Report on the wreck of the *Sub Marine Explorer (1865) at* Isla San Telmo, Archipielago de las Perlas, Panama, and the 2006 fieldwork season.

M. McCarthy

Cover Picture: Project leader J.P.Delgado and SubMarine Explorer

Marc Pike, Open Road Productions/Eco-Nova Media Group Ltd.

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Overview:
Sub Marine Explorer was an innovative vessel that was conceived and launched in 1865-1866 with the twin demands of the American Civil War and the Panamanian pearl fishery in mind. The product of the German immigrant ironworker Julius H. Kroehl, a gifted underwater engineer and inventor, *Sub Marine Explorer* was one of the most important and successful developments in the early days of the submarine boat. It was one of two technological successes and is one of only five submarines known to exist from that early period. It is the only one built for use by the Union still in existence, giving it an iconic status along with its contemporary the confederate submarine *HL Hunley*. Nonetheless its presence at the remote Isla San Telmo in the Archipielago de las Perlas, Panama was unknown until 2001.
Management of what is now recognised as a unique maritime archeological object with a wide-ranging technological, cultural and economic context has become a priority for the many stakeholders, notably James P. Delgado, then Director of the Vancouver Maritime Museum, now Executive Director of the Institute of Nautical Archaeology (INA) and who has led in the identification and analysis of the remains. In the wake its expertise in the interpretation, excavation, conservation and management of iron steel and steam shipwrecks, staff of the Western Australian Museum were invited to join the 2006 team. This report centres on that input and places it into the *Sub Marine Explorer* context.

Background
In February 2001, whilst lecturing on an eco-tour in the Panama region, James P. Delgado, then Director of the Vancouver Maritime Museum was advised of the existence of what was believed to be a 'Japanese submarine' in the intertidal zone at the remote Isla San Telmo, at the southern end of the Archipielago de las Perlas, Panama.

Figure 1: The Panama region showing the pearl islands. Panama tourism website.

A maritime archaeologist, and author/editor of many works including the comprehensive British Museum'*s Encyclopaedia of Underwater and Maritime Archaeology* (1997), Delgado visited the island. Initially finding nothing, he was forced to wait the outgoing tide before the conning tower emerged just offshore. As the tide dropped and the vessel's form was revealed, Delgado realised that it was of a much earlier design, but in being unprepared for such an eventuality, he did not have the equipment or the time required to produce an adequate record of the craft (See Frontispiece).

In March 2002 Delgado revisited the site with another group of eco-tourists and together they recorded the principal dimensions and features of the remains. They also took a series of colour transparencies and video of the submarine as it became exposed at extreme low tide.

Delgado then circulated the images to his colleagues and eventually he was led to a 1902 article by G.W. Baird penned for the *Journal of the American Society of Naval Engineers*. Entitled *'Submarine Torpedo Boats'*, in it there appeared details of Julius H. Kroehl's *Sub Marine Explorer* (Baird, 1902:855). Delgado's informant, the archaeologist Richard Wills, had previously studied an unidentified American Civil War-era submersible boat at the Louisiana State Museum, and he sent cross-sectional drawings of *Explorer* from Baird's article. Based on an 1866 plan of the craft, these matched the Isla San Telmo vessel. Subsequently, other colleagues, Mark Ragan and Robert V. Schwemmer examined other sources, Ragan consulting the U.S. National Archives and there finding a report and plan of the then uncompleted submarine produced by a W.W.W. Wood in 1865; correspondence relating to Kroehl, his Civil War career, and his death in Panama. Schwemmer located articles in New York newspapers of the period that documented the craft and Kroehl's activities, the use of the vessel in the Panama pearl fishery, and *Scientific American* accounts of Kroehl's inventions and patents. Delgado describes this research work and the principle characteristics of the vessel at length in the *International Journal for Nautical Archaeology* (2006).

The place of *Sub Marine Explorer* in the history of the Submarine

Commenced in 1864 with intention of its partaking in the American Civil War on the Union side, and after that in the Panama Pearl industry, *Sub Marine Explorer* is one of only five submarines predating 1870 that are known to have survived.

The other four in chronological sequence are Wilhelm Bauer's *Der Brandtaucher* (1850), on display in Kiel, Germany; the unnamed Confederate submarine mentioned above which appears to date from 1862 and is now a display in New Orleans, Louisiana; the well-known Confederate submarine *H.L. Hunley* and the *Intelligent Whale* of 1866. In his study Baird concluded that 'as a submarine explorer Kroehl's boat was a success,' and that it, along *H.L. Hunley*, were the two most effective submarine craft of the Civil War upon which to base further experimentation. (Baird, 1902:855). Launched in 1864, *Hunley* was the first submarine ever to sink and enemy vessel and for that reason it remains iconic in the chronicles of submarine history even though it took its wartime crew to their death. Two earlier test crews suffered a similar fate, one including its inventor and namesake Horace, L. Hunley. In August 2000 it was recovered from the seabed off Charleston in what is generally considered a benchmark archaeological program. It was excavated to a very high standard and is presently in conservation at Charleston, South Carolina. *Sub Marine Explorer* was the next submarine boat to be built, followed by *Intelligent Whale* in 1866. The latter is now a museum display in New Jersey.

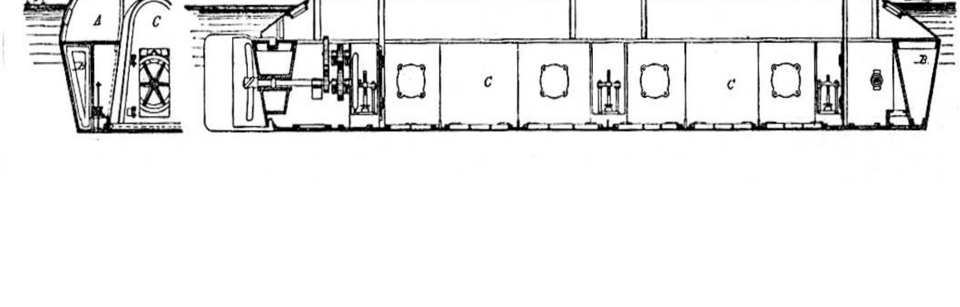
Sub Marine Explorer and *Intelligent Whale* both utilised a pressurized working compartment that opened to the sea via hatches in the floors. This system relied on high pressure air keeping water from filling the inner spaces and thus they had the potential to allow divers to enter and exit the craft in the water column, or in the *Sub Marine Explorer* case at least, also work on the seabed.

Explorer also had two hatches 4½ feet (1.3 m) and 6 feet (1.8 m) long respectively. As the submarine approached the bottom these were opened 'the water being kept at bay during the submersion by the air contained within the machine (New York *Times*, 29 August 1869). In 1865 Wood described how *Explorer* which had a large compressed air chamber operated at 60 pounds per square inch (4 atmospheres), also had 'ease of descent and ascent.' When the operator opened 'the blow off cocks in the ballast or water chambers' releasing compressed air to admit water, 'the specific gravity of the boat is thus increased at will, and the descent may be made rapid or slow as desired by the operator, it is thus perfectly competent to descend to final limit or remain suspended at intermediate depth required' (Wood, 1865:15).

To ascend, 'the blow off cocks would be closed, the exhaust valve of the water chamber opened and air from the compressed air chamber admitted; this being at greater pressure than the water forces it out; and thus reducing the specific gravity causes the boat to rise at the will of the operator governed by the force with which the air is admitted into, and the water forced out of, the water chambers. These two chambers (compressed air and water chambers) thus perform for the boat the same office that the air bladder does for the fish, and at once does away with all necessity for suspended ballast or any other extraneous methods of sinking the vessel. The division of the water chambers into fore, aft, and amid-ship chambers, allows the perfect equilibrium of the boat to be maintained without the necessity of shifting ballast' (Wood, 1865:15-16).

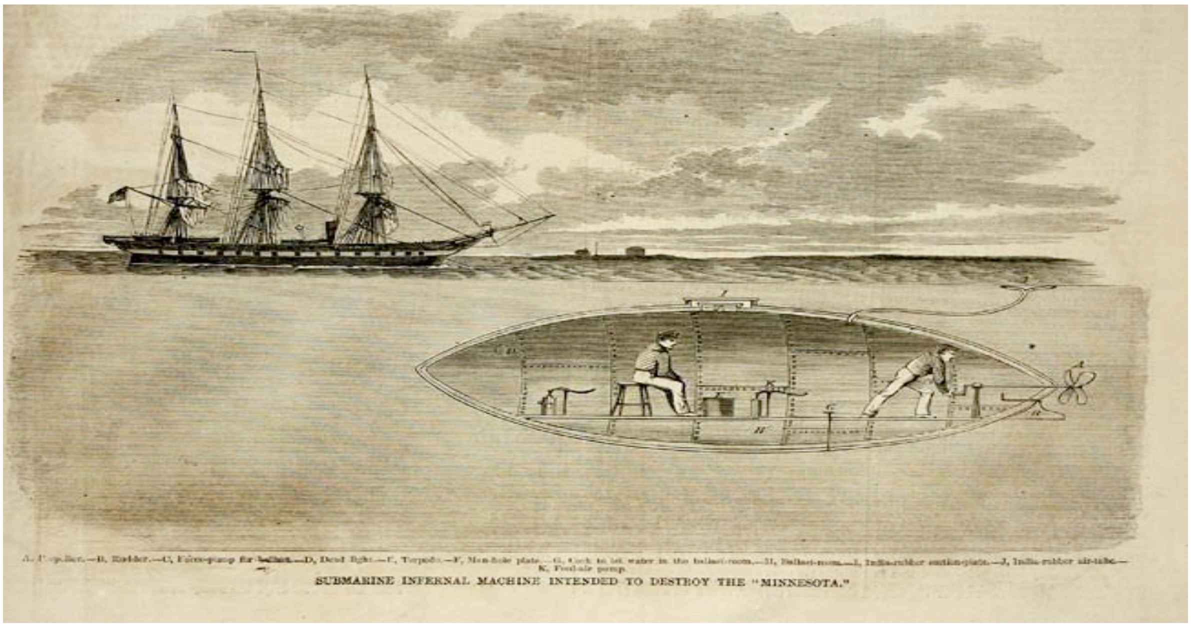
Sub Marine Explorer also had the means to replenish the air in the working chamber by introducing air stored in the compressed air tanks and the working compartment thus had the potential to be both a caisson and a 'lock out' dive chamber. Further carbon dioxide build up was reduced by spraying seawater in a fine mist throughout the chamber to trap 'carbonic acid gas' that accumulated inside the submarine by absorbing it into seawater. 'By this means when the air becomes saturated by the accumulation of carbonic gas, as shown by the burning dimly of a candle, water is thrown in the form of a fine spray or mist through the whole extent of the working chamber, the carbonic acid gas is at once absorbed and oxygen set free, rendering the air even richer (about 5 %) in this important element than before' (Wood, 1865:9). These were all remarkable developments for the time.

