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The Ship as Laboratory: Making Space for Field Science at Sea

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Abstract. Expanding upon the model of vessels of exploration as scientific instruments first proposed by Richard Sorrenson, this essay examines the changing nature of the ship as scientific space on expedition vessels during the late nineteenth century. Particular attention is paid to the expedition of *H.M.S. Challenger* (1872–1876) as a turning point in the design of shipboard spaces that established a place for scientists at sea and gave scientific legitimacy to the new science of oceanography. There was a progressive development in research vessel design from ''ship as instrument'' to ''ship as laboratory'' and changing spatial practices aboard these vessels were paralleled by changes in shipboard culture. I suggest that the ''ship as laboratory'' has now in turn been supplanted by a new model, the ''ship as invisible technician'', as oceanographic research vessels deploy remote-sensing equipment and gather data that are no longer analyzed on board.

Keywords: Oceanography, Marine laboratory, Research vessels, Marine environment, *H.M.S. Challenger*, U.S. Exploring Expedition, U.S. Fish Commission, Telepresence

Introduction

Because oceanography encompasses several disciplines, including chemistry, biology, physics, and geology, historians have found it difficult to chart the history of such a chimera and have emphasized its distinctiveness from other field sciences. As Eric Mills has stated, oceanography ''does not lend itself to neat formulations, scientific or historical'' (Mills, 1993a, p. 1).[1] Early histories of oceanography, whether written for professional oceanographers or lay publics, dealt with this problem by categorizing oceanographic science into clearly defined periods which paralleled the major national expeditionary voyages of the nineteenth and twentieth centuries.[2] Histories of field science too have treated oceanography as a case apart, requiring special analytical attention. In their introduction to the 1996 special issue of *Osiris* entitled *Science in the Field*, Robert Kohler and Henrika Kuklick write:

> Even more than geology and geography, oceanography was created by imperialism […] [I]t was intended to provide navies and commercial fleets with vital intelligence […] Seagoing scientists were often accommodated on the vessels of their nations' navies and were obliged to fashion physical and social niches within the distinctive maritime culture of ships. They appropriated both the instruments and the work organization of naval operations […] Oceanography exemplifies the formative linkage between knowledge and power. It was an offspring of Western expansionism, could hardly have existed without it, and persists in large part thanks to military patronage (Kohler and Kuklick, 1996, p. 9).

These assertions may reflect a bias shaped by naval support for oceanographic research in the United States during World War II and later during the Cold War.[3] Certainly nineteenth-century, land-based exploration was closely tied to national military interests, while the link

[1] Mills dates the origin of the history of oceanography as a recognized sub-discipline of the history of science to the First International Congress of History of Oceanography held in Monaco in December 1966. See Mills, 1993b, p. 5.

[2] See for example Wüst, 1964. While acknowledging that progress in oceanography was not continuous, Wüst used three criteria to delineate distinctive ''eras'' in its development: new scientific results and improved interpretation of data, improvement of instruments and methods, and development of theory. Wüst's divisions can still be found in contemporary university physical oceanography textbooks. See Stewart, 2005. As former chief scientist aboard one of the last national oceanographic ventures, the German *Meteor* expedition (1925–1927), Wüst's inclination towards periodization may have been shaped by a desire to see his own work as part of a progressive history of investigation.

[3] Since the end of the Cold War, the National Science Foundation (NSF) has become a more important source of funding for oceanographic research than the Office of Naval Research (ONR).

between intelligence gathering and field collecting has been well established.[4] But advances in oceanographic instrumentation were not solely appropriated from the navy; they were, and continue to be, driven by private industry.[5] Furthermore, the work organization of a modern research vessel today little resembles that of a modern naval vessel. As a field science, Eric Mills has argued, oceanography may be exceptional only for depending "on the combination of ships, expeditions and instruments" (Mills, 1993b, p. 7). In fact, the history of oceanography may tell us much about the nature of fieldwork in all science. How do scientists transport knowledge? How is scientific work in the field legitimated? What kinds of social reorganization are required by scientific fieldwork?

There is an important history to be examined and it is the history of a field science – part of a complex "mosaic" of social and scientific changes that gave new cohesion to a hitherto fragmented collection of marine sciences.[6] My aim here is to explore questions surrounding the changing usages of shipboard space, to offer a description of how expedition vessels became "floating laboratories" and, taking distance from earlier approaches to the history of oceanography, to show – by examining the ways in which shipboard space has been appropriated for scientific work – that these changes do not lend themselves to simple periodization.

The Ship as Instrument

In his influential article "The Ship as a Scientific Instrument in the Eighteenth Century," Richard Sorrenson re-imagines the vessels of the Age of Exploration as tools of investigation – not merely vehicles of transport, but instruments used to obtain geographical information.[7] New geographical data were gathered as the ship traced the contours of a foreign shore while charting its relative positions. As Sorrenson explains: "on a map, the ship's track is a representation of the probing course of the instrument through the sea, whereas the coastal outlines are the mark

[4] For a description of French naturalists' espionage see Burkhardt, 2001. For an example of exploration linked to military interests see Goetzmann, 1986. On Meteorology see Fleming, 1990. See also footnote 29.

[5] See for example McConnell, 1982, Chap. 5. Modern advances in the field of underwater robotics have been closely tied to the offshore oil industry.

[6] "There has not been a neat, linear, logical development of oceanography as a science […] we suggest a far more subtle (and more confusing) suite of social and scientific developments, a mosaic of change […]" Mills, 1993a, p. 1.

[7] Sorrenson, 1996.

of that instrument's interaction with the coasts under investigation.''[8] While maps made aboard ship only served as representations of geographic realities, the ship as instrument gathered information in its course through real space in the field. Thus, ''[ships] mediated the complex interplay between representation and reality that lies at the heart of eighteenth-century geography.'' Sorrenson insists that the eighteenth century vessel was never ''*merely* a vehicle''. This is a key point if we are to see the difference between ship ''as instrument'' and ship as ''platform,'' a term often used by oceanographers to describe research vessels today. While modern research vessels transport scientific instruments chosen for specific research projects into the field where *they* are deployed, the eighteenth century vessel was both a platform for research *and* an instrument used for surveying. This is not to say that the eighteenth century vessel of exploration, as distinct from its users, had agency. It does suggest, however, that a ship used as an instrument would have to meet certain specifications to serve that purpose. Only vessels of a particular design could be used for surveying.[9] Modifications, or resistance to modification, reveal the relative status of a ship's users insofar as design for one usage took precedence over other possibilities.

