Merchant Marine Deck Officer Agency through Performative Acts

An Oppositional View to Deskilling Theory

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Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

In

Science & Technology Studies

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August 04, 2016

Falls Church, Virginia

Keywords: Actor-network Theory, Tacit Knowledge, Commedia Del'Arte, Deskilling, ECDIS, Experiential Technical Knowledge, Marine Navigation, Merchant M Deck Officer, Mimeomorphic, Performative Act, Performativity, Polimorphic, Situated Action, Skill

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ABSTRACT

I bring together ethnographic interviews with deck officers, studies in actor-network theory, explicit and tacit knowledge theory, and performativity theory in this work. I prove that bridge technologies produce what are called mimeomorphic (repeatable with some variation) actions that contain no deck officer collective tacit knowledge. I argue that deck officer bridge watch situated actions are mostly polimorphic (actions can vary depending on social context), and these actions are in fact performatives (in an Austin sense) derived from a more oral than literate performance production process. These performatives constantly build the mariner's identity within the maritime deck officer community and their successful performatives give deck officers agency in the form of an oppositional view to deskilling. These same performative acts are the value of the mariner's experiential technological knowledge within the ship's bridge technology framework

Dedication

My children – for making me cry… and laugh!

Mom – taught me social tolerance.

Dad – my partner in angling for 'Old Fighter.'

Roger Sherman & Bill Conlon – my Little League coaches

Ed Sullivan – my Babe Ruth coach

Dave Sure, Lionel and Claude Bison – Friendly Ice Cream management, Brunswick Me, in 1974

That young girl (maybe age 5) aboard the USNS General Breckenridge (my first voyage) during the passage from San Diego to Honolulu in 1963, who would without hesitation give me (age 3) a backrub as we sat watching Looney Tunes cartoons in the children's playroom.

Acknowledgements

My dissertation committee – for all of their encouragement and insightful comments

Sheila Rogoff for providing me with a copy of Mortimer Rogoff – Man of the Future

The helpful administration at MITAGS, including Eric Friend and Capt. Alan De Sa

Christian Hempstead of Hempstead Maritime Training

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List of abbreviations

AB - Able Bodied Seaman

AIS - Automatic Identification Systems

ARPA - Automatic Radar Plotting Aid

AtoN - Aid to Navigation

BTM – Bridge Team Management

CAS - Collision Avoidance System

CD - Compact Disk

CDA - Commedia Dell'Arte

CDMA - Code Division Multiple Access

COC - Crew of Convenience

COLREGS - Convention on the International Regulations for Preventing Collisions at Sea

CPA - Closest Point of Approach

CRT - Cathode Ray Tube

CTK - Collective Tacit Knowledge

DCS - Digital Selective Calling

DGPS - Differential-GPS

DOT - Dictionary of Occupational Titles

DR - Dead Reckoning

ECDIS - Electronic Chart Display & Information System

ENC - Electronic Navigation Chart

ETC - Energy Transportation Company

FOC - Flags of Convenience

GHA - Greenwich Hour Angle

GIS - Geographic Information System

GMDSS - Global Maritime Distress and Safety System

GMT - Greenwich Mean Time

GPS - Global Positioning System

GUI - Graphical User Interface

HF - High Frequency

HVAC - Heating, Ventilating, and Air Conditioning

IAEA - International Atomic Energy Agency

IEC - International Electro-Technical Commission
IHO - International Hydrographic Organization

ILO - International Labor Organization

IMARSAT - International Mobile Satellite Organization

IMO - International Maritime Organization

LHA - Local Hour Angle

LMT - Local Mean Time

LNG - Liquefied Natural Gas

LOP - Line of Position

MARAD - U.S. Maritime Administration

M/V - Motor Vessel

MX - Point of Execution

NAVTEX - Navigational Telex

OJT - on-the-job-training

NOAA - National Oceanic and Atmospheric Administration

NRC - National Research Council

NTSB - National Transportation Safety Board

P&I - Protection and indemnity
PPI - Plan Position Indicator

PPU - Portable Pilot Unit

RCDS - Raster Chart Display System

RML - Relative Motion Line

RTCM - Radio Technical Commission for Maritime Services

RTK - Relational Tacit Knowledge

RX - Receiver

SENC - System Electronic Navigation Chart

SOLAS - Safety of Life at Sea

SOP - Standard Operating Procedure

SS - Steamship

STCW - Standards of Training, Certification and Watch-keeping for Seafarers

STK - Somatic Tacit Knowledge

T/V - Training Vessel

UN - United Nations

USCG - United States Coast Guard

VHF - Very High Frequency

VRM - Variable Range Marker

VTC - Vessel Traffic Center

VTS - Vessel Traffic System

Chapter 1 – Introduction

Technical change in the form of workplace automation can only result in some effect on worker skill, or so the literature would have one believe. The vagueness of the term skill as applied by researchers renders it useless as any form or target of measure. According to Staudenmaier, a lack of studies from the worker's perspective leaves unresolved the effects of such technological change.[1] This dissertation fills a void in Science and Technology in Society research in what is taking place experientially when speaking of workers in conjunction with the introduction of automated technology into the workplace. My study of technology adoption from the perspective of merchant marine deck officers describes something very rich without a recourse to the term skill. Using the concepts of experiential technical knowledge, situated action and performativity, and actor-network theory, I show that deck officer agency is in constant flux as their identities are contested from within their shipboard social domain and from without. Just as identities can be contested, so to can established work practices, in this study's case, the practice of marine navigation.

In 1968, from their apartment at 180 East End Avenue in New York City, the Rogoff family's panoramic view of the East River made them witness to a boating tragedy in which a life was lost.[2] Mortimer Rogoff, a seasoned electrical engineer and holding patents in both GPS and CDMA spread spectrum technologies, and who worked as a private consultant in the areas of telecommunications, data processing, and office

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[1] John M. Staudenmaier, *Technology's storytellers : reweaving the human fabric* (Cambridge, Mass.: Society for the History of Technology and the MIT Press, 1985).
[2] Family Rogoff, *Mortimer Rogoff - Man of the Future* (2010).

automation, couldn't help but notice the struggles of commercial and private vessels as these vessels made their East River passages.[3] Mort's experiences as the head of European data systems for ITT and later as a Vice President at John Diebold, Inc. left him with the view that offices were "crying out for automation."[4] Automation to him

> "is the intelligent use of intelligent machines to add to the productivity of the office. This happens because better tools are made available, and those tools are derived from better manipulation, handling, and availability and processing of information and data, which leads you into communications."[5]

People of Mort's guild, the research scientist and engineer, coming as they did through the Second World War with all of its electronic innovations, and pursing as they did further refinements and innovations with the help of Defense Department research funding, saw few boundaries to future innovations.[6] As an aside to his vocation, Rogoff in the 1970's with the vision of freeing navigators from the tedious and time-consuming manual calculations, began working and ultimately published a book, Calculator Navigation, on electronic navigation techniques using the newly available electronic calculators. It was during this work that he conceived of an electronic navigation chart. For electronic navigation and charts in particular, "Liberating the chart from its classical paper foundation endows the chart with a degree of flexibility that has been unthinkable in the paper version."[7] In 1981, Rogoff would help form the company Navigation Sciences that in 1983 applied for a patent, subsequently granted in 1986, for the first integrated marine electronic navigation system, the forerunner of today's Electronic Chart Display and Information System or ECDIS for short.

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[3] Ibid.
[4] Ibid., 60.
[5] Ibid., 87.
[6] Paul Forman, "Behind quantum electronics: National security as basis for physical research in the United States, 1940-1960," *Historical Studies in Physical Sciences* 18, no. 1 (1987).
[7] Rogoff, *Mortimer Rogoff - Man of the Future* 79.

Imagining a technology for mitigating the perceived frailties of the human physique and human decision-making can create controversy. It can, if those that do the imagining promote its benefits at the expense of some social group or social convention. It is at the imagining stage of a technology that its contesting seems most practical. A symmetrical imagining can take place by many groups. Turning imagination into reality expands and in some cases makes more urgent the controversy as actual people or nature feel its impact. Maritime deck officers are the focus of impact for this research. Deck officers' principle responsibility is the safe navigation of the ship while on their bridge watches. Deck officers utilize their domain knowledge in conjunction with technology to ensure the safe navigation of the ship during their bridge watches.