Figure 2: A plan of Sub Marine Explorer showing the key features. (A) Compressed air chamber (B) Sea water ballast (fore, aft and side) (C) Crew chamber (From Baird, 1902).



Both submarines' propellers were hand driven providing them with the ability to move through the water column and against light currents. Thus they combined the principles of the earlier submarines, the ancient diving bell, and the newly-developed caissons then being used to allow workers to set bridgeworks and other foundations in a submerged environment. With high pressure air pumped into them from the surface, caissons were capable of being submerged and lifted in the water column on chains yet had openings in the floor that allowed workers to access the seabed.
Manoeuvrable, yet having the features of the caisson, these two vessels were most advanced submarines of the time. While neither submarine boat was delivered in time for conflict, and while *Intelligent Whale* never progressed 'beyond the experimental, or trial stage, and was ultimately deigned an expensive failure and laid up' (Delgado, in press).
While then the largest submarine ever built, the *Sub Marine Explorer* is very small by modern standards, It is a bulbous, flat bottomed craft, 36 feet (11 m), long, 10 feet (3 m) broad amidships, tapering at both ends. It has an upper pressure chamber of clinker plated double riveted wrought iron, braced in similar fashion to the boilers of the time, being 'built of two shells of best boiler iron ½ inches (1.27 cm) thick, the different pieces lapping 4 inches (10 cm) are double riveted with ¾ inch (1.9 cm) countersunk rivets…' (Wood, 1865:3).
Beneath and between ballast tanks to port and starboard is what is termed the 'working chamber' 6 feet (1.82 m) high, except in the centre under the 'conning tower', where it is 7 feet 11 inches (2.4 m) all wrought to what was described by Wood as the 'four foot line' and cast below and on the floors. The breadth amidships is 3 feet 6 inches (1.06 m). Missing on the wreck, but shown in the vessel's original plans were a rudder, and a single, 4-bladed propeller, 3 ½ foot (1 m) in diameter inside a hinged and rotating propeller guard aft. The hatches below were also described thus, 'the floor is closed perfectly air and water tight by four wrought iron trap doors and three cast iron man hole plates.' (Wood, 1865:4).

Figure 3: A 'simple' submarine of the Civil War era. Note the hand operated propeller, water ballast chamber and inlet valve, ballast pump, trailing air hose and stale air pump. There is no compressed air source, or an ability to exit while submerged. Harper's Weekly. No 2 1861: 701



J.H. Kroehl and *Sub Marine Explorer*

Delgado and his colleagues had also learnt that in 1855, in partnership with two others Kroehl blasted a reef in New York's East River and in the same year, one partner, Van Buren Ryerson, patented a diving bell that he named the *Sub Marine Explorer*. Delgado believes that the bell inspired Kroehl to utilise the lessons learned and his own iron-working skills to propose a submarine and then a bridge of cast-iron pontoons for use in the Civil War. In early 1862 he was hired by the U.S. Navy as an underwater explosives expert and sent to work with the James River and Mississippi Squadrons. After serving as a surveyor during the siege of Vicksburg, Kroehl returned home in July 1863, with malaria. In his convalescence he proposed a submarine that would allow the removal of 'torpedoes' (large submerged bombs) and other obstructions underwater. He also interested investors, who formed the New York-based *Pacific Pearl Company* who saw in his invention an opportunity to recover shell and pearls in the deep water beds off Panama and Mexico. Kroehl was also a shareholder.

Figure 4: Diving in the ancient Panama Pearl fishery. Photo courtesy J.P. Delgado.

The Panama fishery fishery dates back to the 16th century, and was effectively 'fished out' by 'naked diving' to breath-hold limits. Here, as in other similar fisheries, such as the north-west Australian pearl industry of the 19th century and the modern (1990s) Indonesian trochus fishery the limit appears to have been in the 30 to 40 foot range (9 to 12 m), with divers descending for 30-40 seconds on average over the day. While few diving aids were used in ancient times there was some variety, with rocks being used to aid descent in some fisheries and rudimentary 'goggles', sometimes turtle shell, as described by the great 14th century traveller Ibn Battuta, were used for goggles. Some divers used no aids at all. (See McCarthy, 1995; 2000). Here it needs be noted that world-wide there were many variations in method, times spent underwater and depths dived and more work needs be done on what appears to be a reasonably little documented Panama fishery (cf Mackenzie, 1999).

Delgado advises that Kroehl was also Chief Engineer and he supervised the construction of the vessel at the Perrine shipyard on the banks of the East River, Brooklyn. Alerted by Kroehl to its near-completion, the U.S. Navy sent W.W.W. Wood, who was the Union Navy's *General Inspector of Steam Machinery* (and ironclads), to examine the vessel. His report included not only a description of the vessel and a plan of the submarine, but also suggested the potential uses; viz., the 'removal of submerged obstructions in the channels of rivers and harbors. Approaching hostile fleets at anchor and destroying them by attaching torpedoes to their bottoms and exploding such localities as are commanded and covered by the guns of an enemy' (Wood, 1865:16-17). Here Wood could see the vessel used in both the configurations referred to above, i.e. as manoeuvrable dive bell and moving caisson. The report was sent up to the Superintendent of Ironclad Construction for review. Though the Confederate submarine *H.L. Hunley* had sunk USS *Housatonic* a year earlier, the Admiral—with an eye to imminent end of hostilities and what would soon become a pressing need to salvage sunken vessels and their contents—wrote 'I do not think the Navy has any use for such a vessel, but parties exploring sunken vessels or engaged in wrecking may find it useful if it be found to answer' (Wood, 1865:19). This is a common theme, for while warfare invariably hastens and nurtures great technological advances, works-in-progress are generally shelved at the cessation.

Undaunted by a subsequent refusal to take it into the US Navy, Kroehl and the Pacific Pearl Company completed *Sub Marine Explorer* and, in May 1866, after three earlier trials tested it before an excited press and public. With Kroehl and two others onboard the 90 minute trial, including the recovery of mud from the bottom of the East river proved a great success. Soon after, it was partly-disassembled and sent on board ship to the Atlantic coast of Panama and then by rail across the Isthmus, arriving in early December 1866. It was rebuilt and launched by May of the following year and underwent a number of successful tests. Kroehl died on 21 September 1867, 'of fever', however, and there was no further mention of the submarine until August 1869.

Sub Marine Explorer and the Panama Pearl fishery

Delgado and Co. learnt that on 13 August 1869, just two years after Kroehl's death the Panama *Mercantile Chronicle* reported on 'the experimental expedition of the Pacific Pearl Company to the island of St. Elmo, in the Bay of Panama' and it was carried just over a fortnight later in the New York *Times*:

> Inflated with forty-six pounds of compressed air, then partially filled with water, it went down at 11 A.M., remaining under water four hours, when it rose to the surface with 1,800 oysters, or about seven-eights of a ton of shells. The machine afterward made one downward trip each day for eleven days, at the end of which all the men were again down with fever; and, it being impossible to continue working with the same men for some time, it was decided, the experiment having proved a complete success, to lay the machine up in an adjacent cove and convey to the Company the gratifying intelligence. We understand MR. DINGEE proceeded to New York on the 31st ult. with the proceeds of the experimental trial – some 10½ tons of pearl shells and pearls to the value of $2,000 more or less. We are informed that Mr. DINGEE will return from New York in November, when the *Explorer* will be worked regularly. Now that it is on the spot and not liable to further mishap, great results may be looked for if native acclimated men are employed to work it. Could the machine, however, be sent to the Tiburon Islands, where oysters are far more

> plentiful than at St. Elmo its success would be still more decided; it would there perhaps be able to bring up from the bottom a full cargo of shell each descent, and it is capable of lifting to the surface a dead weight of ten or twelve tons at a time, besides it own weight, which is sixty tons. This machine is likely to create a revolution in pearl diving. (New York *Times*, August 29, 1869)

These are remarkable results, verifiable despite the hyperbole in which such reports are normally couched, in that in this same era, a ton of shell from the North West Australian fishery was fetching between £100-150 landed in London. In that same context it also needs be noted that the apparatus, or 'hard hat' diving was trailed there in 1868, in an attempt to access the deep water fishery, but did not become common for another 20 years (McCarthy, 1985) . According to Delgado, as an innovative machine designed to harvest what was known to be a rich and hitherto un-accessible pearl fishery, *Explorer* was also to become one of a number of American industrial initiatives in the region. At the time these included steamship lines to connect the Atlantic and Pacific sides of the isthmus with the booming town of San Francisco, the trans-isthmian Panama Railroad, newspapers, and a possible canal.

