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An Immersive Digital Commemoration of the Japanese Submarine I-124 Sunk in 1942 outside Darwin Harbor, Australia

John McCarthy · David Steinberg · Hiroshi Ishii

Abstract The Japanese submarine I-124 was sunk in a military engagement with Allied forces outside Darwin Harbor, Australia, with 80 submariners aboard on 20 January 1942. To mark the 80th anniversary of this historic event and complement more traditional commemorative activities, a virtual-reality experience was created for general public engagement. The experience was based on a high-resolution multi-beam sonar survey completed in October 2021 by the Australian Institute of Marine Science, and used an animation-based workflow to illustrate the survey of the submarine, the events of its sinking and the historical data used to digitally reconstruct it. The animation culminates in a virtual dive across its decks as they may have appeared in the years after the sinking. Future plans for the site include diver-based surveys for photogrammetric survey and management-based monitoring. The creation of the experience required an in-depth consideration of a wide range of stakeholder needs and Australian and Japanese cultural attitudes to commemoration of World War II casualties. We describe the technical and cultural challenges encountered throughout the project.

Resumen El submarino japonés I-124 se hundió en un enfrentamiento militar con las fuerzas aliadas en las afueras del puerto de Darwin, Australia, con 80 submarinistas a bordo el 20 de enero de 1942. Para conmemorar el 80 aniversario de este evento histórico y complementar las actividades conmemorativas más tradicionales, una experiencia de realidad virtual fue creada para la participación del público en general. La experiencia se basó en un estudio de sonar multihaz de alta resolución completado en octubre de 2021 por el Instituto Australiano de Ciencias Marinas, y utilizó un flujo de trabajo basado en animaciones para ilustrar el estudio del submarino, los eventos de su hundimiento y los datos históricos utilizados para reconstruirlo digitalmente. La animación culmina con una inmersión virtual en sus cubiertas tal como pudieron haber aparecido en los años posteriores al hundimiento. Los planes futuros para el sitio incluyen encuestas basadas en buzos para encuestas fotogramétricas y monitoreo basado en la gestión. La creación de la experiencia requirió una consideración profunda de una amplia gama de necesidades de las partes interesadas y las actitudes culturales de Australia y Japón con respecto a la conmemoración de las víctimas de la Segunda Guerra Mundial. Describimos los desafíos técnicos y culturales encontrados a lo largo del proyecto.

Résumé Le sous-marin japonais I-124 a sombré au cours d'un affrontement militaire avec les Forces alliées hors de la Baie de Darwin en Australie. En ce 20 janvier 1942, il y avait à bord 80 sous-mariniers. Pour marquer le 80ème anniversaire de cet événement

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historique et compléter des activités plus traditionnelles de commémoration, une expérience de réalité virtuelle a été créée pour sensibiliser le grand public. L'expérience s'est appuyée sur une étude par sonar multifaisceaux à haute-résolution effectuée en octobre 2021 par l'Institut australien de science marine (Australian Institute of Marine Science). Elle a utilisé un flux de production à base d'animation pour illustrer l'étude du sous-marin, les événements autour de son naufrage et les données historiques utilisées pour sa reconstruction numérique. L'animation s'achève par une plongée virtuelle à travers ses passerelles ainsi qu'elles ont pu apparaître au cours des années après le naufrage. Les plans futurs pour le site incluent des études recourant à des plongeurs pour une exploration photogrammétrique et une surveillance basée sur la gestion. La création de l'expérience a exigé une prise en compte approfondie d'une grande diversité des besoins des parties prenantes ainsi que des attitudes culturelles australiennes et japonaises à l'égard de la commémoration des pertes humaines de la Seconde Guerre mondiale. Nous décrivons les difficultés techniques et culturelles rencontrées tout au long du projet.

Introduction

The sinking of the Japanese submarine I-124, on 30 April 1942, was a significant tactical achievement in the defense of northern Australia and its shipping during World War II (WWII), and one that left a long-term legacy in one of the most significant wartime wrecks in Australian waters. Today the wreck has importance in many different respects. The site has significant historical symbolism, as one of only a handful of enemy vessels sunk in Australian waters, not just in WWII, but all military conflicts. The wreck has legal significance as part of the development of heritage legislation in Australia, being the first wreck protected under Australia's first federal maritime heritage legislation, the Historic Shipwrecks Act 1974. In terms of archaeological research potential, the submarine remains almost entirely intact and virtually undisturbed, preserving evidence on the exact circumstances of its loss, its original design, and subsequent modification, as well retaining significant

potential to inform anthropological questions such as life and social organization aboard the submarine. There is also an unavoidable management challenge for monitoring the risk posed by the unexploded ordnance, including depth charges, torpedoes, and a deck gun. However, from the perspective of the families of the lost crew, the most important aspect of the I-124 is its role as a maritime grave site and memorial. These management concerns are comparable to the challenges faced in managing Australia's only other Japanese submarine wreck, M24, a midget submarine located in waters off Sydney, and submarine wrecks outside Australia (Casserley et al. 2008; Smith 2008). Wreck sites commonly represent a loss of life, and maritime archaeologists must develop and apply respectful working practices, especially where such sites contain human remains and are relatively recent in date. For the relatives of the 80 submariners who lost their lives aboard I-124, the site is the grave of loved ones. For the state and Japanese society more generally, it marks a national tragedy in which young men fighting for the nation were lost. As such, the site is significant in multiple ways, and to multiple groups of people, and so must be managed sensitively. For I-124, some of the most important stakeholders are the families of the submariners, the Australian public, the Australian Japanese Association of the Northern Territory, and the Embassy of Japan in Australia.