A deck officer's place in the voyage production chain is unique, insofar as they oversee labor on board a ship, and at the same time, are key laborers for a ship's voyage production. New technologies that increased the size of ships over the last 100 years haven't impacted the number of deck officers generally on a per ship basis. The incorporation of communication, navigation, and collision avoidance technologies into deck officer work processes over the last 100 years also shows little impact to their per ship numbers. The deck officer's job isn't disappearing any time soon. They have shown to be a resilient cadre in the face of new technologies. Deck officer work processes change with the introduction of new navigation technologies. Changes in their work processes leaves open the possibility of laborer redundancy at worst, and degradation of shipboard labor culture at minimum. The introduction of new technologies to a ship's bridge however, doesn't seem to deter deck officers from continuing to sign on to these ships and sail aboard them. They must be doing this with a particular view of their personal experiential knowledge vis-à-vis these new technologies. This suggests that they have an oppositional view to the concept that the introduction of technology in the workplace deskills labor. Documenting their views along with documenting their worker environment reveals the special approaches deck officers use giving them agency in the face of the introduction of an ever-increasing number of new technologies into their workplace.

To understand how merchant marine deck officers continue as a valued worker class in the face of ongoing innovation of a merchant ship's bridge navigation technology, explores the relationship between laborer experiential technological knowledge and technology. This relationship uncovers a new notion of technology adoption apart from the deskilling paradigm.

Typical maritime labor / technology studies are about labor leadership negotiating for labor's wellbeing in light of proposed new technologies that seek to reduce jobs or skill levels.[8] The merchant marine worker is left without a voice. Substituted for workers' voices are task time-series studies, impersonal wage / skill measures, vessel casualty reports that note reasons for the casualty (many times pointing to human error), and records of labor disputes and resolutions. Staudenmaier believes that the significance of the introduction of machines that replace labor is lost without an account of the workers'

[8] For such reading see: J.P. Goldberg, *The Maritime Story A study in Labor-Management Relations* (Cambridge: Harvard University Press, 1958).
Eric Sager, *Seafaring Labour: The Merchant Marine of Atlantic Canada 1820-1914* (Montreal: McGill-Queen's University Press, 1996).
F.J. Lang, *Maritime A Historical Sketch, A workers' Program* (New York: Pioneer Publishers, 1943).
R Gorski, ed. *Maritime Labour, Contributions to the history of work at sea, 1500-2000* (Amsterdam: aksant, 2007).

perspective.[9] Not hearing maritime workers' voices keeps one from knowing firsthand, the actual interaction of merchant mariners with technology. Without this knowledge, one can't understand the place of labors' experiential technical knowledge within technology, the personal dimensions of any struggle with work process replacement in light of automation, and how these two dimensions might relate. Knowing how deck officers succeed as a working class may uncover new theories or directions of research for better understanding the value of laborer experiential technical knowledge, its production, and its sustainment. This research achieves its objective through:

- documenting firsthand accounts of merchant marine deck officers incorporating the "Electronic Chart Display and Information System" (ECDIS) technology into their bridge navigation work processes,
- documenting this technology's pathway to incorporation on a ship's bridge,
- dissecting pre and post-ECDIS work processes in terms of explicit and tacit knowledge,
- showing how deck officer performativity is influential in the valuation of their experiential technical knowledge.

1.1 Research Questions

Merchant marine worker's interaction with technology needs telling through a dialogue with merchant marine laborers and a gathering of historical features of merchant ship technology. I address this need by answering the following research questions:

[9] Staudenmaier, *Technology's storytellers : reweaving the human fabric*: 117.

1. How do merchant marine deck officers explain their transitions from work processes for which they are already qualified through certification and experience, to new work processes incorporating technologies that automate some or all aspects of those work processes?
2. What social features highlight deck officers' technology transition explanations, what is the influence of these features, and are any specific to the deck officer domain?
3. What role does experiential technical knowledge play in the technology transition explanations of deck officers, how is this knowledge acquired, and how can this knowledge be classified within a tacit/explicit knowledge model?[10]

1.2 Outline of Chapters

To construct my analytical framework, I conducted a literature review to be able to make logical connections between the idea of skill, types of knowledge, identity and agency. This provides the foundation for an alternative theory of technology adoption and this work is found in Section I – Review of Literature.

I next interviewed deck officers to hear what they have to say regarding their transition from traditional navigation processes to processes involving ECDIS. The interviews provide work process descriptions and anecdotal content for further analysis. Here is sample of some interview questions utilized in this work:

1. Summarize how you organize and pursue your bridge watch.

[10] Harry Collins, *Tacit & Explicit Knowledge* (Chicago: The University of Chicago Press, 2013). 157-63.

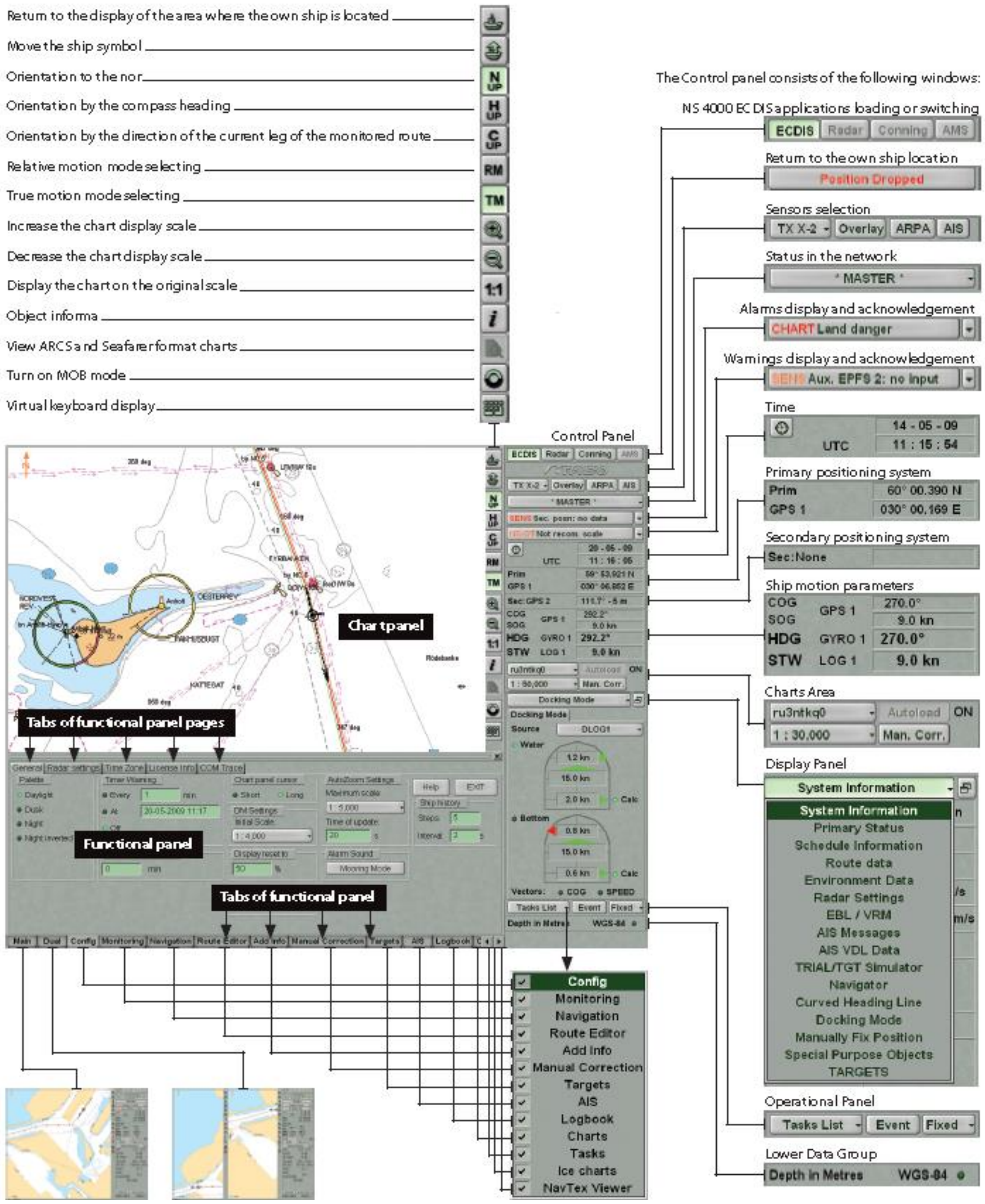

Figure 1 – TRANSAS ECDIS display screen[11]

2. Were there any concerns or difficulties when integrating each new technology into your bridge watch routine, and if so, what were those concerns or difficulties and how did you resolve each concern or difficulty?