***SubMarine Explorer*'s abandonment**

As indicated the decision to leave to leave *Explorer*—a costly investment estimated at $75,000 dollars—c. $19,000,000 today—at Isla San Telmo after the immensely successful returns of 1869 was due to the realisation that humans could not withstand work at pressure i.e. much beyond 45 feet or 1.5 atmospheres for any but a short period of time. This 'fatal flaw' first manifested itself after 1870 as Caisson Disease and for it there was no known cure until Haldane's experiments of 1908. These resulted in the first tables for 'staged decompression' to avoid the divers equivalent of caisson disease, decompression sickness, or the 'bends' as it became known. These same tables appeared soon after in the Australian Pearl industry, together with the first recompression chamber sent from Britain for use at the Broome fishery (Bailey, 2002).

All the *Sub Marine Explorer* men would have been severely afflicted by the disease, for the same New York *Times* article referred to above records them conducting 12 days of diving 'remaining under water four hours' each day to a maximum depth of 103 feet (31 m). As Delgado has indicated in his article, 'not one in a hundred individuals could avoid decompression sickness in such a circumstance'. This also explains the reference to their condition when they finished diving on the 12th day i.e. 'all the men were again down with fever; and, it being impossible to continue working with the same men for some time. The dives were terminated and *Explorer* laid up' (Reproduced in Delgado, 2006). It was first thought that this was manifestation of a European inability to withstand the rigours of the Panamanian situation and the company first began to cast around for local labourers, more able to withstand the climate and working conditions. Though also having an economic element, this has been a common theme throughout European endeavour in tropical climes, viz the use of Aborigines and then 'Malays' as 'naked divers' in the Australian Pearl fishery (McCarthy, 1990). This theme was continued well into the 20th century when as the 'hard hat' became common and both European and 'Malay' divers struggled to cope, Japanese divers took over. There are graphic accounts of the problems European divers were experiencing with the 'bends' at the turn of the century and of their replacement by Japanese divers. They also suffered and died in great number before the advent of the recompression chambers c. 1910, but it was generally understood they were far more hardy (e.g. Bailey, 2002).

Failure to recognise the physiological problem at *Explorer* also lies partly with the remoteness of the Pearl Islands location and the paucity of trained medical practitioners.

Yellow fever and malaria were common there and the symptoms are not dissimilar to the untrained eye to those of caisson disease (decompression sickness), viz joint, eye, nervous, co-ordination and breathing dis-function, paralysis, convulsions, unconsciousness, rashes, and itching.

As Delgado notes, the crew of *Explorer* had most likely suffered on other occasions hence the reference to 'again down with fever' (My emphasis).' He then begs the question, whether Kroehl's death in 1867 was actually from 'fever,' or caisson disease (decompression sickness). To Delgado there is little doubt, for given his craft's 'fatal flaw', his repeated use of it, and need to test it to the limits, it is likely that after a year of testing in Panama, Kroehl is the world's first known victim of decompression sickness.

An unequivocal technological success in the depths to which its contemporaries were working, an un-paralled success in recovering tons of shell at far greater depths, even up to one hundred feet— *Sub Marine Explorer* was to be forgotten as a technological marvel until it was resurrected by Delgado and his colleagues. As Delgado notes, 'consider what the history of submarine development might have been had Julius Kroehl lived past 1867, and had *Explorer* functioned in a more public arena than an isolated group of islands off Panama'. With its 'sophisticated system of buoyancy control, air replenishment, and with the capacity to serve as a lock-out dive chamber, *Explorer* was an evolutionary link in the development of the submarine, aptly identified by Baird in 1902 as an evolutionary craft that forged a link that connected 'the diving bell with the dirigible submarine automobile.' (Baird,1902: 852; Delgado, 2006).

Panama: the first state to ratify the UNESCO convention. *Sub Marine Explorer,* one of its greatest treasures?

While Delgado and his colleagues were researching the new 'find' on April 4 2003, the Republic of Panama became the first state to ratify the UNESCO *Convention on the Protection of Underwater Cultural Heritage* and to date is only and to date is only one of five states to have signed. In that respect it arguably leads the world in its attitude to the preservation of the world's submerged cultural heritage. On the other hand, in contrast to many other parts of the world, Panama has only a handful of archaeologists working out of government institutions and as a result the country depends on the harnessing of external expertise in order to manage its extremely rich underwater cultural heritage. This vast and to an extent hitherto untapped and unpublished 'cultural treasure' includes submerged Pre-Columbian sites, some of Columbus' vessels, innumerable exploration and treasure ships, four of the pirate/privateer Morgan's ships, 49er sites from the California gold rush and French vessels abandoned after their abortive attempt to build the Panama Canal under de Lesseps. Allied is a vast array of terrestrial sites related to ancient indigenous times, the post-Columbian trades, including pearling and slaving, Spanish forts and towns, graves, gold rush encampments, railroads, abortive canal developments and in modern times evidence of the former 'Canal Zone' a land within Panama once occupied by the US. Despite its reverting to the Republic, much of the historic canal related infrastructure is ignored by Panamanians for what it represents, though it remains rich in what is actually part of the global industrial heritage. Thanks to Delgado, in this same period *Sub Marine Explorer* was becoming recognised as part of the immensely rich Panamanian cultural heritage or 'patrimony' and word was slowly filtering out about this new submarine 'treasure' a vessel (like many other famous shipwrecks worldwide) clearly had the potential to act a focus for a raft of studies, some far removed from the technological details and career of the ship itself.

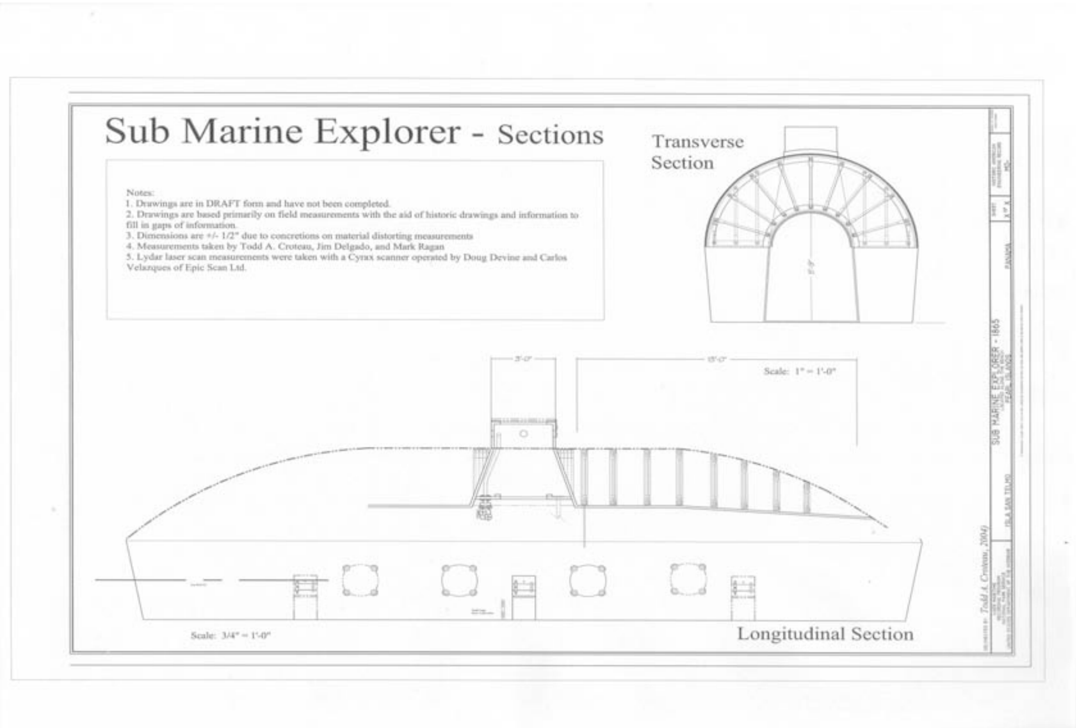
The 2004 Survey

Astounded at the multivariate significance of his find, Delgado planned another visit for late February and early March of 2004, and in order to do so he received a permit from the Director Nacional del Patrimonio Histórico of the Instituto Nacional De Cultura (INAC) in Panama. The 2004 fieldwork at *Sub Marine Explorer* was underwritten by from Eco-Nova Productions Ltd. of Halifax, Nova Scotia, the producers of the enormously successful National Geographic International Television series '*The Sea Hunters'*. In this series Delgado came to have a central role as the show's host and an audience for the entire series worldwide numbering well over 42 million viewers each year in 172 countries. The Sea Hunters is aired in Panama itself to a large audience, being beamed nationally even into receivers at quite remote locations. As one of the series centred on *Sub Marine Explorer* it is pertinent to note at this juncture that many Panamanians—including local and statutory authorities that lay outside of Delgado's reporting structures in the Republic—first came to learn of the importance of the submarine through the Sea Hunters program. Indeed one manifestation of this occurred during the 2006 fieldwork (See Day Book entries below).

The research was also aided by a grant from the Council of American Maritime Museums through the Sally Kress Tompkins Fund. With these prestigious backers and with his own experience and expertise in other archaeological programs in mind, Delgado's aim throughout was to work to standards reached at the examination and excavation of *H.L. Hunley*, and to those also recommended for historic vessel recording projects by the Historic American Engineering Record (HAER) of the National Park Service, for which Delgado once worked.

In providing yet another précis of Delgado's coming report, hand-measurements of the interior of the submarine were the basis for detailed drawings by Todd A. Croteau of the Historic American Engineering Record of the National Park Service. Some of his preliminary work appears below.