Access to the site is restricted due to preservation goals, cultural sensitives, and risks associated with depth and other environmental conditions, including risk from unexploded ordnance. While this remains an accepted access policy for the time being, it limits commemorative activity, such as the practice of laying wreaths or ensigns by divers as sometimes practiced at other wreck sites, such as the HMS *Royal Oak* in Scotland (Travers 2015) and the Italian submarine *Scirè* in Israel (Galili et al. 2013). Such acts can be culturally moderated to a significant degree. During archaeological work in Saipan, McKinnon noted that while U.S. recreational divers tended to take mementos from wreck sites, Japanese divers tended to collect material into makeshift commemorative piles (McKinnon 2014:182). Despite the excellent preservation of the submarine, all commemoration activity for I-124 has necessarily been displaced to other locations. A memorial place for the crew exists on a lookout point along a popular coastal reserve in suburban Darwin. A memorial stone with a plaque was

installed here in 2017, on the 75th anniversary of the sinking, in an event attended by the Japanese ambassador and the chief minister of the Northern Territory. The Japanese prime minister Shinzo Abe and the Australian prime minister Scott Morrison undertook a formal visit to this place in 2018. In 2022 the commemorative event included installation of a second plaque naming the crew. Bow and stern markers were also installed in the park, with paths outlining the shape of the submarine, so that the memorial plaques and visitor seating were in the center of the wreck, approximately where the conning tower would be (Fig. 1). This vividly illustrates the natural desire to connect the memorial activities with the embodied wreck site, even if this is possible only by proxy. The effort to create a tactile experience resonates with the virtual-reality (VR) experience. Similarly, a closer connection is made with acts of remembrance by visiting Japanese naval ships, carried out on occasion from over the site (Lewis 2010:149). In late 2021 and early 2022, even the proxy memorial site became inaccessible to many stakeholders due to international and interstate travel restrictions during the COVID pandemic, with many missing the 2022 services.

Maritime heritage managers bear a responsibility to support engagement with the sites under their care, including access where possible. However, this must be balanced against a wide array of often competing priorities, such as avoidance of unnecessary disturbance of the final resting places of those lost at sea, archaeological investigation and characterization to support future management, and education of the public about maritime heritage. For I-124, balancing these priorities became more pressing in the lead up to the 80th anniversary of the sinking of the submarine, in January 2022, to be marked by a commemoration at the Casuarina Coastal Reserve in suburban Darwin, followed by a second commemorative event at the same location in February 2022 coinciding with the anniversary of Japan's first air attack on Darwin. The Northern Territory Government's Heritage Branch was at the center of discussions about how to acknowledge the anniversary, as both the organizer of the commemorative event and the agency responsible for site management. The challenge faced by the Heritage Branch was how best to commemorate a maritime loss of a site under its care, based on available data, in a way that serves the full range of stakeholders, including the Australian and Japanese communities, is appropriate in tone, and is in a format accessible enough to reach a large audience. The Heritage Branch considered a wide range of options, including commissioning photogrammetric survey, to produce the first comprehensive baseline survey of the site.

Fig. 1 Japanese media capturing footage of users trying the "Experience" in Darwin. (Image courtesy of the Heritage Branch, Northern Territory Government, Darwin, Australia, 2022.)

This proved impossible due to COVID travel restrictions, as they ruled out interstate travel by specialist divers. The postponement of the dive also meant the plan to collect sand near the wreck (a strategy previously adopted in the commemoration of the M24 submarine) to then add to the mortar of the new plaque, could not go ahead (Smith 2008). Ultimately, it was decided to commission a VR experience (hereafter referred to as the "Experience").

Similar restrictions on access apply to many significant maritime archaeological sites, and VR has been shown to allow the public to experience shipwrecks in an immersive way (J. McCarthy et al. 2019). Previous research has highlighted how "using 3-D visualizations to juxtapose wrecks with the ships they once were ... is therefore a means of making shipwrecks less remote conceptually as well as physically" (Firth et al. 2019:193). In the case of I-124, this concept gains an extra dimension in supporting commemoration activities, allowing a sort of virtual pilgrimage to commemorate the victims of the submarine wreck. The development process also supported research and management objectives, being based on an academically rigorous spatial analysis and synthesis of data sources underpinning a digital reconstruction. The Experience was developed over several weeks in late 2021, working to tight deadlines for publication ahead of the anniversary.

Background

Submarine warfare was a relatively recent addition to Japanese military strategy when the I-124 submarine was built. From the middle of the 19th century, after two centuries of isolationist foreign policy, Japan opened its doors to the wider world, adopting new technology and rapidly industrializing. As an island nation, Imperial Japan focused on developing a strong navy. In the early 20th century, submarines were a particular focus of innovation (Delgado 2011:108). Submarines had slowly become a viable technology from 1862 onward, when a submarine had been successfully deployed in the American Civil War. Despite the loss of the entire crew, the submarine *H. L. Hunley*'s military achievement caught the attention of the great powers of the world and inspired imitators. From 1893 to 1895, Irish inventor John P. Holland won the international competition of

submarine design, and his design was first adopted by the U.S. Navy. In this period Japan began to greatly strengthen its naval power, driven by the First Sino-Japanese war (1894–1895) and the Russo-Japanese War (1904–1905). In 1904, five Holland boats were purchased by the Imperial Japanese Navy (IJN), which later contracted two further vessels based on Holland's design, the first Japanese-commissioned submarines (Delgado et al. 2016:8). Innovation began immediately, and Holland himself was impressed with the Japanese improvements to his design (Delgado et al. 2016:12). At the end of WWI the German minelaying submarine U-125 was surrendered to Japan (M. McCarthy 1991:15), and, with some modifications, this became the template for the Japanese minelaying submarine type (Kirai-sen-gata 機雷潜型). Only four IJN submarines were built as this type and were obsolete when the war started (Katsume 2010:121). I-124 was laid down on 17 April 1926 and launched on 12 December 1927, and was used in numerous naval operations, including the sinking of the British cargo ship *Hareldawns* on 10 December 1941. The invasion of Manchuria (1931–1932) isolated Japan politically from Western nations, reinforcing self-reliance and, with it, a continuing strategic emphasis on naval power.

The events leading to the Imperial Japanese threat to Australia had unfolded rapidly, and I-124 was to play a significant role in this. On 8 December 1941, the Imperial Japanese Army landed in British Malaya while the IJN attacked Pearl Harbor in Hawaii.

Japanese occupation advanced rapidly, and attacks now extended as far as Australia, whose ports were a key link in the supply chain for Allied forces. On the morning of 20 January 1942, in the Beagle Gulf outside Port Darwin, oil tanker USS *Trinity* was attacked with three torpedoes fired from the Imperial Japanese Navy submarine I-123 (伊号第百二十三潜水艦 Igoh-dai-hyaku-nijuu-san-sensuikan). This alerted the naval command to the presence of Japanese submarines in the area. However, the ships sent to sweep the area did not locate I-123, but, rather, its sister submarine I-124 (伊号第百二十四潜水艦 Igoh-dai-hyaku-nijuu-yon-sensuikan) led by Lieutenant Commander Kishigami (Lewis 2010:47–55). More Allied planes and ships arrived on the scene, including HMAS *Deloraine*, which is thought to have struck the fatal blow with a depth charge (Lewis 2010:59). This caused the I-124 submarine to surface briefly, before submerging again

for the final time. The next day naval divers located the wreck, which had one blown hatch (M. McCarthy 1991:18) (Fig. 2).