3. Can you relate any situations or incidents where you found any new

[11] Transas, "ECDIS Complete," (Transas), 9.

technology's use problematic or beneficial from the standpoint of your seagoing experience?

ECDIS now requires certification. As a licensed deck officer, I bring some bias into the project, so I have leveraged this bias as an additional interviewee. I became ECDIS certified as part of this study, utilizing this certification experience in this work where appropriate, so that my positions on ECDIS are transparent, and at the same time to document the socialization process of bringing proper ECDIS usage to the masses.

I also researched and developed an understanding of individuals and organizations that have agency in the ECDIS power structure and how these actors propelled the ECDIS technology to the bridges of ships. I identified the arguments and assumptions that maintain ECDIS in the face of any technological, bureaucratic, or conceptual shortcomings. Understanding this kind of maintenance for ECDIS is a requirement for understanding deck officer / ECDIS technological interaction. Section II of this work, ECDIS's Heterogeneity and Contingency, documents this research.

To define deck officer experiential technical knowledge and identify the place of this knowledge in an overall bridge navigation technology framework, I documented pre and post ECDIS work processes and analyzed the location and use of explicit and tacit knowledge in the work processes. Section III – Comparative Navigation Traditions – Pre and Post ECDIS holds this body of research.

Finally, I apply the notion of performativity to the deck officer work environment. I argue that deck officer work can be performative, but the performative isn't always achieved through utterance; it may be achieved through other performance mechanisms such as their situated actions produced using an improvisational performance production process. It is the influence of deck officer performatives during their bridge watches (both before and after ECDIS) that maintains deck officer identity as useful laborers valued for their experiential technical knowledge. Together, these arguments define a novel way to understand technology adoption and one that is oppositional to the notion of deskilling. Section IV - Performativity, ECDIS, and Deck Officer Identity Production contains this research.

Chapter 2 – Review of Literature

The purpose of this literature review is to transition the reader from discussions relating to skill in light of new mechanized and/or automated technology (in this case defined as ECDIS) to a place where deck officer interaction with new bridge technology illuminates (deck officer's) identity, agency and experiential technical knowledge during moments of action. These moments are the work practices that are internal to, though partially externally defined for, the deck officer. The deck officer actively manages the moments of action using various resources in order to maintain the identity of a deck officer in the face of new technologies that automate some work practices. This literature review is foundational to the dissertation's analytical framework for analyzing deck officers' situated actions and the hypothesis that such actions give deck officers agency with respect to the introduction of new technologies to their place of work. For this research, that place of work is on the bridge of ocean-going ships. The existence of such agency is in opposition to the view that the introduction of new technologies that automate work processes are necessarily de-skilling, even if such de-skilling was the intent of those who introduce such technologies. The framework takes shape through:

a) theories of work, labor, and their connection to skill,
b) Suchman's model of action,[12]
c) Collin's model of tacit knowledge and theory of action,[13]

[12] Lucy A. Suchman, *Plans and Situated Actions - The problem of human machine communication* (New York: Cambridge University Press, 1987).
[13] Harry Collins, *Tacit & Explicit Knowledge* (Chicago: The University of Chicago Press, 2010).

d) Commedia Del'Arte theatrical performance genre's highly situational performance creation process which asserts actor performance flexibility over planned theatrical scripts

e) J.L. Austin's performatives utterances, "speech acts,"[14]

f) Callon's moments of translation for analyzing agency in power relations.[15]

2.1 About Labor, Skill, and Deskilling

Staudenmaier states that technical skills are learned experientially.[16] Collins states that doing things that seem difficult are considered skillful.[17] He also states that doing skillful things enables "those who have acquired it to contribute to the domain to which the expertise pertains."[18] A performer of labor may or may not be skillful when compared to another performer doing the same thing in the same domain. Since doing skillful things is something acquired and learn experientially, the term experiential technical knowledge will be adopted here instead of using the term skill, unless the idea/concept of skill is being specifically addressed.

ECDIS is the center-piece of what the International Maritime Organization (IMO) calls its e-Navigation program.[19] This program is an evolving marine special data infrastructure based on common standards, broadband communications technology, and

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[14] J.L. Austin, *How To Do Things With Words* (Cambridge, MA: Harvard University Press, 1962).

[15] Michel Callon, "Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay," *The Sociological Review* 32(1984).

[16] Staudenmaier, *Technology's storytellers : reweaving the human fabric*: 114.

[17] H. M. Collins and Martin Kusch, *The Shape of Actions - What Humans and Machines Can Do* (The MIT Press, 1998). 78.

[18] H. M. Collins and Robert Evans, *Rethinking Expertise* (Chicago: University of Chicago Press, 2007). 24.

[19] Horst Hecht et al., *The Electronic Chart - Fundamentals, Functions, Data and other Essentials - A Textbook for ECDIS Training* (Lemmer: Geomares Publishing, 2011). 339.

government established data infrastructures designed to manage marine transportation safely and securely.

> "… by 2020 the infrastructure for the fully digital navigational world can be expected to be in place as a result of IMO's e-Navigation program and many ships can be expected to be using systems in a fundamentally different way to that of today."[20]

One can invariantly transform the foregoing phrase, "many ships that are expected to be using systems in a fundamentally different way," to say that shipboard laborers using e-Navigation will find their practice fundamentally different. Harry Braverman called this fundamentally different practice machinofacture.

> "the instrument of labor is removed from the worker's hand and placed in the grip of a mechanism and the forces of nature are enlisted to supply power which, transmitted to the tool, acts upon the materials to yield the desired results; thus the change in the mode of production in this case comes from a change in the instruments of labor."[21]

> "The instruments used in production, including those used in transport and communication, have been revolutionized not only in respect to the power, speed, and accuracy with which they accomplish their tasks, but often asked to gain the desired result by way of entirely different physical principles from those traditionally employed."[22]

Clearly e-Navigation as a discipline is enabled by the creation and innovation of faster more efficient technological devices, many of them to automate worker processes; the same ones that Mort Rogoff and his generation worked tirelessly to bring about, and the ones brought about through the enlistment of succeeding generations. All of these inventors, innovators, etc. are, as David Noble puts it, not 'autonomous agents.' They are

[20] Ibid., 347.
[21] Harry Braverman, *Labor and Monopoly Capital, The Degradation of Work in the Twentieth Century*, 25th Aniversary addition ed. (New York: Monthly Review Press, 1998). 117.
[22] Ibid.

> "… members of society and are moved, like everyone else, by the myriad of motivations – some large, some small, some unique to their calling, some quite ordinary and common."[23]

The encouragement to enlist in the pursuit of automation is given to the public by society's structure: via the country's institutions, both public and private, as a characteristic or essence of technology that it can solve problems and is unproblematic.[24] The surest way to a simpler life is through the prospect of automation. Others see such prospect as de-skilling labor.

Technology is the linchpin for complete worker degradation within capitalism. The capitalist enlists science and knowledge work to facilitate a greater role for technology in increasing capitalism's productive forces.[25] The technological focal point, the machine, subsumes the worker. "Along with the tool, the skill of the worker in handling it passes over to the machine…"[26] Thus we have the idea that machines embody something called skill that was once in the ownership of the worker, who seems to now have no agency.