Figure 5: Plan view and section of Submarine Explorer. (Todd A. Croteau, National Park Service/Historic American Engineering Record.



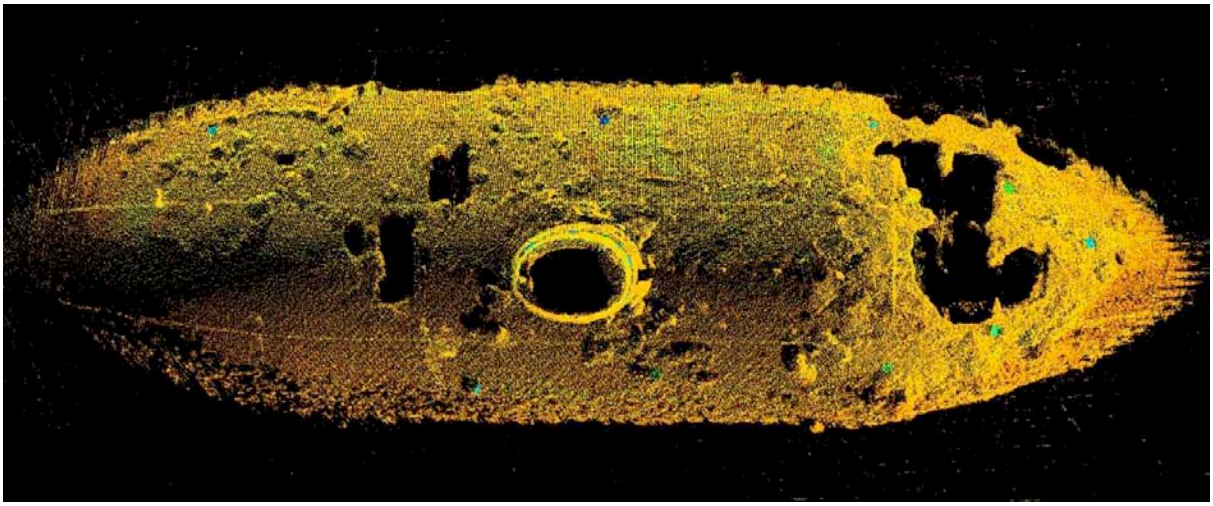
An external record of the vessel was made using a Cyrax 3D Laser Scanning System operated by Carlos Velasquez and Doug DeVine that is described as a '3D laser scanning system for complete, accurate, fast visualization and modeling of complex structures & sites.' (Delgado, 2006).

Figure 6: The Cyrax system being deployed by Velasquez and DeVine at the wreck. Marc Pike, Open Road Productions/Eco-Nova Media Group Ltd..

Delgado also conducted a limited test excavation of the sand in the vessel's stern in order to examine the condition of the buried remains and also to ascertain its relationship with underlying rocks and sediments. Water jetting indicated that the floor aft was missing and that hatches in that area may also have been destroyed. A thick strip of black rubber lined the surviving edge of the hatch opening. Where the floor remained it was covered by a 4 to 6 inch (10 to 15 cm) thick layer of light coloured sand, followed by a layer of coarse grayish sand and gravel, then by lower layer of small basaltic stones mixed with rotting plant matter. The latter indicated that there was mixing of the sediment caused by the sometimes violent movement of water within the hull.
The Cyrax data also showed that the vessel is down by the bows by around 4.4 feet (90-120cm) and this accounts for the light cover of sediments aft, and more forward. A slight cant to port (the seaward side) was also evident. Sloping down into the sediments, the midships portion contained deeper sediments, up to 18 to 24 inches (45 to 60 cm) of material, while the bow was filled with 36 to 48 inches (90 to 120 cm) of sand and gravel. In this test phase, Delgado's team located concreted material, piping, and other unidentified objects which were not disturbed. All were reburied and left in situ.

While Delgado's research team were unable to locate contemporary lines plans, the Lidar Scan of the hull remedied the situation for the upper hull enabling Delgado to produce lines and a recently-completed model; though it needs be noted while it looks pristine, Delgado and his associates were of the impression that the hull, especially the plating aft of the conning tower, had been distorted by an unrecorded salvage attempt. Evidence of this also manifested itself in very thick wire rope wrapped around the conning tower, its apparent distortion and the removal of all machinery, the propeller and rudder, all the hatches, most of the copper and brass-work and all the scuttles and deadlights. All showed signs of having been cut or hacked away. On the beach adjacent the team also located a flanged piece of cast iron, which was identified as forming 'one half of the closure for the bow ballast chamber'. This provided some further evidence of what Delgado sees as modern interference with the wreck.

Figure 7: The Cyrax results. A view from above, by Carlos Velasquez & Doug Devine, Pacific Survey/Epic Scan Ltd.



In concluding his report of the 2004 season and the resultant research Delgado noted that

> 'the challenge now before *Sub Marine Explorer* is one of conservation, preservation and additional documentation. The exterior of the submarine is actively corroding, and through the action of the surf, and perhaps human intervention, is de-concreted, accelerating the deterioration of the craft's outer shell. Exposed in the intertidal zone, the submarine is also exposed to wet and dry cycling, and to the full effects of tidal surge and waves. As the tide drops, the interior of the submarine becomes a sea cave, with water and air rushing in and out. The drop of an outgoing swell sucks in air through the open conning tower, and exposes the upper portions of the working chamber. The incoming swell floods through the hole in the stern and pushes the air back out as it floods the interior. This creates strain on the interior of the sub which is manifested through the vibration of the hull. The large valve in the operator's station visibly

vibrates with each surge, and the shell plating of the compressed air chamber flexes with each wave.
The inflow of water also washes in sand, cobble and some larger rocks. This batters at the edges of the iron and continues to break it. Since the bow rests lower than the stern, the higher elevation of the aft end of the craft means that this is where the corrosion and damage is greatest, as is also the case with the ocean-facing beam, the port side. Waves channel along the port side, and the compressed air chamber is breached for nearly the entire length of the port hull . . . This wreck is not in a stable environment.

The 2006 SubMarine Explorer Season

In concluding his 2004 report Delgado noted that *Sub Marine Explorer* 'is a unique and significant craft in danger. If a move to rescue the submarine cannot be mounted, then at a minimal level a more comprehensive effort to document the craft must be undertaken'. In that context he sought funds and received an 'Ocean Exploration Research Grant' of USD $36,000 from NOAA via the Council of American Maritime Museums and again obtained the permission of the Panamanian authorities, with a number of minimal disturbance aims foremost; viz., to document the submarine, its features, corrosion status and its physical strength; to learn more about Julius Kroehl and his submarine, including their place in the Panama pearling industry; commence rewriting the history of early submarine development and to ascertain if the submarine could or should be recovered and conserved.
When initially approached by Delgado to assist with the 2006 season—and unaware that he had already catered for it by the appointment of Prof. Don Johnson and Larry Murphy—this author demurred, advising that it would be probably more appropriate to reserve the place offered for conservators and corrosion scientists on the basis that as a well-recognised archaeologist his requirements might be better served by specialist others. Delgado for his part re-iterated that what he sought from the Western Australian Museum in this instance was not conservation and corrosion science expertise, as has often been the case in years past (e.g Carpenter, 1990; MacLeod, 2002; MacLeod, *et al.*, 2004; Richards, *et al.,* 2006); but its expertise in understanding iron and steamship archaeology, site management, contextual studies, outreach and the submarines as 'archaeological sites' in their own right. These are some of the author's research interests and as he had also studied the development of the Australian pearling industry, the request made of this author was considered pertinent and the invitation to participate at no cost to the Museum was duly acted upon.
What follows is a chronological account of the 2006 season at *Sub Marine Explorer* from the perspective of this author in his own right and as representative of the Western Australian Museum, assisting the leader J.P. Delgado. It is reproduced here in order to give the reader some further insight into the program.

(WA Museum *Sub Marine Explorer* Day Book Excerpts)
AIM: To assist James Delgado and his team in the *Sub Marine Explorer* studies
Participants JP Delgado, OIC., Director Vancouver Maritime Museum; Larry Murphy Chief Submerged Resources Centre, National Park Service; Prof. Donald L. Johnston, Professor Emeritus University of Nebraska; LCMDR Joshua S. Price, Naval Sea Systems Command, USN, Mr Todd A. Croteau, Historic American Engineering Record; Dr Jacinto Almendra, Conservator Panama Viejo (Ancient Panama); Dr M. McCarthy, Curator of Maritime Archaeology, WA Museum.

On Site Activities :
Day 1: Arrived at site at 3.00PM finding it exposed to the break in the hull port side. Swell mod. Viz. 3 feet. All in for a check/familiarization snorkel. Found it in a remarkable mix of states, the port hull at the skirt gone, the many holes in the wrought iron, the cast iron fore and aft gone,—new scouring at the bow (eastern end)—revealing a hitherto undiscovered pearl shell trapped under branches . . . considered whether the sub came off its mooring and whether evidence of a pearling camp would be visible near the creek bed to the west.
Some Research ideas. Mooring? pearl camp?. pearl shell plume.

Figure 8 *The bow view when snorkelling and diving on the wreck at high water. Warren Fletcher, 2004, reproduced in Delgado 2006.*

Day 2: Anchored off with the tower just awash (See Figure 9 & 18 below) and MM (self) and JPD (Delgado) in for an examination of the interior. JD straight in on his back digging a furrow with his tank —V. tight!! MM More circumspect, dug a hole removing rocks and then slipped in. JD was interested in showing me some features & getting my opinion . . . settled in to the confined space well. The light from the tower and opening aft comforting. This is not my normal fare!