The vessels Sorrenson describes, used by early British and French exploring expeditions, were commissioned for the primary purpose of charting the seas and discovering new territories. Naturalists accompanied these voyages, yet the work of natural history was subordinated to the work of mapping and territorial exploration. Vessels were chosen and modified to meet the requirements of naval priorities. And it is to these tasks that Sorrenson's model is most applicable. For example, the surveying method used by the U.S. Exploring Expedition (1838–1842), termed a ''running Survey,'' employed gunfire to determine 'base line' distances between ships, and took horizontal angular measurements by sextant to fix geographic positions (Figure 1). By observing the time between the flash and report of gunfire, officers could measure angles between the ships and the shore in order to calculate distances. By repeating the procedure as the ships moved around Pacific islands, triangulations were plotted and the contours of the islands charted (Ehrenberg et al., 1985, p. 169). Here, then, the essential characteristics of the naval vessel – its armaments – defined scientific practice, just as imperial context defined the objects of scientific research.

However, exploring expeditions were not mounted solely for the purpose of surveying and charting; and naturalists assigned to these

[8] Sorrenson, 1996, p. 229.

[9] For example allowing surveying in shallow coastal waters. Sorrenson, 1996, p. 226.

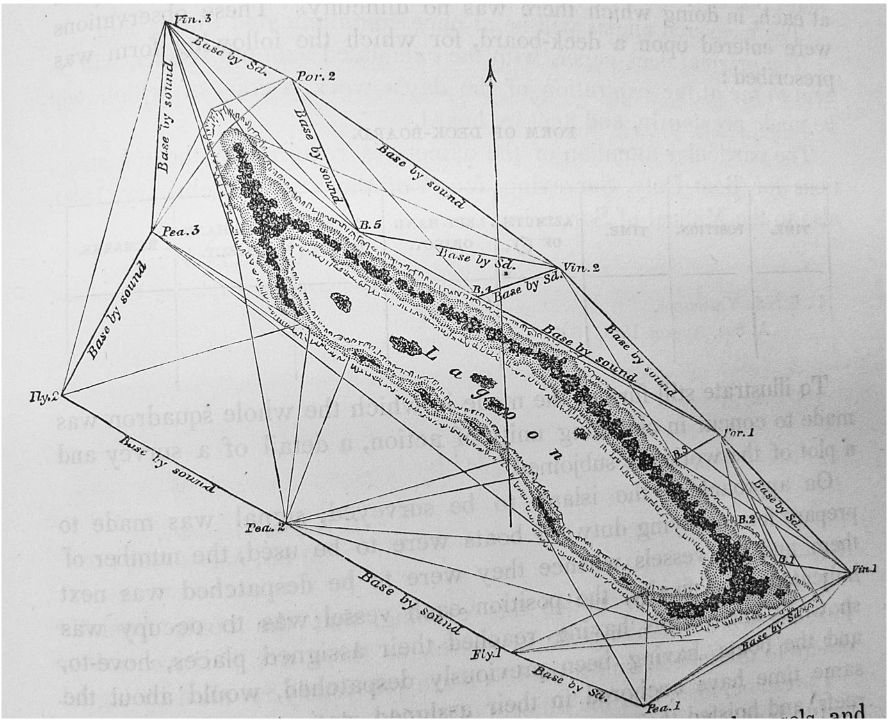

Figure 1. Diagram showing the method for surveying an island in the Paumotu group by the U.S. Exploring Expedition. This survey was completed in 3 h and 35 min (Wilkes, 1845, p. 452). Special Collections, University of Washington Library

voyages sought to turn the ship and its spaces to other scientific uses. The journal entry of U.S. Exploring Expedition naturalist Titian Peale, expressing frustration that survey work was being prioritized over natural history collection, is suggestive:

> Reached the island of ''Raraka,'' […] *No Naturalists were permitted to land*. The men collected a few shells differing from those on the other islands we have visited, but its other zoological productions are left for future and more fortunate Naturalists. […] [A] survey is made, *nothing more* is requisite […] *What was a Scientific Corps sent for?* (Poesch, 1961, pp. 153–154).

Margaret Deacon's study of early marine science suggests that the value and quantity of scientific work accomplished during expeditions was largely determined by the degree to which scientific work was valued by the captain and officers (Deacon, 1971, p. 192). However, there is ample evidence that as the work of naturalists was accorded enhanced priority, and shipboard space was redesigned to accommodate them, social relations between scientists, officers, and crew altered as well. Attention to the evolution of scientific space aboard expedition vessels thus throws light on the modification of mission priorities, on the changing shipboard status of naturalists, and on tactics serving to legitimatize a new science at sea.

Sorrenson's model, casting vessels of exploration as instruments for creating knowledge, draws our attention to these ships as spaces for doing science. Though he focused on ships of the eighteenth century, his attention to the ship as more than a vehicle of transport can be extended to throw light on the evolution of shipboard scientific space in later periods.

The Challenger Expedition

The voyage of *H.M.S. Challenger* (1872–1876), commanded by naval Captain George Nares, and undertaken at the prompting of the expedition's chief scientist, Scottish naturalist Charles Wyville Thomson, with backing from the Royal Society, is frequently cited as the event that gave rise to modern oceanography (Weir, 2001, p. 3).[10] This pioneering accommodation of shipboard science by modifications of vessel space changed the social relations of scientists and crew and was pivotal in paving the way towards the development of the modern oceanographic research vessel or "floating laboratory."

The eighteenth-century "ship as instrument" in which the world external to the vessel was made to yield knowledge by means of the ship's passage, was supplemented in the nineteenth century by the "ship as laboratory," where elements of the external world were made to yield knowledge by being severed from the field and brought into the scientific spaces of the vessel. In the late nineteenth and early twentieth centuries, ships also came to serve as mobile marine observatories, extending the work of coastal marine stations and allowing the observation of magnetic or meteorological conditions at sea.[11] In our own time, oceanographic research vessels can, I believe, be conceived as "invisible technicians," their remote-sensing equipment being deployed to gather data that is no longer analyzed aboard but instead transferred

[10] John Murray, a member of *Challenger*'s scientific corps, wrote: "[*Challenger*] circumnavigated the world, traversed the great oceans in many directions, made observations in nearly all departments of the physical and biological sciences, and laid down the broad general foundations of the recent science of oceanography." Hjort and Murray, 1912, p. 11.

[11] *Carnegie* (1909–1929) was used for observations of terrestrial magnetism.

to land-based research centers.[12] These models are not mutually exclusive. While the modern research vessel, unlike any eighteenth-century ship, might sometimes serve as an "invisible technician," for many scientists oceanographic vessels retain earlier usages: as instrument, laboratory, and observatory.

"The Field" and the Extension of the Laboratory

Sorrenson's model of exploration vessels as instruments draws upon Bruno Latour's examination of the processes by which knowledge is moved from peripheries to metropolitan centers (Latour, 1987, p. 220). Latour draws attention to the transport of scientific knowledge from the field to what he terms "centers of calculation," focusing on the necessity of gathering information in ways that allow its transport, and favor its acceptance as valid in places where scientific results are confirmed and publicized. For our purposes, it is worth noting that in the nineteenth century the laboratory (which was of course land-based) was widely perceived as the space producing authoritative science.[13]

"The field," as a type of space in which scientific knowledge is produced, has only recently come under serious investigation. Historians of science have urged that field practices be analyzed as "practices of place," with scientists forced to adapt procedures to particular environments (Kohler, 2002). Fieldwork may not allow the particular exclusions provided by the metropolitan laboratory, and may require the assemblage and cooperation of people who would not be part of the same work world outside the field (Kohler and Kuklick, 1996, p. 2). The ocean was a field environment where naturalists, officers and crew, all of whom maintained distinctive and exclusionary social worlds, were forced into new associations.

