of the diesel engine would cause a massive fire. However, there are fire detectors and extinguishers equipped to put out the fire. Therefore, fire would not lead to an explosion of the ship. No traces of fire were found in the ship after the recovery of the ship.

There is no possibility of an engine explosion by overload because the fuel and exhaust supply line are automatically isolated in the occurrence of overload. Even in case of an overload of oil pen vapor, the possibility of fire is extremely limited due to the automatic safety measures that are installed.

In order to check the condition of the engine at the time of the incident, survivors' statements were used as a reference. At the time of the incident, ROKS Cheonan was operating at a low speed of 6.7kts, which indicates that the possibility of the engine overheating is very low to almost nonexistent. The survivors did not report witnessing any fire or hearing anything resembling a metallic explosion sound that would have resulted from an engine explosion.

(4) Modeling and Simulation

No diesel engine explosion modeling and simulation were performed due to no possibility of a diesel engine explosion with little practical significance expected.

(5) Indication and Warning

There were no unusual indication and warning regarding a diesel engine explosion prior to the incident.

(6) Statement from Relevant Personnel

There was no relevant statement to support that a diesel engine explosion was the cause of the sinking.

(7) Conclusion: No Possibility

Although the ROKS Cheonan diesel engine had exceeded its life cycle, no operational problems were ever identified from the normal depot maintenance(W-5 or W-6). Fundamentally, a diesel engine explosion is highly unlikely by nature. While the destruction of the main components can scatter debris as a result of overloading the diesel engine, this would be restricted to the interior of the engine room and would not lead to an explosion. Furthermore, since the ROKS Cheonan was operating at a low speed at the time of the incident, there could not have been an overloading of the engine. Therefore, it was assessed that an engine explosion was not the cause of the incident.

4) Gas Turbine Defect

ROKS Cheonan has one LM-2500 gas turbine, and it is used mainly for high speed maneuvers.

(1) Damage Indicators

Damage patterns	Investigation result
• Broken apart or ripped apart bulkhead of gas turbine room and upper deck from the center of detonation	Observed
• Outward bending of side shell plate of gas turbine room above waterline	Observed
• Trace of fire occurrence and soot	None
• Damage holes due to fragmentation from an explosion	None
• Damaged gas turbine room	Observed
• Outward bending of hull shell plating	None

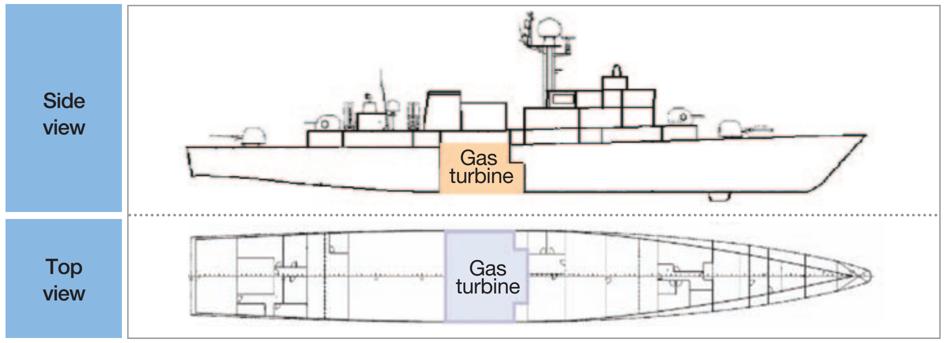
(2) Visual Inspection

The starboard shell plating and upper deck were blown off in an outward direction from the gas turbine room by explosion. An inward deformation of the hull occurred and no traces of fire, soot or damage holes due to fragmentation were found.

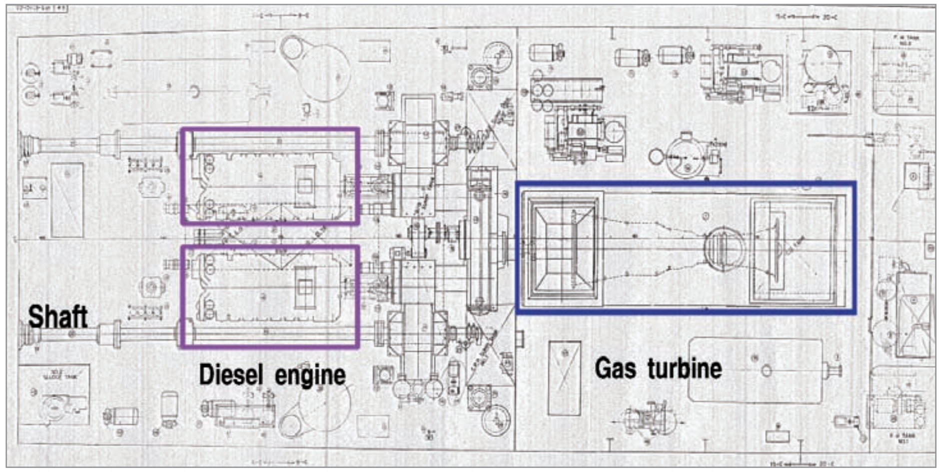
(3) Environmental Condition

① Location of the Gas Turbine

The gas turbine room is located in the middle of the ship and in front of the diesel engine room. The drawings of the gas turbine, shaft, and screw are shown in 〈Figure II-2-8〉.



〈Figure II-2-7〉 Location of the gas turbine of ROKS Cheonan



〈Figure II-2-8〉 The positions of ROKS Cheonan gas turbine, diesel engine, and shaft

② Phenomenon and Checklist of Gas Turbine Explosion

In a gas turbine, the compressor compresses the air and the diesel fuel is burned to generate gas in the G/G(Gas Generator) in order to operate the PT(Power Turbine) which then generates propulsion force. By nature, the gas turbine explosion is highly unlikely. Although fires can occur, there is a fire resistant wall that prevents the spread of fire. The characteristics and causes of damage for the gas turbine are listed in 〈Table II-2-4〉.

Cause of damage	Characteristics
• Defective gas turbine components - Fracture between Gas turbine HSFCS and reduction gear	• Damage to key components of gas turbine • Fire within the protective box

〈Table II-2-4〉 Cause of damage to gas turbine & characteristics

In regards to the gas turbine damage, key components of the gas turbine can be damaged. However, since these components are within a protective box, the possibility of this damage causing further damage to the whole ship is very low. In addition, if fire starts due to the damaged components within the protective box, the automated alarms and extinguishing system within the box immediately put the fire out.

The following 〈Table II-2-5〉 lists the result of the analysis on the possibility of the gas turbine explosion. The analysis referred to documents regarding maintenance and operation of ROKS Cheonan, testimony of the survivors, and inspection after the recovery of the ship.

Category		Checklist	Analysis Result
Check related documents		• Engine records and operation records(life cycle, etc.) • Anything unusual during "operations" • Regular maintenance schedule and implementation	Although the life cycle was over, regular maintenance was done and no problem operating it
Survivor statements	Sounds	• Too much noise from the gas turbine	None Heard
		• Sound of metal breaking, internal shock sound	None Heard
Condition during recovery	Gas turbine	• Damage to exhaust, compressor or turbine[9]	Partially damaged
		• Damage to protective box and evidence of soot	Bow side lost, stern side intact
		• Physical damage to connective device of gas turbine(reduction gear)	Partially damaged
		• Activation of fire alarm in gas turbine room	Not activated
		• Damage to key components such as exhaust	Not damaged
	Protective wall	• Evidence of fire or soot on walls • Damage to gas turbine armrest bold, etc.	Detached away but recovered

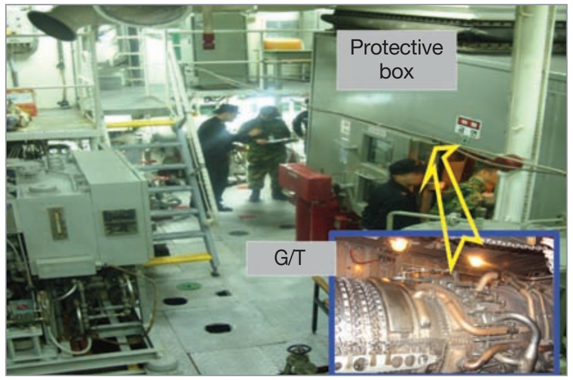
〈Table II-2-5〉 Analysis on possibility of gas turbine explosion

After checking the maintenance and operations records of ROKS Cheonan with the ROK Navy maintenance information systems at ROK 2nd Fleet N4 to confirm the gas turbine condition before the incident, it was found that the gas turbine had been in operation since 1988. Although 20 years had passed, the gas turbine had been in operation for a total of 5,213 hours, had only reached a quarter of its dismantle maintenance cycle, and maintenance was conducted regularly. The summary of maintenance records for the past 3 years is shown in 〈Table II-2-6〉 below.

Year	Maintenance records
2007	• Turbine frame, turbine fins, and converter etc. 17 cases
2008	• Vibration detecting circuit inspection etc. 15 cases
2009	• Fixed side fin inspection and repair etc. 36 cases

〈Table II-2-6〉 Gas turbine maintenance records for past 3 years

In addition, after checking with national agencies, manufacturers, and Navy engine operators for manuals and technical materials, it was confirmed that since the gas turbine uses diesel fuel by design, its explosion is highly unlikely. There is a slight possibility of fire(almost none), but the gas turbine is inside a protective box, and thus the possibility of fire spreading to the rest of the ship is next to none. Even if fire occurs, there are fire detectors and extinguishers equipped in the protective box to put the fire out. Therefore, fire from the gas turbine would not lead to an explosion of the ship.



〈Figure II-2-9〉 Gas turbine protective box

After recovering the bow and stern of ROKS Cheonan, it was found that the gas turbine room had been lost. However, after an extensive search, components of the gas turbine were recovered. There was no trace of damage holes to the bulkhead between the gas turbine room and the diesel engine room which would have been produced by an engine damage. In case of the gas turbine damage, the turbine blades would disperse and create damage holes on the nearby walls. The CCTV footage recorded up to the incident also shows no indication of damage to the gas turbine or fire. Also, the survivor statements indicate that ROKS Cheonan was maneuvering at a speed of 6.7kts and therefore was not operating the gas turbine.

(4) Modeling and Simulation

No gas turbine explosion modeling and simulation were performed due to no possibility of a gas turbine explosion with little practical significance expected.

(5) Indication and Warning

There were no unusual indication and warning regarding a gas turbine explosion prior to

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[9] Gas turbine was initially lost, but was recovered on May 9th, with no heavy damage.

the incident.

(6) Statement from Relevant Personnel

There was no relevant statement to support that a gas turbine explosion was the cause of the sinking.

(7) Conclusion: No possibility

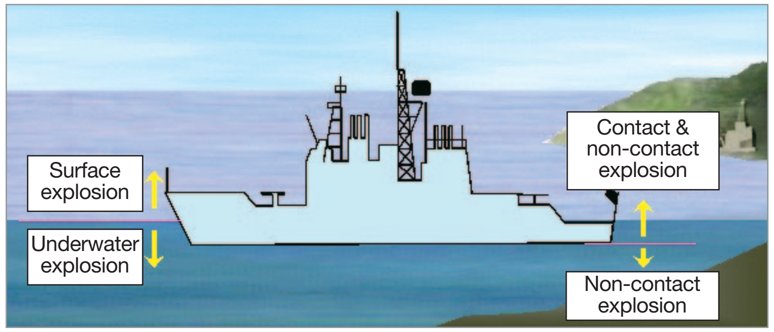
Although the life cycle of the gas turbine had been exceeded, regular maintenance had been conducted, and the gas turbine had been in operation for only 25% of the hours set for dismantle maintenance under fine condition of continuing operation. Based on the structural characteristics of the gas turbine, the possibility of an explosion is highly unlikely, not to mention how the ship operated safety measures that would have prevented a large scale fire from the gas turbine room spreading to other areas of the ship. In addition, the gas turbine was not in operation at the time of the incident. Therefore, it was concluded that a gas turbine defect is not the cause of the incident.

〈Figure II-2-10〉 Bulkhead between gas turbine room and diesel engine room

〈Figure II-2-11〉 Gas turbine room just before the incident(CCTV)

3. External Explosion

External explosion refers to the possibility that ROKS Cheonan was sunk by an explosion generated by an external force. The possibilities were categorized by detonation points (surface/underwater) and contact types(contact/non-contact) as shown in 〈Figure II-3-1〉.



〈Figure II-3-1〉 Classification of external explosion by detonation point

The agents involved in a surface explosion include a cruise(anti-surface) missile, ballistic missile, and naval gun/coastal defense artillery. Those that could have caused an underwater explosion include straight running torpedoes and buoyant mines, which detonate upon a contact with the hull(contact explosion); moored mines and bottom mines, which utilize acoustic and magnetic influence methods to detonate under the ship; and acoustic and magnetic influence torpedoes, which are normally delivered from submarines and submersibles(non-contact explosion).

In this investigation, for the purposes of promptness, effectiveness, and efficiency, the JIG first attempted to identify whether the explosion was contact or non-contact through a damage observation. Then, a more profound analysis was conducted with emphasis on a non-contact explosion, excluding contact explosion scenarios based on the observation result. The team formulated the report in the following order: surface explosions, focused on missiles such as cruise(anti-surface) missile and ballistic missile(excluding the attacks of naval gun and coastal defense artillery due to improbability); torpedoes and mines including contact and non-contact explosions; followed by land control mines(MK-6) that had been used by ROK in the past(a variant of depth charge).

1) Surface Explosion(Cruise Missile and Ballistic Missile)

A surface explosion refers to an explosion due to an external attack occurring above and at the sea surface. The attack can include naval guns from ships, coastal artillery fire from the surface, and cruise(anti-surface) missiles and ballistic missiles.

It was assessed North Korea to possess enhanced surface strike capability with longer range of targeting based on its production of new missiles and the continued test launches of improved versions of these missiles since the 1990s.

(1) Damage Indicators

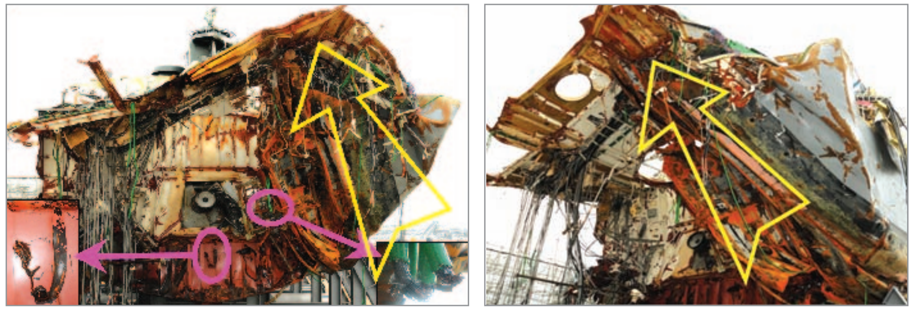
Damage patterns	Investigation result
• Petal-shaped crater at the detonation location	None
• Local shell dishing	Observed
• Trace or soot from heat or fire on electric line, various cables and structure, caused by explosion	None
• Fragments and holes created by fragments on the shell plating and upper deck	None
• Mass hearing loss and burned patients by shock wave and explosion sound	None
• Round hole(jagged) impact on superstructure	None

(2) Visual Inspection

A summary of our investigation following the salvage of ROKS Cheonan is shown in 〈Figure II-3-2〉. The hull was severed through the gas turbine room and approximately 7.8m of the starboard was lost. The port was ruptured and severed with no loss besides small portions of the bottom. The CVK was bent upward, 680mm for the stern section and 1,475mm for the bow section.

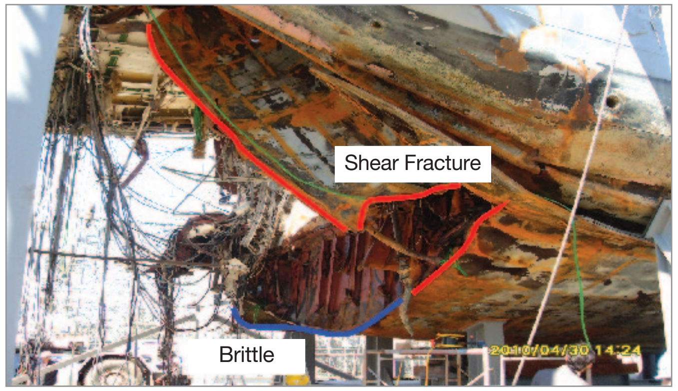
〈Figure II-3-2〉 Breakplane of bow and stern

Concerning the fractures of the breakplane as shown in 〈Figure II-3-3〉, the lower part of the port was severed(shear fracture) by an instantaneous upward force; the bottom part was torn(brittle fracture) by a strong force in a short time; and other parts showed fractures due to large tensile force. Therefore, the shape of the damaged structure indicated typical bubble effect, where the explosion occurred below the port side of the gas turbine room and caused the ship to sever as the explosion power was exerted in an upward and starboard side direction.



〈Figure II-3-3〉 Direction of the deformation, PORT-bottom → STBD-top

In addition, there were no craters observed on the top part of the salvaged hull, with no heat damage in the breakplane and no evidence of fire in any part of the ship. The electric and other wires did not show signs of melting or any other heat damage. Rather, they



〈Figure II-3-4〉 Shape of the split section were cut by the exertion of a large force in a short period of time. Also, there were no indications of chain explosions either in the magazines or fuel tanks that can be caused by a surface explosion or other explosions in any part of the ship other than the lost section.

(3) Environmental Condition

A surface explosion occurs upon contact with or nearby detonation of an explosive on the surface or in the air, and should result in a petal-shaped crater at the detonation point, local dishing, shock damage, and remains of the weapon system. In particular, the plating around the point of explosion can be fragmented or lost due to the explosion pressure in case of a massive explosion. In addition, heat damage, fire, and evidence of heat or flame on the electric cables and other structures will appear. In this case, an external explosion leading to an internal explosion is highly probable and can cause hearing injury and burnt skin due to an explosion sound and shockwave. Also, unlike an underwater explosion, the superstructure of the ship is damaged in case of a surface explosion. A rapid sinking is unlikely and the ship can stay afloat for a significant amount of time considering the stability, since the explosion energy is mostly dispersed through the atmosphere.

(4) Modeling and Simulation

No surface explosion modeling and simulation were performed due to no possibility of a surface explosion with little practical significance expected.

(5) Indication and Warning

There were no indication and warning about a guided missile attack that could have caused a surface explosion. The radar around the incident site detected no flying objects.