Skill is a loose concept and susceptible to influence. There is no single agreement amongst researchers as to both the meaning and measure of skill. Two dimensions of skill that researchers tend to agree on as being primary are conception, which relates to autonomy, and execution, which relates to complexity.[27] These two dimensions correlate highly with complexity correlating strongest with all other dimensions, thus job

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[23] David F. Noble, *Forces of production : a social history of industrial automation* (New York: Oxford University Press, 1986). 43.
[24] Ibid.
[25] Christian Fuchs, *Digital Labour and Karl Marx* (New York: Routledge, 2014).
[26] Karl Marx, *Capital, Volume 1* (London: Penguin, 1867). 545.
[27] William Form, "On the Degradation of Skills," *Annual Review of Sociology* 13(1987).

complexity has become the general measure of skill. [28] [29] The problem with the term complexity is defining a basis and baseline measure for it. In addition, job complexity being a dominant factor in the concept of skill doesn't tell us where it is located, in the human or the job description, or ease the task of measuring it.

The meaning of deskill is necessarily as difficult to characterize as skill. If skill is in the job, then

> "deskilling is dividing the work to be performed into different processes, each requiring different degrees of skill and force,"[30]

such that had work been previously

> "executed by one workman, that person must possess sufficient skill to perform the most difficult tasks, and sufficient strength to carry out the most laborious of the operations into which the art divided."[31]

In this instance, the job description is the knowledge of the job and controls its processes. If the description changes requiring less human effort of any kind, then there is deskilling of the job. If skill is in the individual, then deskilling is the worker stepping

> "to the side of the production process instead of being its chief actor. In this transformation, it is neither the direct human labor he himself performs, nor the time during which he works, but rather the appropriation of his own general productive power, his understanding of nature and his mastery over it by virtue of his presence…"[32]

In this instance, someone extracts and incorporates the knowledge of the worker into a machine.[33]

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[28] K. I. Spenner, "Occupations, work settings and adult development," (Durham, NC: Duke University, 1986).
[29] A.R. Miller et al., "Work, Jobs, and Occupations," (Washington DC: National Academy, 1980).
[30] C. Babbage, *On the Economics of Machinery and Manufacturers* (London1832).
[31] Ibid.
[32] Karl Marx, *Grundrisse* (Harmondsworth, 1973). 705.
[33] Braverman, *Labor and Monopoly Capital, The Degradation of Work in the Twentieth Century*: 145-46.

A definitive deskilling theory with accompanying persuasive models remains elusive. Alternative effects of capitalism such as the ability for other worker classes to participate in professional labor argues for other alternative theories, in this paper's research, of alternative models for understanding the effects of changing modes of production on labor value and worker agency.

2.2 Sociology of Translation

One result of the prospect of automation are the many technological devices in use on the bridges of ships today, GPS receivers, depth sounders, gyro compasses, communication radios, auto-pilot steering. How they come about, come into use, continue in use, and sometimes evolve is of interest if one is to consider who has agency with respect to them. Callon developed an analytical framework for investigating such development through his sociology of translation.

ECDIS is not a live entity in nature like a scallop, but it has a similarity to man-made larvae collectors used by some scallop fishermen.[34] The intransigents of France's St. Brieuc Bay scallops to attach themselves to larvae collectors for perpetuating their existence, albeit for French dining tables, is not unlike the possibility of reticence of merchant marine deck officers to embrace ECDIS as their principle tool for navigation, when the possibility exists that such a device can devalue their traditional work processes. In both of these cases, some technological innovation thought to be helpful could also spell the demise of the entity required for the innovation to succeed. It isn't likely that the Bay's scallops understood their final destinations should they choose or

[34] Callon, "Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay."

succeed in attaching themselves to larvae collectors, but the safer navigation that ECDIS is thought to provide does arguably give deck officers a better understanding of their voyage's route. The idea that knowing more about one's route may be a cause for reticent use of a new technology isn't illogical in a study involving human laborers. The processes involved in introducing and building support for new technologies is similar to the development of scientific theories. It happens through a process known as translation.

Callon proposes four moments of translation in his scholarship on the domestication of scallops and fishermen of St. Brieuc Bay:

1. problematization, which is the defining of an issue by an entity in terms of other entities and defining the roles of the other entities such that the definer becomes the de facto spokesperson for this built up network,
2. interessement, which is the array of actions used to build and maintain the network defined in the problematization statement,
3. enrollment, which are mechanisms utilized to ensure the defined entities play their roles,
4. mobilization, which is the negotiation process of identifying network goal supportive spokesperson representatives for the network entities.

Use of these moments of translation can help one to understand how ECDIS came to the bridges of merchant ships and the agency of deck officers with respect to that process. Deck officer agency with respect to technology relates to their worker class.

2.3 Identity through Performativity

Harry Braverman was most interested in the effects of the capitalist mode of production on the worker class generally. He states that,

> "Class consciousness is that state of social cohesion reflected in the understanding and activities of a class or a portion of a class. It's absolute expression is a pervasive and verbal attitude on the part of a class towards its position in society. Its long-term relative expression is found in the slowly changing traditions, experiences, education, and organization of the class."[35]

Marx's ruling class contrasts with the worker class and it produces what he calls "patterns of social domination."[36] Marx states, "the ideas of the ruling class are in every epoch the ruling ideas …"[37]

> "The class which has the means of material production at its disposal has control at the same time over the means of mental production, so that thereby, generally speaking, the ideas of those who lack the means of mental production are subject to it. The ruling ideas are nothing more than the ideal expression of the dominant material relationships, the dominant material relationship to grasp as ideas; hence of the relationships which make the one class the ruling one, therefore, the ideas of its dominance."[38]

Each new ruling class is compelled "to represent its interests as the common interest of all society, that is, expressed in ideal form: it has to give its ideas the form of universality, and represent them as the only rational, universally valid ones."[39] The expression of ruling class ideals and worker class activities are forms of repetitious performativity.[40]

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[35] Braverman, *Labor and Monopoly Capital, The Degradation of Work in the Twentieth Century*: 20.
[36] Craig J. Calhoun, *Classical sociological theory*, Blackwell readers in sociology (Malden, Mass.: Blackwell, 2002). 77.
[37] Karl Marx and Friedrich Engels, "The German Ideology," in *Classical Sociology Theory*, ed. Craig J. Calhoun, et al. (Malden, MA: Blackwell Publishing, 1845), 83-4.
[38] Ibid.
[39] Ibid., 84.
[40] Gill Jagger, *Judith Butler - Sexual Politics, Social Change and the Power of the Performative* (New York: Routledge, 2008). 26.

The idea of performativity comes from J. L. Austin's concept of the performative utterance.[41] Performative utterances do not describe something, but act on something. They are not true or false statements, but succeed or fail in their action.

> "Speaking generally, it is always necessary that the circumstances in which the words are uttered should be, in some way, or ways appropriate, and it is very commonly necessary that wither the speaker himself or other persons should also perform certain other actions, whether 'physical' or 'mental' actions or even acts of uttering further words."[42]

For Butler, gender identity materializes from performative acts, not because of being born with a particular set of body parts; it is not prediscursive.[43] It is not a natural or material fact, but a result of performative acts. This is dialectical. "In its very character as performative resides the possibility of contesting its reified status."[44] Her work on gender identity makes it possible to look at worker identity as something not imposed on the worker with little room for maneuvering. Butler sees the doer as being produced in and by performative acts and not as a pre-existing true self.[45] Deck officer identity materializes similarly. Their identity as knowledgeable, valuable, and skilled workers come about through their performatives and not because they have a license, their work tasks, or the tools that they use. Deck officer work involves speech, mental and physical actions. All such acts can be considered performative if they might succeed or fail. Successful performatives bring about safe navigation and an identity as a valuable worker class and thus agency.

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[41] Austin, *How To Do Things With Words*.
[42] Ibid., 8.
[43] Judith Butler, *Bodies that matter : on the discursive limits of "sex"* (New York: Routledge, 1993).
[44] "Performative Acts and Gender Constitution: An Essay in Phenomenology abd Feminist Theory," *Theater Journal* 40, no. 4 (1988): 520.
[45] Ibid.

Deck officer work relationships with new bridge technologies can be characterized as a discourse. A discourse is performative in terms of risk and trust: risk in a safe navigation failure and trust in the tools they use.[46] Giddens believes that modern society is less trustful in its social relations and that trust must be actively won.[47] This can be said of deck officer work, which involves a level of trust in the technological tools they use and the power structures that bring them about.