Robert Kohler, building on the work of Owen Hannaway and Steven Shapin, recognized that one of the cultural practices western scientists brought to the field was the conception of the "laboratory." As Kohler explains: "laboratory and field are different cultural terrains, to be sure, but they are contiguous, and there is a steady traffic across the border; and field scientists regularly mix and match lab and field methods" (Kohler, 2002, p. 189). Kohler raises the question: how is an audience not present in the field (a place with no cultural standing as a space for

[12] I am applying to a new context the concept developed by Steven Shapin with reference to Boyle's seventeenth-century laboratory. Shapin, 1989.

[13] Usage of the word "laboratory" increases dramatically after the mid nineteenth century. See google Ngram Viewer, search term "laboratory."

the production of scientific knowledge) to be persuaded that the knowledge produced there is as valid as that produced in a laboratory? Kohler argues that field scientists were compelled to bring laboratory practices into the field because they carried the authority that had become associated with laboratory spaces in metropolitan centers. Kohler's insight helps elucidate the introduction of laboratory space on expedition vessels.

The Ship as Laboratory

Marine scientists have long considered vessels bearing scientific instrumentation as scientific spaces. As early as 1855, Matthew Fontaine Maury, the so-called "father" of modern oceanography, advocating the use of a standardized system of wind and current observation charts, declared: "every ship that navigates the high seas, with these charts and blank logs on board, may henceforth be regarded as a floating observatory, a temple of science" (Maury, 1883, p. vii). Yet, surprisingly, the equation between laboratories and research vessels has until recently received little attention from historians. A notable exception is the work of Anne-Flore Laloë. Building upon the work of Sorrenson, Laloë has shown that the story of *Bathybius haeckelii*, the chemical precipitate mistakenly identified as a marine organism by Thomas Henry Huxley, reveals the ways in which nineteenth-century vessels served as "spaces of science." Laloë writes: "[b]oth the space of the ship and the science performed aboard the ship altered the concept of the ship, indeed reinventing it as more akin to that of the laboratory where sciences and practices interact in deeply prescriptive ways" (Laloë, 2012, p. 129). Another example is Ralph Kingston's case study of Nicolas Baudin's 1800 expedition. Dubbing Baudin's vessel a "floating laboratory," Kingston describes how naturalists competed with one another for research resources both during and after the voyage, and he shows how science on board ship was shaped by social dynamics similar to those of a laboratory. But though employing the phrase "floating laboratory," Kingston does not focus on the history of its adoption by marine scientists, or upon the development of shipboard scientific space (Kingston, 2007).[14] What did the categorization of some shipboard space as

[14] The primary mission of the Baudin Expedition (1800–1803), which consisted of two vessels, was to map the coast of Australia. Upon departure the expedition included a complement of 23 scientists and artists. The marine work was carried out by naturalist François Péron (1775–1810).

laboratory space imply for working relationships on board vessels? The answers throw light on the origins of modern oceanography in the late 1800s, a period in which, it is important to note, the term "laboratory" was gaining general currency.

"As No Ship of Any Nation was Ever Equipped Before"

When the naturalist Sir Joseph Banks, who accompanied Captain James Cook on his first voyage, had the vessel modified prior to its second voyage in ways calculated to better serve his own research agenda, Cook refused to embark, contending that the vessel was top heavy. Cook prevailed, with the backing of the Admiralty, and the ship was refitted to his specifications while Banks withdrew from the expedition (Sorrenson, 1996, p. 227).[15]

Naturalists regularly competed with officers over space needed to work and store specimens. The French naturalist Adelbert Von Chamisso wrote in his journal during a Russian voyage of exploration in 1815:

> My berth and three of the drawers under it comprise the only space on the ship that belongs to me. […] In the narrow room of the cabin four people sleep, six live, and seven eat. […] In the intervals [between meals] the artist takes up two sides of the table with his drawing board, the third side belongs to the officers, and only when they leave it unoccupied may the others compete for its use. If one wishes to write or engage in some other occupation […] he must wait and seize the scarce fleeting moments, then utilize them greedily. But I can't work that way (Chamisso, 1986, p. 21).

The conchologist Joseph Couthouy, who accompanied the United States Exploring Expedition (1842–1844), found competition over space a problem when trying to secure storage for his sizeable collection of coral. As Couthouy came out of his cabin one morning, he was confronted by the expedition's commander, Lieutenant Charles Wilkes, who barked that he "would not have the whole ship lumbered up with coral[.]" He claimed it gave off an unpleasant smell and "endangered the health of the crew by producing malaria." When Couthouy protested that previous expeditions had collected as many specimens, and that to

[15] See also Beaglehole, 1974, p. 293. As Beaglehole explains: [Cook's ship] "was not chosen as a passenger ship or a floating laboratory or as an artist's studio, but precisely because she was what she was – a soundly-built collier, with adequate room for her crew and her stores."

do less would reflect badly on the scientific mission, Wilkes responded that he "did not care a damn for what had been previously done" and forbade Couthouy to store his specimens anywhere below deck (Musselman, 1999, p. 86). Powerless in the face of naval command, Couthouy wrote in his journal: "of course there is no reply to this" (Stanton, 1975, p. 121). Couthouy's experience was not unique for scientists at sea during the nineteenth century. What measures could naturalists take to surmount these sorts of obstacles and secure greater control over their working environment?

At the annual meeting of the Royal Society on November 30th, 1876, Joseph Dalton Hooker, the society's president, a celebrated botanist and veteran of five expeditions, addressed the assembled members (Hooker, 1876, p. 337). The society had an unusual achievement to celebrate that year: the return of *H.M.S. Challenger* from its four-year expeditionary voyage. The first expedition to be devoted primarily to marine exploration and sounding, *H.M.S. Challenger* had circumnavigated the globe, travelling nearly 70,000 nautical miles. The Royal Society had selected the ship's scientific crew, while the ship itself, a steam corvette, was provided by the Admiralty, who modified it to suit its scientific mission. Guns were removed and laboratory and living spaces for the civilian corps of scientists constructed in their place (Deacon, 1971, p. 335).[16] In the words of the expedition's chief scientist, Charles Wyville Thomson, the H.M.S. *Challenger* had been equipped for scientific research "as no ship of any nation was ever equipped before" (Thomson, 1873, Preface).[17]

Certainly Hooker recognized the scale of the achievement as he addressed his audience: "the most important scientific incident of the year is unquestionably the return of the 'Challenger' from her voyage round the world and three years and a half of persevering exploration [...] It is impossible for any one who has not taken an active part both in the

[16] As a naval vessel, *Challenger* participated in several military actions before being refitted for dredging: an unsuccessful intervention in Mexico and a punitive shelling of the Fijian Island of Rewa in 1860 (20 years after the US. Exploring Expedition carried out a comparable punitive military action in Fiji). The shipboard modifications were satirized in a humorous poem published in Punch magazine: "broadside guns have made room for ship batteries magnetic; Apparatus turns out ammunition; From main-deck to ground-tier I'm a peripatetic, Polytechnic marine exhibition." Unknown Author, 1872, p. 255.