(6) Statement from Relevant Personnel

Although all the survivors heard a blast, none of them smelled explosives or saw fire. The marine sentries from the 6th Brigade stated that they observed a white flash light.

(7) Conclusion: No Possibility

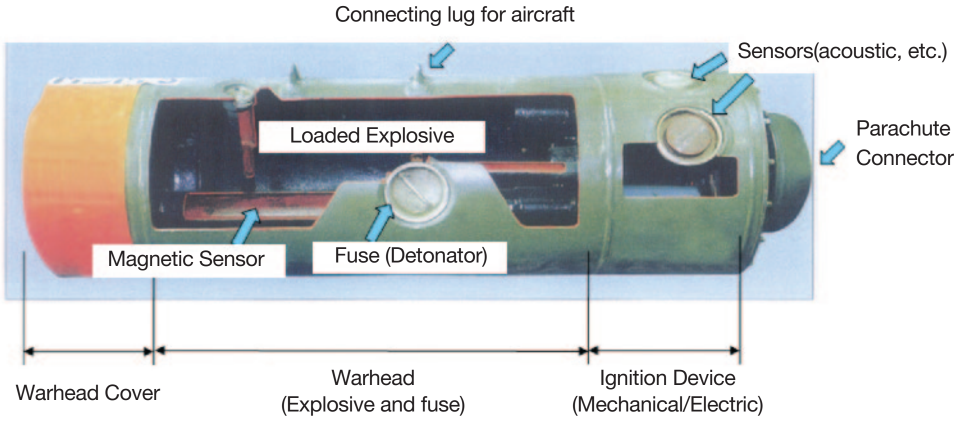
The analysis of the hull, which provides the most reliable evidence, indicates that the shell dishing was caused by a non-contact underwater explosion. No crater or fragmentation from a surface explosion above the waterline was observed, nor were traces of fire and remains of any weapon fragment present. Combining the lack of evidence and other additional testimonies that can support the possibility of a surface explosion, it was concluded that there is no possibility of a surface explosion.

2) Mines(Floating, Moored, Bottom)

Mines are one of the most effective naval weapon systems for port or naval blockade/defense and can be defined as a “weapon system that detonates below or around the waterline of an enemy ship in order to inflict damage.”

Mines target below ship's waterline, the most vulnerable part of a ship, and differentiate themselves from other weapon systems in that they do not pursue the enemy but wait for it to approach. The difficulty of detection allows a mine field to pose a direct threat to enemy naval forces and restricts naval advances or transportations over the sea, with the risk of serious loss and danger, once installed.

A mine is consisted of a warhead cover, warhead, and ignition device as shown in 〈Figure II-3-5〉.



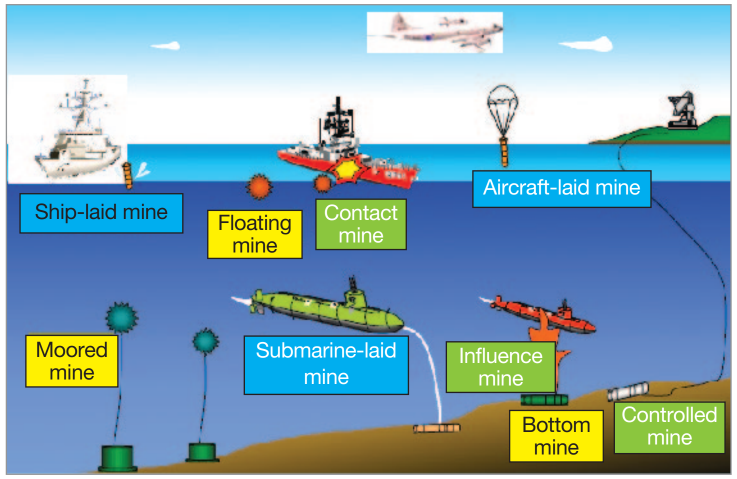
〈Figure II-3-5〉 Structural diagram of a mine

The warhead cover serves following functions: diminishing air resistance when dropped from an aircraft, mitigating the impact to the warhead upon the contact with sea surface, and enhancing integrity on the seabed.

The warhead portion is composed of a warhead and fuse. The warhead is loaded with the main explosives, and the fuse contains a safety load device and a triggering device, which operates above a certain water pressure value and detonates the mine after receiving the signal from the ignition device in the controlling portion. When storing and handling a mine on the ground, a safety pin/rod prevents activation. A detonation power source is attached to the water pressure switch, and the ignition signal is relayed to the fuse through a cable. The explosion occurs through a series of chemical-mechanical parts that relay and amplify the detonation energy inside the fuse. The chemical-mechanical parts are composed of an electric detonation tube, connecting tube, secondary explosives, main detonation tube and main explosives.

The ignition device is comprised of an ignition device, sensor, water pressure switch and batteries. The ignition device is the “brain” of the mine that controls the mine, sorts the target according to the target detection algorithm and ignites the mine. It contains a signal amplifier, signal processor and function controller. The water pressure switch connects the operation and detonation power sources after installation.

A mine can be laid by a variety of means such as an aircraft, submarine or ship and is categorized accordingly. A mine can be employed in a broad range of depth, from shallow sea to deep-sea. Also, as shown in 〈Figure II-3-6〉 below, mines are categorized into bottom, moored, and floating mines according to its position. When classifying according to triggering method, a contact mine is ignited by impact; an influence mine is ignited by a change in the general physical surroundings such as the magnetic field generated by the ship, underwater acoustic signature or pressure; and a controlled mine is ignited by an artificial decision. In recent years, the majority of mines are combined mines laid on the seabed which operate upon the change of the magnetic field, acoustic signature and pressure generated by the passing target.



〈Figure II-3-6〉 Mine types categorized by laying position and method

(1) Damage Indicators

Damage patterns	Investigation result
• Holes on shell plating	None
• Damage due to fragmentation	None
• Inward bending of hull at the detonation point	Observed
• Heat damage or occurrence of fire at damaged sections	None
• Contact from the bow direction, causing explosion	None
• Multiple fragments exist within hull in case of nearby explosion	None
• Shock wave and bubble effect by UNDEX	Observed
• Rapid tilting or lifting of hull by shock wave produced by UNDEX	Observed

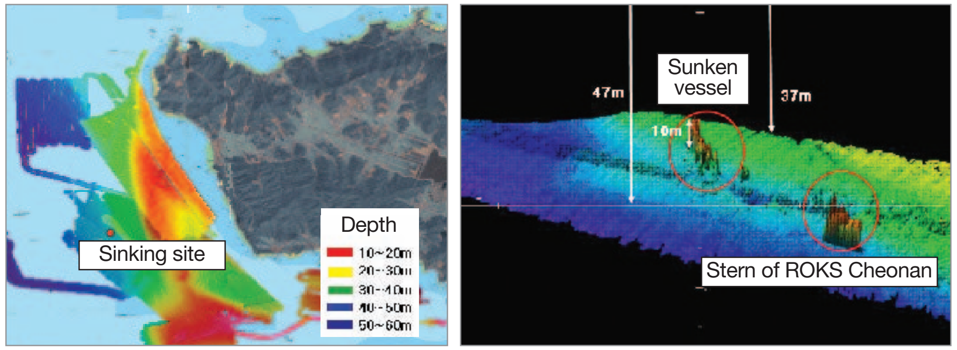
(2) Visual Inspection

As addressed in the surface explosion investigation and analysis result, explosion observations of ROKS Cheonan correspond to a classic case of hull separation due to a shock-wave and bubble effect generated by an underwater explosion. Therefore, there is no possibility of contact explosion by surface or moored mine. Although non-contact underwater explosion of moored mine cannot be excluded considering the damage patterns observed, the operable environment of moored mine was severely limited, and with extreme vulnerability of moored mine to be affected in the underwater environment, its employment was assessed highly unlikely.

(3) Environmental Condition

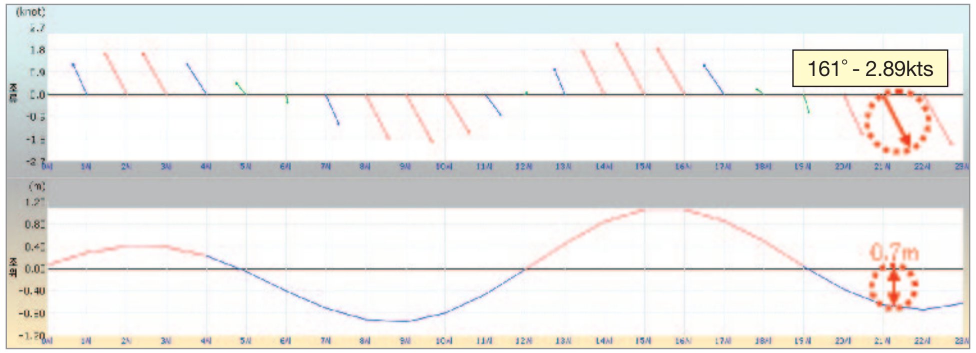
An examination of incident site showed that it is 2.5km SW (37° 55' 45"N, 124° 36' 02"E) of Baekryong Island. The water depth in this area is 47m and the seabed geography is as displayed in 〈Figure II-3-7〉.

At the time of the incident, a SW wind was blowing relatively strongly at 20kts, as



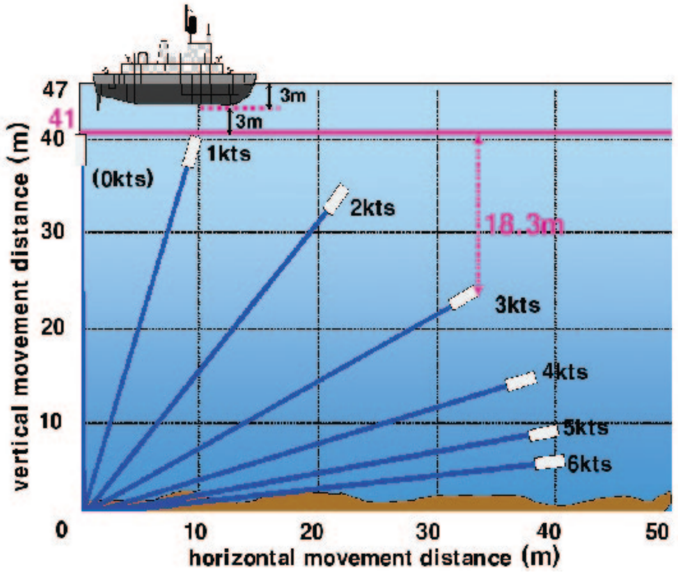
〈Figure II-3-7〉 Seabed geography and water depth of incident site

shown in 〈Figure II-3-8〉. Wave height was 2.5m, current was 161°-2.89kts, and the visibility was 2.5nm. In particular, on the day of the incident, flood tide(high water) was at 0225 (2.3m) / 1515(2.7m), and ebb tide(low water) was at 0843(0.7m) / 2147(0.8m). The average tidal current speed in the region is 3~5kts, and the tide difference is 4m at maximum, which poses severe limitations to the installation of moored mines.



〈Figure II-3-8〉 Seabed geography and water depth of incident site

Therefore, since strong current(3~5kts) and depth(47m), as well as large tide difference(max 4m) and wave height(2.5m) pose significant challenges to moored mine fixation and optimum depth maintenance, employment of moored mine would have been highly unlikely. Drifting level of moored mines by current speed is displayed in 〈Figure II-3-9〉. At current speeds of 3kts, the location of a moored mine will be 18.3m below its original position, and the effects generated by its influence and explosion will be sharply reduced.



〈Figure II-3-9〉 Drifting level of moored mines by current speed

(4) Modeling and Simulation

While conducting modeling and simulation on the possibility of a heavyweight torpedo, the hull whipping analysis and advanced mathematical analysis were conducted with different charge sizes and explosion depths. Same charge size and explosion depth scenarios can be applied in assessing the possibility of a mine.

(5) Indication and Warning

In the vicinity of Baekryong Island, the industry concentrates its activities during the blue crab season from August to October as well as the blue crab and san eel season from April to June. Even during the slack season from November to March, 40~50 fishing vessels per day engage in fishing.

Moreover, after examining ROKS Cheonan's track on the day of the incident, it was found that it departed from Daechung Island base at 06:00, March 26th, entered its patrol area at 08:30 and conducted its patrol operation in a zig-zag manner irregularly once or twice per hour in the identical region, thus resulting in patrol near the incident site at least more than 10 times(At the time of the incident ROKS Cheonan was moving in 327°, 6.7kts). This indicates that there were no prior mine installations.

In addition, the operational installation of a single mine results in a very low success rate; therefore, multiple number of mines should be laid at the same time in order to raise the possibility of success. However, no mines have been discovered. There are numerous surface vessels such as fishing and merchant vessels operating in the vicinity of Baekryong Island. Targeting a warship would result in a very low likelihood of success.

(6) Statement from Relevant Personnel

According to statements of survivors, they experienced and observed lifting of the hull and explosion sound once or twice by shock wave and bubble effect.

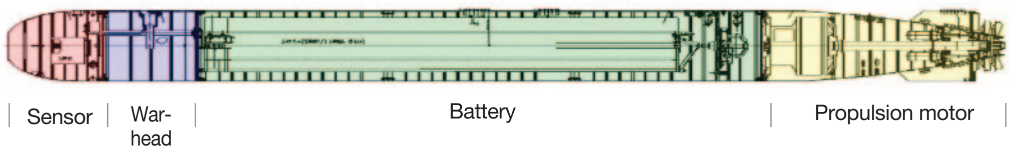
(7) Conclusion: No Possibility

The rapid current speeds of 3~5kts, tidal difference of 4m, and depth of 47m pose difficulties for effective mine operation. Also, given that ROKS Cheonan had taken an irregular route around the incident location over 10 times on the day of the incident, and that no anchors or mooring devices that are parts of moored mines were found during the search of the seabed, it is assessed that an explosion of moored mines is impossible.

3) Torpedo

Torpedoes can be installed on vessels, aircraft, and submarines to attack enemy submarines or vessels. The torpedoes are categorized as lightweight and heavyweight torpedoes.

Torpedoes are assembled in the following structure: the sensor section, warhead section, battery section, and propulsion motor section.



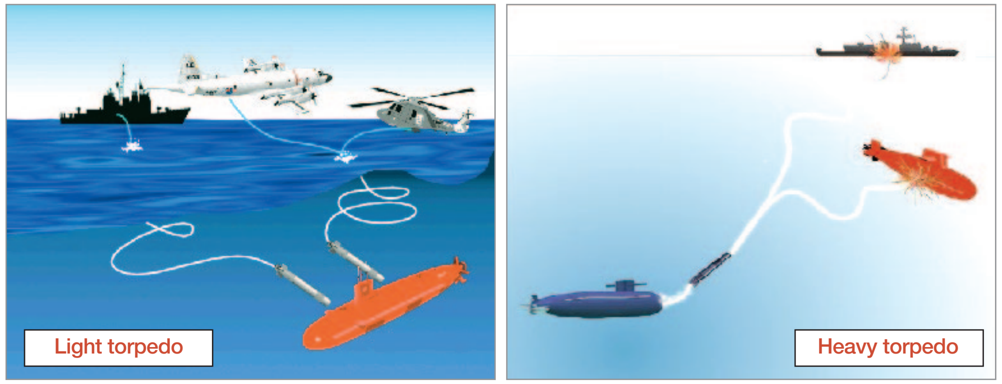
〈Figure II-3-10〉 General structure of a torpedo

The sensor section uses sound signals to locate targets. This device has two modes: a passive mode that tracks sounds from targets, and an active mode that sends out sound signals to locate targets once the signals bounce back from a target.

The warhead section carries main explosives that cause damage to the target. There are two detonation methods: a proximity and acoustic fuse that uses magnetic sensors, and an impact fuse that detonates upon contact.

The battery(fuel) and propulsion section provides propulsion power to a torpedo. Either electric or combustion propulsion method is selected depending on the strategic situation, operating concept, and sound volume level. The engine propulsion is capable of high-speed propulsion; however, this method generates too much noise, making the torpedo vulnerable to enemy detection. Other electric propulsion problems include decrease of power depending on the depth of water. However, these issues have been recently resolved with the development of a closed-cycle engine[10).

Surface vessels and submarines use sonar or towed array sonar[11), and in other instances, they use dipping sonars[12) or sonobuoys[13) to detect targets and guide torpedoes. The following 〈Figure II -3-11〉 illustrates the basic operating concept of torpedoes.



〈Figure II-3-11〉 Operating concept of heavy and light weight torpedoes

Torpedoes that operate underwater use acoustic sensors installed on the front end to analyze sound specifications of targets to detect them, and estimate target information(azimuth, distance, speed, etc.). As the following table shows, torpedoes can employ straight

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10) Closed-cycle engine: An engine that, unlike ordinary diesel engine, functions by burning reprocessed exhaust gas and stored oxygen without the help of air from the outside. Used in ships and submarines.

11) Towed array sonar: The system of naval assets to insert the cable underwater equipped with sound detecting device. This device detects underwater targets, and is mainly used for a long range target detection.

12) Dipping sonar: A device that is dipped in the surface by helicopters or surface vessels to detect underwater targets. This device is equipped with a cable and the helicopter or surface vessel can control the sonar's degree of depth.