This was the last direct engagement between a full-size Japanese submarine and Allied forces in Australia. In May 1942, five months after the sinking of I-124, the Japanese navy changed their strategy to rely on "midget" submarines (甲標的Kou-hyouteki). An attack was made on Sydney Harbor, with three full-size submarines, each deploying a midget submarine and reconnaissance aircraft. These met with limited success (Jenkins 1992; Grose 2007; Smith 2007), but no further attacks on Australian soil occurred before the end of the war. The only recorded remains of enemy incursions are the fragmentary remains of aircraft in the Northern Territory, the midget submarines in Sydney Harbor, and the largely intact I-124.

From Salvage to Survey

Between 1942 and 2019, 11 descriptions of the wreck of the I-124 submarine were produced (Carter and Hegarty 2020:vi). These ranged from early military and salvage-focused investigations to more detailed archaeological assessments (M. McCarthy 1990, 1991), but none was comprehensive, due to the challenges of depth, dive time, current, and visibility. Since I-124 was the first Japanese submarine that the Allied forces could access, with the exception of HA-19 midget submarines at Pearl Harbor, diver recovery of codebooks was attempted from HMAS *Kookaburra* and USS *Holland* in the days after the sinking (M. McCarthy 1991:25–26; Lewis 2010:67). Divers reached the submarine and made brief descriptions, describing it as mostly intact, but with one blown hatch. Despite some claims that IJN codebooks were retrieved from I-124, there is no evidence of code breaking material being found, or the wreck having been penetrated, which would have been extremely challenging in hard hat and tethered diving gear due to the narrowness of the hatches (M. McCarthy 1991:27; Lewis 2010:87–92).

The submarine remained undisturbed until it was rediscovered in November 1972 by a group of salvors, who located it with sonar equipment and who intended to remove part or all of it for scrap. In February 1973 the Japanese government became aware of this endeavor, and it became a diplomatic issue, with their representative in Australia confirming that the wreck belonged to the Japanese government (M. McCarthy 1991:30–33). This claim was strongly opposed by the salvors, one of whom, Harry Baxter, threatened to blow the wreck apart. The ongoing threat to the site and the risk of damaging international relations was a pressing issue in 1976 when the 1976 Commonwealth Historic Shipwrecks Act was enacted

Fig. 2 Location map of the I-124 submarine wreck, outside Darwin Harbor. (Image by John McCarthy, 2022; contains bathymetric data from Geoscience Australia CC_3.0.)
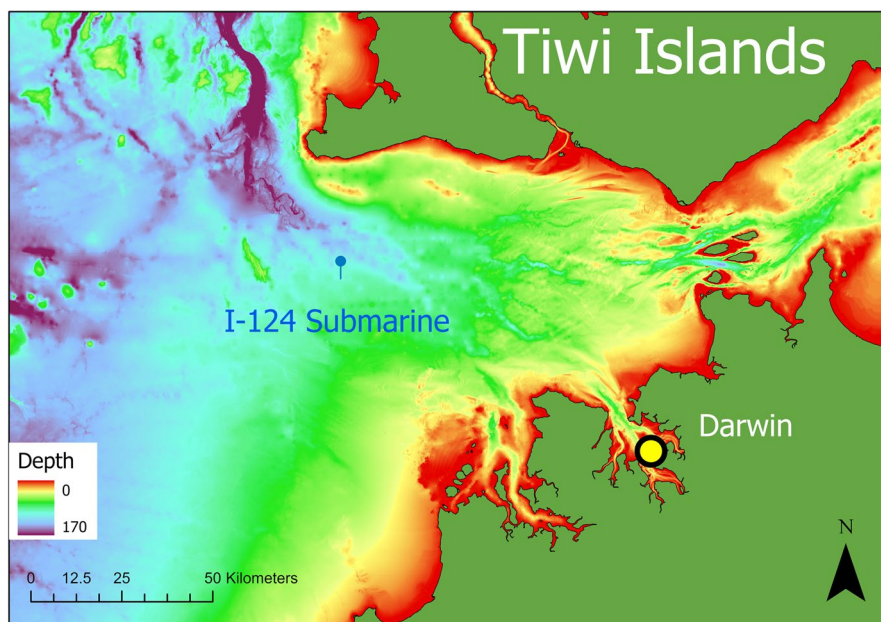
(Lewis 2010:140). The wreck of I-124 was designated under that act, including a 500 m radius around the site (M. McCarthy 1991:33). Further attempts to dive the site were mostly prevented because of this new status, but Harry Baxter followed through on his threat by dropping explosives onto the site and causing damage to the conning tower (M. McCarthy 1991:33; Lewis 2010:143–145). In 2018 the Underwater Cultural Heritage Act (UCHA) replaced the 1976 Commonwealth Historic Shipwrecks Act. The site has remained relatively undisturbed in recent years, but debate continued about its condition, management, and fate. In 1984 naval divers from HMAS *Curlew* visited the site and recorded "mine carrying rails" on the afterdeck and other features, but, as with all previous surveys, provided only incomplete and anecdotal descriptions of deck features that often conflicted with previous accounts. (M. McCarthy 1991:31–34; Lewis 2010:146–148). This left confusion about the true layout of the submarine.

The divers on the 1994 survey, although visiting the site for practical reasons, nevertheless stated that "the general feeling of the team during the dives was one of respect for the men of l-124" (Lewis 2010). The opportunity to visit the site has been extremely limited, with only a handful of divers visiting the site since its loss. The inability of the wider public to visit such an important site and share in this feeling of respect has led some to debate the possibility of raising the submarine for museum display (M. McCarthy 1991:51–52). In the 1980s, a small but determined Japanese campaign developed to lobby for the recovery of the crew's remains and their return to Japan. This campaign initially had the support of the families of the submariners and may reflect, in part, Shinto beliefs in return of bones to the land of one's birth (McKinnon 2014). Eventually it seems that consensus was reached by both Japanese and Australian stakeholders that the submarine should remain undisturbed as a monument to the crew and the historical events that led to the loss of the submarine (Lewis 2010:160–161). In March of 1989 the first inspection of the site by professional archaeologists was undertaken by teams from the Western Australian Museum and Northern Territory Museum operating from RV *Flamingo Bay*, deploying a side-scan sonar and a remote-operated vehicle (ROV) (M. McCarthy 1991:8; Lewis 2010:149–153). Despite limited visibility, the ROV-captured footage that showed the condition of the site including the damage to the conning tower thought to be caused by Harry Baxter (M. McCarthy 1991:37). There have been no recorded surveys of the site since then, except for occasional multi-beam or side-scan sonar surveys (2009, 2016, 2017, and 2019), which have gradually improved in quality (Carter and Hegarty 2020:23–30), culminating in the most recent and highest resolution survey in November 2022 (Fig. 3). This multi-beam sonar survey of the wreck was carried out by the Australian Institute of Marine Science on the research vessel *Solander*, and provided one of the primary datasets for the Experience.