[17] Even Z. L. Tanner, captain of the U.S. Fish Commission Steamer, *Albatross*, the first vessel specifically constructed for oceanographic research, later wrote of *Challenger*: "[She] was the largest and best-appointed vessel ever employed in deep-sea exploration [...]" Tanner, 1897, p. 345.

organization and conduct of such an expedition as this of the 'Challenger,' to estimate the number and value of the factors that have mainly contributed to its success.''[18]

There was, however, an element that only a veteran explorer could truly appreciate. ''Essential to complete success as all these requirements were,'' Hooker continued, ''they would have been wholly unavailing but for another […] and that is, concord. The trials of social life on shipboard are proverbial; and, according to the early traditions of the naval service, a philosopher afloat used to be considered as unlucky a shipmate as a cat or a corpse. In this case, thanks to the admirable spirit in which the Commander and his executive worked with the head of the Scientific Staff and his subordinates, I am informed that harmony reigned on board throughout the voyage'' (Hooker, 1876, p. 351).

To the modern reader it might seem odd that Hooker highlighted this concord between what were then often called ''natural philosophers'' and crew. Today we might assume that scientific operations on a ship specifically commissioned for research would not suffer from lack of ''concord'' between scientists and crew or from the absence of a specific chain of authority for its scientific staff. But *Challenger* marks one of the first expeditions that left little record of having been plagued by problems reported since the time of Cook.[19] Unsurprisingly, considering the confined space of a sailing vessel, many of the conflicts between scientists and crew reported in earlier expeditions arose over uses of space.

The lower decks of a nineteenth century wooden sailing vessel were not conducive to setting up a scientific laboratory. The pitching of the ship, the cramped quarters, the varying temperature and humidity, and the danger of using any combustible chemicals under these conditions might dissuade anyone from attempting to build a space suitable for work with microscopes and chemicals. However, that is precisely what the Royal Society set out to do when it provided guidelines for refitting *Challenger*. There were of course major problems to surmount. As Thomson noted in the voyage narrative: ''ship-life is generally unfavorable to steady work, and during a great part of the time the motion of the ship makes it impossible to have even the limited space at one's command in his cabin'' (Thomson, 1878, p. x).

[18] As H. Charnock has noted, ''the *Challenger* expedition was a huge undertaking, […] possible only in the prosperity of Victorian England'' Charnock, 1973, p. 4.

[19] Eric Mills writes of the *Challenger* expedition: ''its success provided a model for future expeditions and a sense of community, an esprit de corps, that still has a significant influence on oceanography […]'' Mills, 1983, p. 19.

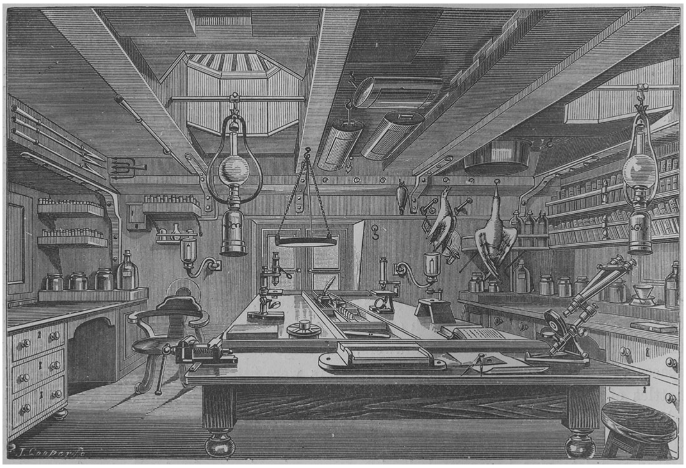

Figure 2. Zoological laboratory on the main deck of *Challenger* (Thomson, 1878, p. 4). Special Collections & Archives, UC San Diego Library

Thomson provided lengthy and detailed descriptions of the scientific workspaces aboard *Challenger*, almost in defiance of the assumption that scientific work on board a vessel would not be feasible (Figures 2 and 3).

> The Particular build of the 'Challenger' gives her an immense advantage for her present purpose […] Sixteen of the […] guns have been removed, and the main-deck is almost entirely set aside for the scientific work. […] Two sets of cabins have been specifically built on the after part of the main-deck for the […] scientific work.[20]

Paying particular attention to the numerous gimbals and fasteners employed to keep scientific apparatuses upright and stable (Figure 4), Thomson described the "natural history work-room" which, he noted, was a "novel addition to the equipment of a surveying ship."

He concluded with an assurance that despite the many extra precautions required, "the operations carried on in the work-room on shipboard are […] very much the same as the ordinary routine work of a museum work-room and a physiological laboratory, […] only modified by the special nature of our work" (Thomson, 1878, pp. 15–16). In short, the work of the land-based laboratory could be conducted at sea in "much the same" way. Whatever the accuracy of Thomson's claim, it

[20] Thomson, 1878, p. 27. Helen Rozwadowski has called attention to "[t]he unprecedented step of dislodging the captain from his traditional place as lone occupant of the aft cabin[.]" Rozwadowski, 1996, p. 415.

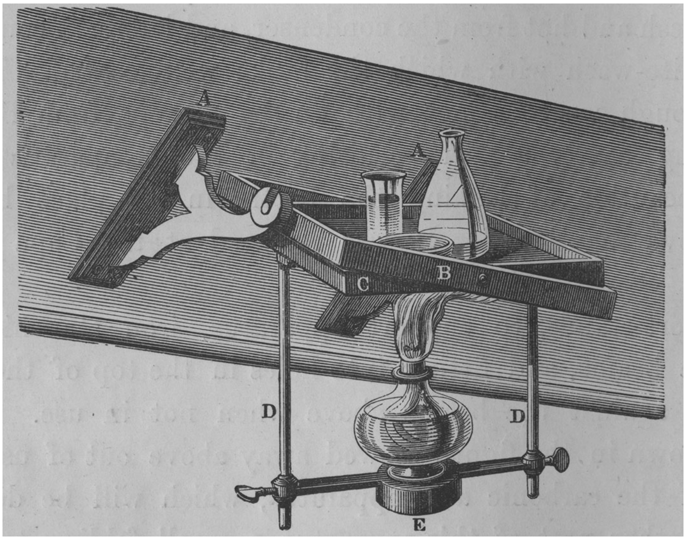

Figure 3. Sea-going sand-bath. Thomson writes of this apparatus that it "suited itself so easily to the motion of the ship, that even in very rough weather the lamp was perfectly safe as shown, and there was no danger of spilling the contents of even the flattest evaporating dish" (Tizard, 1885, p. 14). Special Collections & Archives, UC San Diego Library