13) Sonobuoy: A device in which a sound detector is attached to a buoy to float on the surface to detect underwater targets or search seabed geography.

running method, as well as acoustic homing and wake homing methods by using sonar. The detection mechanisms are as follows:

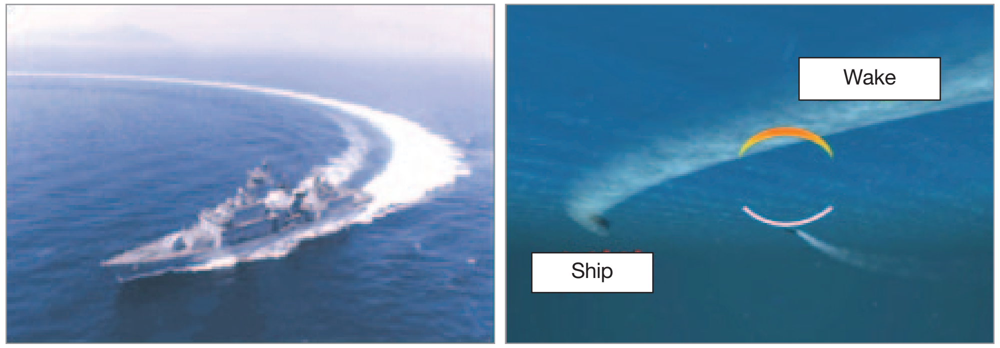
Detection method		Characteristics
Straight running method		• No detection ability • Straight and zig-zag method of cruising
Acoustic homing	Passive mode	• Detects by analyzing noise generated in the propulsion section of the targeted vessel • Mainly used for detecting surface vessels
	Active mode	• Detects by transmitting signals from torpedoes and analyzing the reflected signals from the bodies of targeted vessels • Mainly used for detecting submarines
Wake homing		• Detect by using navigation tracks generated by operation of targeted vessels • Navigation sensors installed on top of torpedoes detect targets by transmitting and receiving sound signals, and analyzing the signals that correlate to navigation of vessels • Used for detecting navigation of surface vessels

〈Table II-3-1〉 Detection method and characteristics of torpedoes

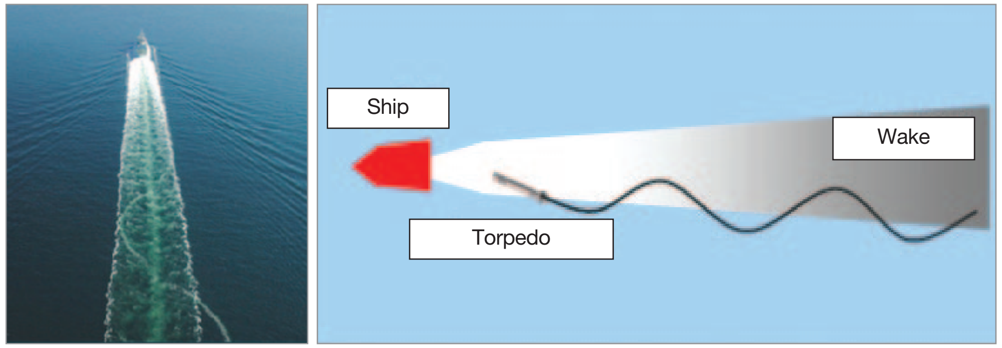
A straight running torpedo does not have detecting abilities and is normally used with impact fuses. The cruising methods are direct and zig-zag cruising. The following settings are inputted on this type of torpedo: first cruising distance, rotating degree and second cruising distance. Once this torpedo is launched, it first cruises the distance set by the first cruising distance, then rotates according to the rotating degree and cruises up to the second cruising distance. The torpedo detonates upon a successful contact with the target.

A passive acoustic homing torpedo detects the target by analyzing the noise generated from the propulsion section of the target vessel and tracks the target by analyzing its azimuth. This method is mainly used for detecting surface vessels. An active acoustic homing method transmits signals from torpedoes and analyzes the reflected signals from the hull of the targeted vessel. This method is mainly used to detect submarines.

Wake homing is a method that tracks navigation signals generated from propellers and hull of surface vessels. Navigation signals vary depending on the shape of hull and cruising speed. Small bubbles(couple of ten ㎛ in diameter) remain on the surface for more than 10 minutes following the passing of a surface vessel. In order to detect these signals, a navigation sensor is installed on the top of torpedoes to analyze the signals correlated to vessel wake using transmitted and received sound signals. This detection method is used for detecting wake signals of surface vessels and involves tracking the boundary of the created wakes.



〈Figure II-3-12〉 Wake produced by surface vessel



〈Figure II-3-13〉 Mechanism to track wake produced by surface vessel

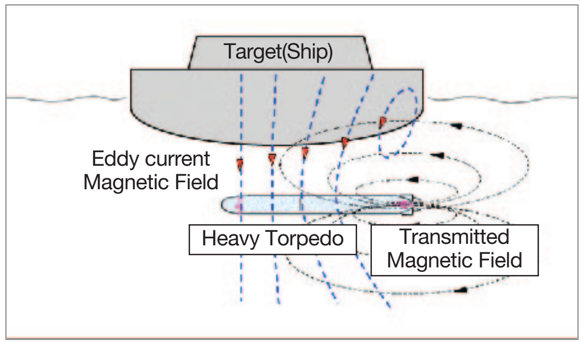
A fuse is an influence equipment used to detonate warheads of torpedoes when they are guided to their targets. The types and operating mechanisms of fuses used in torpedoes are shown in 〈Table II-3-2〉.

Fuse		Operating mechanism
Impact fuse		• Detonates by detecting the impact during hull contact ⇨ Explodes at the side of vessels
Proximity fuse	Magnetic influence fuse	• Detonates by detecting the reflected signals from the Eddy current of hull while cruising through hull bottom ⇨ Explodes at the bottom of hull
	Acoustic influence fuse	• Detonates by detecting the reflected sound signals from the hull while cruising through hull bottom ⇨ Explodes at the bottom of hull

〈Table II-3-2〉 Types and operating mechanisms of fuses

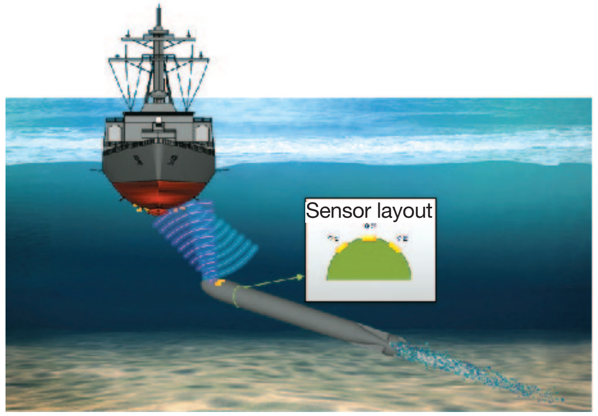
Impact fuses are installed with firing switches that detect the impact during a contact and trigger detonation. Firing switches react against all impacts that happen from all angles and at a low acceleration. This method causes an explosion at the sides of vessels.

Magnetic proximity fuses detonate by generating currents at specific frequencies and detecting eddy currents formed on the surfaces of targets. This kind of fuse usually causes an explosion at the central areas of vessels.



〈Figure II-3-14〉 Operating mechanism of magnetic influence fuses

Acoustic proximity fuses transmit acoustic signals from the high frequency(several hundred kHz) transmitting sensors installed on the center upper area of torpedoes. Two high frequency receiving sensors detect the receiving signals and assess the existence of a nearby target, and detonate. This method also normally causes explosion at the central areas of vessels.



〈Figure II-3-15〉 Operating mechanism of acoustic influence fuses

(1) Damage Indicators

Damage patterns	Investigation result
• Holes on shell plating	None
• Local dishing of hull	Observed
• Inward bending of hull at the explosion point	Observed
• Heat damage or occurrence of fire at damaged sections	None
• Multiple fragments exist within hull in case of proximity explosion	None
• Damage by shock wave and bubble produced by UNDEX	Observed
• Rapid tilting or lifting of hull by shockwave produced by UNDEX	Observed
• Holes and debris	None
• Torpedo debris	Observed

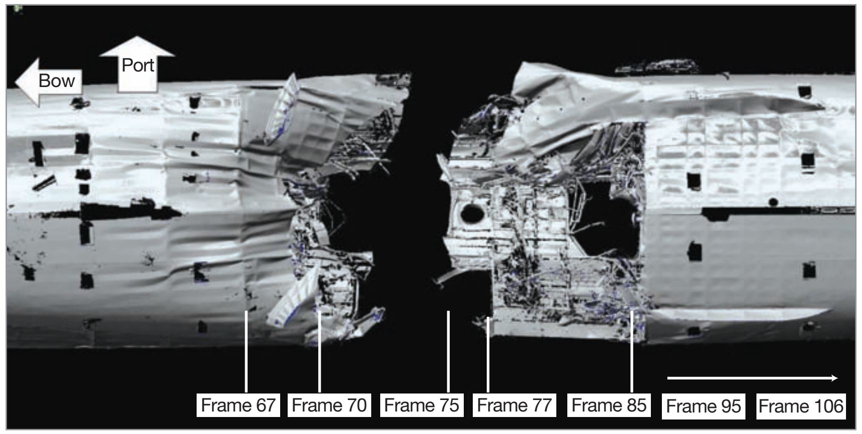
Torpedo is a weapon system capable of contact and non-contact detonation. A contact torpedo detonation causes identical damage as a contact mine detonation while a non-contact torpedo detonation causes identical damage as a non-contact mine detonation.

(2) Visual Inspection

ROKS Cheonan was broken in half by a whipping effect and upward bubble pressure on the port side bottom area of the gas turbine room towards the starboard side . The CVK and the fractured surface were twisted and ripped upwards. The CVK area is where the gas turbine engine was installed and the parts of the ship bottom were blasted away while the stiffeners and the ship structure reinforcements were crushed inward and on top of each other towards the starboard due to pressure. Wires on the port side and the starboard side were cut from tensile force. No traces of fire, soot, and laceration that would indicate internal fire were found. Additionally, sectional paint jobs on the bottom of the hull were scratched off in a wide range.

After Frame 106, no traces of damages from impact were found. In regards to the port side shell plating, local bending of plating appeared from the severed area to Frame 95. As for the starboard plating, local bending of plating appeared from the severed area to Frame 90. Additionally, areas from Frames 67 to 70 were significantly bent in an upward direction.

There were significant deformations on the external plating of the stern section between Frames 75 and 85 on the port side, and significant deformations were observed between Frames 70 and 71 on the bow section. The platings were bent severely in a round shape towards the inside. The stern CVK was deformed towards port in the main deck direction of the stern(upward direction). Furthermore, a significant bending appeared on the severed CVK from Frames 70 and 85. This effect is highly likely to have taken place during the initial sagging of the hull which would have been generated by the tensile force.



〈Figure II-3-16〉 3D laser scan image on the split section of ROKS Cheonan

(3) Environmental Condition

The sea conditions and currents were identical to those mentioned on the mine section and these environmental conditions were not severe enough to limit torpedoes from detecting and tracking ROKS Cheonan.

The water depth at the sinking site poses significant limitations on the installation of normal mines. However, it does not limit the employment of heavy/midget class submarines. The tidal difference, water speed, and wave height are not limiting factors for a torpedo attacks by a submarine.

(4) Modeling and Simulation

The US investigation team presented the result of “ROKS Cheonan modeling by US Navy” on April 26, 2010. The presentation stated that there is the highest possibility for a torpedo explosion to have occurred under the CVK of the hull. It also indicated that an explosion of an explosive weight of 250kg occurred at a location below Frame 75, 3m to the port from the centerline and at a depth of 6~9m. The ADD investigation team assessed based on examination of material deformation that the hull suffered an instant severance by a strong force from the port side of the hull and the propagation of brittle fracture towards the starboard direction led to the separation of the hull. The Joint Investigation Group modelled a part of the hull, focusing on the site of separation, and conducted simulations with different depths and explosive charge sizes and obtained a similar result. The simulation result of the UK team was also similar to those from the US and ROK teams.

(5) Indications and Warning

The incident site is deep enough for an employment of a torpedo against a surface vessel, and an acoustic guided torpedo can be guided to the center of a ship. Therefore, it is very likely that a submarine targeted and attacked ROKS Cheonan from a location northwest of the incident site. A light torpedo(45kg of TNT or less) does not have sufficient explosives to break a hull apart, and the use of a straight running contact torpedo(impact inertia method) leaves many traces. All these assessments lead to the unlikelihood of these weapons' employments.

(6) Statement from Relevant Personnel

The survivors from ROKS Cheonan heard 1~2 explosion sounds. The port watchout, who fell down as the bow tilted to the starboard, was splashed in the face with water. The post sentries of the 6th Brigade, Marine Corps. witnessed a flash of white light[14)](20~30m in width, 100m in height).

(7) Conclusion: High Possibility

The ROK ADD, UK, and US investigation teams made the assessment that the explosive was precisely guided to the center of the ship where it exploded in the proximity of below the gas turbine room 3m to the portside from the center, where the shockwave and bubble effect generated by the explosion caused the separation of the ship.

Therefore, there is a high possibility of a torpedo attack. An acoustic guided torpedo which can be launched from a submarine is assessed to be the likely weapon system used.

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14) Testimony from the LCM technical expert who participated in the land control mine emplacement project.

4) Explosion of Land Control Mine(modified MK-6)

As the analysis on the cause of the sinking of ROKS Cheonan continued, the media engaged in persistent speculation regarding the various possibilities. One possibility raised involved land control mines (modified MK-6) that the ROK Navy had installed in the late 1970s near Baekryong Island and removed at a later date.

Investigation on the land control mines commenced immediately after the Joint Investigation Group was established in late March. The investigation group proceeded based on the statements from the LCM[15] technical expert who had participated in the emplacement of the land controlled mines at the shore of Yeonhwari, Baekryong Island in the late 1970s.

The technical expert participated in the initial research at Je-il Precision Engineering located in Changwon, Kyungnam Province and in the emplacement of the mines in the waters off Yeonhwari. In his explanation on the design of the land control mine (LCM) and the structure of the detonation cable, he argued that the detonation cable, when cut and exposed to seawater, can induce voltage in accordance with the volta battery principle[16], which then can ignite the electric detonator. His argument was based on the fact that 1 layer of the detonation cable consisted of net-shaped metal lines plated with zinc and the electric wire in the core that delivers power was made out of copper[17].

On April 3, experts from the ADD as well as the technical expert were invited for a joint discussion. He emphasized that there is enough possibility, based on the volta battery principle and the experiment in which he found the detonator to be sensitive enough to explode when he measured the electric current with a measuring device. He presented that he had seen measurements of approximately 1V and 5~10mA. However, the explosive experts from ADD assessed that there is low possibility for the explosion of a mine due to naturally induced electric power because most electric power is discharged into the seawater even if it is induced and because there were doubts whether the zinc and copper wire together can produce enough electric power for the detonation.

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15) LCM: Land Control Mine.

16) A battery made by connecting wires after putting in two metal boards of different ionization inclination in electrolysis such as diluted acid.

17) At this period, media also raised possibility of explosion of unrecovered mine off the Yeonhwari.

Upon the establishment of the Joint Investigation Group office in Pyeongtaek, a detailed investigation on the issue commenced. The group obtained a 50cm-long detonation cable on April 19 and tested on April 21 in Pyeongtaek harbor whether electric power can be generated from the detonation cable in seawater. The experiment found 0.47V but no electric currents. The Joint Investigation Group consulted[18] Hanhwa Co. on April 23 to seek opinions from the expert agency on whether the generated electric power in seawater would be sufficient for detonation. In response to the request to review "the possibility of the underwater explosion of the military KM6 detonator," Hanhwa Co. stated that detonation is not possible because at least 0.45A is required to detonate the military standard KM6 detonator and the voltage and current generated by the Galvanic action between two different metals underwater are only ㎂ or ㎃ local electric current(corrosion reaction).

(1) Damage Indicators

Damage patterns	Investigation result
• Damage by weak shock	None
• Global dishing of shell plating	Observed
• Overall hull deformation	None
• Mine debris	None

(2) Visual Inspection

Localized damage by shock is shown around the gas turbine room, but no global dishing was found on the hull. Also, no dishing was found near the screw and around the bottom of the magazine.

(3) Environmental Condition

① Emplacement of Land Control Mine

The emplacement of land control mines was carried out by ROKN HQ. It was conducted to prevent the landing of North Korean amphibious forces on Baekryong Island. The major content involved removing the safety pin, safety cover, fulminating mercury(igni-

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18) Hosted by a CPT(R), recommended from the National Assembly.

tion explosive), and pistol from MK-6 depth charges and equipping the MK-6s with electric detonators(US electrical detonator[19], M6 series[20]) and detonation cables.

On November 14, 1975, modified MK-6s were approved for emplacement. Technical review and test on the modified MK-6s were completed by ADD in July 1976. Contracts were established with Je-il Precision Engineering(which supervised the overall modification project) and Geumsung Wires(which supplied cables) by December 1976 for the project. The land control mines were all assembled by April 1977 and transported to the northwest of the island using LST 816 in June 1977. Emplacement and test fire were conducted between July and October 1977.

After the mines were assessed to be unnecessary they were neutralized by removing[21] the detonation cable(from the land control group to the shore) and the control box(detonation cable connected to each mine) in late 1985. However, the main bodies of the mines were left unrecovered at the seabed. After about 16 years, fishers in Baekryong Island requested to recover the main bodies of the mines from the seabed in June 2001, and the ROK JCS assessed the recovery operation to be unnecessary in November of the same year, but in July 2008, JCS reviewed the operation again and decided to remove the mines. From August 11 to September 26, 2008, the Navy Special Operations Squadron and the Marine Search and Rescue team were committed with equipments (RIB, etc.), and resulted in successful recovery of 00 munitions. The average depth of the water was 6m, and the distance from the shore was 200~400m for the location of the mine sweeping operation.

The detonator and booster were removed from the recovered land controlled mines and were disposed of in the detonation training field of the 6th brigade from September 22~24, 2008. The main bodies of the mines were transported using a periodic transport vessel to the ordinance and ammunition depot in the Logistics Command and were retained until July 2009 when they were disposed.

The emplacement status is shown in 〈Figure II-3-17〉.