Methodology

Objectives

Once the decision was made to proceed with a VR approach, the project team agreed on a series of objectives. The foremost objective for developing a VR experience was to provide an immersive experience of visiting the wreck site to support commemorative activities and respond to restrictions on site access. It was determined to build the Experience around a view of the wreck as it might appear to a diver swimming over it. The scenes, particularly the virtual dive experience, functioned as an immersive sensory experience. In a government press release, it was advertised to the Northern Territory community as "[a]n innovative and inclusive way to allow everybody to experience the thrill of wreck diving and learn about our maritime past." The Experience would be also connected to existing commemoration events by a virtual visit to the memorial monument outside Darwin. The loss of I-124 was tragic for the families of the submariners, and the site is the grave of 80 submariners. Particular care had to be taken in the design of the Experience with all educational, technical, and practical considerations being secondary to the goal of respectful commemoration. This strongly influenced the narration, the choice of which scenes to depict, the choice of music, the sequence of presentation, and the use of source material. Acknowledging that VR can be a powerful immersive tool, there is a heightened risk that an insensitively designed experience might distress a user who

Fig. 3 The most detailed multi-beam survey of the I-124 submarine to date, carried out by the Australian Institute of Marine Science in November of 2021.
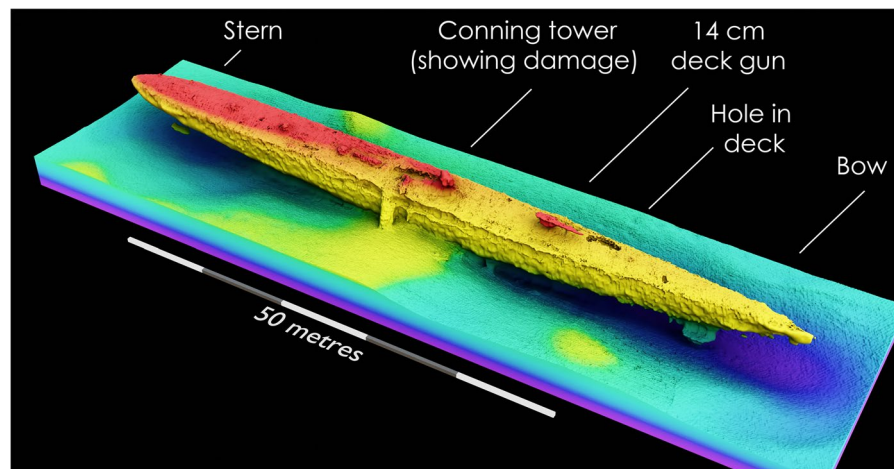
finds themselves virtually transported to the grave site of a relative, or back in time into what was a violent military conflict. There is also a risk of cultural misunderstandings, not least due to the significantly different perspectives on WWII held by Australia and Japan. The inclusion of a Japanese maritime archaeologist in the project team provided a more balanced perspective, in particular the script for the English and Japanese versions of the narration and press releases associated with the Experience's launch. Voiceovers of both English and Japanese versions maximized accessibility, with bilingual subtitles added to each version. A background musical track was added to the Experience, but the choice of music was debated at length. Eventually it was decided to use the Gunkan-kōshinkyoku (軍艦行進曲). This was written in 1904 and served as the Imperial Japanese Navy's official march, and would have been played at the launch of I-124 in 1923. However, as a military march its tone was unsuitable for some sequences, and it was reserved for the introduction and credit sequences.

The opportunity for education and engagement of a wider audience with maritime heritage was also considered as an important secondary objective, making use of the wide appeal of VR as a technology and remaining long after the commemoration events. This consideration influenced the development of the script so that the Experience included not just a view of the digitally reconstructed wreck on the seabed, but also in action, showing the events around its loss. This provided historical context for the wider public and also demonstrated maritime archaeology techniques of historical analysis and sonar survey in an accessible way.

The Experience also highlights the legally protected status of the wreck, considering the possibility that a virtual dive might inspire interest in real diving.

Another objective of the project was the furthering of archaeological research into the site, providing an updated analysis of field data and comparison with other sources. The digital reconstruction of I-124 that underpins the Experience was not simply artistic, but consolidated all available baseline data for the submarine in an academically rigorous manner. This created a valuable asset to support future survey and monitoring at the site. For example, in future dive surveys, efficient diver movement around the site will maximize the limited time possible to spend at such depth for the capture of photographic data for photogrammetry. The 3-D reconstruction allows planning of diver swim lines in three dimensions, locating deck features on each line to give the divers navigational cues, vitally important when underwater visibility is limited to a few meters, as it often is in this area. The digital modelling process also highlighted areas of uncertainty of the submarine's design, while analysis of the 2021 multi-beam data highlighted areas of probable corrosion or collapse of the outer hull. By identifying these areas, a checklist of accurate locations for targeted survey can be provided to divers.

VR Design and Implementation

VR experiences may be designed as an interactive exploratory experience, where a user might freely explore or interact with their environment, but this approach increases the cost and complexity

of hardware and greatly restricts the audience. Such interactive experience can also take much longer to complete and can encourage a focus on the technology rather than the content, in this case a heritage-centered experience. Early in the project a decision was taken to rely instead on a VR experience built on passive viewing of a pre-rendered panoramic animation, where a user is taken through a series of scenes without interactivity. These two types of VR experience are similar in many respects, but the passive approach requires less-expensive equipment and can even be experienced through a screen on a tablet or phone, meaning that it is likely to be experienced by many more people. This mode, sometimes referred to as 2.5-D, was previously applied with positive results by the lead author on an Icelandic shipwreck (J. McCarthy and Martin 2019). It also allows more directorial control, so that a distinct message or series of messages could be communicated in a way that might be more fragmented or even missed in an interactive VR experience. The method applied for this project builds on that used in the Icelandic virtual dive, but with significantly increased quality and application of numerous lessons learned.