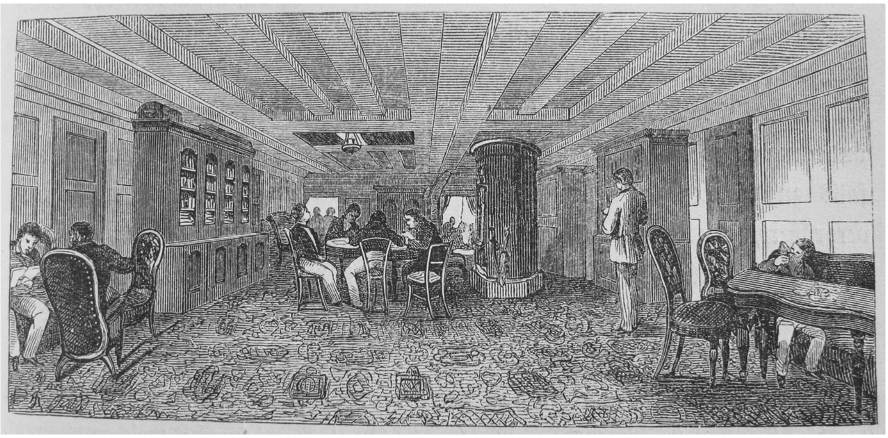

Figure 4. Converted gunroom aboard the refitted *Novara* (Scherzer, 1863, p. 4)

was in the interest of the chief scientist of the expedition to present the laboratories of *Challenger* and, by association, the knowledge produced in them, as equivalent to those of land-based science. Laboratory space, as emblematic scientific space, conferred legitimacy on both its workers and their work.

This was not the first time an expedition vessel had been refitted with spaces specifically designed for scientific work. For instance, the flagship of the U.S. Exploring Expedition had been modified to include, in addition to the ship library, a reading room to house the many scientific texts brought along for reference.[21] The commander of the expedition, Charles Wilkes, explicitly tried to reserve this space for the scientific work of the mission and to forestall its private appropriation by his officers:

> The accommodations, though not large, will […] be found to be ample, and will naturally prevent any one from appropriating its small conveniences to himself; or using its table for writing (intended for books and the facility of reference to them), as there no doubt exists sufficient room in the several apartments appropriated to the different officers for that purpose, without incommoding any one (Quoted in Skallerup, 1974, p. 189).

The Austrian frigate *Novara* provides another example of early efforts to refit naval space for science. The gunroom (the junior officers' mess room) was converted into a reading room, providing both officers and scientists with space in which to use the expedition's collection of charts and books (Figure 5). But no separate laboratory space was provided. Each member of the scientific staff was still to consider his own cabin as his private designated workspace (Organ, 1998).

A Place for Shipboard Science

In a letter to his mother dated July 15th 1873, Joseph Matkin, Steward's Assistant on *Challenger*, enthused:

> [I] had the privilege of examining some of the curiousities in the Analyzing room the other night, & was much surprised & interested by what I saw. The mud that comes up from the bottom of the sea is softer than velvet […] The wonderful Prawn was in spirits of wine in a glass jar & was almost as large as a small Lobster. He had a pair of wings folded over his back like a pigeon's. I also saw several things through a large Microscope, even more wonderful (Matkin, 1992, p. 89).

[21] As Helen Rozwadowski has argued, while ships had a long history of carrying books, scientists required larger library collections for their work, including species monographs with which to analyze and compare newly collected specimens. Rozwadowski, 2005, p. 204. The *Albatross* library contained over 400 volumes. See Tanner, 1897, p. 404.

Figure 5. The naturalists' workroom aboard *Challenger* (Tizard, 1885, p. 509). Special Collections & Archives, UC San Diego Library

Matkin's description of the "Analyzing room" stands out in sharp contrast to the impression of the work of the "scientifics" recorded thirty years earlier by Lieutenant William Reynolds of the U.S. Exploring Expedition.[22]

> The Scientifics cut up & dissect and overhaul, and use magnifying power to better see, and make drawings & paintings, and search their books, and write down learned descriptions […] and tell *us* all about the mysteries of organization, &c., &c. And they have dead & living lizards, and fish floating in alcohol, and shark jaws, & stuffed turtles, […] and many other equally interesting pieces of furniture hanging about their beds & around their state rooms – such sweet looking objects as doubtless glad scientific eyes to behold. Catch any of them in my *room* – no, no! – I'll *visit*, when I have a curiosity in that way (Reynolds, 2004, p. 13).

These two passages record two different types of workspace: the private cabin of the landlubber naturalist, and the collective workroom of the scientific crewmembers. The "analyzing room," representative of the expedition's mission, unlike the private cabin of one of the "scientifics," carried with it an aura of "privilege" to those permitted to enter. Helen Rozwadowski has argued that oceanographic research vessels of the late

[22] During the late nineteenth century, writers referring to scientists on board expedition vessels used the following terms: "philosophers," "naturalists," "scientifics," "scientists," "civilian scientific staff."

nineteenth century became sites of a new maritime culture shared by sailors and scientists (Rozwadowski, 1996, p. 410). These descriptions suggest how new uses of shipboard space were being experienced and negotiated.

But what was driving this cultural change? Historian Philip F. Rehbock notes that conditions of service in the royal navy were improving in the late nineteenth century. A career at sea was becoming attractive to middle-class men and a series of reforms instituted by the Admiralty were elevating the status of the common sailor to that of a skilled working man (Matkin, 1992, p. 11). This set the groundwork for some common acknowledgement of craft skills between men of different social classes and occupations. Skills of the crew now sometimes received explicit recognition by the scientists, while the scientific hierarchy, whose status was marked by the spaces it controlled, received marks of respect from the crew that sometimes paralleled those accorded naval officers. In reference to the common sailor, the "blue-jacket," Thomson recorded in his narrative of the *Challenger* voyage: "I must not omit to record my debt of gratitude to my friends the blue-jackets, who, greatly to their credit, treated us civilians throughout with as much respect and consideration as they did their own officers" (Thomson, 1878, p. xiii).

The scientists hoped to be accepted by the officers as equals. Thomson, exhibiting some deference to the professional knowledge of the naval officers', observed:

> [T]here are many things in Lisbon to interest "philosophers" as our naval friends call us, – not I fear from the proper feeling of respect, but rather with good-natured indulgence, because we are fond of talking vaguely about 'evolution,' and otherwise holding on to loose ropes; and because our education has been badly neglected in the matter of cringles and toggles and grummets, and other implements by means of which England holds her place among the nations (Thomson, 1878, p. 114).