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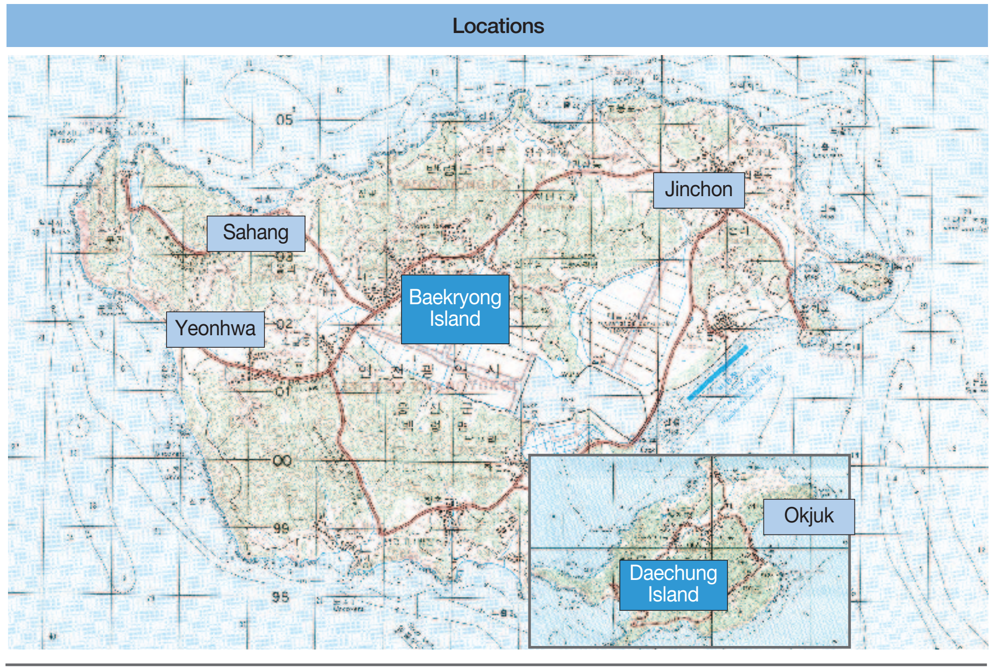
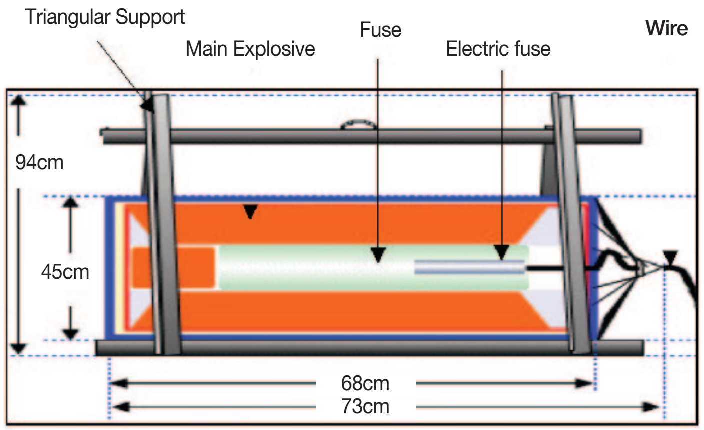
[19] Testimony from the LCM technical expert who participated in the land control mine emplacement project.
[20] Result of ADD investigation on US battery blasting cap which was extensively used in 70s.
[21] Testimony from a military contractor who participated in the work at the time.



〈Figure II-3-17〉 Emplacement of the land control mine

② Structure and Operating Principle of the Land Control Mine

The land control mine is a modification of the hydrostatic pressure MK-6 depth charge. The design and specification are shown in 〈Figure II-3-18〉.



- Length: 68cm
- Diameter: 45cm
- Weight: 190kg
- Charge size: TNT 136kg

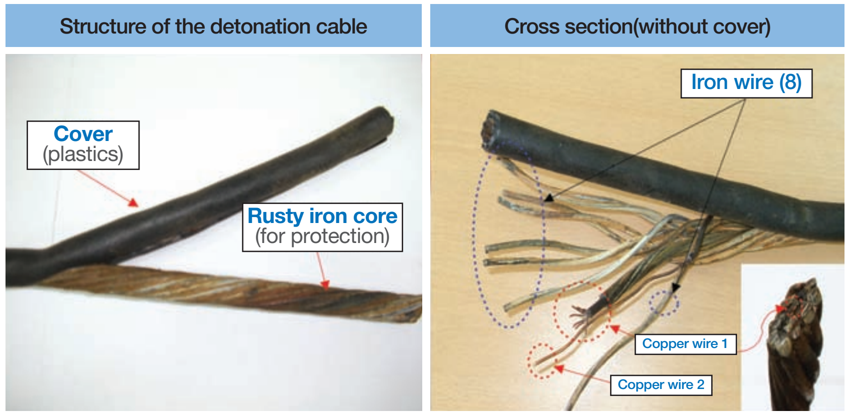
〈Figure II-3-18〉 Design and specification of the land control mine

The land control mines were laid 400~450m away from the shore at a depth of 7~10m, being fixed in metal triangular stands. Detonation cables connecting the mines to the ground control group allow individual detonation of the mines(See 〈Figure II-3-19〉). A generator was installed separately as the power source for the ignition.


Detonation cable connected to the mine
Mines welded to the metal triangular stand

〈Figure II-3-19〉 Detonation cable and metal stand

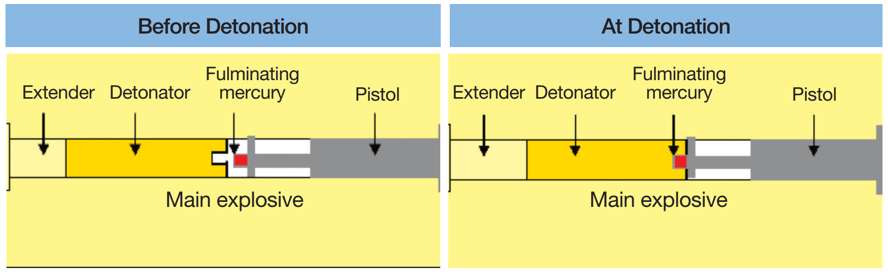
The detonation cables supplied by Geumsung Wires had a diameter of approximately 1.6cm and were covered with plastic. 2 lines of copper wires covered with plastic were combined with 8 lines of tensile strength reinforced wires, and therefore the cable was not easy to bend. The cable was designed to lie at the seabed due to its weight(6kg per 10m). The detonation cable is shown in 〈Figure II-3-20〉.



- Copper wire 1: 7 lines of copper wire at the core, covered with double plastic
- Copper wire 2: 1 copper wire at the outer, covered with single plastic

〈Figure II-3-20〉 Detonation cable in detail

MK-6 depth charges were modified by removing an extender, pistol, and fulminating mercury. Afterwards, an electric detonator was installed and sealed with silicon. A detonation cable was connected to allow for remote control from the shore(See 〈Figure II-3-21〉).

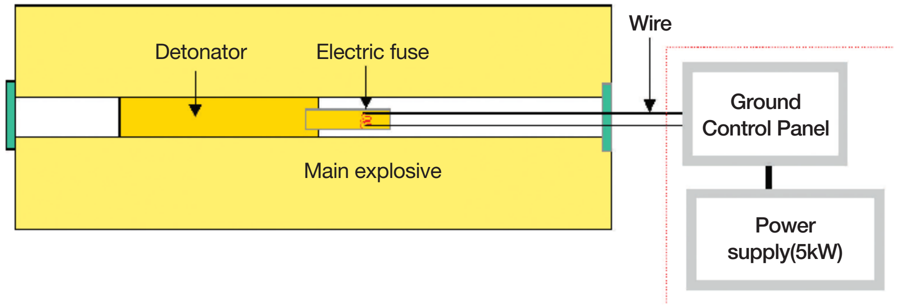


① Extender and pistol are actuated by water pressure exerted when dropped
  - Extender: Water pressure exerted between 11~22ft below surface push priming powder toward fulminating mercury, making it ready to detonate
  - Pistol: When reaching a pre-set water depth, water pressure makes a firing pin hit fulminating mercury and detonates the mine

② With the detonation of fulminating mercury(explosive), priming powder and the main explosive detonates

〈Figure II-3-21〉 Detonation process of MK-6 depth charge

A modified MK-6 works in the similar manner to the ROK Army's claymore. The process is as shown on 〈Figure II-3-22〉.



① Detonator ignites when power is supplied to electric detonator from the outside.
② With a detonator ignited, priming powder and then main explosive explode.

〈Figure II-3-22〉 Detonation process of land control mine

The water depth at the incident site is 47m. Also, the land control mine had been underwater for approximately 30 years and thus would have lost its ignition function. The mine was installed so that it would not move. Therefore, it is not possible for the mine to have moved from its original location to the incident site.

(4) Modeling and Simulation

The simulation of a torpedo was applied for the underwater explosion of a land controlled mine. Given the charge size and water depth, it was assessed that hull separation is not possible. The UK Investigation Team conclued that the damage of ROKS Cheonan would require the explosive charge 20 times larger than the land control mine(MK-6).

(5) Indication and Warning

Information regarding indication and warning was not collected due to no possibility of explosion of land control mine.

(6) Statement from Relevant Personnel

There was no testimony that could indicate an explosion of land control mine.

(7) Conclusion: No Possibility

Referring to the modeling and simulation of the hull whipping caused by an underwater explosion, which was conducted by the US investigation team and the Ship Structure Management Team, the Joint Investigation Group assessed that a land controlled mine with a chage size of 136kg at a depth of 47m cannot break ROKS Cheonan in half.

Another possibility suggested involved the power supply detonation cable on the seafloor being tangled with propeller blades and detonating. The detonation cable consists of a rigid steel and copper line which poses difficulty in clinging. In addition, its weight (6kg in 10m) would not provide enough buoyancy for the mine to float from a depth of 40m. The condition of the stern, which was found intact, also eliminates the possibility of an explosion occurring nearby the propeller section.

In conclusion, there is no possibility of a land control mine(MK-6) detonating by itself at the time of the incident, 30 years after its installation. Even if such an explosion occurred, there would have been insufficient explosive power to separate the hull at a depth of 47m with its small charge size(136kg). In addition, given the weight of the detonation cable, a mine would not be tangled with propeller blades. The above indicate that there is no possibility of a land control mine detonation.

Part Ⅲ

Detailed Analysis Results by Team

1. Shape and Trace Analysis

Shape analysis of the hull's shell was conducted in the following three areas: first, the salvaged bow and hull's overall form, second, the deformation of hull's structure and the shape of the rupture, and third, microscopic traces such as pressures, pushes, cuts, and scratches. Through these analyses, the location of the explosion, and the size and direction of the explosion's pathway were assessed as well as how it influenced the hull.

1) Overall Shape

The overall length of ROKS Cheonan is 88.32 meters. The 3D precision measurements using a 3D scanned image of the ruptured bow and stern and the actual measurements of the hull indicate that the breakplane was located at the center of the gas turbine room(47.6m from the portside, and 45.4m from the starboard side).

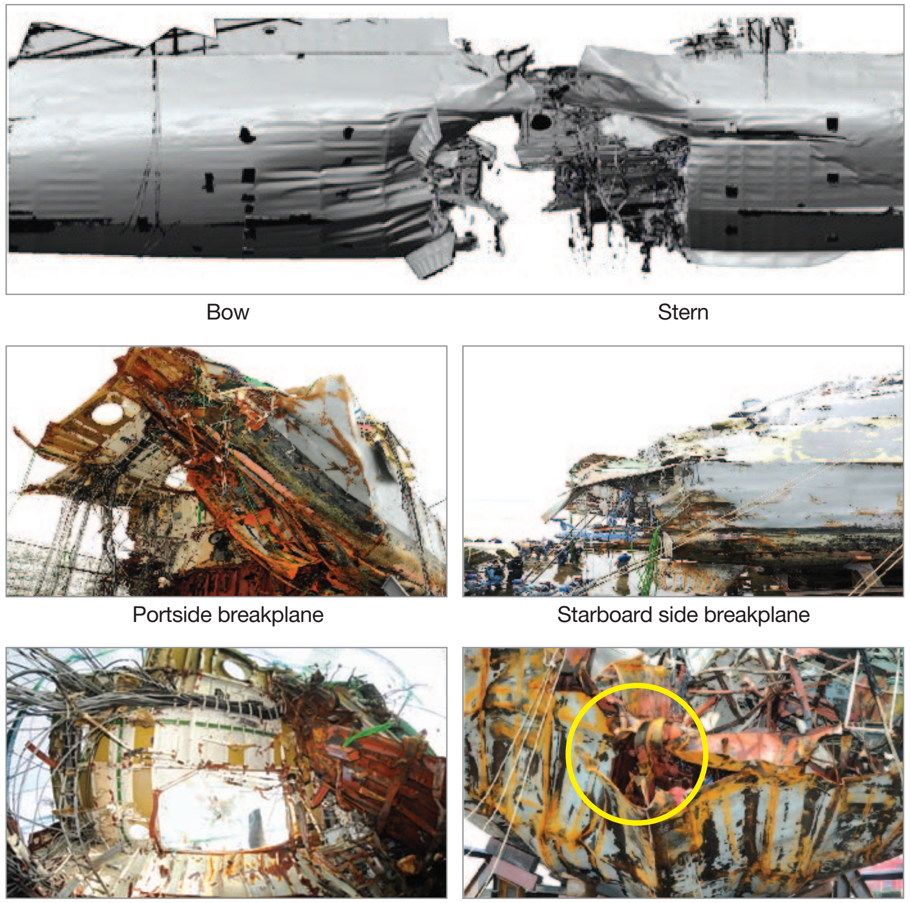
When the ruptured parts were fitted together, the portside had resulted in an outer shell length of 50.32m in the bow and 38m in the stern, and hence experienced no loss except for the parts of the stern hull bottom. However, the starboard side had experienced a 7.8m loss with the bow part being 47.2m and the stern part being 33.32m long. The degaussing room on the main deck, CPO mess hall, machine control room, construction storage, crews' galley, demist and stack on the O-1 deck, and harpoon missiles were lost. These losses were localized at the upper and lower parts of the gas turbine room.

〈Figure III-1-1〉 Overall shape

2) Shape Analysis

Shape analysis was conducted with the emphasis on structural deformations, the shape of the breakplane, the detached structures, and the shape of the damage. These analyses allowed for the assessment on the starting point and traveling direction of the external force(such as explosion or shock) that influenced ROKS Cheonan.

〈Figure III-1-2〉 indicates that the bow and stern's hull bottom are bent upward due to water pressure; the portside breakplane is bent and pushed upward; and 7.8m of the star-


Bow
Stern
Portside breakplane
Starboard side breakplane
Gas turbine room
Center Vertical Keel

〈Figure III-1-2〉 Shape analysis

board side is fallen off at the gas turbine room's fore and aft.

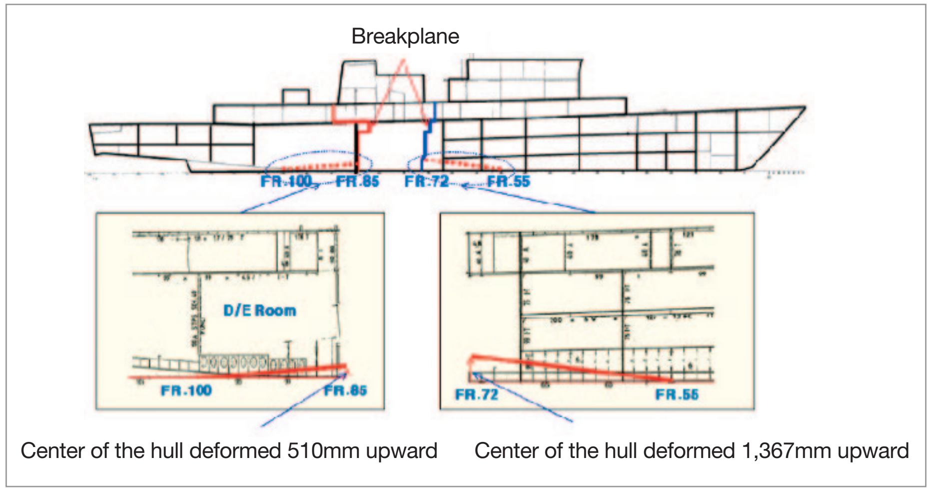
Also the portside ceiling of the gas turbine room is bulged up, while the exhaust opening has fallen off due to water pressure. Also, the bow side CVK is severely rolled upward and twisted to the starboard side.

The upward bending of the bow and stern's hull bottom indicates that an underwater explosion had occurred. The portside breakplane was bent upward; the starboard side breakplane was partially ripped out; and the keel was twisted towards the starboard side.

These signs indicate that the explosion force traveled diagonally from the portside bottom towards the upper parts of the starboard side. When the ship's maneuvering direction is taken into account, the fact that the gas turbine room was detached confirms that the point of explosion was at the gas turbine room on portside of the bow's hull bottom.

3) Form of the Hull Deformation

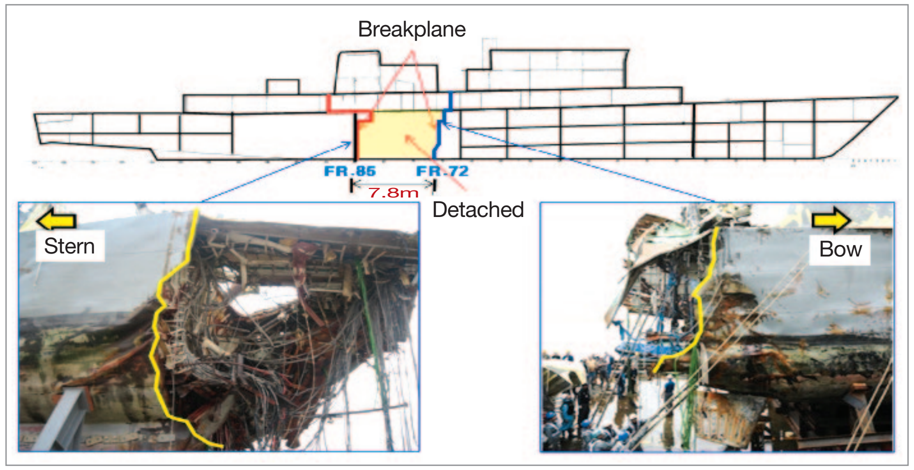
A precise deformation analysis was performed by 3 experts from the Defense Agency for Technology and Quality. The starboard side fracture was cut along Frame 72 and Frame 85 with a detachment of 7.8m as seen in 〈Figure III-1-3〉 and 〈Figure III-1-4〉. The bow CVK deformation began in Frame 55 and moved upward towards Frame 72 for 1,367mm, and the stern CVK deformation began in Frame 100 and moved upwards towards Frame 85 for 510mm.