In contrast to performative utterance is the constative utterance.[48] Constative utterances just describe something. Constative utterances seem to define natural categories or boundaries that can potentially constrain performative acts. Constative utterances propagate an idea of stability in their descriptions. Plans for action denote similar stability in their descriptions.

2.4 Situated Action

Suchman states that plans are seen as constructions of actions after the fact, an account when asked to explain how something was done that lacks the detail that "characterizes situated action."[49] An argument against an oppositional view of deskilling in the face of technology would mean that through plans and not actions is the way in which the world unfolds. It is said, that when Micronesian navigators take to the sea in boats from their islands and head to their destination, that they can't tell you their navigation track

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[46] Michel Callon, "What Does It Mean To Say That Economics Is Performative?," in *Do Economists Make Markets? On the Performativity of Economics*, ed. Donald A. MacKenzie, Fabian Muniesa, and Lucia Siu (Princeton: Princeton University Press, 2007), 316.
[47] Anthony Giddens, *Beyond left and right : the future of radical politics* (Stanford, Calif.: Stanford University Press, 1994). 14.
[48] Austin, *How To Do Things With Words*.
[49] Suchman, *Plans and Situated Actions - The problem of human machine communication*: xi.

beforehand, but will instead point in the direction of their destination.[50] They begin with a goal in mind and their navigation is dependent on the prevailing conditions or situation. The navigator in the Western world plans the voyage and follows a charted course. If the situation demands change, the Western navigator modifies the plan and then acts to the modified plan. In the case of Micronesian navigators, Finney says that they use tacit, intuitive and holistic knowledge based on experience to achieve their goals.[51] Western navigators can be no different. They are both doing instrumental things regardless of their cultural preferences, activity type or expertise. Suchman generalizes all activity whether planned or ad hoc as "situated actions" that are "taken in the context of particular, concrete circumstances."[52]

> "In this sense one could argue that we all act like Trukese, however much some of us may talk like Europeans. We must act like the Trukese because the circumstances of our actions are never fully anticipated and are continuously changing around us. As a consequence, our actions, while systematic, are never planned in the strong sense that cognitive science would have it. Rather, plans are best viewed as a weak resource for what is primarily ad hoc activity."[53]

The implication of rational plans being the basis for future action finds itself embedded in the development of expert and artificial intelligence systems. This is of interest here because regulations force deck officers being confronted by ECDIS, essentially a planning and plan monitoring system, to embrace it, as well as to integrate ECDIS into their daily bridge work processes. The expectation from a regulatory standpoint is that rational (better purposeful) action will prevail due to the presence of ECDIS on the bridge

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[50] T. Gladwin, "Culture and Logical Process," in *Exlporations in Cultural Anthropology: Essays Presented to George Peter Murdock*, ed. W. Goodenough (New York, NY: McGraw Hill, 1964).
[51] David Turnbull, *Masons, Trickerster and Cartographers* (Abingdon: Routledge, 2000). 147.
[52] Suchman, *Plans and Situated Actions - The problem of human machine communication*: viii-ix.
[53] Ibid., ix.

of a ship. This is due to the hidden decisions made within ECDIS that presuppose rational action, or more directly, safe navigation.

The circumstances of the work process action convey the action's meaning, to include its material (artifacts) and social (identity) nature. Suchman's theory of action, that shows action's primacy over plans, has five propositions. The first is that "plans are representations of situated action."[54] The plan could not exist without an imagined situation, creating an object of the situation. In simplicity, the plan could provide a choice of alternatives or boundaries given an anticipated situation and the actor need only choose the correct alternative based on the action's goal. The alternative view, and the one Suchman supports, is that plans always fall short and therefore calls for improvisation on the part of the actor. The navigation track on the chart with attendant course and speed changes is a reference, as are the rules by which one must guide one's vessel in the presence of other vessel traffic and reduced visibility. The moment the vessel proceeds on its track, its disposition is not in the hands of the plan, but in the hands of the deck officer on watch. The plan hopes to set one up for success and that is all.

The second proposition is that during action, "representation occurs when otherwise transparent activity becomes in some way problematic";[55] going from Heidegger's "ready-to-hand" to "unready-to-hand."[56] A vessel proceeds in the open ocean with clear skies, its ECDIS containing its charts and plotted track, but then a component in ECDIS fails or its output isn't understood. What was transparent has become very visible because of what isn't visible; how ECDIS works or access to how it works. The next

[54] Ibid., 50.
[55] Ibid.
[56] Ibid., 51.

action is to consult with another deck officer if one is close by, or the ECDIS manual, a more time consuming though likely more definitive action. With reference to the manual, Julian Orr in his study of copy machines technicians finds "the technicians always turn to it when they do not understand the state of the machine and ignore it when they do."[57] The situated action then includes the formulation of rules and processes that are contingent on the situation and the action is accountable to them. Of course, this doesn't even begin to address the issue of fall back resources. In the world of electronic navigation, the use of a paper chart and its attendant training, including the ability to create charts from scratch, is unlikely to be trained or tested upon beyond some initial overview. As time passes, it is mostly forgotten as electronic charts become dominant through ECDIS use.

The third proposition is "the objectivity of the situations of our actions is achieved rather than given."[58] Rather than taking Durkheim's social facts as the reference for our actions, social facts are dropped and "our everyday social practices render the world publically available and mutually intelligible."[59] The task is to describe the common normal or typical practices.

The fourth proposition is that language is an important resource for objectivity of situations and it has an indexical relationship to the circumstances that it presupposes, produces, and describes. This is a very similar concept to performativity. Charles Pierce[60] termed indexical, language use, where the significance of its use is situational.

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[57] Julian E. Orr, *Talking About Machines* (Ithaca: Cornell University Press, 1996). 112.
[58] Suchman, *Plans and Situated Actions - The problem of human machine communication*: 50.
[59] Ibid., 57.
[60] Charles Peirce, *Collected Papers* (Cambridge, MA: Harvard University Press, 1933).

For instance, instruction manuals are, "composed of representations, which inherently afford multiple interpretations and uses, and instructions which require interpretation by their users in the context of their application."[61] In language, the significance of an expression is beyond what is said and beyond any physical emphasis like tone or movement. The meaning includes the circumstances of the situation at hand, just as the meaning of instructions is inconclusive without their interpretation. It is fallacious to consider instructions or system rules whose goal is 'exhaustive action' as guaranteeing particular or implied reasoning.

Given the indexical nature of language, Suchman's fifth proposition states that, "mutual intelligibility is achieved on each occasion of interaction with reference to situation particulars, rather than being discharged once and for all by a stable body of shared meanings."[62] When a ship meets another in an overtaking situation in international waters, the vessel overtaking sounds the appropriate sound signals and proceeds to overtake the other. Upon successful completion of the overtaking event, an observer could conclude that both parties understood the sound signal and overtaking situation, or on the other hand that it was a successful overtaking event despite a lack of understanding. Rules for understanding situations are "learned tacitly through typifications over families of similar situations and actions."[63] This learning takes place in what is called the documentary method, by "the ascription of intent on the basis of evidence, and the interpretation of evidence on the basis of ascribed intent."[64] For

[61] Orr, *Talking About Machines*: 110.
[62] Suchman, *Plans and Situated Actions - The problem of human machine communication*: 50.
[63] Ibid., 67.
[64] Ibid., 64.

Suchman, "every meaningful action must be accounted for separately"[65] thus for technological interaction such meaning might be found in the communication or negotiation process in order to "detect, remedy, and at times even exploit the inevitable uncertainties of action's significance."[66] Suchman's propositions taken together argue that the world unfolds through actions not through plans.