This new etiquette of mutual acknowledgment was encouraged by the civilian and naval expedition leaders, chief scientist Thomson and Captain Nares. For instance, Matkin records in one of his letters that early in the voyage Thomson lectured the ship's company on the scientific objectives of the mission:

> I have been asked by the Captain to try & explain to you, as well as I am able, what is the object of our expedition & what we are doing from day to day. […] [I]t gives me pleasure so to do, for we are to be common shipmates for the next few years, & doubtless, each one has some interest in the work, & the results, if successful, will be creditable to us all (Matkin, 1992, p. 58).

The new rhetoric of mutual respect and cooperation should not be taken as evidence that frictions had been eliminated. In fact, Matkin complained that the scientists were unwilling to share information about their work with others (Matkin, 1992, p. 41). And a popular account of the *Challenger* cruise by one of its naval officers, W. J. J. Spry, describes the scientific party with a tone betraying a continued sense of his own caste, condescension toward the civilians, and determination to bend them to naval ways:

> [T]he varied incidents at sea, all tend to rouse feelings and sensations […] reserved alone for those whose business is on the great waters. To those constituting the scientific staff, the routine, especially of a man-of-war, was entirely different from that they had hitherto enjoyed on shore […] At first, etiquette and usages of naval every-day life seemed particularly vexatious and annoying; but after awhile, […] one and all perceived [….] the necessity of order (Spry, 1877, p. 41).

But there is little evidence that the dramatic episodes of conflict over space characteristic of earlier voyages (that could go so far as a captain's throwing collections overboard) continued into the late nineteenth century. A place for oceanography, and for those who pursued it, had been secured on *Challenger* (Figures 6 and 7).

A Laboratory for Social Experimentation

The confined spaces of the ship forced different types of workers, from disparate social and cultural backgrounds, into close contact with unfamiliar people and practices. It would take time for new relationships to become institutionalized and for specialized spaces to be appropriated for new practices. To return to the statements of Steward's Assistant Matkin, and Lieutenant Reynolds, there is an important difference between "microscopes" in an "analyzing room" and "interesting pieces of furniture hanging about [the scientifics'] beds & around their state rooms." Matkin was entering space consecrated to the expedition's mission, while Reynolds, visiting private apartments, was looking upon the "curiousities" possessed by their tenants. In his address to the Royal Society, President Hooker drew specific attention to the fact that *Challenger* did not have separate mess rooms. As Hooker explained: "the contrary practice […][of having a single mess on the *Challenger* expedition] has, as I am assured, been attended with the happiest results – and this not-withstanding the addition to the

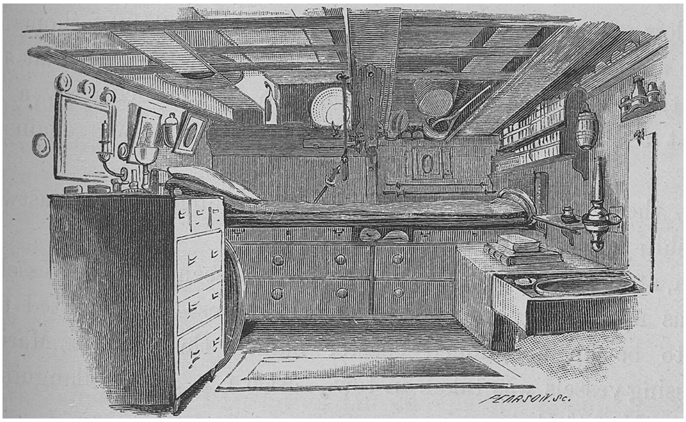

Figure 6. The cabin of naturalist Henry Moseley aboard *Challenger*. Note the lack of scientific equipment (Tizard, 1885, p. 645). Special Collections & Archives, UC San Diego Library

Figure 7. The cabin of geologist Ferdinand Hochstetter aboard Novara, showing hammers, bottles, guns, and measuring implements. State Library of New South Wales – DG*6/1 (pencil sketch by expedition artist Joseph Selleny)

mess of that dreaded element, the philosophers'' (Hooker, 1876, p. 351).[23]

[23] On a traditional naval vessel the captain dined alone in his stateroom. ''[V]arious officers dine with the captain – but only when invited to do so, for the strictest form and etiquette is observed on board of a ship of war.'' Unknown Author, 1862, p. 182.

The fact that the naval officers and the scientists were now eating together, a modification of earlier practice, is cited as an "experience" [an experiment], whose "results" would hopefully dispel enduring "prejudices." As Chief Scientist Thomson wrote in the preface to his narrative, "the somewhat critical experiment of associating a party of civilians, holding to a certain extent an independent position, with the naval staff of a man-of-war, has for once been successful" (Thomson, 1878, p. xvii). This critical experiment had been one of social organization, with the ship serving as laboratory.

There was already a long history of using the captive population of a ship's crew for experimentation. Captain Cook, after returning from his first voyage around the world, was elected to the Royal Society and awarded the prestigious Copley Medal for testing antiscorbutics on his men during the course of the voyage and publicizing the results (Cook, 1776).[24] On the Austro-Hungarian *Novara* expedition (1857–1859), one of the ship's physicians, Eduard Schwarz, who spent his time ashore collecting human crania for ethnological purposes, also conducted experiments at sea on the crew to test his theories about the causes of night blindness. Schwarz compiled data on the health of the crew in a series of tables, translating these captive subjects into quantifiable scientific information (Wolf, 1997, p. 845). Like the well-delineated space of a laboratory on land, the bounded world of a ship, isolating human subjects under military command, provided ideal conditions for controlled experimentation.

Research vessels also lent themselves to technological innovation. The first ship specifically built for oceanographic research, rather than modified to serve it, the U.S. Fish Commission steamer *Albatross* (1882–1921), was also the first U.S. government vessel to be equipped with electric lighting (Shor, 2002, p. 46).[25] Electricity allowed scientists to extend their working hours and permitted them to process specimens gathered at night. Electric lighting even served as a lure for marine creatures.[26] By extending working hours and permitting scientists to

[24] See also Tilghman, 1981. For a history of the trials and errors associated with the treatment of scurvy among sailors, see Naish, 1999, pp. 79–87.

[25] See also Allard, 1999, pp. 1–21. Edison lamps had already been used for marine research on the French research vessel *Talisman*. "Il était plus de huit heures lorsque le chalut rentrait à bord pour la quatrième fois; la nuit était faite, mais nous avions les lampes Edison pour suppléer au jour." Folin, 1887, p. 276.

[26] Commander Z. L. Tanner of the *Albatross,* describes night collection by Edison lamp: "[A]n ordinary Edison 50-candle incandescent lamp, attached to a properly insulated cable, is lowered […] 6 feet or more from the ship's side […] Slow-moving forms which are floating on the surface collect in large numbers at the water line as the vessel sags slowly to leeward and more active species gather to feed upon them. As soon as the light is lowered, the latter gather around it, as moths about a candle, sometimes in great swarms, and it is then that the net reaps its richest harvests." Tanner, 1897, p. 367.

gather specimens at night, electricity amplified the research vessel's extension of scientists' reach in time as well as in space.