Center of the hull deformed 510mm upward

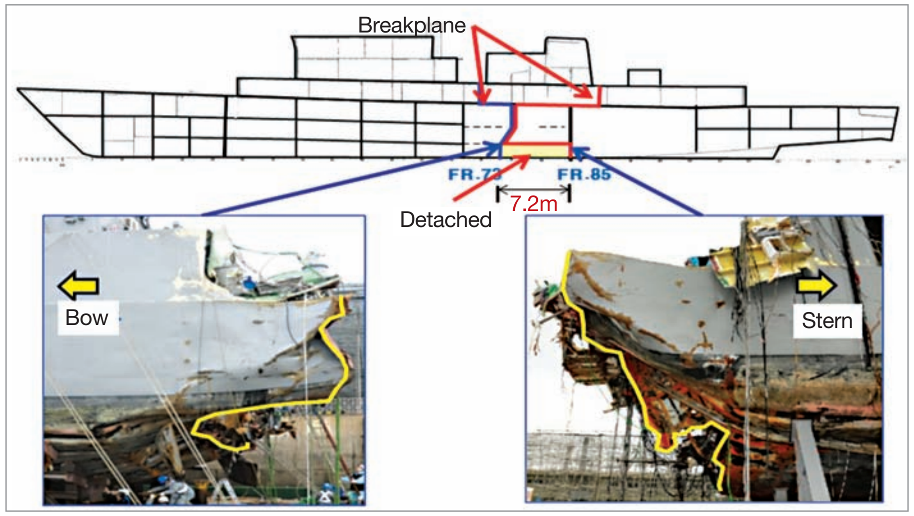
Center of the hull deformed 1,367mm upward

〈Figure III-1-3〉 Starboard breakplane & CVK deformation



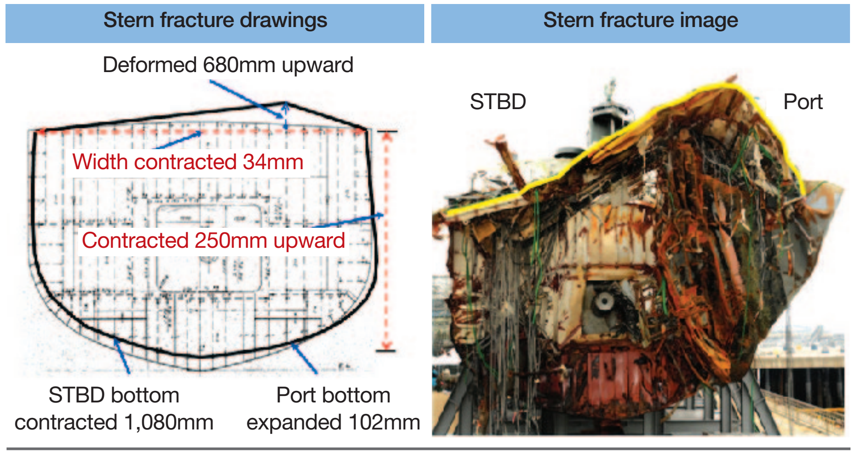
〈Figure III-1-4〉 Starboard fracture

As seen in 〈Figure III-1-5〉, the portside was fractured from Frame 73 on, and the detached portion is about 7.2m long on the bottom. For the stern, the inside of the ship was bent upwards between Frame 85 and Frame 73(7.2m), and the bow was bent upwards from Frame 70 and 73(1.8m) on the inside of the hull. This enabled the JIG to rule out internal explosion, fatigue fracture, and grounding. It was assessed that the shock wave, generated by a strong non-contact underwater explosion initiating from the bottom portside, was delivered to the internal structures on the starboard side, and the hull was inflicted with serious damage as a result.



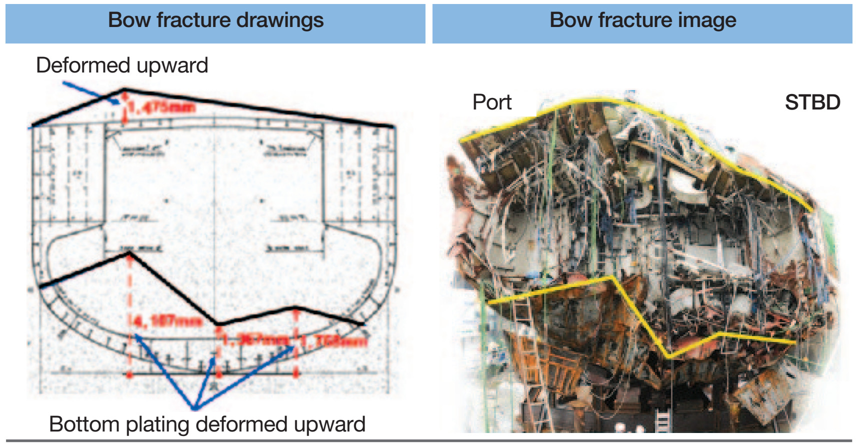
〈Figure III-1-5〉 Portside fracture

The stern fractured surface on Frame 85, as shown in 〈Figure III-1-6〉, shows that the center line of the ship contracted 250mm, that the portside bottom expanded 102mm along the width, and that the starboard bottom was compressed 1,080mm. The width of the Main Deck was compressed 34mm, and the hull was deformed 680mm upward from the point 3,600mm port from the center line.



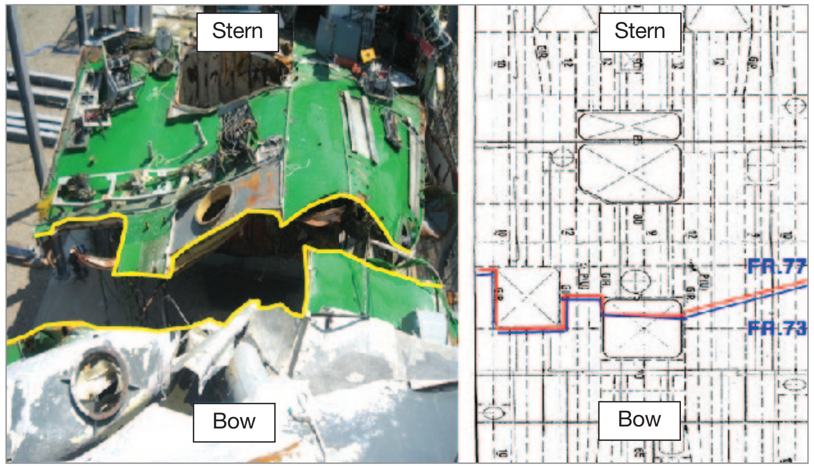
〈Figure III-1-6〉 Stern breakplane deformation

From the baseline, the bow fractured surface, as seen in 〈Figure III-1-7〉, shows that the bottom was lifted upward at a maximum of 4,107mm at the point of 2,400mm to the portside. The CVK was deformed upward by 1,367mm, and the starboard bottom was bent upward by 1,758mm at the point of 1,800mm away from the baseline. The main deck was lifted 1,475mm from the baseline at the point 2,400mm to portside.



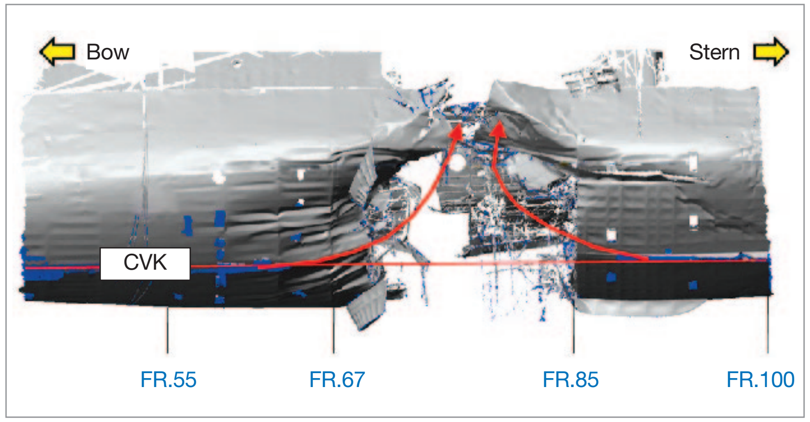
〈Figure III-1-7〉 Bow fractured surface deformation

For the main deck, as seen in 〈Figure III-1-8〉, the breakplane is located along Frames 73~77. The fracture occurred by the concentration of stress of an external force impacting on the round end of the deck opening, and the port side is more severely deformed upwards compared to the starboard side.



〈Figure III-1-8〉 Main deck deformation

The precision analysis on the deformation of the hull, as seen in 〈Figure III-1-9〉, supports the assessment that a non contact underwater explosion occurred below the portside gas turbine room, and the shock force generated migrated to the internal structures on the starboard side to cause the deformation.



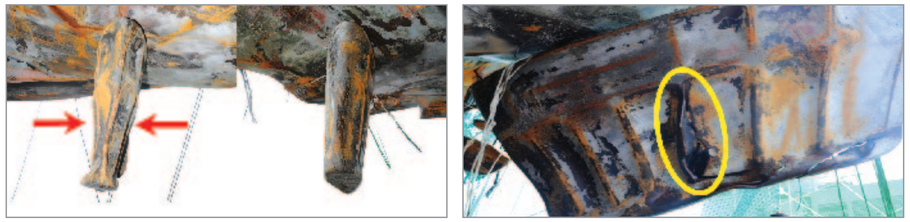
〈Figure III-1-9〉 Fractured surface of portside bottom

4) Trace Analysis

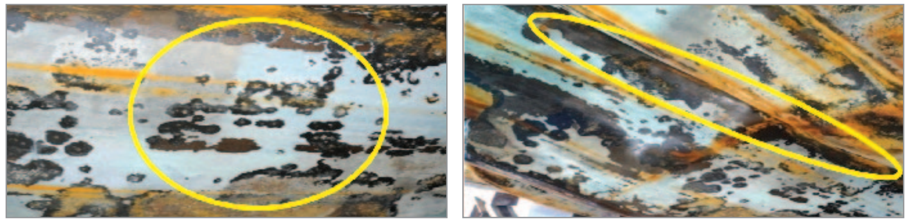
Trace analysis examined minute traces of the pushes, pressures, cuts, and scratches on the hull and determined the types of external forces, such as an explosion or a shock, and assessed the origin of the force.

As 〈Figure III-1-10〉 shows, the portside stabilizing fins were crushed on the bottom portside, and the fin on the starboardside was torn with pressure marks. The bow breakplane's keel on the starboard side hull bottom had marks caused by a strong water pressure and bubble dishing marks on the bow breakplane region, where paint had been scratched off by a strong water pressure. The wires at the breakplane were truncated with a strong force without traces of melting by heat, and the gas turbine room's rear bulkhead stiffeners were pushed toward the upper starboard side, and traces of ripping were also observed.

Such pressure, water pressure, dishing, truncation, cutting, pushing, and ripping traces were assessed to have been caused by a shockwave and bubble effect from an underwater explosion.



Stabilizing fins(compare left & right) Stabilizing fins(torn by pressure)



Water pressure marks on hull bottom Dishing on hull bottom

Truncated wires Bulkhead pushed outward

〈Figure III-1-10〉 Trace analysis

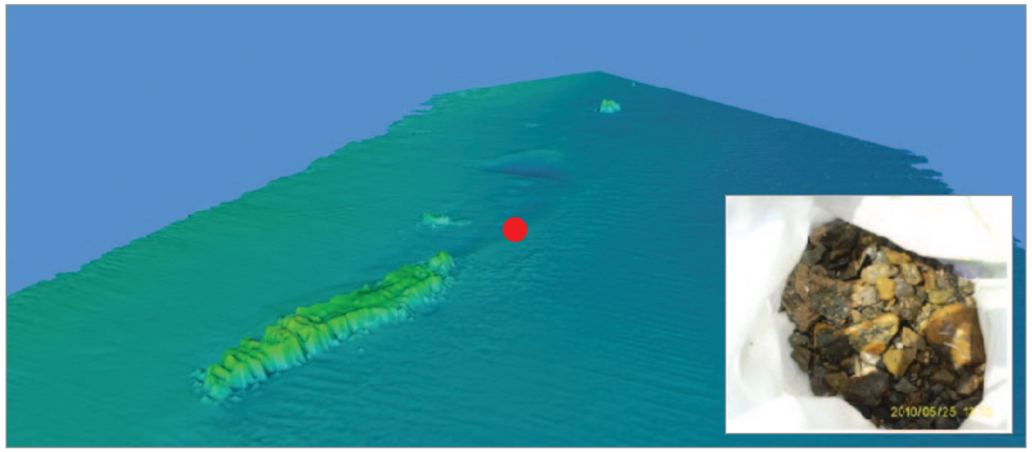
5) Sub-Conclusion

The overall study of shape and trace analysis indicates that bubble effect and shockwave caused by an underwater explosion were the external force exerted on the hull. The explosion originated from the point below the bow part gas turbine room on the portside bottom, and the explosion force traveled from the portside bottom diagonally toward the starboard side and caused the bow and stern to separate.

2. Evidence Analysis

1) Evidence Collection

Evidence was classified into gathered items from the sea area, collected items from the bow and the stern, and gathered items from the seabed. First of all, 12 warships including ROKS Jeju, ROKS Yeosu, ROKS Yangyang, ROKS Pyeongtaek, ROKS Jinhae, ROKS Chunghaejin, ROKS Sunginbong, ROKS Ongjin, ROKS Gimpo, ROKS



〈Figure III-2-1〉 Soil with explosive substance near the explosion point and the collected location

Goryung, ROKS Dokdo, and USS Salvor, 5 coast guard boats which participated in the initial rescue operation for survivors, Daechung Island base, Baekryong Island base, Sochung Island R/S, and the 6th Brigade were committed in collecting items from the sea area. The JIG organized shore searching groups and thoroughly searched the seashore using RIBs. A total of 431 items was collected through the collection operation, and 29 items were selected and examined including soil collected from the origin of detonation, metal pieces that were suspected to be fragments, and materials that may have adhered some explosive components.

The evidence collection included the 10 items of clothes gathered from the severely wounded victims and lookouts, which were analyzed in prior to evidences from the hulls. As for the collected evidence from the hulls, an on-scene examination was conducted for urgently collected items, when the stern, bow, and stack were salvaged. Then items required to go through explosive components and metal component detection analysis were collected and analyzed more precisely on the overall hull when the hull was transported to the 2nd Fleet Command in Pyeongtaek.


Stern
Bow

〈Figure III-2-2〉 Collection activities on the barge when the hull was salvaged

During the stern salvage, from 1430 to 2330 hours on April 15, collection activities using gauze were focused on the breakplane. 11 items such as fibers and insulation material dispersed on the breakplane, and 2kg of mud from the diesel engine room were collected. After moving to the 2nd Fleet Command in Pyeongtaek on April 18, the first precise examination was conducted between 0800~1700 hours. A careful observation was executed on the breakplane, along with O-1 deck, and the crews' mess hall(the areas near the breakplane). Asbestos, and fiber were collected from the breakplane, and metal fragments squeezed in fissures or mud were also extracted. 25 bags of mud were also collected from the diesel engine room and crews' mess hall floors(total of 147 items collected). Second precise examination was conducted on April 21 between 0800~1800 hours. During the process, new metal fragments and additional 60 items of evidence were discovered. The team used gauze to wipe the entire breakplane to collect evidence.


Metal fragment in a corner of the mess hall bulkhead
Metal fragment near the stern portside bilge keel


Collection of metal fragments from mud inside the crews' mess hall
Collection with a gauze of the crews' mess hall bulkhead exterior


Breakplane(gauze)
Stiffeners from the upper starboard side of the breakplane

〈Figure III-2-3〉 Evidence collection at the stern

On April 24, when the bow was being salvaged, an on-scene analysis aboard the barge was conducted from 1220~1620 hours. Metal fragments were collected from the bow breakplane starboard side, and gauze was used to wipe and collect foreign substances on the damaged and fractured regions of the hull and stabilizing fins. 46 items such as fibers and heat insulations dispersed on the bow breakplane were collected, including 6 glass fibers and sponges underneath the stack damage area.


Adhesives near the stabilizing fin
A piece of clothing at the keel region


Pieces of cloth near the breakplane central drainpipe area
Adhesives on the outer shell near the waterline


Adhesives on the hull bottom(gauze)
Metal fragments near the breakplane

〈Figure III-2-4〉 Evidence collection at the bow

On April 26, after moving the bow and stack to the 2nd Fleet Command in Pyeongtaek, detailed analysis on the bow and stack area was conducted from 0800~1600 hours and metal fragments dispersed around the bow breakplane curvatures were collected. Through wiping with gauze, 33 items including asbestos and sponges on the breakplane, fibers tangled around the central pipelines, asbestos and fibers from the lower stack, and soot samples from the stack interior were also collected. From May 1 to 8, detailed analysis was conducted four times on the stack, and 19 additional items such as white powder from the internal and external surfaces of the stack, sponge, and fiber were collected. Thus, a total of 316 items were collected from the salvaged hull.