2.5 A Model for Crafting Situated Actions

Turnbull asks with reference to situated nature of Pacific Islander navigation, what devices / techniques are necessary in an oral culture for the preservation and transmission of knowledge?[67] His response calls for metaphors, narratives, redundancy, concrete models and communal interaction.[68] Commedia Dell'Arte (CDA), a theatrical performance (a job or acting labor) genre dating back to 16th century Italian peninsula, contains such devices. It is usually described as having a stable group of actors performing a repertoire of plays with similar plots using similar situations in a fixed group of characters or character types. Each character type is played by an actor who specializes in the role and draws on a repertoire of speeches routines etc., that are generic and contextual enough to suit situational variations while the play is being performed (aka, situated actions). The actors seem to improvise their performances (the things they do while doing their job of acting) to the situational action content of each scene. The recipe of Commedia Dell'Arte performance allowed performances (acting labor) to take place on short notice, and gives Commedia Dell'Arte its distinctive characteristic. Scholars debate the actual process of putting on a performance (an acting job) and the

[65] Ibid., 67.
[66] Ibid., 69.
[67] Turnbull, *Masons, Trickerster and Cartographers*: 152.
[68] Ibid.

degree of flexibility within the performance (acting job), with some crediting the performers with the ability to quickly generate performances (acting jobs) making improvisation its key feature, while others credit CDA's formulaic features, so that actors are seen to just actively piece together preset memorized routines.[69] These two debates are similar to Suchman's debate regarding plans and situated action. These two accounts of Commedia Dell'Arte are seen as extremes of one another and CDA's true nature likely lies somewhere in between.

Scholars note "the extent to which practitioners of this theater form were quick to assert the predominance of performance (the acting process) over written text and the superiority of the actor over the playwright."[70] Downplayed is the writer or director's role in preference to the actor's knowledge and ability to reach a performance (acting process) goal. "… on the whole the actors showed a marked disregard for the preservation of their work in textual form," in much the same way technicians disregard instruction manuals when a system is functioning as expected.[71]

There is marked social preference for textual over oral culture and literary critics tend to deride the repetitive and trait nature of the recurrent plots, subplots, plot mechanisms, themes and preoccupations of this particular form of theater, but these are just the typifications that should be studied in situated action. This derision is similar to that

[69] Tim Fitzpatrick, *The relationship of oral and literate performance processes in the commedia dell'arte : beyond the improvisation/memorisation divide* (Lewiston: Edwin Mellen Press, 1995). 8.
[70] Ibid., 15.
[71] Ibid., 15-6.

commonly associated with power and control aspects of work between resident laborers and management.[72]

> "Their recourse to more specifically textual and literate strategies placed the power in the hands (or the pen-hand) of the author of the text rather than with the performer, ensuring desirable literary outcomes such as originality, coherence, unity of perspective, stylistic consistency, etc."[73]

This is similar to granting to plans more importance than action. Finnegan notes that though there is a preference for and respect for literal forms of performance (acting), "oral literature is still a living art and there is constant interplay between oral and written forms."[74] Deck officers trained one to two decades ago studied techniques that have since been subsumed by many new bridge technologies. They could operate the new technologies as they saw fit, and in conjunction with older process forms until recently, when many of them are now being written into regulations that seek to implement new technologies over their older forms. Deck officers had degrees of freedom just as "the performers (actors) of the Commedia Dell'Arte had techniques and processes of performance (theatrical acting) which meant they could avoid the hegemony of the full play script for a considerable period."[75]

When a performer acts based on a full play script, they are but describing what is in the play script. In comparison to scripted acting, the oral nature of Commedia Dell'Arte can be likened to making speech acts. Their actions bring about the theater. Fitzpatrick makes four claims regarding oral-formulaic theory: 1) Oral text is variable and depends

[72] Ibid., 17.
[73] Ibid., 16-7.
[74] R. Finnegan, *Literacy and Orality* (Oxford: Blackwell, 1988). 61-2.
[75] Fitzpatrick, *The relationship of oral and literate performance processes in the commedia dell'arte : beyond the improvisation/memorisation divide*: 34.

on the occasion of performance, unlike the fixed text of a written book - composition occurs in performance rather than prior to and divorced from the active performance, just as plans are weak resources for situated action. 2) "The process of composing and transmitting oral literature is through composition and performance rather than through verbatim memorization and recall,"[76] thus objectivity is achieved rather than given. 3) In oral literature "there is no concept of a 'correct' or 'authentic' original version, therefore no stable meaning to be applied to every situation. 4) The situated nature of performance is central: and is an "overriding and autonomous category of human interaction, independent of textual, literate means of transmitting meanings,"[77] just as technical manual's content is necessarily empty until interpreted by users in specific contexts. Flexible performance (theatrical labor) has limitations in the extremes. It isn't governed by "explicit and detailed learnt text or by a performance tradition which is extremely codified,"[78] or extreme improvisation, but is

> "defined as a mode of performance in which the performer, given the limits and possibilities concomitant with his/her role in the context of situation and the more or less explicit goals which he/she brings to the situation, has both the liberty to generate with some flexibility actions and words appropriate to the context, and also the resources to do so in a coherent, pertinent, and acceptable way. Such resources range from the general cultural to the specific and individual."[79]

A general model for capturing a performance looks like this:

[76] Ibid., 23.
[77] Ibid., 24.
[78] Ibid., 48.
[79] Ibid.

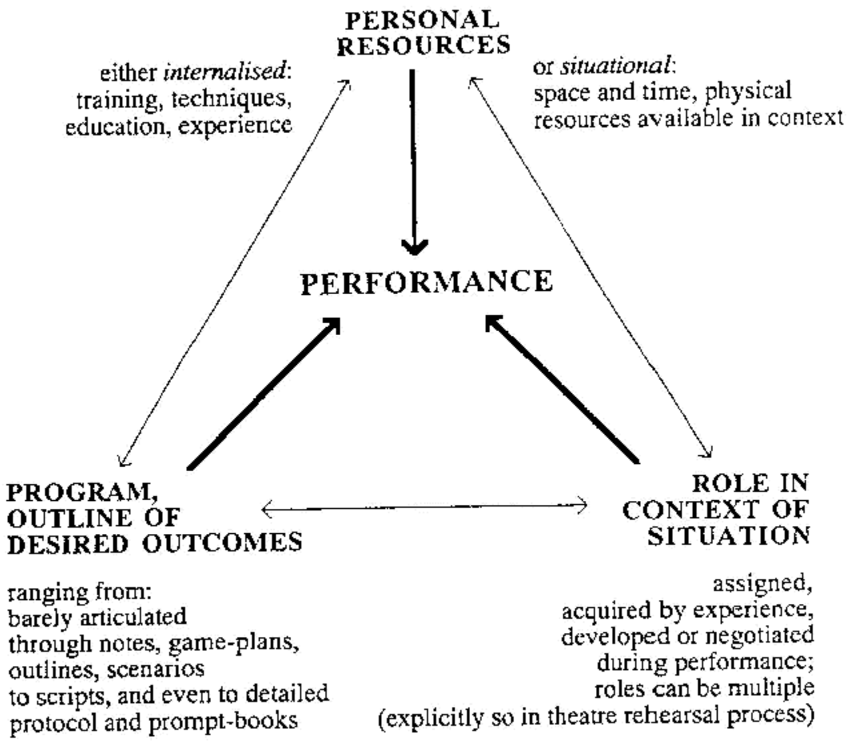

Figure 2 - General CDA model for capturing a performance [80]

Comparing a literary or scripted use of the general model and one for CDA looks as follows where the solid lines reflect a script based performance process and the dotted reflect CDA:

[80] Ibid., 54.