Labscape and Seascape

Field scientists of the Victorian era favored landscapes and techniques that allowed them to reproduce some of the routines of laboratory work. Given the scientific authority of laboratories at the time, this is not surprising, Robert Kohler notes that biologists "tried to import laboratory methods to the field [and that] the most successful imports were generally the simplest – counting and tabulating" (Kohler, 2002, p. 192). The ocean, as a relatively uniform field environment, had a number of attractive aspects from this perspective. Thus the scientists of *Challenger* came to prioritize what they termed "observing stations" at sea over land-based collecting. An observation station in the South Pacific could be used for measuring and sampling using the same techniques employed at a station in the North Atlantic. As Thomson wrote in the preface to his narrative, "we traversed a distance of 68,890 nautical miles, and at intervals as nearly uniform as possible, we established 362 observing stations" (Thomson, 1878, p. xvi). Samples of quantifiable data gathered from each of these "stations" could be compared using a uniform set of criteria. Thomson insisted that exploration of the conditions of the deep sea was the primary object of the expedition's mission. "We dredged from time to time in shallow water in the most remote regions, […] and collections of land animals and plants were likewise made on every available occasion; but I rather discouraged such work, which in our case could only be done imperfectly" (Thomson, 1878, p. xvi). The ocean was attractive to late nineteenth-century naturalists because it presented a more uniform research environment than was possible on land. At sea the position of each station could be marked as a single point on a chart, depth measured, a sediment core and water samples gathered, temperature taken at different depths, specimens collected with a dredge or trawl, specimens in the water column gathered by tow-net, atmospheric and meteorological conditions observed, and the direction and speed of water currents determined.

The Ship as "Invisible Technician"

By establishing precedents for scientific practices of place and space, the *Challenger* expedition left a lasting impact on the way science would be conducted at sea. Laboratory space takes up much more room on modern research vessels than it did on *Challenger*, and some vessels have become more laboratory than ship.[27] A stable instrument platform, unlike a moving vessel, allows sampling in an identical space over extended periods of time. Physical oceanographer Walter Munk has stated that the nineteenth century was ''a century of undersampling'' (Munk, 2000, p. 1–3). By this he meant that although oceanographic research vessels like the *Challenger* made consistent measurements at different ''stations'' as the ship crossed the ocean, differences between stations were interpreted as variations in space rather than in time; and observations at any one station could not be repeated, leading to an underestimation of the importance of seasonal changes in the ocean basin. Only at the end of the twentieth century, with the advent of satellite technology, did an era of ''constant sampling'' begin.

These developments in oceanographic technology reflect an enduring aim: to extend the reach of marine science in the field, while shortening the time between data collection and analysis. The expansion of human sensory immersion in the field has been accompanied by a reduction in the time needed for data collection. Anthropologist Stefan Helmreich writes, ''the sensory trajectory through which the deep sea has been scientifically apprehended has travelled from the tactile, to the auditory, to the visual [...]'' (Helmreich, 2009, p. 35). This expansion of human sensory immersion is reflected in a passage from an 1887 account of the voyages of the French *Travailleur* and *Talisman*, describing their dredges as ''the hand of man descending to even the deepest depths.''[28] It is also reflected in American scientist Emily Nunn Whitman's description in 1882 of the use of a diving suit for specimen collection at the Bay of Naples (Figure 8):

[27] The Floating Instrument Panel, or FLIP, built in 1962, is a good example. The Flip is towed to a ''research station'' and partly flooded, tilting the structure upright. This provides scientists with a stable platform, minimizing the effect of ocean movements that can interfere with instrumentation on conventional research vessels. Physical oceanographer Walter Munk recalls that FLIP was once used to substitute for the lack of a suitable island in a Pacific-wide study of wave formation in which all other observation sites were land-based. Munk, 1980, p. 11. See also Shor, 1978, pp. 102–105.

[28] ''La drague est la main de l'homme descendant sur les fonds meme les plus profonds.'' Léopold Folin, *Sous Les Mers: Campagnes D'Explorations du 'Travailleur' et du 'Talisman'* (Paris: Librairie J. B. Baillière et Fils, 1887), p. xix. This nineteenth-century allusion to the technological extension of the human senses has been repeated in our century in an article on seafloor observatories: ''The next great leap in our understanding of the earth-ocean system will require us to put our 'eyes' and 'ears' in the ocean [...]'' Collins et al., 2000.

Figure 8. "The Diver at Work" – The Zoölogical Station at Naples (Whitman, 1882, p. 793). Special Collections, University of Washington Library

> It is not only necessary that [marine animals] be taken […] to aquarium and laboratory, it is important that the biologist visit them in their native homes and examine their surroundings. Encased in a heavy water-proof suit, […] the biologist is let down […] he can remain three hours and over walking about among the seaweeds and rocks […] the minutest characteristics of a plant or animal can be distinctly observed. It is possible to make use of a lens, and one can seize with pincers the tiniest objects.[29]

By allowing biologists to observe animals in their native environment, diving suits not only enhanced the scientists' reach, but also reduced the time between observation and analysis.[30] Emphasis on the need to minimize such time is apparent in an account of work done on the Coast Survey Steamer *Blake*:

[29] Whitman, 1882, p. 798.

[30] It should be noted, however, that in the late nineteenth century the use of diving suits for scientific research remained rare and was primarily restricted to shallow depths in conjunction with marine stations rather than deep-water vessels. Only in the 1950s with the invention of SCUBA equipment did diving become a commonly employed method for underwater research.

> No attempt to analyze water specimens was ever made […] Agassiz […] decided that the proper facilities were not to be had on board the vessel. He suggested […] that a properly furnished station be established on shore, convenient to some deep-sea basin, whence water specimens might be delivered […] by quick runs of a steamer […] With a station at the Tortugas, […] the 'Blake' could deliver a specimen from 2,000 fathoms within twelve hours […] (Sigsbee, 1880, pp. 89–90).

A similar means of expediting specimen collection and analysis was envisioned in 1885 by Anton Dohrn, director of the Naples Zoological station. In a description of the station's facilities, American naturalist Charles Edwards referred to Dohrn's blueprint for an ideal research vessel:

> [A] floating laboratory […]specially constructed […] [with room for] six to ten investigators. Two laboratories […] outfitted for a six months' voyage together with a library would furnish ideal conditions for work. With such a floating biological station unknown regions could be entered with all the resources of modern equipement [sic] […] [T]he floating laboratory would be used, at first […] with the Naples Station […]depths would be searched […] Small boats would be sent out to gather [specimens] […] A portion of the catch would be examined […] another part […] [taken to] the Naples Station. […] [The] vessel serves as dwelling house and laboratory from which would center all the activities of a marine station (Edwards, 1910, pp. 221–223).[31]

In Dorhn's view, such a vessel would be an extension of the marine station, a hybrid space serving as a platform for collecting specimens, a laboratory for experiment, and base for observation in the field.