Figure 9: Dr Jacinto Almendra, Conservator Panama Viejo (Ancient Panama) with pearl shell found stacked on the beach near the submarine. The conning tower is just visible over his right shoulder (M.McCarthy). See same view at low tide later in Figure 18.

Out after 30m and ashore to discuss and help others in their work hydrography, corrosion studies, Todd taking B/W photography with 4X5 large format view camera, a beautiful wooden beast c. 1950 to give high definition architectural quality archival images. This is the best way of storing & preserving data.

Figure 10: Todd A. Croteau, Historic American Engineering Record and LCMDR Joshua S. Price, Naval Sea Systems Command, USN, with the 4X5 large format view camera.

As the tide dropped towards 1.30 LW and a 10.7’ drop the sub became progressively more exposed JD took the YSI Multiparameter Sondmeter into the sub for full cycle monitoring….worried at his delay and considering that the interior must be getting dry—I descended into the tower & was stunned by the sight—Jim was also reveling in the aura of it all. We checked the details of the internal arrangements. . . lots of pics & theories, & lots of TV. [note: It was later learned that despite his knowledge of the wreck, and the many times he had successfully entered and exited by the same route, Delgado had been stuck for 5 minutes at the starboard stern entry]

Then assisting Larry (Murphy) and Don (Johnson) with their [corrosion study] work—finishing with the sub again descending in the tide.

Figure 11: Larry Murphy with the drill and other corrosion measuring equipment. Note the yellow cable hooked up to Johnson and Murphy's meters on the beach: M.McCarthy.

PM [evening] exchanged pics and philosophy

Day 3: AM early Todd [Croteau] & Josh [LCDR Price] doing a recce of the stern.
Mc[self] Jacinto [Conservator, Panama Viejo] to the area that looks promising for a pearling inhabitation at the watercourse to the east of the wreck & where coconuts grow. Did a line search and found on an elevated area pearl shell frag[ment]s some assorted shell, a glass sherd and 2 ceramic frags of indeterminate age. Inconclusive with lots of possibilities . . . [then searched other areas with inconclusive result] . . . Todd and Jim [Delgado] on internals as the tide dropped, Larry and Don on the corrosion issues.. . .Back [inside] for more internal discussion, setting Larry's meter & assisting, finishing as yesterday c. 4.30PM.

Day 4: Up quite croaky and pleased to have Bert [Ho] keen to take over my prescribed role as dive tender to Josh [Price] in assisting Larry and Don with their corrosion potential work—their 'ground' [epoxy'd in place on the submarine hull] being a great success & their YSI meter v. successful. The 'ground' [was] developed for *[USS] Arizona* & used on [a wreck at] Ellis Island [& a] B 29 [bomber] and the GMC [meter], an off-the-shelf 'probe' produces readings in Mv [millivolts] with little variation, i.e. a simple system.

Figure 12: Don Johnson pointing out surface corrosion features . M.McCarthy.

Figure 13: close up of the 'ground' using epoxy to not only secure the wire connected to the meters on shore but also to ensure that the drill hole does not become a locus of further corrosion. M.McCarthy

I did lots of photo ID and ordering [of photos]. & Larry, JPD and I discussed results and work needed.

After lunch in [with JPD] getting the dimension of the pressure chamber with Jacinto [observing]. Swell [inside] causing lots of problems . . . had 'pescadores' [fishermen] come alongside to sell fish. Earlier some had come to sell pearls at the wreck but I was called away by the TV crew though I wanted to talk diving.

[**A visit from the local waterbourne police**. The day book fails to record an important visit by authorities c. Day 3 [though it is recorded on camera]. They came armed and in small boats and soon were speaking to James Delgado in Spanish. The TV crew filmed the exchange, I took stills. It was an extremely important event.

From what I was later advised, first the authorities were demanding to know what the foreign 'gringos' were doing at '*their*' submarino' [my emphasis]. Apparently, though Delgado had obtained the necessary permits in Panama news had not filtered through to the authorities in the islands and having been advised by fishermen of our presence went to investigate.

Apparently they had learned of the importance of the submarine mainly from the Sea Hunters series and were not about to allow any foreigners to interfere with it.

Figure 14: The water police arrive. Panama's newest treasure is regularly monitored. M.McCarthy.

For a while the exchange seemed tense until Senor Jacinto Almendra the official Panama archaeologist on the project joined in. Then the head official recognised Delgado from the *Sea Hunter* series that had recently aired in Panama and advised he had learned of the importance of the *SubMarine Explorer* through it. From then on all was well.
[An aside: this is a very important affirmation of the value of popular TV programs in alerting folk to the importance of their submerged maritime heritage and the fact that it is 'theirs'.

Day 5:
To the site early. JPD in [side]. Larry, Don, Bert & Josh on corrosion, me photographing. Then [at high water] . . . back into the sub via the stern joined by Josh.

Then preparing the water jet on board Cheers [the charter boat] and to the sub as the tower became less swell affected & fixed in on board over sandbags. Josh and Bert supervised by JPD then excavated along the side to seaward to see if the hull was concreted to the seabed—inconclusive, but with a bottom of basaltic rocks it appears not to be so.
Lunch on board & photographing Larry and Don at work and assisting Todd in his measurements.

Day 5: to the site for some AM corrosion studies &c. MM/JPD & Todd on board organizing data till lunchtime.
Mc & JPD to shore for a dive inside to do a final check & hopefully to recover some Fe [iron] samples. Todd doing a Total Station [survey] in the hope of adding to the missed Cyrax Laser

Scanner area—but the tide was not low enough. JPD also recovered Larry's instrument & tried to dislodge some cast iron floor—unsuccessfully. I felt under the floor & felt rubber, possibly encountering a hatch as described in the [contemporary] accounts **.** Packed up, cleared the beach and left the site [but not before all who had not done so were able to examine the submarine interior] .

Figure 15: Jacinto and Elias inside: the first modern Panamanians to enter the 'killer submarine'? M.McCarthy (See p. 31 on the notion the submarine was on some way cursed)

Contextual Studies.

24/02/2006: [Of relevance to the analyses following… a summary of the **visit to a pearling village.** Returning to Panama, via Casalleta pearling village, an important visit helping put the present-day pearling industry into its context. In essence, the village had been relocated some years ago from its earlier location. The season had not opened the weather being far too cold and the water very cool, preventing diving. Some very small pearls were offered for sale and the shells appeared similar in size and appearance to the black lipped shell of Shark Bay. The diving gear was modern mask fins and snorkel and somewhat surprisingly the depths the divers describe work to were in the 3-4 metre range. This will need verification].

Figure 16: Casseletta village from the sea. Bert Ho.

25/02/2006: [Of relevance to the analyses following… a **trip across the isthmus.** Accompanied by Panama pilot Capt. Jim Dertien

… a comment made on the trip **re a scrap metal dealer having an interest in *Sub Marine Explorer.*** While traveling in the mini-bus with Capt. Dertien mention was made of a lady in Panama who was out seeking scrap iron opportunities for sale to the burgeoning Chinese market. Capt. Dertien advised that at one stage she had an interest in the submarine. Apparently the Sea Hunters program and official assertions of a stakeholding interest in the wreck have seen off that threat at present, though there were real fears for a time. See ref to the police visit above.

In the trip across the isthmus accompanied by Panama pilot Capt. Jim Dertien, the team viewed the World Heritage sites at Portobello & San Lorenzo on the Caribbean coast, and discussed the wrecks offshore, the pre-canal cross-isthmus trails and structures. The team also saw some of the steam vessels abandoned after the abortive French attempt to build the canal, the remains of the French canal itself, the abandoned and recycled buildings used during the American occupation of the former Canal zone, the canal and its infrastructure, including the locks, notably the Gatun lock.

An analysis of *Sub Marine Explorer*

2006 AIMS

1) **To learn more about Julius Kroehl, *Sub Marine Explorer* and their place in the Panama pearling industry.**
4) **To commence reassessing the history of early submarine development.**

As can be seen in what is presented in the précis above, J.P. Delgado has unequivocally and very effectively set the scene for a belated international recognition of the importance of *Sub Marine Explorer*. It is undeniably a groundbreaking submarine boat, one of only two that proved successful up to the mid to late 1860s. It incorporates a number of innovations and was a brilliant success marred only by the fact that its inventor/operator Kroehl took it to depths and stayed down for times far to great for the medical/physiological knowledge of the time.

Until the advent of Delgado and his informants, Messrs Ragan, Schwemmer and Wills, only GW Baird's 1902 work *Submarine Torpedo Boats* was in recognition of the importance of this boat. Few modern commentators had access to it, however and *Sub Marine Explorer* had disappeared from the record. Delgado's article in the *International Journal of Nautical Archaeology* and the appearance of the *Explorer* in the immensely popular *The SeaHunters* documentary series presented to over 42 million world-wide have reversed well over a century of anonymity for both the inventor and his craft. The history of the development of the submarine is presently being rewritten by expert others as a result. Delgado will certainly have a role in that context.

For his part Julius H. Kroehl is firmly established as an innovative force in submarine design, one like Horace L. Hunley who paid with his life in pursuing his vision. The extent of Kroehl's engineering and metal-working genius will not be fully understood until technological, metallurgical and ironworking analyses of the material remains subsequent to the 2006 field season are completed, however. As is common, once a focal point is obtained and developed though scholarship and publicity, it is expected that other archival and scientific material pertaining to these activities will emerge in coming years.