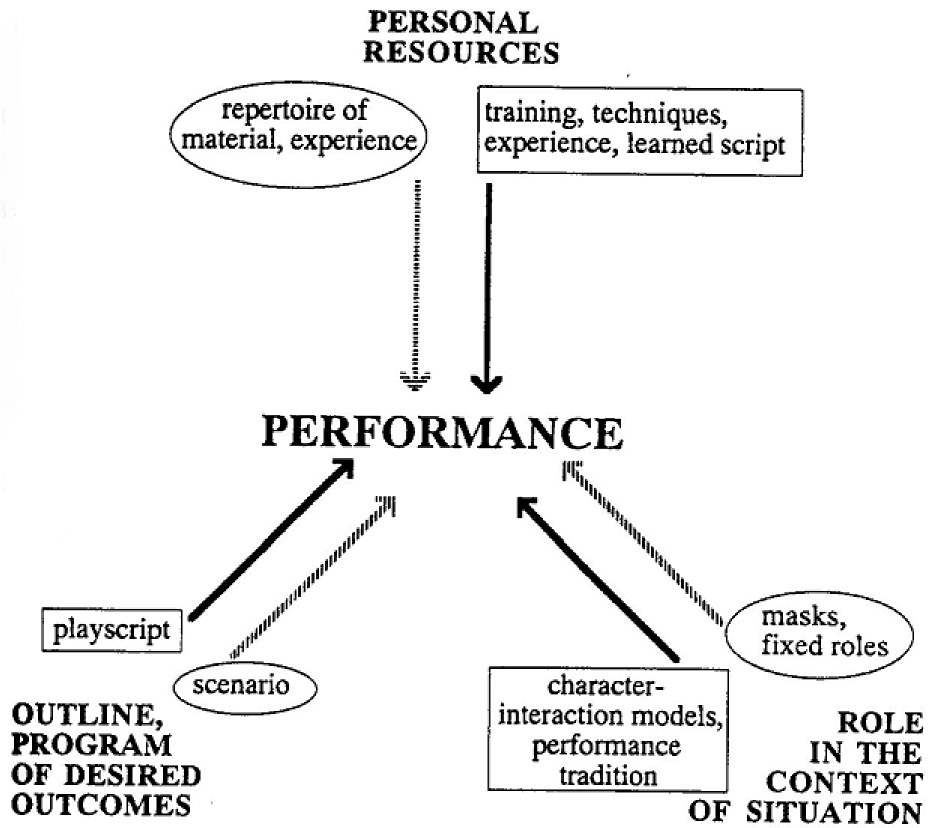

Figure 3 - Comparing a literary or scripted use of the general model and one for CDA[81]

CDA employed flexible performance techniques similar to those used in everyday social transactions.[82] CDA performers used daily interpersonal strategies and linguistic techniques to produce their theater just as deck officers produce their everyday bridge watches. CDA performers had techniques and structures for performance enabling them to avoid the hegemony of literate play scripting for a considerable period of time, until subsequent literate theater forms began to dominate and assert the dominance of a script's

[81] Ibid., 57.
[82] Ibid., 5.

author as the authoritative form or process.[83] Historically, deck officers enjoy similar flexibility in constructing their bridge watches.

CDA is a hybrid of oral and literate performance processes that privileges flexible characteristics of performance while being dependent on a somewhat tight performance structure. On a continuum of fully improvised on the left at one end and fully scripted on the right at the other, CDA is to the left of center.[84] Comparing oral and literate performance processes with regard to flexibility, memory use, authority and social status, oral: is variable and dependent on the occasion of the performance, composition and transmission is achieved via performance in composition rather than via verbatim memorization. It has no correct or authentic version, meaning is derived at the point of performance.[85] The performance characteristics of a primarily oral mind-set is found in varying degrees in many cultures and subcultures, including high technology.[86]

The literate aspect of CDA is in the form of the scenario.[87] CDA scenarios aren't particularly well documented, but some written examples survive today.[88] An agreement by theatrical scholars on the true use of surviving examples of written down scenarios is up for contention; however, they can be seen as documents that facilitate the oral performance process, and their very incompleteness sheds light on the importance of flexibility in performance.[89] In CDA, the scenarios written or otherwise, serve to set up the general schemas and subschemas that indicate the temporal and spatial details and

[83] Ibid., 16.
[84] Ibid., 14,78.
[85] Ibid., 23-24.
[86] Ibid., 39.
[87] Ibid., 79.
[88] Ibid., 96.
[89] Ibid., 81-85.

actions needed by participants in the performance in order for them to synchronize their actions.[90] Such agreement enabled them to "access pre-patterned material to actualize the sequences which constitute the wider plot-processes."[91] The general nature of the scenario allowed flexible performance, giving performers the leeway in generating their dialogue and actions that were appropriate for the situational context and in pursuit of situational goals, and doing so in a way coherent and acceptable to the audience.

In CDA, the scenarios provided the goals, the schemas the ordering.[92] Schemas can be general or specific, with specific ones inheriting from general ones.[93] Formulas drive schemas.[94] Formulas are the ready-made personal resources of the actors gained from experience and strung together by the actor as they interact with other performers to achieve a stated scenario's goals.[95] The deployment of these ready-made resources involves the manipulation of proximate resources such as space and time of performance, and of the performer's whole culture, every bit of training, and experiential knowledge.[96]

2.6 Assessing Worker Knowledge Requirements in Light of Automation

Applying the claims of the Commedia Dell'Arte's production process in conjunction with Suchman's idea of situated actions, Butler's idea of gender identity, and postulating that deck officer work is of similar nature, one can argue that deck officer bridge watch actions are performative acts. Justifying deck officer oppositional view to deskilling requires arguing that their acts are situated, improvised, and performative. If not, then

[90] Ibid., 44.
[91] Ibid., 81.
[92] Ibid., 75.
[93] Ibid., 69.
[94] Ibid., 72.
[95] Ibid., 76.
[96] Ibid., 67.

their actions would require them to acquiesce to new technology and act in strict accordance with plans regardless of context; they would have no agency. To argue successfully, one must understand what deck officers do during their bridge watches, what ECDIS does on their bridge watches, and their agency relative to ECDIS. One way in which one might understand deck officer bridge work, and what ECDIS does during bridge watches is to document bridge watches, both before and after the introduction of ECDIS. Using this documentation to see if knowledge, and what kind of knowledge, is transferred from the deck officer to ECDIS can point to whether some concept of deskilling or scripting of work takes place with introduction and use of ECDIS, and how deck officer's agency affects such scripting.

Situated actions constructed within the CDA framework are what Collins calls polimorphic actions.[97] Constructing polimorphic actions correctly requires that one embed oneself in the society in which the action takes place. The same action constructs differently in different societies. The same polymorphic action has many potential constructions. The opposite of polymorphic actions is mimeomorphic actions.[98] Mimeomorphic actions need to occur in the same way each time, but can accommodate a small amount of variability. Automation of human mimeomorphic actions can occur because the knowledge necessary to produce the action is explicit, or if tacit, can be mimicked. Polimorphic actions require a different kind of knowledge that is tacit and can't be mimicked without some rearranging the world.

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[97] Collins and Kusch, *The Shape of Actions - What Humans and Machines Can Do*: 32.
[98] Ibid., 36.

Collins provides a model with which one can compare work processes before and after the introduction of a new technology. The method documents the tacit and explicit knowledge that exists before and after the introduction of a new technology and where it exists. Collins's model of tacit knowledge can be leveraged in order to break down the forms of tacit knowledge used in situated actions where deck officer and ECDIS interact.[99] Collins defines three types of tacit knowledge:[100]

1. Relational Tacit Knowledge (RTK) – "are cases where the parties could tell each other what they need to know but either will not, or cannot for reasons that are not very profound, such as not knowing what the other party needs to know."[101] Replicating these actions by technology is possible, though sometimes with great difficulty.
2. Somatic Tacit Knowledge (STK) – are cases where some humans can render what is explicated to them, but others cannot, such as performing a physical act such as riding a bike. In some cases, technology can't render explicated STK due to the nature of the human body, though replicating many of these actions by technology is possible, though sometimes with great difficulty.
3. Collective Tacit Knowledge (CTK) – such knowledge requires interaction and experience in a social environment. Such knowledge is polimorphic, adaptable and used in different situations to solve different problems depending on the contextual circumstances. This type of knowledge is the hardest to explicate into technology.

[99] Collins, *Tacit & Explicit Knowledge*: 8.
[100] Ibid., 85-86.
[101] Ibid., 91.

Collins created an analysis method called an action survey to document actions, which I have adapted in this study to those of deck officers on watch in a pre-ECDIS bridge work environment, and those of deck officers and ECDIS on watch in a post-ECDIS implementation bridge work environment.[102] The method is simple, but the process of documenting is not. A researcher documents what type of action takes place, either mimeomorphic or polimorphic, and who or what does the task. The type of knowledge in use for the action to occur follows from the type of action that takes place.

For this dissertation, vignettes for chart correcting, voyage planning, and for navigating, will be documented, their contents analyzed for the types of knowledge used, and these results placed in an action tree for analysis of any knowledge transfer occurring before and after ECDIS implementation. By definition, collective tacit knowledge is applied in context and such action is polimorphic, meaning that the action varies depending on the situated context. Relational tacit knowledge and somatic tacit knowledge can be mimicked within some variation and such action is termed mimeomorphic. Documenting whether a bridge watch navigation action is polimorphic or mimeomorphic occurs in the action survey. Mimeomorphic tasks can be automated and polimorphic tasks cannot be automated without losing some choices of action. Mimeomorphic actions are like plans or constative speech acts. They describe a fixed process through repetitive action, their context being fixed, therefore, they cannot be performative. Only polymorphic actions can be considered performative.