Oceanographers have continued to use research vessels as hybrid workspaces into the twenty-first century. This multiple-usage of ship-

[31] See also the description of the survey ship *Carnegie* (1909–1929) by Acting Director of the Department of Terrestrial Magnetism of the Carnegie Institution, John Fleming: "the scientific program […] computed values […] forwarded from port to port in such a form that they could be immediately utilized by workers ashore, and by the hydrographic offices of the world." Fleming, 1932, p. xvi. The impetus to extend reach and reduce time propelled the development of the "man-in-the-sea" programs throughout the 1960s and 1970s. By permitting long-duration "saturation dives" without the need for decompression, underwater habitation structures extended the range of field observation. As Helen Rozwadowski recounts, in 1963 "the Oceanic Institute of Hawaii tested a pilot underwater structure at a depth of 30 feet off Manana Island with the intention of constructing a permanent undersea laboratory that would serve as a 'base camp' for stepwise explorations of adjacent depths […]" Rozwadowski, 2004, p. 372.

board space is described in the preface to a scientific text entitled *Experimental Biology at Sea*:

> For some the ship is a floating laboratory, enabling experiments to be carried out on freshly collected material. For others the ship is a mobile instrument platform and for a few the ordinary research ship is used in conjunction with other, more highly specialized vehicles […] The distinction between these two categories is not absolute and much work uses a research ship both as a laboratory and as an instrumented vehicle (Macdonald and Priede, 1983, p. vii).

In the course of the last decade, sensor buoys (Argo Floats), remotely operated vehicles (ROVs), and autonomous underwater vehicles (AUVs) have been used to gather data and transfer it nearly instantaneously to laboratories on land via satellite. The entire ocean, criss-crossed by sensors, has come to be reconceived as a "natural laboratory" or "laboratory system."[32] The introductory paragraph of the website for the recently launched National Oceanic and Atmospheric Administration vessel, *Okeanus Explorer*, insists that the ship "is *not* a research vessel."[33] The first ship to be equipped with a permanent ROV, *Okeanus* can transmit data (including images and high-definition video), via high-speed Internet to scientists and their publics (anyone with an internet connection) anywhere in the world: a feat referred to as "telepresence" (Figure 9).

Two important changes have taken place: technological advances have extended the field of scientific observation far beyond the bounds

[32] "[T]he U.S. National Science Foundation […] is on the verge of investing […] in the construction […] of an innovative infrastructure known as the Ocean Observatories Initiative (OOI) […] [T]his initiative will […] implement electro-optically cabled observing systems in the northeast Pacific Ocean […] [I]nteractive, distributed sensor networks […] will create a large-aperture 'natural laboratory' for conducting a wide range of long-term innovative experiments within the ocean volume using real-time control over the entire 'laboratory' system." Barga and Delaney, 2009, p. 32. Since the publication of the Barga and Delaney article several ocean observatory systems have become operational. Canada led the way with the completion of the first array of the Victoria Experimental Network Under the Sea (VENUS) in 2006. This was followed by the launch of the North-East Pacific Time-series Undersea Networked Experiments (NEPTUNE Canada) in 2009. Lavoie, 2013. In the United States, the regional cabled observatory component of the National Science Foundation's Ocean Observatories Initiative, led by Delaney's University of Washington team, finished laying their ~900 km of main submarine cable in 2011. The Argo Floats program, established in 2000, achieved its goal of deploying 3000 floats in 2007. At the time of writing, there are 3552 floats deployed with the target of maintaining a $3° \times 3°$ array. See also Fricke, 1994, pp. 46–55.

[33] Unknown author, "NOAA Ship Okeanos Explorer", accessed online April 15th, 2013, http://www. moc.noaa.gov/oe/.

Figure 9. An artist's representation of telepresence, a fully automated seafloor analytical laboratory of the future. Credit: Scientific concepts by John R. Delaney; graphic design by Center for Environmental Visualization, University of Washington

attained by earlier research vessels, and the term "laboratory", attractive to marine scientists for its connotations of authority and control, has been re-defined to include *observational* as well as experimental science. As University of Washington oceanographer John Delany recently observed: "there will be massive amounts of data flowing ashore, all available to anyone who has any interest in using it. This is going to be much more powerful than having a single ship in a single location [...]" (Delaney, 2010). In a New York Times article of 2007, Delaney described the potential of remote observatories even more succinctly: "[...] we're going to turn Juan de Fuca Plate into a national laboratory" (Yardley, 2007). But if the Juan de Fuca Plate, or an entire ocean, can be considered a 'laboratory,' the word has changed in meaning, the space of observation and analysis engulfing the field. In this new ocean-laboratory oceanographers can now present their work as "experiments."[34]

[34] The term "experiment" is frequently found in modern oceanographic projects. A few examples are the Mid-Oceans Dynamics Experiment (MODE), the Tasmania Internal Tide Experiment (T-Tide), and the North-East Pacific Time-Series Underwater Networked Experiments (NEPTUNE).

As oceanography changes, the model of the ship as laboratory pioneered by the *Challenger* expedition is no longer fully adequate. Perhaps, to adapt Steven Shapin's concept, the model of the ship's place in some contemporary oceanographic research is already that of "invisible technician." Research vessels continue to serve as scientific instruments by deploying remote sensors, yet the ships themselves – supply vessels to a system of sensors embedded in the ocean – are no longer primary collectors or producers of scientific knowledge. To quote the president of Ocean Networks Canada, Martin Taylor: "The strength of our observatories is they are able to provide data without [scientists] going out in ships, but we need ships to service and maintain them" (Lavoie, 2011).

Conclusion

In this paper I have examined three models for understanding the work of oceanographic vessels. I have attempted to throw light on the history of fieldwork at sea, on the development of shipboard laboratory space, and on the social relations of science production. I have focused on changes in the allocation, design, and control of shipboard space. The process by which science and scientists found a place on expedition vessels had a literal physical dimension; and the evolution of the physical spaces in which naturalists worked, from cabins to laboratories, helped confer authority to a new ocean science. This history teaches us not to approach field science as a simple series of expedition events or set of technological advances, but as a process in which changing treatments of workspace reveal evolving social practices and shifting interests.

In casting eighteenth-century vessels as scientific instruments, Richard Sorrenson began a story I have sought to continue. Oceanography provides a model of "laboratory space" that moved into the field, expanded to include new forms of observation and activity, and eventually engulfed the field. Changes in research vessel usage accrued gradually over time, and earlier usages persist alongside later innovations. For some, the research vessel remains a floating laboratory, for others it has become an observation platform, or even an invisible, yet essential, "technician" servicing a "natural laboratory system" expanded to encompass the entire ocean.

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