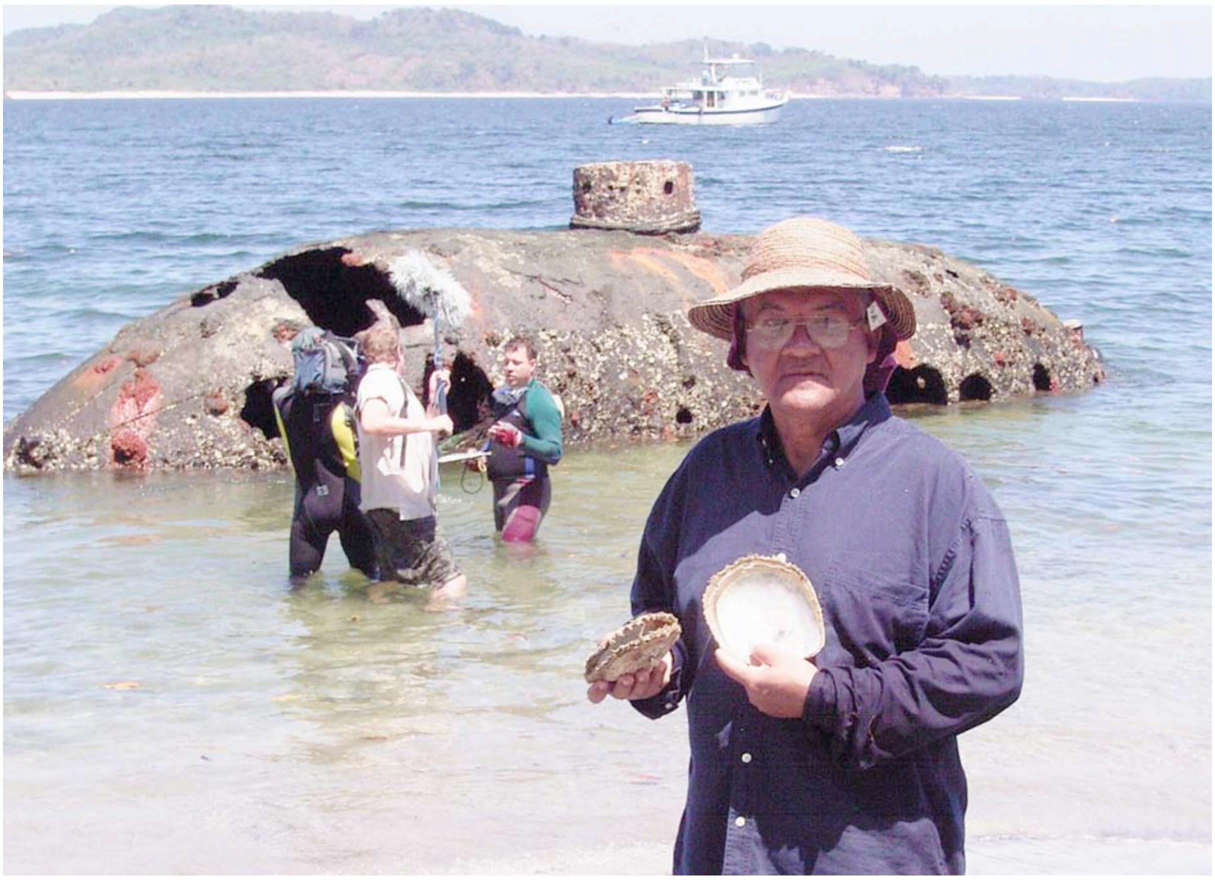
Kroehl's place and that of the *Panama Pearling Company* (PPC) in the exploitation and development of the Panama pearl fishery is recognised as transitory, but the attempt has undeniable importance in any analysis of the application of advanced technology, misplaced innovation, and overseas capital to the fishery. Direct reflections of it are seen in the Western Australian fishery in exactly the same period through the 1860s application by Charles Edward Broadhurst of capital and advanced technology (for NW Australia) in the form of the 'Hard Hat' (apparatus diving) and steam power (SS *Xantho*). He introduced these two elements a full 20 years ahead of their time in order to exploit deep water shell deposits as those in shallow water became depleted by naked diving techniques (McCarthy, 1995; 2000).
A final analysis of Kroehl and the PPC and proper contextual studies needs await further research of the various stages in the Panama fishery however. The visit to the Casalleta pearling village and the interactions with 'pescadores' (fishermen) and the pearl sellers who joined the team on the beach adjacent the wreck are some of the beginnings of those essential archival and oral history studies. At first glance the methods used by the Panama pearl fishers today are an advance on those witnessed in another contemporary fishery, the Indonesian Trochus shell (mother-of-pearl) fishery as conducted off the Australian coast in 1990. There

only hand made wooden goggles were used (McCarthy, 2000), while in the Panama fishery today modern mask fins and snorkels have replaced traditional methods. This begs the question when did the change occur and what methods were used up to then? These questions are of direct relevance to Kroehl.

Figure 17: A modern diver from Casselleta and another from 1990 in the Indonesian Trochus shell fishery in NW Australia (M.McCarthy & J. Carpenter). The method used by the Indonesian diver (with the exception of wooden goggles) reflects ancient global practice.

This author's search for and subsequent examination of what may prove evidence of a pearling camp associated with *Sub Marine Explorer* that was conducted with Dr Jacinto Almendra, Curator of Panama Viejo and others, was as a result of the lessons learnt in the Australian pearling industries. The results were inconclusive, however for the cultural remains opposite a rivulet near the wreck, they contained indications of pearling activity provided to Almendra an indication of a pre-Columbian life occupation together with modern activity (Pers Com). While that in itself is exciting and significant, again this brief inspection can only be considered a pointer to the need to proceed in those directions in order to put the submarine, the fishery, Kroehl's and the Panama Company activities into a broader context.
Delgado also appears to have made a very strong case for Kroehl's recognition, albeit in a tragic sense, as possibly the first victim of Caisson disease and in that context, of the 'bends' as it still afflicts divers today. While a dubious honour, the link is strong and the discovery tends to re-write the physiological/industrial history books. Certainly Kroehl's successors in the *Sub Marine Explorer* suffered Caisson Disease and they will now precede the first documented case that of a year later in American bridgeworks (Delgado, 2006).

Figure 18: Pearling and its history: context for Sub Marine Explorer. M.McCarthy. Compare Figure 9.



2006 AIM: To further document the submarine, its features, corrosion status and its physical strength.

a) **Documenting the submarine and its features**

General

The hull was found to lie roughly beam on to the shore in the intertidal on a beach of sand overlying small basaltic rocks. This is consistent with it having come ashore from a mooring nearby rather than it having been run into the shallows and deliberately sunk as often occurs with wooden hulls being laid up between seasons. Normally this exercise is conducted where seas and swell will have a minimal effect. This particular Bay, which I suggest might best be called Kroehl Bay in deference is clearly swell affected.

The wreck was completely awash at mean high water, its ‘conning tower’ just below the surface and at low tide about one metre of its length amidships to starboard (landward side) it was totally dry at low water. Many holes were visible in the starboard side and on the upper part of the outer hull. A large hole was visible on the hull aft. On the port (seaward) side, while the initial reaction is one of being more intact than the shoreward side, as the tide dropped it served to expose a large and long gash c. 60cm high that ran almost the full length of the hull. Deep scour pits were evident at the bow and stern. Control of movement and holding station in the scour pits was limited due to the strength of the water flow.

Figure 19 Oceanographer Bert Ho and the system devised to mount his sonar array to the 'rubber duck'. A useful example. M. McCarthy.

Water movement, moving particles in the water column and poor through-water visibility generally made an examination of any features underwater quite difficult. Photography suffered in a similar fashion.

At low tide the submarine could be accessed without diving gear, but though the first day provided a very low tide and little swell, thereafter the tides and lifting swells were less conducive to a 'dry' examination of the vessel due to the surge inside. This is caused by breaks in the hull for and, more noticeably aft and it rendered control of movement and holding station almost impossible.

External Hull (wrought iron upper section)

Laser scan, total station, manual and video/TV photography and manual recording at low water and at mid tide from 2002, 04 and 06 have all sufficed to see this area well documented in a general sense. Given that this skin is lapstrake (clinker/clencher) in form fastened with flush rivets externally, examination of the features, including the lap and fastening pattern (it is double riveted) was best conducted from the inside. With the concretions and oysters on both external and internal faces precluding accurate measurement this avenue of inquiry can be considered adequate at present.