All animation work was carried out in Blender, an open-source free 3-D digital modelling software. Video resolution is a special challenge in 2.5-D VR experiences, as the entire field of view must be rendered even though the viewer will only see a small part of it at any one time, making video file sizes very large and render times very long, so much so that the Icelandic animation took 40 days to render its 5,400 frames of $2,160 \times 2,160$ (J. McCarthy and Martin 2019:106). The I-124 Experience was rendered in a much higher resolution of $8,192 \times 8,192$ and was also designed with a 180° view rather than the 360° view previously used. This prevented viewers from looking behind them, but doubled the resolution of the animation. This also makes it easier to direct the viewer's likely focus of attention throughout the animation and avoids having to generate content in all directions. The render engine was also changed. Using the previous render engine, which relies on raytracing to calculate the scene's lighting, computer rendering times for animation frames of such a high resolution would have increased to at least an hour for each frame, requiring almost a year to render a full draft of its 8,340 frames (30 frames/sec. over 278 sec.). Fortunately, this issue was overcome by

taking advantage of new software updates, switching to the newly released Evee OpenGL render engine. Although this provides slightly less visually realistic results, this can be overcome through modifications of a wide range of settings, such as volumetric fog and post-processing of VR-optimized glow effects in Adobe Premiere. Even for frames of 8,192 resolution, use of the Evee render engine meant that individual 180° frames could be rendered in less than a minute, making it possible to draft and modify animated sequences frequently throughout the animation design process, allowing for much closer collaboration between heritage specialists and stakeholders.

Other important technical innovations included the use of the EeVR plugin, which overcomes the inability of the Evee render engine to generate panoramic views, and the application of Ambisonic sound effects in Adobe Premier, which created spatially responsive surround-sound effects that respond to the changing orientation of the viewer's head. Modeling of 3-D assets such as the I-124 reconstruction was undertaken almost entirely within Blender, with some texturing undertaken in Adobe Substance Painter, including rust effects on the submarine hull. VR video editing was completed in Adobe Premier. Significant effort was also directed toward final preparations of the completed VR animation for upload to different platforms, including directly to an Oculus VR headset (Quest 2), to YouTube, and to the Oculus/Facebook platform. By optimizing the video and associated files, such as online descriptions, thumbnails, previews, etc., the discoverability and ease of use of the VR animation was maximized.

Building the Reconstruction

Creation of an accurate digital reconstruction of I-124 was the first step. The project began with a thorough review of published material and with gathering of archival material, much of which was provided by Tom Lewis, an historian who had previously published histories of the I-124 (Lewis 1997, 2010). Background data on the design of I-124 and, by extension, the other four submarines of the I-121-class, are somewhat limited. Contemporary plans exist and include internal and external detail and six cross sections along the submarine hull. These also exist in a simplified form, prepared for publication in Tom Lewis's books and provided by the author. There

are also a handful of contemporary photographs of some of the four I-121 series submarines, including at least one image of I-124 itself (Fig. 4).

All source data, including the high-resolution multi-beam data, was brought into a 3-D spatial environment and scaled to the same size. This process proved very useful for interpreting the data (as in the case of the *Batavia* study (J. McCarthy and van Duivenvoorde, this issue), but development of the digital reconstruction highlighted several significant knowledge gaps. Despite the availability of interior and exterior plans and elevations with cross sections, such plans capture rectangular features in full detail, but do not fully represent more complex 3-D forms, such as the shape of the hull at the bow and stern, and the precise shape of many deck features, such as the conning tower and deck hatches, remains partially ambiguous, even after detailed analysis of these sources (Fig. 5).

The multi-beam survey data provides a more complete view of the morphology of the upper hull, but the sensors, being almost directly over the wreck, did not capture detail on the lower parts of the hull. Between all datasets, there is therefore almost no information on the lower hull shape or the design of the torpedo tubes, stern mine tubes, and propellers. The handful of contemporary photographs of I-121 series submarines are of limited quality and show only the upper parts. Although some deck features can be seen reasonably clearly, the dark shape of the hull and the high contrast and low resolution of many images means that smaller details and shapes are indistinct. There are no surviving examples of the I-121 class submarines, and, as a short-lived series of post-WWI minelaying submarines, they are overshadowed in secondary literature by more famous Japanese attack submarines, particularly those