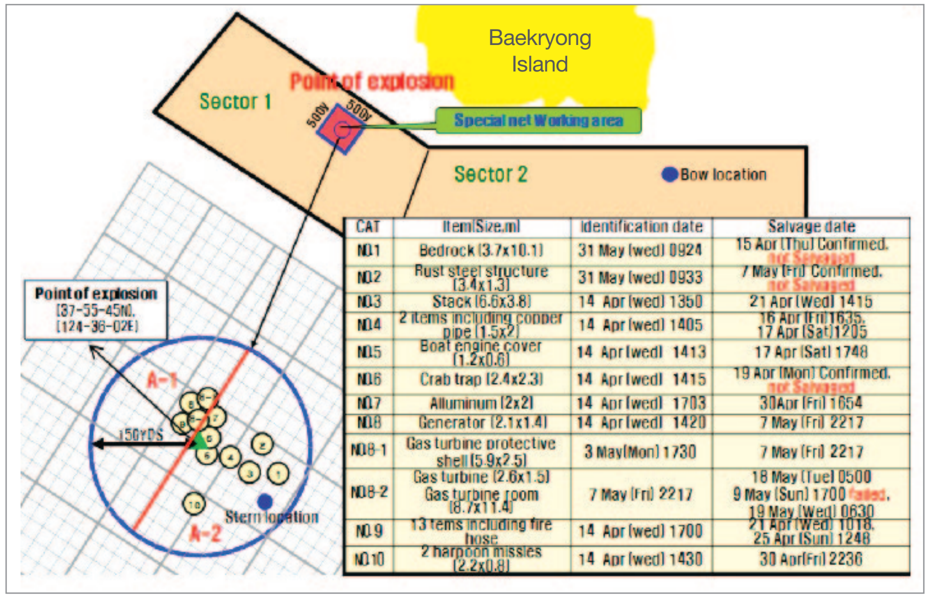

Fibers from the upper stack
Soot in the stack


Adhesives on the stack interior
Fibers underneath the crews' mess hall overhead, beside the stack


Sponge underneath the stack
Insulations(asbestos) underneath the stack

〈Figure III-2-5〉 Evidence collection at the stack

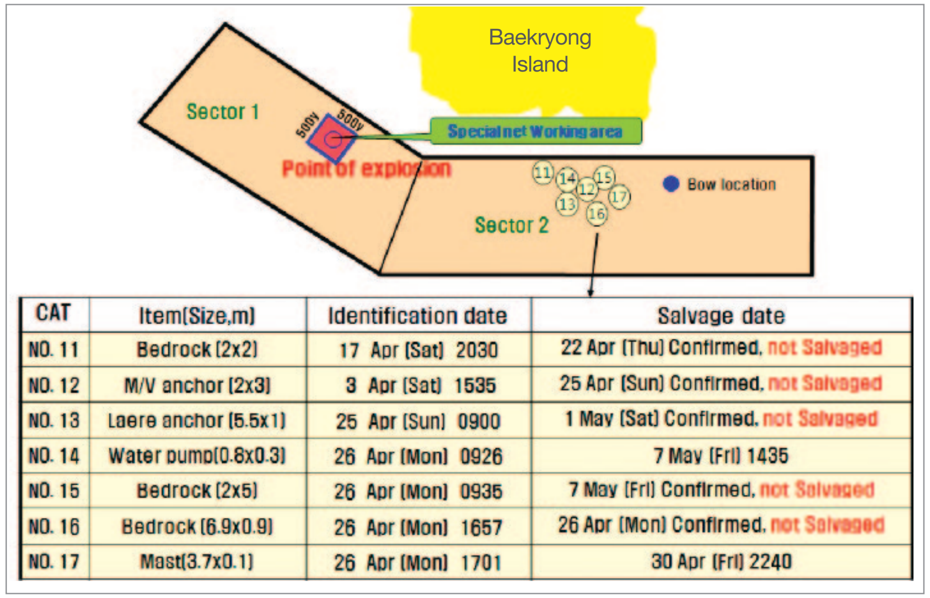
The JIG sought multiple measures in regard to the collection of items from the seabed, committing 8 ships from ROK[1] including a mine searching ship, and a rescue ship; the US committed the USS Salvor; and Korea Ocean Research & Development Institute(KORDI) ships Jangmok and Yiuhdo were employed for the search operations. 106 divers and the robot Haemirae were also committed in the search operations, but currents of 3~5 kts on average, the water depth of 47m, and the underwater visibility of 30cm made the operation very difficult. Until April 3, the focus was on rescue activities, and until April 24, salvaging the stern and the bow was on main concentration. Therefore, the evidence from the seabed, such as hull debris from the detonation, was actually collected after April 25.



CAT	Item(Size,m)	Identification date	Salvage date
NO.1	Bedrock (3.7x10.1)	31 May (wed) 0924	15 Apr (Thu) Confirmed. not Salvaged
NO.2	Rust steel structure (3.4x1.3)	31 May (wed) 0933	7 May (Fri) Confirmed. not Salvaged
NO.3	Stack (6.6x3.8)	14 Apr (wed) 1350	21 Apr (Wed) 1415
NO.4	2 items including copper pipe (1.5x2)	14 Apr (wed) 1405	16 Apr (Fri) 1635, 17 Apr (Sat) 1205
NO.5	Boat engine cover (1.2x0.6)	14 Apr (wed) 1413	17 Apr (Sat) 1748
NO.6	Crab trap (2.4x2.3)	14 Apr (wed) 1415	19 Apr (Mon) Confirmed. not Salvaged
NO.7	Alluminum (2x2)	14 Apr (wed) 1703	30Apr (Fri) 1654
NO.8	Generator (2.1x1.4)	14 Apr (wed) 1420	7 May (Fri) 2217
NO.8-1	Gas turbine protective shell (5.9x2.5)	3 May(Mon) 1730	7 May (Fri) 2217
NO.8-2	Gas turbine (2.6x1.5) Gas turbine room (8.7x11.4)	7 May (Fri) 2217	18 May (Tue) 0500 9 May (Sun) 1700 failed, 19 May (Wed) 0630
NO.9	13 tems including fire hose	14 Apr (wed) 1700	21 Apr (Wed) 1018, 25 Apr (Sun) 1248
NO.10	2 harpoon missles (2.2x0.8)	14 Apr (wed) 1430	30 Apr(Fri) 2236

〈Figure III-2-6〉 Sector 1 hull identification and salvaging status

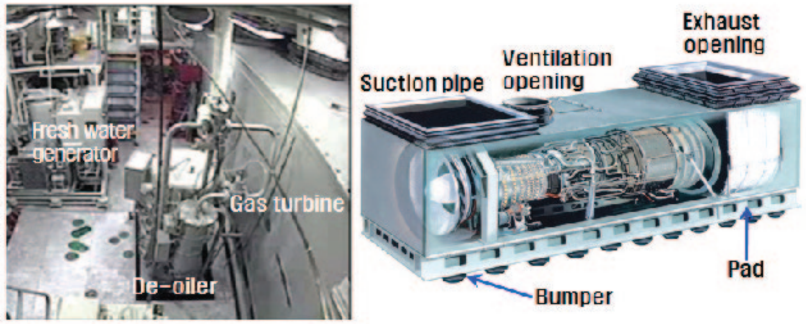
The search operation was divided into sector 1 which included the origin of detonation, and sector 2 that included the sinking point of the bow as shown in 〈Figure III-2-6〉, and 〈Figure III-2-7〉. An extended search(ROKS Gimpo, ROKS Goryung, and ROKS Ongjin) was conducted on the outer ring of sector 1 and 2. As for detailed searching in sector 1, ROKS Yangyang and Ship Haemirae were utilized from April 14 to 16, and they identified items and collected some light items from waters surrounding the origin of detonation(1NM × 1NM). Through detailed searching in sector 2, ROKS Goryung identified items between April 25 and 26, and KORDI investigation ships(Ship Jangmok and Ship Yiuhdo[2]) were committed in order to conduct more precise investigation and search operations between April 17 and 20.



CAT	Item(Size,m)	Identification date	Salvage date
NO. 11	Bedrock (2x2)	17 Apr (Sat) 2030	22 Apr (Thu) Confirmed, not Salvaged
NO. 12	M/V anchor (2x3)	3 Apr (Sat) 1535	25 Apr (Sun) Confirmed, not Salvaged
NO. 13	Laere anchor (5.5x1)	25 Apr (Sun) 0900	1 May (Sat) Confirmed, not Salvaged
NO. 14	Water pump(0.8x0.3)	26 Apr (Mon) 0926	7 May (Fri) 1435
NO. 15	Bedrock (2x5)	26 Apr (Mon) 0935	7 May (Fri) Confirmed, not Salvaged
NO. 16	Bedrock (6.9x0.9)	26 Apr (Mon) 1657	26 Apr (Mon) Confirmed, not Salvaged
NO. 17	Mast(3.7x0.1)	26 Apr (Mon) 1701	30 Apr (Fri) 2240

〈Figure III-2-7〉 Sector 2 hull identification and salvaging status

Although aforementioned search operation identified the locations of various items, the bad weather, strong currents, and limited underwater vision caused difficulties for the collection operations. However, when permitting, the JIG continuously conducted search



〈Figure III-2-8〉 The gas turbine room layout and gas turbine configuration

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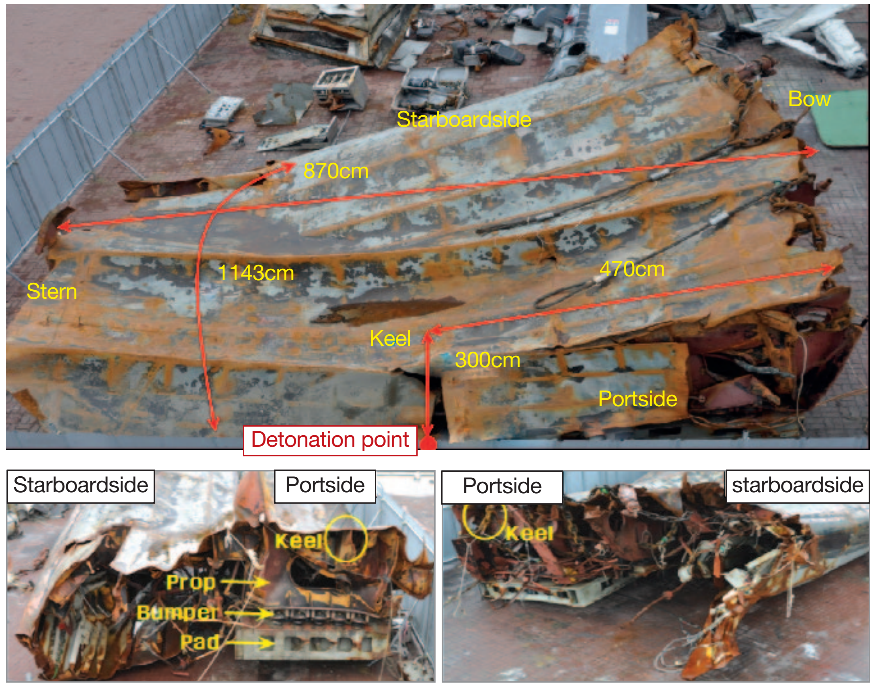
[1] ROKS Goryung, Gimpo, Ongjin, Gwangyang, Sunginbong, Pyeongtaek, Chunghaejin, and Yangyang.

[2] ROKS Jangmok and Yiuhdo are equipped with side scan sonars that can identify items which are larger than 1m.

operations and salvaged the gas turbine protective shell, the generator armature, and the motor on May 7. On May 8, between 0930 and 1400 hours, the JIG collected 14 materials including fibers, and metal fragments from the salvaged items. Moreover, the JIG attempted to salvage what seemed to be the hull of the gas turbine room, but the ground condition of the area consisting of bedrocks, bad weather, and its heavy weight halted our attempt.

At last, on May 9, Navy UDT divers identified that the unknown material was in fact the actual gas turbine room. ROKS Gwangyang attempted to salvage it, but failed because the 5-inch(12.7cm) rope was severed on the water surface. Considering the limited capabilities[3] of a 60-ton crane of the ROK Navy and the harsh underwater conditions of the area, the JIG decided to use a commercial crane and signed a contract with Yoosung Development. On May 17, a civilian company-owned crane arrived on scene, prepared to salvage the item, and succeeded in salvaging the item around 0630 hours on May 19.

The salvaged gas turbine room was 8.7m in length and 11m in width on the hull bottom and on the starboard side, and weighed about 30tons as shown in 〈Figure III-2-9〉.



Stern-side breakplane

Bow-side breakplane

〈Figure III-2-9〉 Salvaged bottom shell portion of gas turbine room

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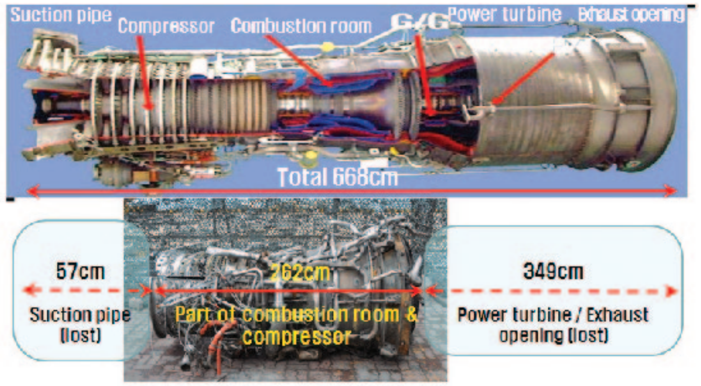
[3] Maximum water depth of 20m, salvage height 25m.

The point about 3m away from the gas turbine room's portside hull bottom, which was expected to be the location of detonation, was damaged. The gas turbine pad, bumper, and props that were formed with a strong steel-frame structure were not severed, but the fore and aft regions of the pad which are relatively vulnerable were severed. 3 pieces of gauze were used to wipe the hull bottom and the breakplane, and 2 metal pieces were collected from the gas turbine room.

Also, as for the turbo engine(gas turbine) which was salvaged on May 18, the suction pipe(57cm) and the power turbine/exhaust opening(349cm) were missing from the 668cm long body that is consisted of the suction pipe, compressor, combustion room, power turbine, and exhaust opening. The combustion room and the part of the compressor(262cm) were intact. Considering that this equipment is covered by the protective shell, the JIG assessed that metal fragments or explosive components are unlikely to be detected, so the JIG confirmed the deformation of shape without conducting an extra collection search.



〈Figure III-2-10〉 Salvaged gas turbine

As for the evidences collected from the seabed using a special net, the JIG explained operation purpose and methods to the ROK Navy HQ, Navy Operations Command, Navy Search and Rescue Group, and ROK Marine 6th Brigade, and coordinated with them in terms of operation command and control, preparation and teaching collection and separation workforce, providing RIBs for transporting collected items, preparing working places on the Baekryong Island, and detailed matters that had to be prepared.

At the same time, the investigation result of underwater configuration by KORDI and the estimation result of an object's traveling distance by an explosion by ADD were provided to the on-scene collection team. The collection operation for items on the seabed was started on May 10, and 21 items including the torpedo propulsion motor device were collected after over 10 days of the operations.

Category	Total	Examined	Not examined
Total	797	357	440
Gathered items from the sea area	431	29	402
Collected items	345	307	38
Gathered items from the seabed	21	21	0

〈Table III-2-1〉 Evidence status

As mentioned above, 29 items gathered from the sea area, 307 collected items, and 21 items gathered from the seabed, totaling 357 items overall, were examined.

The collected evidence was prioritized, considering the location that they were collected and the characteristics of the collected items, and then examined by KCIC scientific investigation lab and the NISI. Both physical and chemical analyses were conducted on 118 items. On the basis of the results the JIG organized an evidence assessment committee conducting 3 discussions to select the evidences for the investigation.

CAT	TOT	Fibers	Metals	Plastics	Asbestos	Soil	Gauze	Other
TOT	357	33	67	31	34	42	96	54
Metals	164	7	67	11	3	25	35	16
Explosives	311	33	41	25	31	31	96	54

〈Table III-2-2〉 Examination status

* The total is a figure that excludes the overlapping items.

Also, the CCTV hard disk that could be used to verify the situation during the incident was primarily gathered and restored during the bow salvaging operation. Recovery process of the collected hard disks included hard disk separation, hard disk washing(of fuel and mud), providing electricity, hard disk operation, and data recovery. Data recovery in the hard disk took 8 days to complete, and on May 2, images from 6 CCTV locations out of 11 locations were successfully recovered, and the JIG was able to verify the images from right before the incident.

The evidence collection activities utilized every possible mean including the JIG, Navy search/rescue group, and civilian resources, and overcame difficult conditions of the scene, weather, and water. The collection, recovery, and examination status by each of the stern and bow salvaging and search/rescue operation stages is shown in 〈Table III-2-3〉.

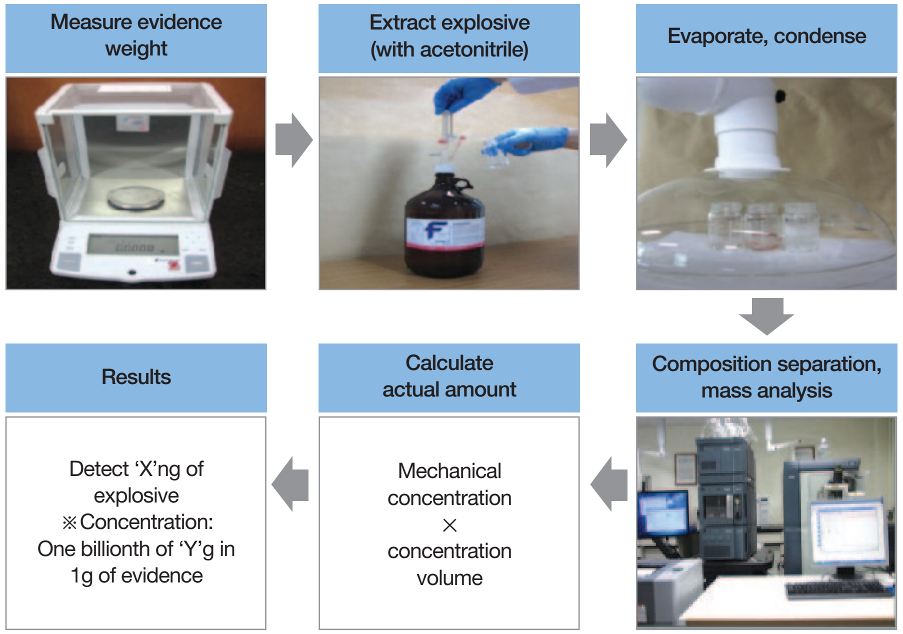
CAT	Contents
Stage 1 Stern salvage (Apr 15)	• Collected survivors' clothing, items on the sea, items on the stern(626 items), request for examination(219 items) • Prepared to collect evidence on the seabed(approved by the Minister of National Defense) - Discussion with ROKAF Safety Director and company representatives: Apr 17 - ROK Navy HQs coordination meeting: Apr 19 - Making special nets(Apr 26), arrived on scene(Apr 30)
Stage 2 Bow salvage (Apr 24)	• Collected from the bow region and the stack, request for examination(98 items) • Collected CCTV: Apr 24(Sat) 1100 hours, ward room • Prepared to gather and collect underwater evidence ＊Committed collection team to Baekryong Is.(13 personnel) on May 1
Stage 3 Propulsion motor device /gas turbine salvage (May 15~24)	• May 7, salvaged the generator and gas turbine room's protective shell • May 15, collected propulsion motor device ＊Daepyung Corp.(Daepyung No. 11 and 12) • May 18~19, salvaged gas turbine and gas turbine room ＊Yoosung Development(Ship Yoosung) • Collected underwater evidence such as gas turbine's protective shell and the torpedo propulsion motor system(73 items), requested for examination(40 items)

〈Table III-2-3〉 Status of the evidence collection, recovery, and examination by stages

2) Chemical Analysis

Chemical analysis was focused on detecting explosive substances, and the KCIC scientific investigation lab used the High Performance Liquid Chromatograph(Acuity model of Waters Inc.) and the Mass Spectrometer(Q-TOF Premier model of Waters Inc.) method to carry out analyses of 311 items.