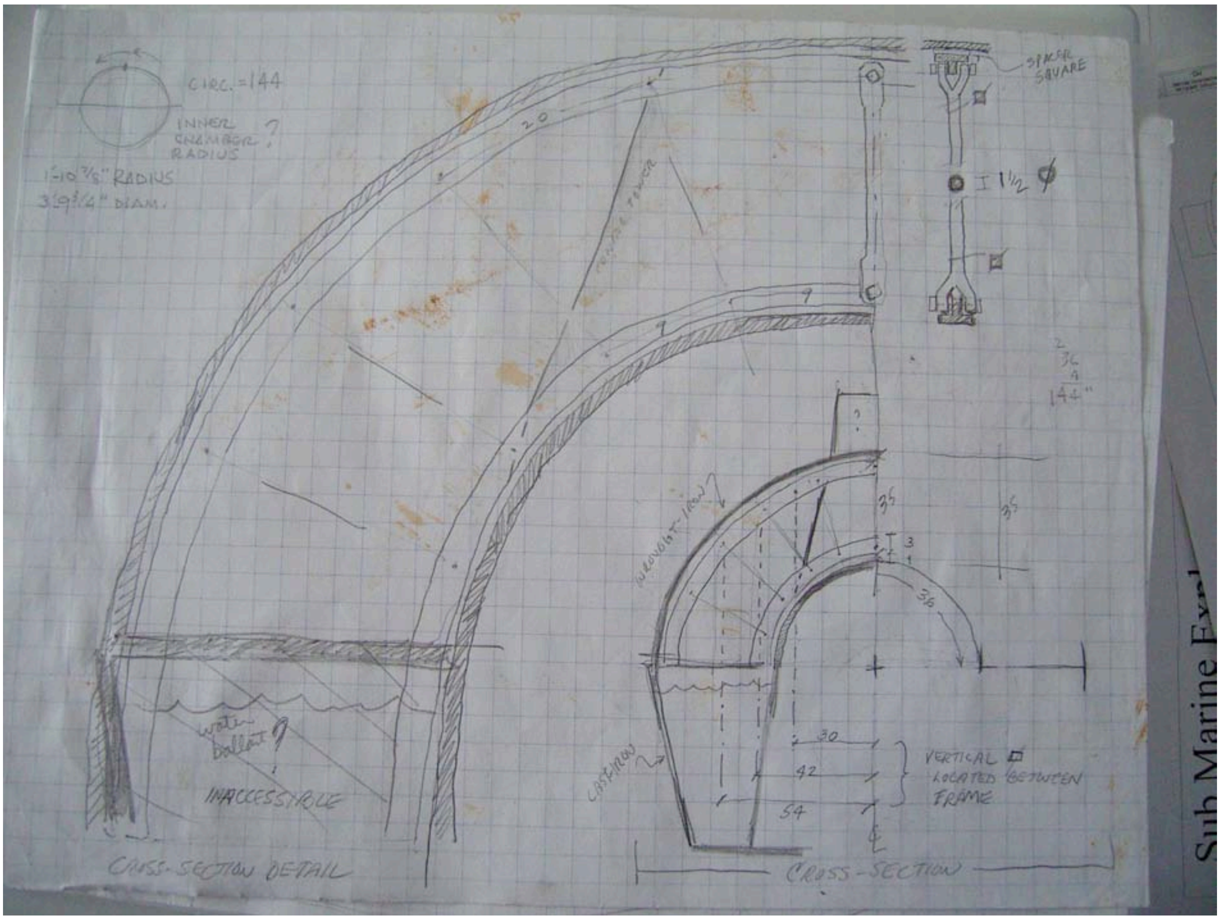
Pressure chamber

As indicated the upper surfaces and starboard side are largely intact bar a number of holes of varying sizes in the casing, some apparently caused by early salvage entailing the forcible removal of features like viewing ports forward and in the tower. Most accessible copper or copper alloy fittings topsides have suffered accordingly. The port side of the hull 'between wind-and wave' on the seaward side is almost entire gone. Nearly all the adjustable stays along this side of the pressure chamber, above the ballast tanks and across to the mid-line of the vessel are also gone.

This all appears the result of a number factors, wave effect, the usual aeration suffered by all ships/wrecks in this zone; and in the *Sub Marine Explorer* case by heavy floating logs. One was found washing around in the surf adjacent the wreck when the team arrived for example. Its size, weight and the force with which it rolled back and forth in the surge proved most remarkable. This may also account for the relatively clean appearance of the upper hull at the bow and stern when compared with the hull amidships. There it exhibits large amounts of what have come to be termed post the explorations of RMS *Titanic* in 1985 as 'rusticles'. These are agglomerations of corrosion products that tend to flow downwards from their source and to change in appearance over time as their corrosion status changes.

By accessing the inside of the pressure at low water or mid tide via existing holes in the aft casing and along a forward port side completely eroded at the inter-tidal, as described above, the pressure chamber's internal features were further recorded. A covering of oysters and the ever-present layer of uneven concretion on the internal frames, stays and plating precluded all bar a useful approximation however. A small hatch allowing access to the pressure chamber from inside the working chamber was located in the port side of the conning tower. Evidence of piping and its flange was found on the starboard side of the tower and this appears to be associated with an internal cock allowing high pressure air from the pressure chamber to the working chamber. Concretions, oyster growth and more severely swell effects proved a severe deterrent to accurate recording on a number of days, rendering all measurement an approximation. Nonetheless as a result of the recording conducted by Mr Croteau in 2004 and 2006, assisted by numerous others including the author, and given the quality of his work and sketches, this could now be considered complete allowing the pressure chamber area to remain un-accessed in the future, thereby reducing any negative impact caused by crawling around in those spaces.

Figure 20: An example of Todd Croteau's working sketches.



<u>External Hull (Cast iron lower section)</u>

While the sides, where they are not buried under sand are accessible at all tidal states, at high and mid tides, flat calms are required to examine the aft and forepeaks peaks given that the swirl around them rarely allows one to maintain station. The scour pits while an asset in one sense, prevent the recorder gaining enough of a foothold to resist the seas, as indicated. With only one low tide (Day 1) exposing the lower cast iron framework coinciding with a low swell, the examination of the lower sections of the cast iron lower hull at either end remained unfinished, though LCDR Price and Mr Ho, acting under the project leaders direction were able to deploy a water jet and to examine the previously buried port side at the turn of the bilge. Photographs taken by Delgado's eco-tour teams in 2001 & 2002 indicate that at an indeterminate time before 2001, the cast iron frames forward and aft were exposed by the removal of plating. Possibly effected to remove valuable machinery and to access the interior at low water, this would render it possible to examine the frames, fastening patterns &c in detail at extreme low water spring tides, when the vessel can appear totally dry on the starboard side and in other areas bar the scour pits at the bow and stern. This opportunity is yet to present itself however. At high water, or mid tide where there was also a very low swell and good underwater visibility an opportunity to closely examine these features could have again presented itself. Unfortunately this did not occur in the 2006 season due to the poor visibility and water movement. Thus this avenue of inquiry remains incomplete. It is an essential work however, if only to ascertain how access was gained to the fore and aft peaks and what remains of the materials salvaged in times past.

Finally in examining the interface between the submarine and the sediments in as minimal disturbance fashion as possible Price and Ho water-jetted along the port side, using a fire-pump system developed by the author and mounted on sandbags and timber on the conning tower. Satisfied that, unlike the stern of the SS *Xantho* (1872) which was found to be firmly fixed to an underlying stratum of limestone reef by two pillars of limestone (McCarthy, 2000: 144), the *Sub Marine Explorer* was not affixed to the seabed or its layer of small granitic 'cobbles', they ceased the test.

<u>The ballast tanks</u>

One of these was examined aft on the port side, but in the prevailing conditions few details were evident, bar the photo-recording of a very well preserved brass valve designed to allow the entry and egress of water from the chamber. Three are shown on the starboard side of the contemporary drawings and in modern submarines they would have had the effect of a 'kingston valve'. A small section of the recess designed to take cast iron plating for the plating of the tanks was also visible. In one of Delgado's 2002/2004 pictures taken at extreme low water holes are visible along the recess. These are for rivets and their uniform appearance tends to belie thoughts that the plates were removed in a gross fashion e.g. with explosives to access the machinery and metals in the interior.

<u>The working chamber</u>

Having entered the vessel at high and low water and at mid tide, and bearing in mind the acknowledged in-efficiencies of working in a submerged environment when an alternative is available, it is evident that the ideal time for documentation of the interior of this submarine is low water spring tide when there is no water forward and little aft. Because waves pulse in an out of the vessel at mid to high water, the ideal time would be at low water spring tide with low swell and calm seas. Mid tide is very difficult in all bar calm seas. The next ideal is at high water when the vessel is completely inundated, but excellent underwater visibility is needed with few, if any particles in the water column able to cause problems with flash photography.

Though Delgado and Croteau had produced a very good record of the central valve controls at the 'con' i.e. the control position immediately beneath the conning tower inner hatch in 2004, there remained much to be done in locating, examining and recording the cocks, taps and piping joining the pressure chamber to the working chamber and ballast tanks. Details of the thrust block, stern tube, hatches, steering mechanism and ballast tank operations were also required. This proved especially so as Delgado had shown in 2004 that contemporary plans of the vessel were of it in an as-yet-unfinished state, with many departures from the record produced by Wood.

In 2006, while spending many hours inside, sometimes immersed at high water and most often at low or mid tide, often in very difficult and turbulent conditions, Delgado successfully identified a number of features. Assisted by Croteau and this author, lines of double riveting were found joining the wrought iron strakes in upper portions of the working chamber and also joining the cast iron lower hull at the 'four foot line' as it was described in contemporary accounts. A line of pulleys attached to the interior port and starboard walls of the working chamber were evidently for a wire-operated steering mechanism. This rendered a recessed ratchet system to port and starboard of the 'con' position that had earlier considered to have been for rod operated tiller arms more likely to be for the operation of ballast tanks' kingston valves. Despite many further attempts to examine and record these features, this issue was not able to resolved due to the twin forces of poor visibility and turbulence in side the hull.

It also became evident in the examination of the fittings, pipes, cocks and apertures in the inner hull linking the pressure chamber with the working chamber and ballast tanks that while some remained, others had been removed. Nonetheless Delgado and Croteau were able to provide a record enabling them to begin accounting for the various systems on board. Their hypotheses were the subject of many discussions.
While examining the sediments in the working chamber forward Delgado found a large water worn rock weighing c. 5 kilos at least, that appears somehow to have worked its way into the vessel, begging the question whether the floor was intact forward as first thought.

Figure 21: J.P. Delgado with a rock found inside the submarine. View through the missing viewing port. M.McCarthy.

Perhaps the removal of the outer plating visible in low water spring tide photos of the forepeak may be an external manifestation of similar damage to that seen aft. There, as indicated earlier, is a gaping hole in the plating. This is evident on both port and starboard sides and with a little excavation of the overburden and rocks it was seen to extend down to the original floor of the vessel. In good conditions divers could enter and exit through either gap. As there was no attempt to waterjet inside there was no opportunity to examine the floors or hatches by any but a light hand-fanning. A raised flange running across the vessel aft, rubber (gutta percha?) gasket material and what appeared as a concreted raised plate may have been some indication of one of the hatches that allowed divers entry and exit while the submarine was suspended in the water column, or allowed the operators to access the seabed when the vessel was in contact with it.
Having not had a repeat of the favourable conditions presented to the investigators on Day 1, the team were not able to identify the purpose of all pipes, cocks, apertures and internal

features or to resolve all the issues relating to their existence. The difficulties experienced, as the wave-effects became more evident, attest to the need to keep access to the interior to a minimum.