Fig. 4 Example source data for the I-124 submarine reconstruction: (*A*) original plans of the interior, (*B*) simplified plans of the exterior derived from the same archival source, and (*C*) a photographic view of I-124. (Images courtesy of Tom Lewis.)
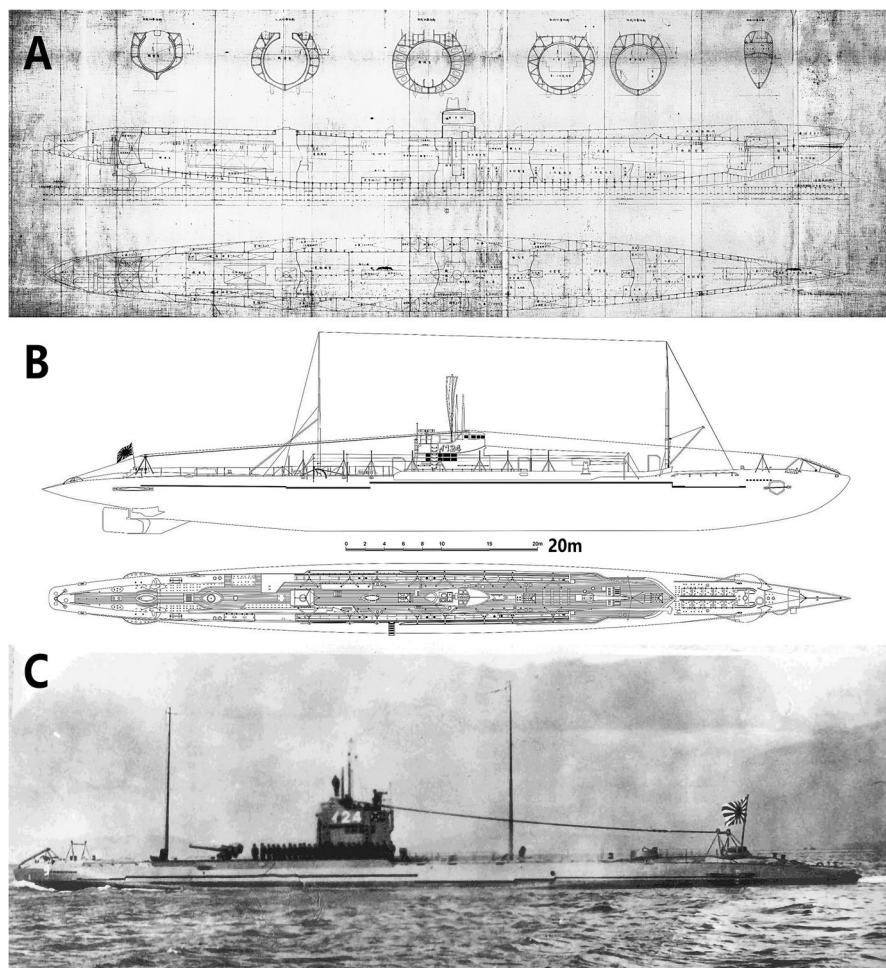
Fig. 5 Comparison of the digitized spatial data available for the digital reconstruction of the I-124 submarine, including, from the *top left*, the external plans, internal plans, simplified external plans, the reconstruction itself, shiplines from a German World War I submarine (as both outlines and paper cutouts, and, at the *bottom*, the multi-beam survey data. (Figure by John McCarthy, 2022.)
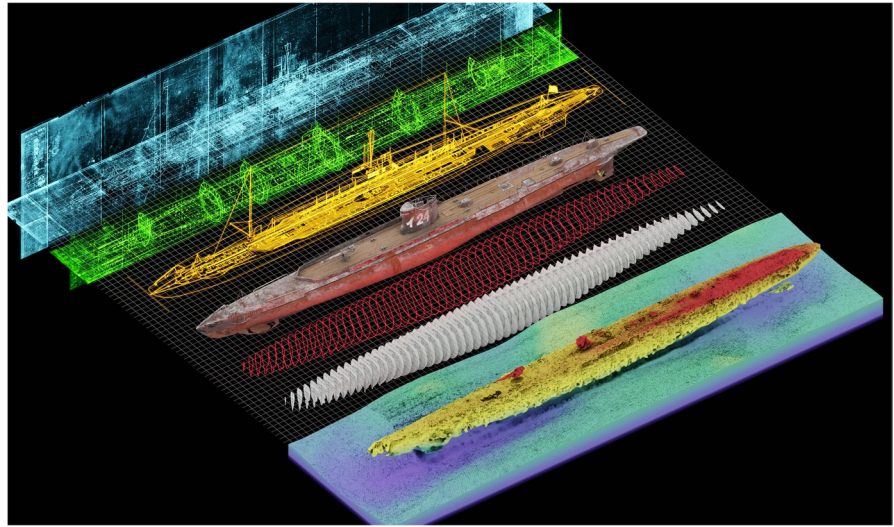
developed during WWII, when Japan produced some of the most advanced submarines in the world, such as the I-400 submarine aircraft carriers. However, the I-121 submarines were closely modeled on German WWI-era UEII class minelaying submarines, one of which, SM U-125, was surrendered to Japan in 1918. These are better represented in the literature and provide a reasonable basis to fill in some of the missing detail, although it has been noted that there were some poorly understood innovations in the Japanese design.

Post-launch modifications of the submarine are also known to have taken place. These include the name change from I-24 to I-124 in 1938, when the lower number was reassigned to another submarine, and a series of modifications in 1940, when the submarine was altered to carry refueling tanks for seaplanes on its deck (Lewis 2010:24–26). Almost no detail was found in the literature review on these later modifications, nor did the multi-beam data provide much insight on these relatively small deck features (Fig. 6). Further post-construction modifications have resulted from corrosion and damage by salvors. While the multi-beam data does capture some of the damage to the conning tower, showing the fairing lying to starboard, and some possible holes in the outer hull caused by depth charges, salvors, or corrosion, these details are not well understood and have not been represented in the reconstruction due to the amount of speculation that would have been

required to represent them. In light of future plans for detailed dive survey and photogrammetric recording that should resolve them, it was decided to base the digital reconstruction on the submarine as it was launched, signaling this through use of the name I-24, rather than I-124. This approach will provide a useful baseline against which to compare future surveys to highlight post-launch modifications and also damage and corrosion.

The VR dive experience developed through numerous drafts, with modification of sequences, audio tracks, and with additional sequences added to address particular objectives. Two key platforms were targeted for dissemination. The first was the Oculus Quest 2, the market-leading headset at the time of the project and one of the first consumer-grade headsets capable of storing and playing high-resolution VR animations without tethering to a computer. Although few people yet own or have access to this or indeed any other headset, this is slowly changing, and this model was considered to offer the best resolution for in-person demonstrations. The second dissemination platform was YouTube, where a much larger segment of the population could access the video, using any VR headset, including low-cost cardboard headsets paired with a smartphone, or even a tablet, smartphone, or computer screen, to "look around" the video without being fully immersed. Users are advised at the outset of the Experience on available options and