(1) Analysis Procedure

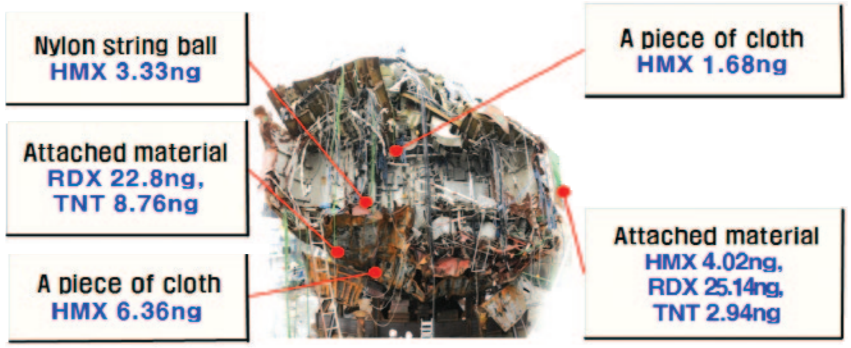


〈Table III-2-4〉 Explosive composition analysis procedure

(2) Analysis Results

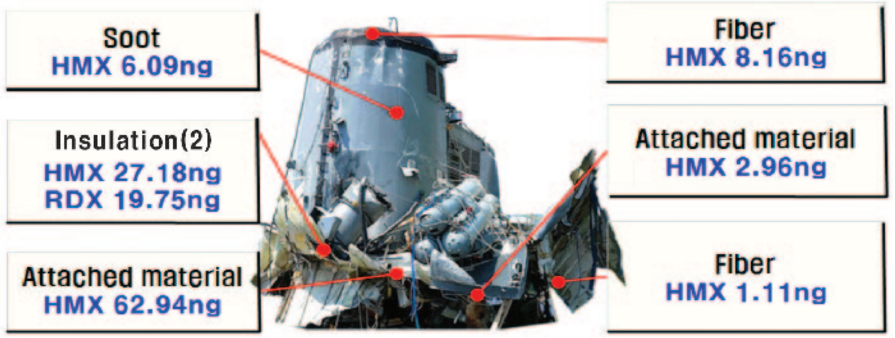
The explosive substances were detected on the bow breakplane, stack, gas turbine room, and oceanic and seabed evidence. In total, 527.91ng of HMX(28 items), 70.59ng of RDX(6 items), and 11.7ng of TNT(2 items) were detected.

First, HMX was detected on the bow breakplane on items such as the nylon string ball from the 1st platform, attached materials on the shell of the draft line, and cloth near the piper and keel, and the JIG detected RDX, and TNT as well on the attached materials on the shell of the draft line and stabilizer. In total, 15.39ng of HMX, 47.94ng of RDX, and 11.7ng of TNT were detected on 8 items.



〈Figure III-2-11〉 Detected explosives in bow area

On the stack that was detached due to the explosion pressure, HMX was detected on the internal soot, upper fibers, attached material underneath, attached material inside the pipe, crew galley's overhead bottom fiber, and the lower insulation. RDX was detected on the lower insulation(2 items). In total, 108.44ng of HMX and 19.75 of RDX were detected on 8 different items.

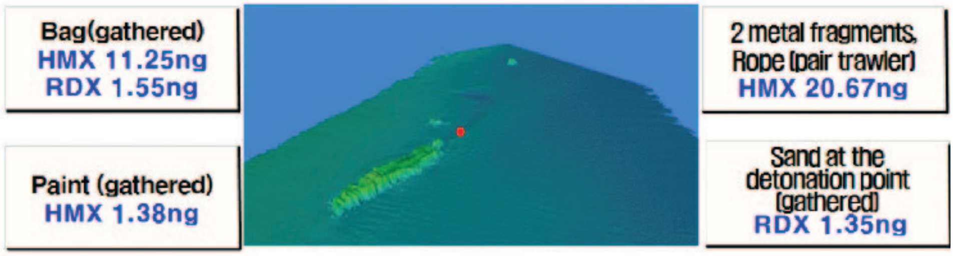


〈Figure III-2-12〉 Detected explosives in stack area

From the gas turbine room, which was damaged and lost from the explosion pressure directly impacting it, a total of 370.78ng of HMX was detected in 13 locations including the inner asbestos portside(2 items), plastic fragments at the protection compartment's ceiling(2 items), metal fragment within the protection compartment, metal fragment on the entrance shell, extracted gauze on the portside entrance shell(3 items), extracted gauze on the breakplane(2 items), and soils/fibers from inside the generator(2 items).

〈Figure III-2-13〉 Detected explosives in gas turbine room

The evidence collection operation of the seabed was conducted with bull trawlers during the search and rescue operation. Amongst the collected items, HMX was detected from the bag, rope, metal(2 items), and paint fragments, and RDX was detected from the bag, and sand around the incident site. In total, 33.3ng of HMX and 2.92ng of RDX were detected from 7 locations.

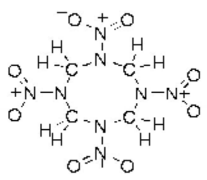
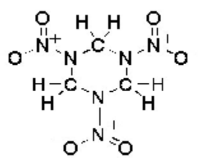
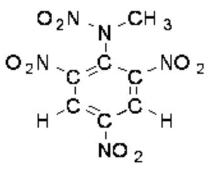
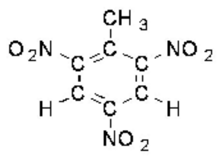


〈Figure III-2-14〉 Detected explosives from seabed evidences

After a comprehensive analysis on these discoveries, the team was able to confirm that explosives were detected in locations near the explosion area(bow portside, stack, gas turbine room, and seabed area). Additionally, the adhered materials were detected on the adhesive materials(insulation, fiber, and asbestos) and the explosive charge used in the incident consisted of HMX, RDX, and TNT.

After checking the manufacturing methods of the explosives, it was possible to confirm that pure RDX is manufactured through the Woolwich method for RDX production, but 5~10% of HMX can be generated if Bachmann method is used. In production of HMX, pure HMX is manufactured only through the Bachmann method.

Based on these facts, the JIG checked the type of explosives, and as a result, the JIG found that HMX(High melting point explosive, explosion speed of 9,100m/sec) is a colorless molecular crystal powder that has a high density and melting point and that since it is the most high-efficient explosive, it is used in precision weapon systems. RDX(Research Department explosive, explosion speed of 8,700m/sec) is a colorless crystal powder, which has comparatively high density and explosion speed, and since it has a stable sensitivity, it is commonly used in weapon systems. Tetryl(Tetranitromethylaniline, explosion speed of 7,850m/sec) has greater explosion power than TNT, and it is used as a substitute for TNT. It is widely used in mines and grenades. Lastly, TNT(Trinitrotoluene, explosion speed of 6,900m/sec) is widely used as a military explosive. It is chemically stable, so it is used in various propellents and explosives.

HMX	RDX	Tetryl	TNT
			
$C_4H_8N_8O_8$	$C_3H_6N_6O_6$	$C_7H_5N_5O_8$	$C_7H_5N_3O_6$

〈Table III-2-5〉 Molecular structure of the explosives

In order to determine whether the detected explosives were from ROK weapon systems, the JIG verified the records of firing exercises around Baekryong Island. As a result, the JIG was able to confirm that infantry battalions conducted integrated island defense firing exercises using 6 types of ammunitions in the year 2009, and 1,558 shells in total were fired. The artillery battalion's sea fires consisted of three types in 2009, which included a total of 636 shells fired. The firing of cannons consisted of three types with 712 shells and 257 shells in 2009 and 2010 respectively. But the majority of explosives used by the 6th Brigade and the infantry/artillery firearms contained RDX. Friendly torpedoes, sea mines, or ship-to-ship(Harpoon) missiles were not tested in the West Sea. It was also confirmed that the majority of ship gun ammunitions contain RDX.

CAT	Model	Charge	Major components
ROK	Torpedo A	DXC-04	Ammonium perchlorate, RDX, Al
	Torpedo B	DXC-05	HMX
	Mine A	H-6	RDX, TNT, Al
	Mine B	DXC-03	Ammonium perchlorate, RDX, Al
	76mm	Comp-A3	RDX
	40mm	Comp-A4	RDX
	Missile A	Destex	TNT, Al
	Missile B	DXC - 10	HMX, NTO, Al, Binder
Soviet SAET-60M(torpedo)			RDX, TNT ※Bonn International Center for Conversion. 2005

〈Table III-2-6〉 Explosive components of major marine weapons

Explosive experts' opinions indicate that when a high explosive warhead is fired in the ocean and arrives at the sea surface, it explodes from the shock, and when high explosives explode on the sea surface most of the explosive components are transformed into explosive ash and explosive gases in order to generate the explosion. These are then lost in the water. The minute amount of unexploded explosive residue can be left in the water or on the seabed, but taking the currents and other factors into consideration, this is highly unlikely. On the basis of these factors, the JIG concluded that the detected explosives were not from friendly fire.

CAT	Ammunition type	Explosive components
1	High explosive A	RDX, TNT, WAX
2	High explosive B	RDX, TNT, WAX
3	High explosive C	TNT
4	Self-blasting bomb A	RDX, WAX
5	Tank gun high explosive	RDX, TNT , WAX
6	Coast gun high explosive	RDX, TNT, WAX
7	High explosive D	TNT
8	High explosive E	TNT
9	Hail bomb	RDX, WAX
10	High explosive F	RDX, TNT, WAX
11	High explosive G	TNT
12	76mm	RDX, WAX
13	40mm	RDX, WAX
14	Depth charge	RDX, TNT, AL, WAX

〈Table III-2-7〉 Explosive component by friendly ammunition types

The analysis attempted to determine the origin of the explosives using chemical fingerprint testing[4], and NISI conducted an isotope analysis of detected explosive residues from the collected items and explosive samples from the US, France, Canada, and ROK. However, the limitations arose in determining the specific origin of the explosives.

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[4] A testing method in order to determine the origin by looking at unique chemical fingerprint which is varied by the substance's raw material and manufacturing environment.

3) Physical Analysis

Even before the bow and the stern were salvaged, the physical analysis focused its efforts on securing North Korean torpedo samples, which were to be used for a comparison. Samples of a North Korean test torpedo were discovered by a civilian diver around Pohang on March 12, 2003. These had been stored in the Jinhae branch of ADD for research purposes, and the JIG was able to secure 3 pieces of a North Korean test torpedo for comparison.

In order to analyze the hull material of ROKS Cheonan, the JIG obtained standard metal and material parts of the hull from ADD; analyzed these components and their ratios; and also confirmed the component ratio of the gas turbine room by making several requests(these information are treated as corporate secret) to Samsung Tech-Win that manufactures and delivers military ship parts for detail information on the materials used for the gas turbine.

The aluminum fragments found on ROKS Cheonan's hull were small in size, between 1mm and 7mm. Furthermore, since they were mixed with mud and located in a gap on the breakplane, it was difficult to identify them with the naked eyes. After salvaging the stern, the bow, and the stack, the JIG concentrated on collecting microscopic items, and were able to collect a total of 164 metal pieces. KCIC scientific investigation lab conducted physical analyses on the collected items and the comparison samples by using SEM(Scanning Electron Microscope; Phillips Co. model XL30)/EDX method, and through a process of elimination by comparing these metallic fragments with materials found in North Korean test torpedo and in ROKS Cheonan, identified 6 pieces of aluminum and aluminum alloy fragments which were assessed to be parts used in a torpedo[5].

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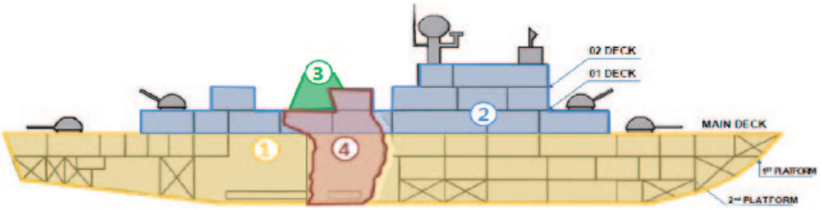
[5] According to experts' opinions, the hull is not directly damaged or penetrated by a torpedo in case of an underwater explosion. Also, the torpedo external shell is made of Al alloys, causing it to become microscopic fragments or melt in the water when it explodes, so they may be swept away by the tides and is difficult to discover.

(1) Composition of the Comparison Samples

The composition of ROKS Cheonan is as seen on 〈Figure III-2-15〉; the main material of the main hull is steel, and the main material of the superstructure and the stack is aluminum. The main equipments such as the compressor, combustion, and the power turbine are composed of different materials such as aluminum alloys, or heat-resistant nickel alloys.

In case of a lightweight North Korean test torpedo, all of its components are made of aluminum alloy. The main body consists of 97.28% Al and 2.72% Mg; the propellers consist of 96.22% Al and 3.78% Mg; and the fixed-propellers consist of 95.88% Al and 4.12% Mg
.



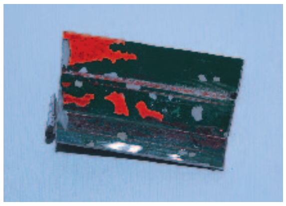
① Main hull: main composition element Fe(Steel)
- Plane(outer bulkhead): Fe(99.125%) + minute C · Mg · P · S(0.875%)
- Section steel(plane support): Fe(99%) + minute P · S(0.1%)
- Column: Fe(97.01%) + minute C · Si · Mg · P · S(2.09%)

② Superstructure: main composition element Al(Alloy)
- Plane: Al(93.15%) + minute Cu · Fe · Si · Mg · Mn · Cr · Zn · Ti(6.85%)
- Section steel / column: Al(97.08%) + minute Cu · Fe · Si · Mg · Mn · Cr · Zn · Ti(2.92%)

③ Stack: main composition element Al(Alloy)
- Plane: Al(94.6%) + minute Cu · Fe · Si · Mg · Mn · Cr · Zn · Ti(5.4%)
- Section steel: Al(97.08%) + minute Cu · Fe · Si · Mg · Mn · Cr · Zn · Ti(2.92%)

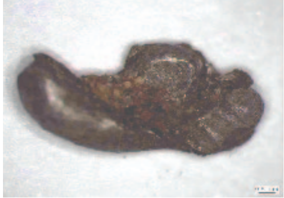
④ Gas turbine room: main composition elements Fe, Al, Ni and others
- Protective compartment: Fe(97.3%) + Mn(1.5%) + other(1.2%)
- Air suction pipes/web: Fe(68.72%) + Cr(17~19%) + Ni(8.5~11.5%) + other(3.28%)
- Suction web hatch: Al(94.3%) + Mg(2.4~3.0%) + other(2.7~3.3%)
- Compressor
  - Rotor:1~14 gear [Ti(92.5%) + Al(5.0%) + Sn(2.5%)],15~16 gear[Fe(97.3%) + other(2.7%)]
  - Stator: Ni(69%) + Cr(16%) + Fe(8%)
- Oxidizer: Ni(69%) + Cr(16%) + Mo(15%)
- Power turbine
  - Casing: Ni(77%) + Cr(15%) + Fe(8%)
  - Rotor: Ni(50%) + Cr/Co(30%) + Mo/Al(9%) + other(11%)
  - Stator: Ni(50%) + Cr(20%) + Co(12%) + Mo(10%) + other(8%)
- Exhaust opening: Fe(99.125%) + Carbon and others(0.875%)

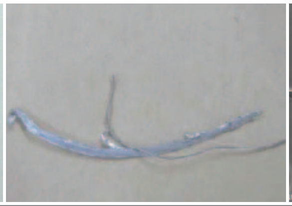
〈Figure III-2-15〉 ROKS Cheonan hull composition

CAT	Body (Al 97.28%, Mg 2.72%)	Propeller (Al 96.22%, Mg 3.78%)	Stationary fin (Al 95.88%, Mg 4.12%)
North Korea torpedo			

〈Figure III-2-16〉 Composition of North Korean light weight torpedo samples

(2) Composition of the Collected Items

Location	Gap on wall of food table in the galley	Fwd starboard side of crews' mess hall	Near bilge keel of the stern portside
Item			
Comp.	Al 96.08%, Mg 3.92%	Al 100%	Al 100%

Location	Central region of the stern starboard	In the mud from crews' mess hall	External wall of crews' mess hall
Item			
Comp.	Al 96.07%, Mg 3.93%	Al 100%	Al powder(contains Mg)

〈Figure III-2-17〉 Composition of evidences

The JIG analyzed and compared 6 identified items with the samples from ROKS Cheonan's hull and the North Korean test torpedo, but the JIG was only able to conclude that each of the metal pieces is not identical to one another. Although every possible analysis method was employed such as the multi-element analysis by NISI and the precise composition examination through KAIST, the information concerning the types of metal used in torpedoes and their composition is classified in every nation, and therefore, there were fundamental limitations to the analysis. Especially, experts' opinion was that it would be difficult to find fragments since they would have been broken down into minute pieces in case of an underwater explosion.

(3) Analysis Result

A precise analysis was conducted on the 3 samples of a North Korean test torpedo(body, rudder, and propeller), 6 samples from ROKS Cheonan(stack shell plating, stack interior stiffener, stern interior, and outer bulkhead of the mess hall), and 6 main collected items, but the JIG was not able to identify any metal fragment that was actually used in the torpedo, which sank ROKS Cheonan.

4) Sub-Conclusion

From examining 219 items out of the 626 collected items, including items from the stern, survivors' clothing, and gathered items from the sea area, the JIG detected 12.63ng of HMX from 2 locations and 2.9 ng of RDX from 2 locations, and also identified 6 pieces of aluminum and aluminum alloys during the first stage when salvaging the stern(until April 15).

123.83ng of HMX from 10 locations, 67.69ng of RDX from 4 locations, and 11.7ng of TNT from 2 locations were detected from the 98 collected items from the bow region and the stack during the second stage, when salvaging the bow(until April 24).

391.45ng of HMX was detected from 16 different locations when the JIG analyzed 40 collected items from the generator, gas turbine room, and torpedo propulsion motor device during the third stage when salvaging the propulsion device and the gas turbine(until May 19).

In conclusion, ROKS Cheonan was hit and sunk by an underwater weapon carrying mixed explosive composed of HMX(527.91ng in 28 items), RDX(70.59ng in 6 items), and TNT(11.7ng in 2 items).

3. Testimony Analysis

Before collecting testimonies from the 58 survivors, the JIG first acquired the Military Capital Hospital director's approval and consulted respective surgeons in order to ensure that the individuals were stable enough to give out testimonies. 50 survivors including the Commanding Officer issued their testimonies one day after the incident, on March 27, in the Military Capital Hospital. 8 severely injured personnel and those who had participated in the rescue activities were not included. On the next day, the JIG collected testimony concerning the location of the incident, measures that were taken following the incident, and crew members' behavior. On March 31, because the initial testimonies were assessed to be incomplete, the JIG asked for additional testimonies from those personnel whose testimonies were needed to be double checked and from those that the JIG did not inquire initially. On April 1, the JIG collected detailed testimonies from crew members regarding their actions right before and after the incident.