Missing for and aft, and only visible in photographs taken at extreme low tide on Delgado's second visit is evidence that plates have been removed from both the bow and stern in order to facilitate access to the inner chambers. This would have required either explosives to fracture the plate, or drills to remove the rivets. The relatively neat appearance of the frames to which the plates were fixed, tends to suggest the latter. Further as Delgado records that the submarine entered modern Pearl Islands folklore as a 'killer submarine' part of a Japanese plot to poison the local pearl fishery, it may be that the Panamanians would have had little to do with it

While this could have occurred any between late 1869 and the advent of Delgado's first eco-tour, indications are that it occurred many years before the latter event. Casting back to comments about the Japanese submarine and Japanese activities worldwide in the pearl fisheries and in 1930s salvage of accessible vessel for scrap metals, therein lies a clue (One well-known example is *SMS Emden* in the Cocos Keeling Islands). Equally it could have been Panamanian pescadores (fishermen), who could not have missed seeing the vessel in the intertidal at Isla San Telmo, but against that they may not have had the tools required (see following). Clearly an oral history program amongst the remaining pearl fishers in respect of their knowledge of the submarine is indicated

b) To document the submarine's corrosion status and its physical strength.

Though this author facilitated the study of the status of an iron wreck via the predisturbance analysis of the SS *Xantho* in 1983 (Beegle, C.J., MacLeod, I.D. & North, N.A., 1983; McCarthy, 2000) and has facilited many other in the ensuing years, his expertise in electrochemistry and corrosion studies is limited to all bar the facilitation process itself. To that end, in the lead up phases advice as given to the project leader on personnel and expertise required for the studies at *Sub Marine Explorer*. Having obtained that expertise, in the 2006 Season the author provided assistance to Prof Don Johnson and Mr Larry Murphy the two corrosion specialists present. This took the form of photography, tending cables, posing questions pertinent to their work and subsequent report, seeking elucidation of features such as 'rusticles' &c &c. The methods used by Johnson and Murphy appeared state-of-the-art, with some innovations new to the author such as the use of cabling to allow remote monitoring of ECorr, Ph. &c over and the application of inert epoxy to, not only obtain a suitable 'ground', but also to ameliorate the effects of drilling and taking samples. Their report refers and it will include the results of this phase. Suffice it to note that they have conducted numerous similar studies together in times past (e.g. at USS *Arizona* and the Ellis Island Ferry) and independently at other sites. Murphy and Johnson were (with the author) also part of the expert team gathered to consider the best means of managing the Confederate submarine *H.L. Hunley* in 2000? They will be discussing their data with their colleague the WA Museum's corrosion specialists, Dr Ian MacLeod and at the instigation of the author with Ms Vicki Richards another of the Museum's conservation scientists. She also specializes in in-situ preservation of endangered sites.

It is pertinent to observe from the point-of-view of an experienced maritime archaeologist, often accessing the sort of expertise provided by specialists like Murphy and Johnson that to the eye and hand the submarine appeared surprisingly strong indeed. Some of the edges of the upper surface of the wrought iron pressure hull did appear some what fragile, however, and occasionally investigators and visitors needed be warned of the possibility of dislodging

corroded edges in the holes being used for entry. On two occasions this did occur. Further to the impression of strength, on the last day, in an attempt to take cast iron samples from the floor inside the wreck for Johnson, Murphy and their colleagues to study, the project leader found himself unable to dislodge one.
Without reference to Murphy and Johnson's analyses, it appears to the eye that the main short term threat to the submarine lies in the danger of collapse of the pressure chamber on the seaward side as a result of the usual natural forces.

Figure 22: The gap in the hull on the port (seaward side), recorded by J.P. Delgado prior to the 2004 fieldwork.

2006 AIM: To provide stakeholders with a detailed assessment of the remains such that they might be able to obtain the funds to preserve it and if they wish to provide it with a safer environment, or even to conserve it

Overview: The various reports by Johnson, Murphy, Croteau, Ho, Price, after 2006 and their predecessors in 2004 will attend to this aim. These are many facets to this as will be seen in each report. The majority will be technical in flavour, providing the reader with answers from a materials science, logistical and hydrographical perspective.
What follows cannot be considered scientific in nature, more it builds on from the author's experience and understandings in the fields of iron, steel and steamship archaeology, museology, exhibition design, wreck access and site interpretation. It also comes from the perspective of one having led the SS *Xantho* program (albeit often from the rear in some phases e.g. the cutting and lift, conservation and disassembly) from its inception at the pre-

disturbance phases 1983 through to its recovery, deconcretion, conservation, disassembly and re-assembly in the public gallery after over two decades. In the intervening period there have been of necessity, hundreds of experts, practitioners and volunteers involved. advisory committees, museum boards, conservators and directors have come and gone, but continuity has been maintained through the author's leadership. What follows is presented in that context.

<u>SubMarine Explorer is at risk from natural and human effects</u>. While the eye and hand alone affirm that the wreck is strong, it is evident that outer hull on the port (seaward) side will collapse down and onto the ballast and working chambers. This will be as a slow but inevitable result of the usual forces at play 'between wind and wave', or by a catastrophic impact with a large log rolling in a heavy swell.
The very act of identifying its importance has increased the risk of collapse and damage, more people will want to see it, more will want to enter it. Some like souvenir hunters and/or the Panama salvage agent mentioned above might want to remove materials from it.

The options at *Sub Marine Explorer*

<u>The possible solutions</u> could be considered short, medium and long term and low, middle and high budget. They can vary from a '<u>do nothing</u>' and allow it to disintegrate approach, to increasingly expensive and long term <u>remediation</u> programs. Either way all should be preceded by the placement of appropriate signage and interpretation materials nearby stressing the importance of the wreck and urging caution in all visitations. These will need to be maintained on a regular basis (McCarthy & Garratt, 1998).

The possible remedial actions range from the simple and relatively cheap to the complex an expensive such as the <u>**short term**</u> closing of access holes, welding supports to replace those lost, and applying anodes. As proposed when there was an enhanced risk of diver injury during access to a recently scuttled warship off the coast of Western Australia some years ago, in any event where diver access is to continue, weld-mesh could be fixed to the entry and exit holes on the submarine secured by welding and/or by graphite filled padlocks. These could be fixed in such a way and in places where they do not impinge on the visual aspect of the wreck, nor do they reduce the visitor experience in any bar the internal entry elements. There is an imperative for this, for present proven safety hazards and accelerated deterioration caused by uncontrolled access to the interior will be thereby reduced. The ramifications of introducing a different ferrous metal to the submarine's electrochemical environment would need be examined beforehand, if this step were to be considered, however. Regular monitoring and maintenance would be required.
In the <u>**mid term**</u> and if there were <u>access to suitable funds</u>, the vessel could also be stabilized, raised and taken into Panama and then sunk in a <u>safe, secure environment in Panama waters,</u> preferably in waters only accessible with a permit, less saline and turbulent compared with those in which it lies presently, thereby commencing an in-water conservation regime. Again anodes could be attached as has prove successful in many other instances and diver access can be both controlled and even enhanced in a touristic sense once a safe historic dive experience is developed and maintained..
<u>A mid-term solution</u> could also be the vessel's removal into deeper water offshore, with some of the protective elements above applied, all again with appropriate signage and or buoyage. It would still be an object of great interest, though non-divers would not benefit. The effects of

the change form the intertidal to a fully immersed environment would need be examined beforehand and the pros and cons weighed up accordingly.

If there is a desire to save the submarine for the future **(long term),** where there are limited funds, but plenty of labour and if public/tourist access is to be given a low priority then the notion of providing a strong rock groyne to seaward of the wreck and filling it with porous local beach sand landfill, could if properly constructed serve to see the wreck encased in damp sediments, at the existing water table, free of the cyclic effects of wave, tide and human intervention. This approach has been mooted at a number of 'at risk' sites in Western Australia of late. There is also a consideration that violent storms, even across the short space of open water in the channel opposite with a result 'short fetch' could dislodge the barrier and harm the vessel however. This eventuality would need be factored in to all deliberations.

The vessel could be raised, transported and placed in a pre-positioned and readied conservation tank housed in a suitable public environment, where deconcretion, desalination and conservation could commence in accordance with modern best-practice. In respect of the lessons of the *SS Xantho, HL Hunley, USS Monitor* and *Holland 1* there will clearly be a need to commit to the provision of conservation facilities and staff before any move is made. Commitment need also be contingent the equally important realization that decades of work and personal commitment is required.

In taking decades to complete, one of the fundamental problems iron, steel and steamship programs have and will continue to have where engines and vessels are raised is the question of continuity, an element that should be provided by the chief archaeologist and if possible the senior conservator.

Finally, even when considered along with the other maritime heritage sites in the region, *Sub Marine Explorer* is undeniably one of Panama's greatest treasures. Certainly when one considers the UNESCO Convention on the underwater cultural heritage— to which Panama is the first signatory—the future management of SubMarine Explorer will need be in accordance with its strictures. The author's paper entitled *The submarine as an archaeological site* refers (McCarthy, 1998).

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Figure 23: Bert Ho, Jim Dertien, Josh Price and Larry Murphy at San Lorenzo, overlooking the mouth of the Rio Chagres on the Atlantic coast. M. McCarthy.

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