Fig. 6 Comparison of the multi-beam survey data with the digital reconstruction of the original appearance of I-124. (Figure by John McCarthy, 2022.)
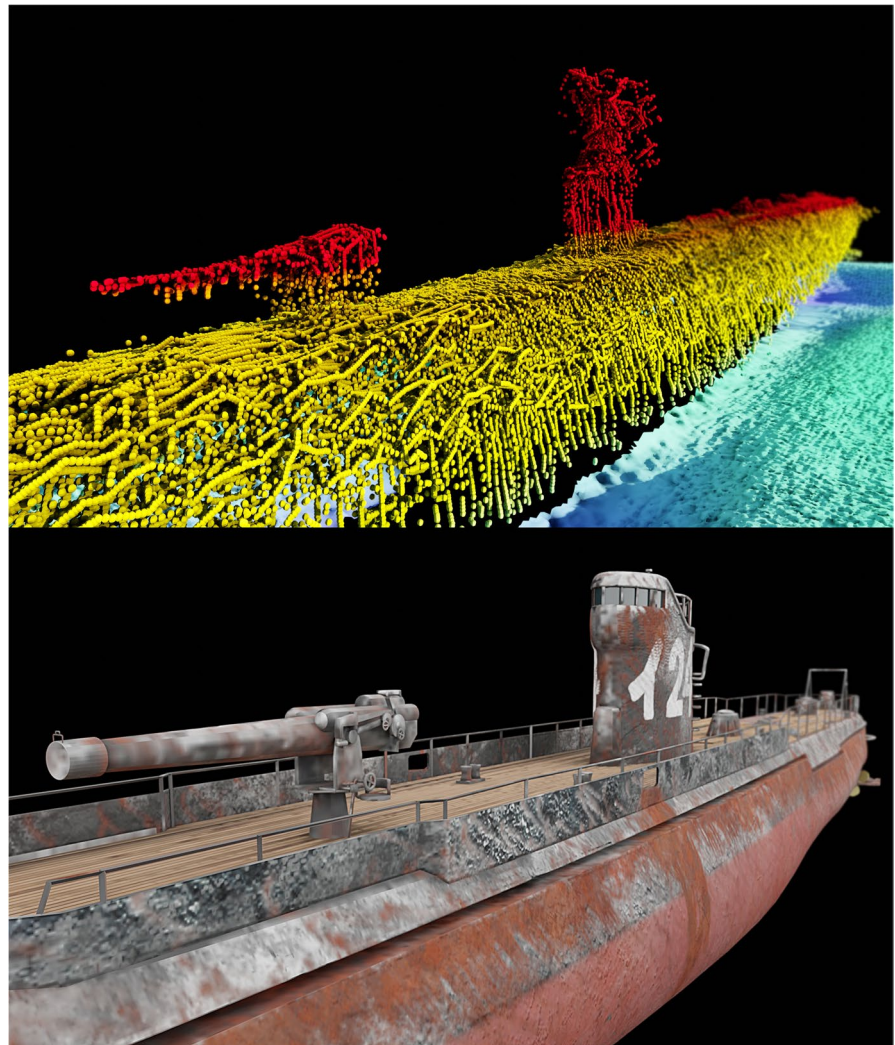
advised to use VR headsets if available, as the stereoscopic view provides a sense of scale that enhances the experience, allowing the users to see ship plans blown up to full size and the submarine reconstruction shrunk down to float beneath their noses. The final animation was 4 min. 38 sec. long, and comprised of nine sequences (Fig. 7):

Sequence 1: Viewing Instructions (18 sec.)—simple instructions on what platforms could be used and how to achieve the best resolution, supporting audiences unfamiliar with VR.

Sequence 2: Opening sequence (21 sec.)—a simple outdoor scene in front of the memorial plaque, allowing novice VR users to acclimate to the vir-

tual environment, with a brief verbal introduction to the history and location of the wreck.

Sequence 3: Multi-beam survey (29 sec.)—illustrating the capture of multi-data as a survey ship sweeps it sensors across the submarine hull. This demonstrates the key data underpinning the reconstruction and provides insight on maritime archaeological science.

Sequence 4: Multi-Beam mesh sequence (29 sec.)—the multi-beam data is scaled down to around a meter in size and spun around in front of the viewer to illustrate detail on the wreck.

Sequence 5: Ship plans sequence: (34 sec.)—the viewer is flown through the historical plans, blown up to the full size of the submarine and glowing in
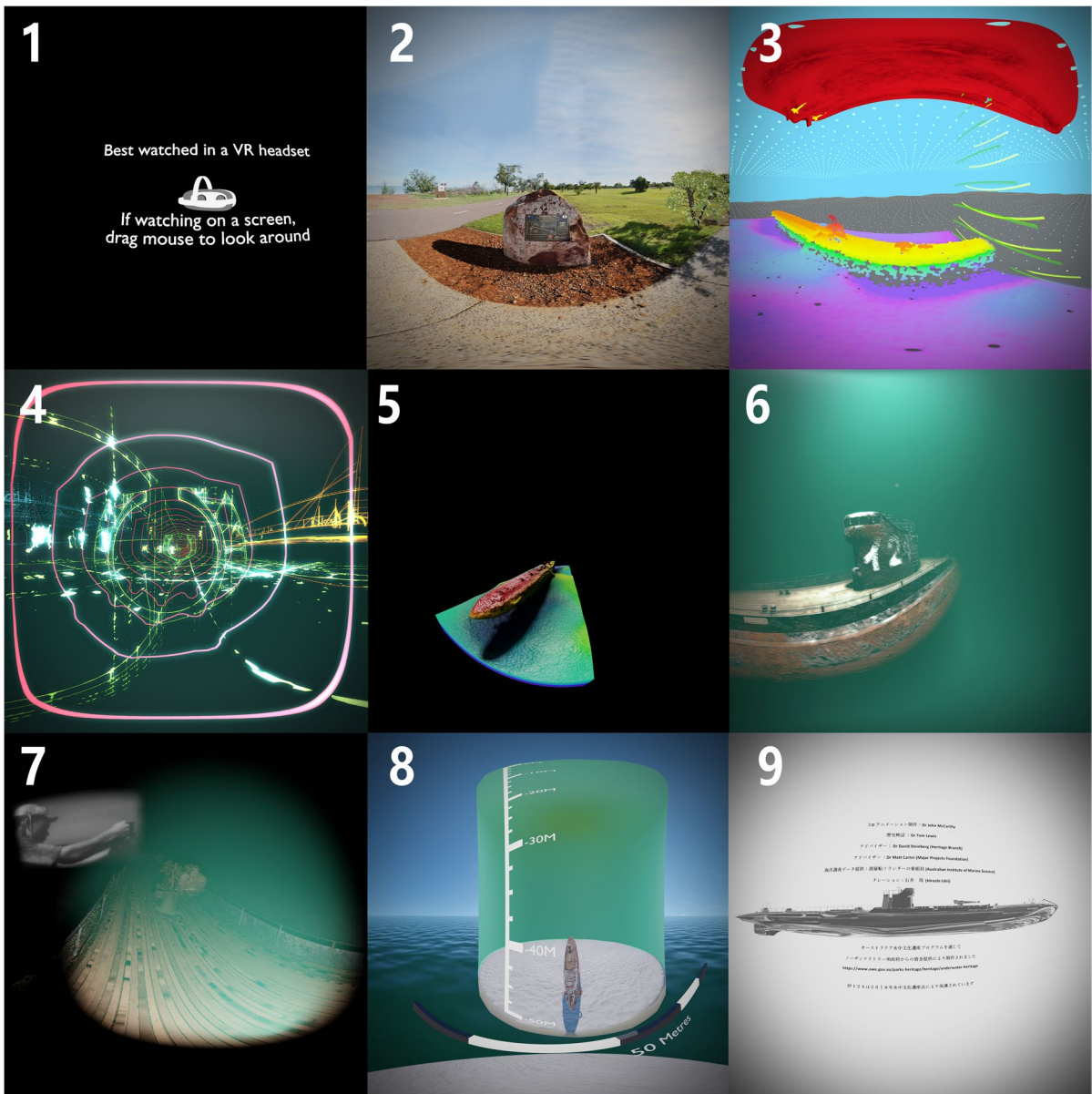
Fig. 7 Stills from the nine sequences making up the virtual submarine dive. (Figure by John McCarthy, 2022.)

neon colors, demonstrating how historical data has informed the reconstruction.