Along with these testimonies, the JIG also acquired the Commanding Officer's reports, phone logs with the Squadron Commander, and records of the communications officer's with the radar base soldier on duty.

Testimonies of the 2 sentry soldiers were collected. They witnessed the sinking of ROKS Cheonan at the guardpost in Baekryong Island. The JIG inquired 2 statements from each sentry soldier about the incident on March 28(1), April 2(2), and April 4(1). On May 2, the JIG conducted the polygraph tests on these individuals to conclude that their testimonies were truthful, and therefore the JIG accepted these testimonies as evidence.

1) Situation during the Incident

The Commanding Officer(CDR) and 26 of the other survivors said they heard the sound of an explosion, "Gwang! Gwa-ang," followed by a power outage. Then their bodies were lifted up 30cm~1m in the air before falling towards the starboard side of the ship. 41 survivors said that they smelled oil, and that there were no witnesses of flames, fire or a water column, nor did any injury result from these factors. There were 50 patients with bruises, fractures and sprain.

In particular, the chief radar officer said that an initial 'koong', then 'gwang' explosion sound was followed by a blackout. An ammunition serviceman said that he heard a 'gwang', when the ship tilted to the starboard side and the 'gw~ang,' and it seemed as if the stern was being ripped off the hull. Such testimonies indicate that an underwater explosion caused the initial explosion sound, then the pressure broke out, causing shock and the secondary explosion sound, and this is consistent with the UNDEX bubble effect.

Major points of testimonies

- While I was checking KNTDS, operations and the daily schedule, I heard an explosion sound, then was lifted 30~40cm in the air and fell towards the starboard side. I was later rescued by my subordinates (Commanding Officer)
- While working on administrative duties at the XO's stateroom, I heard a 'gwang' sound, was lifted up in the air, and then fell as the power went out. When I opened the door and escaped to the deck, there was no stern, and the mast fell to the starboard side and was being rocked (XO)
- While on bridge duty, a 'gwang' sound occurred and the ship was tilted 80~90 degrees to the starboard side. I did not see any light, flashes, flames, water pillars, or smoke (duty officer)
- While I was working at the chief mechanic's office, I lost consciousness due to the explosion and shock. I stepped on the washstand and doorstep to escape and conducted rescue operations (chief mechanic)
- At the bow R/S, I was having a conversation with fellow service members when I heard a 'koong' sound and the lights went out. I also smelled fuel. I could not make an assessment on the cause of the incident (chief gunner)
- While I was on watch officer duty, I heard a 'koong' sound, after which I was lifted a little in the air, but did not smell any explosive or other substances (communications officer)
- I heard a 'gwang' sound while sleeping in the operations officer stateroom, and I opened the outer hatch and escaped to request rescue to the 2nd Fleet's situation cell (combat information officer)
- While studying for the non-commissioned officers' ability test at my berthing cabin, a 'koong' sound was followed by a power outage. Although there was no smell of explosives, I thought that the incident had occurred because of some external force (chief steerer, MCPO)
- While sleeping in my berthing, a 'gwang' sound was followed by the smell of seawater and fuel, but I had no idea what the cause was (internal machinery chief)
- I was sleeping in the berthing, and at the time, I did not hear any explosion sound. But I did feel the bed caving in, and I smelled fuel, but not explosives. I believed the cause of the incident was an attack from either a North Korean submarine or semi-submersibles (Chief electrician)
- While sleeping in the 2nd floor of the CPO berthing, I heard a 'gwang' sound, and my head banged against the 3rd floor bed. Then I fell to the ground. I didn't smell explosives, but I did smell fuel. I determine it to be due to an external explosion (chief deck officer)
- While on communications stateroom safety watch duty, a 'gwang' sound was followed by 30~40cm of lifting into the air, and then I fell toward the starboard side. When I came up to the port, the place was flooded with water, and therefore I felt water splashing under my feet while moving. I did not smell explosives, but did smell fuel (communications chief)
- While sleeping in the berthing, a 'gwang' sound pulled me to a corner of the room, and I heard tools falling. Nothing special, other than the smell of fuel (internal combustion engine chief)
- While working on my PC at the ammo admin room, I heard a 'gwang' sound followed by power outage when my body and the objects around me floated in the air then fell (Chief firearms officer)
- An initial 'koong' sound was followed by a secondary 'gwang' 2~5 seconds later, when the power went out and oil was splashed onto my face (Chief sonar officer)
- While sleeping in the CPO berthing, I did not hear shock sounds but anyway I fell from the third floor bed, and when I regained my consciousness the seawater was coming in and I smelled fuel (chief maintenance officer)
- While resting at the sailing crew berthing, a loud sound was followed by the tilting of the ship, and my fellow crews said we must escape because there was flooding, and I smelled fuel (deck officer)
- I was sleeping in the sailing crew berthing and smelled fuel after a 'koong' sound (steering petty officer)
- While asleep on the gunnery crew berthing two-story bed, I heard a 'gwang' sound, then my body was flung toward the starboard side bulkhead, hitting my arm and my legs, falling to the ground (control petty officer)
- While sleeping at the gunnery crew berthing, I heard an explosion sound, and I did not smell explosives, but did smell fuel, and the bridge had tilted about 90 degrees, but I could not verify the bow parts (ammunition petty officer)
- While on duty at the combat information center, I heard a shock sound, then was flung toward the starboard side bulkhead, along with other objects sliding down toward it (sonar radar officer)
- While on duty as the assistant watch officer, a 'gwang' sound was followed by the ship tilting 90 degrees, and I escaped to commence rescue of the crew members (deck officer)
- While sleeping at operation crew berthing, I banged against the right bulkhead and fell off to the floor (communications officer)
- I could not hear a shock or explosion because I was asleep in the gunnery crew berthing, but I heard the portside cabinets falling to the floor, and I could not see lights/flames/water pillars but I think that a torpedo accident had occurred (radar petty officer)

- While playing a cellphone game at the operations berthing one-story bed at the starboard side, a ‘gwang’ sound was followed by a severe shaking, and then the ship started to tilt toward the starboard side (Comms. officer)
- While on safety watch officer duty at the combat information center, I heard a loud sound and the ship tilted to one side, and I was pressed under piles of computers and other equipment, and sustained fractures at the head, waist, and legs (electrical warfare petty officer)
- While doing night-shift at the sonar room, I didn’t detect any special signal or sound, but a sudden ‘gwang’ sound was followed by power outage, and I thought that the ship had abruptly collided with something. When I came out to the outer deck the portion from the stack on was fallen off, and I thought that a war had broken out (sonar petty officer)
- While sleeping at the operations berthing, a ‘koong’ sound was heard once, when my body floated up by 5~10cm, but there was no smell of flame or explosive at the time (sonar petty officer)
- While working night shift at the sailing portion, I was flung forward after a ‘kwa-gwa-gwang’ sound, but I could not smell any explosive or fuel (steerer)
- I was working night shift, and rescued by other crew members since I lost my consciousness at the time of incident. I don’t think this was caused by some internal factors but an external force exerted a shock (fire control petty officer)
- While resting at the front gunnery berthing, a ‘gwang’ sound was followed by lifting in the air when the ship tilted 90 degrees and the objects in the room slided toward the same side (radar petty officer)
- While listening to music at the gunnery crew berthing, a one-time explosion sound was followed by power outage, and the ship tilted, making tools fall to the ground. Later on I saw that the stern wasn’t there. I think the cause is a torpedo or a sea mine (firearms petty officer)
- While on safety watch duty, I was sprung toward the right after a ‘gwang’ sound. I smelled fuel and I think the incident’s cause is a torpedo attack (radar petty officer)
- While sleeping at the operation crew berthing, a shock was followed by the ship tilting, and the cabinets fell to the ground, and when I came up to the deck I smelled a lot of fuel (radar petty officer)
- While reading at the gunnery crew berthing, I heard a one-time ‘gwang’ sound, and my body was lifted then the ship tilted. The stern was invisible from the portside (tracking petty officer)
- While sleeping at the operation crew berthing, a one-time ‘gwang’ sound was followed by power outage, when the bed tilted to the right. When I regained consciousness, I sensed the heavy smell of fuel (radar petty officer)

- While reading a book at the sailing crew berthing, I was lifted about 50cm~1m in the air and lost consciousness. After recovering my consciousness, I moved to the bow with 2 other crew members (gearing petty officer)
- While resting at the elec/maintenance room, I was lifted about 50cm with a ‘gwang’ sound. Then the ship was tilted to the starboard side and no flame was observed (electricity petty officer)
- Wearing winter workwear and 2 layers of coldproof wear, I was on sentry at the starboard side bridge wing, and the weather was so cold that I only watched the bow as I worked. The ship tilted to the starboard side with a 'gwang' sound, and I moved to where the life belts were on the port side through the bridge because water flooded in up to my thighs. This was followed by severe shaking at the bow bottom, but did not smell explosives (deck petty officer)
- While sleeping at the operation crew berthing, I heard a sound of mixed explosion and shock, and afterwards the ship tilted to the right, and I was sprung toward the portside section, where I was stuck. I did not witness any water pillar or flash of bright light, but did smell lots of fuel, and I assess it to have been due to a sea-mine or a torpedo or another type of external shock (radar petty officer)
- When listening to music at the deck administration room, a ‘gwang’ sound was followed by floating up in the air, and my body suddenly tilted to the left. I didn’t smell explosives, but definitely smelled fuel (deck petty officer)
- While on the engine messenger duty, I heard a ‘gwang’ sound when my body was lifted 50cm in the air, when the ship tilted and the power went out (steerer)
- While sleeping at the operation crew berthing, I floated in the air a little then fell, when I heard the bed breaking and water flowed in (radar petty officer)
- While sleeping at the operation crew berthing, a ‘gwang’ sound was followed by the ship tilting to one side, and I floated in the air from the 3rd floor bed then fell, and when I escaped to the deck to see the surroundings, the ship was invisible, having been cut in half including the stack (communications petty officer)
- While conducting duty as the steerer, I heard a loud sound at the stern’s portside, and then the bow was lifted up for the body to float upward, and the ship tilted toward the starboard side 90 degrees. I could not make out whether the loud sound was a shock sound or an explosion sound, but I heard the hull being ripped apart, and the smell of fuel came up from the stern (deck crew)
- While preparing to wash at the sailing crew berthing, a ‘gwang’ sound followed by a feeling of being hit by something, and a lot of weight was felt. At the same time the ship rocked side ways, tilting finally toward the starboard side. Right after the incident, I heard seawater flooding and smelled fuel (deck crew)

- While preparing to take a shower at the berthing, a 'kwang' sound, then I floated up in the air, falling toward the right. I couldn't see because the lights were out, and there were no flames or smoke, but I did smell fuel (galley crew)
- After hearing a clang of steel banging against each other, the ship tilted, and when I came outside the deck, I smelled a little bit of fuel. Coming outside, 1/3 of the deck bridge had been submerged (communications crew)
- While resting beside the stairs of the sailing crew berthing, I heard a 'koong' sound followed by lifting 30cm in the air then fell, when I escaped to the portside, and when I got there I smelled oil and the stern was invisible (deck crew)
- While on R/D duty at the combat information center, a 'kwang' explosion sound was followed by a 50cm jump in the air when the power went out, and when I opened my eyes 2~3 seconds later, the ship had tilted completely toward the starboard side, I did not smell any flame or explosives but did smell oil (radar crew)
- I heard a 'kwang' sound then the ship tilted when I heard another 'kwa~ang' sound as if the stern had been torn off, then the power went out and the ship tilted completely 90 degrees to the starboard side. I smelled a lot of fuel (firearms crew)
- While preparing to wash at the operations crew berthing, I heard an extremely loud explosion sound, and I could not smell explosives, but did smell fuel at the hull bottom parts. When I escaped the stern was invisible (steering crew)
- While stooling at the head, a 'koong' sound was followed by the ship tilting 90 degrees toward the starboard side, so I fell to the point beside the door of the deck administration room, and I did smell serious fuel (galley crew)
- While I was sleeping, I heard a 'gwang' sound when the ship started to sink, and when I escaped to the outer deck, the stern was invisible. I smelled none other but the fuel (electronics crew)
- While on duty at the portside bridge wing wearing winter workwear and coldproof clothing, a sudden 'gwang' sound was followed by 1m floating in the air then I fell onto the floor, but by that time I could not smell explosives neither could I see a water column or a fire (deck crew)
- While taking a shower at the head, I heard a big, short noise, then the noise of objects falling to the ground (medical crew)
- While taking the washed laundry to the drying machines, I heard some sort of a sound between a 'bang' and a 'koong', the sounds of steel bashing against each other, and also felt the ship floating in the air. I smelled burning fuel from the stack, but other than that I didn't notice any flash, flame, or smoke (ventilation crew)
- While washing at the head, I heard a 'gwang', but I could not tell whether the sound was coming from the inside or the outside (firearms crew)

2) Cause of Explosion

Considering the fact that the area that they were patrolling was close to the NLL, and because the ship broke apart so suddenly in a midst of normal operations, several survivors(11) thought that the ship had been sunk by a torpedo.

Major points of testimonies

- After the accident occurred, as I came out to the portside deck, the stern was severed and could not be seen, and based on the loudness of the explosion, and the wireless communication report that ROKS Sokcho was opening fire, I assessed that this must have been an enemy torpedo attack(Commanding Officer)
- There was no smell of explosives, and considering the ship's separation in half, I would expect this incident was caused by either torpedo or mine explosion.(Executive Officer)
- Based on the nature of the patrolling area and hull structure I predicted that this was an attack from the North(combat information officer)
- My job is radar detection, so I'm sensitive to external shock sounds, and I thought initially that we were hit by a merchant ship, but looking at the area after escaping to the bow, I thought then that we were hit by a torpedo(radar chief)
- After rescuing the crew, having come to the outer deck, I saw that the stern was missing from the stack location, so I thought that a war had broken out, and also thought that something that could cause this kind of shock was a torpedo(radar officer)
- We were on the same route we'd always gone, and there was nothing special for hours, but we were suddenly sunk, so I think that a torpedo is more likely than a sea mine(steerer)
- I think it's a torpedo or a sea mine; if an explosion occurred within the ship, I would have been flown toward the bow or stern but I clearly flew toward the starboard side(ammo officer)
- I felt that we were hit by something and it was an external shock, so I think it's either a sea mine or a torpedo, but not rocks(radar officer)
- I think it's a North Korean torpedo attack or a sea mine explosion, a torpedo attack to the portside caused the ship to tilt to the starboard side and the explosion sank it(deck crew)
- The explosion was so loud that I can still recall it and I also fell and got hit by things and all the while I thought we were hit by a torpedo(steerer)
- The cause of the incident is, I think, a light torpedo from a North Korean sub hitting the portside stern, causing the ship to crack in half and the heavy stern to sink(deck crew)

3) Communication Details

The JIG confirmed that some survivors during the early stages of incident used imprecise diction such as ‘aground’ and ‘shipwreck’ when reporting because they had no mind to judge the situation accurately, the JIG also confirmed the communication records between commanding officer and the Squadron Commander determining the cause of this incident to be a torpedo, and between the communications officer and the radar base including the assessment that this incident is from a torpedo attack.

Main contents

- Chief gunner ↔ Chief of the situation room, 2nd FLT: 2128, Mar 26
  - Chief gunner: This is Cheonan. We’ve sunk. We run aground
  - Chief of the situation room: You’ve ran aground?
  - Chief gunner: The ship tilted to the starboard side and we need rescue.
  - ※ Chief gunner later stated that the urgency of the situation led him to use the word “ran aground” to receive expeditious rescue.
- Combat Information Officer ↔ Duty Officer, 2nd FLT: 2130, Mar 26
  - Combat Information Officer: ROKS Cheonan is in distress near Baekryong Island. Please instruct emergency departure of Daechung 235 sub-squadron.
  - Duty Officer: What is your status? (The communication ended due to poor signal)
  - ※ Duty Officer misunderstood the word distress with grounding, then reported and promulgated accordingly.
- CPO ↔ Radar base (wireless): 2151~2152, Mar 26
  - Radar base: Report cause of sinking
  - CPO : We think it’s a torpedo, torpedo, torpedo, we think it’s a torpedo, over
  - Radar base: Are you sure that it’s a torpedo?
  - CPO: We think we’ve been hit by a torpedo
  - Radar base: We are sending RIBs to rescue crew
  - CPO: End of contact, over
- Commanding Officer (CDR) ↔ Squadron Commander: 2232~2242, Mar 26
  - Commanding Officer: I think we’ve been hit by something.
  - Squadron Commander: What do you think it is?
  - Commanding Officer: I think it’s a torpedo, and I can’t see the stern at all.
  - Squadron Commander: The stern? Where from the stern?
  - Commanding Officer: I can’t see the stack, please send us some motorboat or RIBs right away.
  - Squadron Commander: Any survivor?
  - Commanding Officer: There are 58 survivors, many of them are bleeding, and 2 are severely injured and can’t stand up.

4) Sentries

Two sentries(from the Marine 6th Brigade), who were on guard 2.5km away from the location of the incident, testified that they heard a ‘gwang’ sound around 2123[6] hours and saw a white flash of light(20~30m wide, 100m high).[7]

Main points of testimonies

- While on guard, a ‘gwang’ sound(much louder than the sound of gunfire, loud enough to astonish) was heard and a bright flash of light from 4~5km away spread through the region then disappeared (PO3)
- While on guard, I heard a ‘koong’ sound, then when I looked 4km out towards the sea at a 270° direction a bright flash of light(20~30m wide, 100m high) was seen for 2~3 seconds (PO3)

5) Sub-conclusion

Results of the survivors’ and sentries’ testimony analysis revealed the following: many crew members had floated into the air before falling; two crew members heard the explosion sound twice; no one saw flames, fire or water columns, and no one suffered burn wounds; some personnel suffered from fractures and bruises; many of the survivors be-

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[6] The sentry said that he checked his watch right after hearing the shock. He witnessed the light flash when it was 2123 hours, but did not verify it up to seconds. After checking with the company records, it says a ‘thunder’ was heard on 26 Mar. at 2123 hrs at the guard post.

[7] Weather condition during the incident occurred: 40% sea fog, 78% moonlight, visible range within 500m.