Sequence 6: Submarine reconstruction sail past (32 sec.)—a torpedo flies past the viewer, followed by the submarine reconstruction itself, representing the moment the Allied ships began their attack.

Sequence 7: Diver swim over (77 sec.)—a slow recreation of a diver's view when swimming across the wreck on the seabed, with marine growth on the wreck showing it has been submerged for some time.

Sequence 8: Miniaturized reconstruction (32 sec.)—the submarine is shown revolving slowly at a small scale, allowing a view of the entire reconstruction at once, which was not possible in the underwater scenes.

Sequence 9: Final credits (12 sec.)—acknowledgments of all stakeholders and funders.

Stakeholder Feedback and Alterations

Stakeholder feedback was sought throughout the project, with some of the discussion with Japanese stakeholders being handled by Japanese team member and Flinders Maritime Archaeology Program postgraduate Hiroshi Ishii. This resulted in changes to the script, modifying terminology for certain Japanese words such as "commemoration" to ensure the most respectful options were used. Elements of the animation were also altered. In most cases this was to minimize the risk of distress to family members. The initial draft of Sequence 6 depicted a reconstruction of the military engagement, with detonation of depth charges and bubbles escaping to signal the blowing of the deck hatch and rupture of the crew compartment. The sequence was modified to show the submarine firing its torpedo and submerging, which occurred a few moments earlier. Although the scene is underwater, presence of Allied ships is retained through the audio track, with repeated pings from sonar sweeps as the ships searched for the submarine. In Sequence 7, where the viewer "dives" over the wreck on the seabed, sound is also used to enhance the experience. As in a real dive, there is near total silence with only the noise of a diver breathing, which, combined with the darkness, builds a sense of stillness. Originally it was planned to add glowing virtual labels to identify features along the submarine in this sequence, but this was removed as it detracted from the solemnity of the Experience. Instead, brief historical video clips of Japanese submariners from original WWII footage fade in and out in the darkness, highlighting the human aspect of the wreck site.

The narration had to strike the right balance; acknowledging the Australian perspective that this was an enemy ship and its loss a wartime victory for Australia, whilst also recognizing that after 80 years the animosity of conflict has long faded, but that the loss of human life retains an enduring significance for all stakeholders. To address this, the script ends with a statement that "[t]he I-124 was laying mines and hunting Allied ships outside Darwin Harbor when it was sunk, but now, decades later, we can reflect and recognize the submarine as the final resting place of Lieutenant Commander Koichi Kishigami and his crew of 80."

The Experience as a Bridge between Land-Based Services and the Wreck Site

The VR experience was unveiled at the 80th anniversary commemoration services in Darwin, which also included unveiling of a new plaque. A year earlier Mr. Shingo Yamagami, ambassador of Japan to Australia, had visited the memorial and noted that the individual names of the deceased were not listed. He initiated a new plaque, to complement the existing one, naming the individual submariners. Release of the Experience supported this event, but its deployment was constrained during the main ceremonies for the sake of decorum. Attendees were not given VR headsets at the event itself, but opportunities for experiencing were taken during preparations and in the following days. This included special demonstrations for visiting Japanese media. The Northern Territory Minister for Heritage, the Honorable Chanston Paech, highlighted the value of the experience in media coverage of the commemoration, and reporters also highlighted that the VR experience may provide some comfort for the families of the submariners.

The VR experience also released online on the morning of the 80th anniversary alongside a press and media pack release in English and Japanese, leading to widespread online, TV, and print-media coverage in Australia and Japan, but also in many other countries, from Iceland to the Philippines. This media attention helped to disseminate the Experience to a much wider audience. There have been over 40,000 views of the English and Japanese YouTube versions at the time of writing, with over 94% approval by viewers who chose to "like" or "dislike" the video. The online nature of this element of the commemoration also allowed those relatives of the submariners who were unable to travel to the event, due to COVID travel restrictions and other reasons, to partake in the event with a degree of immediacy. On the Australian national television news broadcast by 9 News on 21 January 2022, Yumiko Shaw, a representative of the Australian Japanese Association of the Northern Territory, stated that "they were so excited to watch that video, and we really appreciate it."

Conclusions and Future Work

The wrecks of ships, aircraft, and submarines are a form of heritage commonly associated with tragedy. The wrecks of these craft often have multiple

cross-cultural connections, so that commemoration can become a complex issue. Compounding these challenges is the fact that maritime losses are some of the most inaccessible forms of heritage, restricting the typical impulse to physically connect to the sites where such tragedies took place, with displacement of commemoration activities to proxy locations. The efforts of those designing the monument on land for I-124 to replicate the wreck symbolically with markers demonstrates a powerful need to connect with the physical remains of the shipwreck in a memorial context. VR is emerging as an effective means to provide both virtual access to sensitive sites in which there are access restrictions and also new dimensions to commemorative initiatives. The Experience further fulfills this need in a highly accessible way, placing the wreck itself back into the minds of those there to acknowledge the lost submariners, making something that is truly remote more tangible and available.

In terms of site management, the VR approach allows an innovative response to the risks of commemorative activities to underwater archaeological site preservation, ranging from damage during recreational diving to the removal of monumental elements to augment exhibits on land. Creation of the digital reconstruction has also highlighted knowledge gaps with a high degree of clarity and lays the groundwork for a detailed analysis of a future comprehensive photogrammetric survey. This project has demonstrated how VR can provide a highly effective tool for commemoration of maritime historical losses. However, this requires sensitive directorial decisions and consultation with stakeholders throughout the project design, ideally a design team that includes members with cultural knowledge and authority.

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