Re-arranging how the world works is how polimorphic actions of workers disappear. As polimorphic actions disappear, one can argue that the worker's social connection to the

[102] Ibid., 174.

labor at hand has lost value. A displacement of the polimorphic action's collective tacit knowledge occurs. The reasons for its existence disappear. Experiential technical knowledge is what a laborer gains while doing or having done work. If the laborer is no longer doing a displaced action, then they can't be gaining that specific experiential technical knowledge. It isn't lost until all those in the society who practice with it are no longer alive and or until all documented references to it disappear. This is what happens in a rearranged world. A rearranged world can only come about through the power by humans or by a force of nature.

2.7 Research Framework

One can now establish a research framework for uncovering new notions of technology adoption without resorting to the concept of skill or its opposite de-skilling. The framework consists of utilizing Callon's theory of translation, Collins' theory of action and tacit knowledge, the notion of performativity, and Suchman's theory of situated action in conjunction with the improvisational theatrical production process in Commedia Dell'Arte. With these theories in hand as tools, the following steps make up this research framework:

1. Documenting moments of translation whereby ECDIS comes to represent safer navigation as a mechanism for uncovering attempts to reduce deck officer agency and what power deck officers might have to maintain their agency.
2. An analysis of pre and post ECDIS work processes in order to highlight the placement and type of knowledge within the marine navigation task. Such an

analysis will provide insight into reasons deck officers can have agency with respect to ECDIS.

3. Show that deck officer situated actions, understood as performative acts developed through improvisation is the mechanism by which deck officer identity and thus their agency is established and maintained.

Chapter 3 – ECDIS's Heterogeneity and Contingency

3.1 Reassembling Marine Navigation through ECDIS

ECDIS did not just materialize and produce safe navigation. A group of entities, both established and ad hoc, fostered ECDIS along for almost three decades. Technological innovators brought Electronic Chart Display and Information System (ECDIS) to the market in the 1980's, but were initially unsuccessful at gaining a foothold in the commercial maritime marketplace. Custodial stewards for maritime safety formed committees to study the innovation. ECDIS research projects were undertaken and concluded that ECDIS would make navigation safer through the development of proper functional and technical standards, and proper user training. A market for ECDIS emerged, but did not meet commercial expectations or regulatory (safety) expectations. Achievement of market success arrived when ECDIS became mandatory on the bridges of all commercial ships. Safe navigation success has been less forthcoming. Though ECDIS or ECDIS-like devices have existed aboard ships since the 1980's, ship casualties have not seen a strong sustained downward trend.[103] The lack of distinctive ECDIS safety success over the past twenty-plus years is problematic given the amount of resources expended to engineer, assess its capability, and promote its use.

ECDIS is a technological device utilized by deck officers on the bridges of ships that displays via a monitor screen a ship's position in real-time by integrating a number of

[103] D. Filipkowski, "See More- Analysis of Possibilities of Implementiaton AR Solutions During Bridge Watchkeeping," in *Marine Navigation and Safety of Sea Transportation: Advances in Marine Navigation*, ed. Adam Weintrit (London, UK: CRC Press, 2013).

disparate technologies.[104] The display renders a view of one's ship as an overlay on top of a computer graphics representation of hydrographic survey data in the form of an electronic navigation chart. ECDIS provides the capability to view, on demand, layers of hydrographic information as well as other information that is of interest for the safe navigation of a ship. The other information includes aids to navigation like buoys, dangers to navigation like wrecks, meteorological data, real-time tidal/current data, and vessel traffic information. ECDIS also provides a decision support capability that enables navigators to utilize the hydrographic and other information for the purposes of safe navigation. ECDIS has been a mandatory device on the bridges of newly built tankers and passenger vessels since July 2012 and on new cargo vessels since July 2013.[105] By July 2018, ECDIS will be a mandatory instrument aboard all existing merchant ships.

ECDIS devices or like-devices began to show up on the bridges of the world's merchant ships in the late 1980's, just like radar in the 1950's, calculators in the 1970's, and GPS receivers in the 1980's. Magazine articles describing ECDIS or ECDIS-like capabilities began appearing in the early 1980's touting a new navigation experience or dimension. The Woods Hole ECDIS Test Bed Project stated, "It is likely, in fact, that ECDIS is the beginning of a new paradigm for marine navigation altogether."[106] Though not excessively expensive at the time, about $30,000,[107] ECDIS implementation at that time

[104] IMO, "Performance Standards for Electronic Chart Display and Information Systems - IMO Resolution A817(19) Revised by MSC Res. MSC.282(82) adpoted 5 December 2006," (London, UK: International Maritime Organization, 1995 (2006)).
[105] "International Convention for the Safety of Life at Sea," ed. International Maritime Organization (London, UK1974 (as amneded)).
[106] Woods Hole Oceanographic Institute Maritime Policy Center, "ECDIS Test Bed Project - Evaluation of Proposed IMO Perfornace Standard for ECDIS HGE draft version 2, September 1992," (1993), 15.
[107] Rogoff, *Mortimer Rogoff - Man of the Future* 87.

was stymied due to the potential for product liability claims surrounding its use, and legal issues surrounding the admissibility of its electronic charts as a legal chart should the need arise due to the circumstance of a ship's casualty. This is the setting in which the process known as marine navigation was "reassembled"[108] around the world through domestic and international committees, and supported by a litany of research papers on the fledgling ECDIS or ECDIS-like technology by private, academic, and government agencies.

3.2 Overview of Commercial Maritime Entities and Their Agency

Rearranging the world of marine navigation is no small effort. Such a rearranging requires the development of expertise, the building of strong and binding relationships, and the ability to produce a product. An overview of the maritime shipping domain is a good starting point for understanding the influential entities involved in ECDIS and in understanding the processes by which ECDIS came to the bridges of commercial maritime ships. ECDIS is a tool that is found on ships of all nationalities. This overview covers US entities primarily, other nation's or transnational entities where necessary, but in general what is said regarding US entities is replicated in similar form in all other maritime nations.

Merchant marine deck officers hold merchant marine officer's licenses issued to them by an issuing authority recognized by the International Maritime Organization (IMO), a United Nations organization established in 1959 to create the regulatory framework for safe operation of the world's shipping. Obtaining a merchant marine license (or as the US Coast Guard now calls them, a "credential") requires passing a comprehensive exam

[108] Bruno Latour, *Reassembling the Social* (Oxford: Oxford University Press, 2007). 8.

along with 365 days of at-sea training aboard a ship of 1000 gross tons or more.[109] There are other classes of merchant marine licenses, but only the Unlimited Deck Officer class is part of this research. These shipboard personnel are the captains, mates, and pilots who guide ships through a port, across the oceans, and when required due to circumstance, provide life-saving assistance to those in peril on the world's oceans. They are the repositories of all the current accumulated collective tacit knowledge for their profession.

The United States Coast Guard (USCG) has the oversight responsibility for administering the licensing and credentialing processes for all U.S. seagoing personnel in conjunction with the IMO's requirements. The USCG is also the U.S. ship safety inspection agent for the IMO. This includes inspection for a vessel meeting the minimum crew complement, or manning requirements for a particular class of vessel, and allows them the right to inspect foreign vessels at U.S ports. It is through these kinds of inspections that the IMO provisions can be overseen by its member states, since the IMO has no enforcement power to do such oversight.

Previous to the IMO standards, the Maritime Administration under the Merchant Marine Act of 1936 set the curriculum requirements for licensed officers, with the Coast Guard and its predecessor agencies overseeing the examination and licensing processes since 1871.[110] The U.S. has been licensing Merchant marine officers since the mid-1800's.

Generally speaking, the maritime industry remains hidden from the U.S. consumer, unless one has some affiliation with the maritime industry, or one lives in the vicinity of

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[109] CFR, "Merchant Mariner Credential," in *46 Chapter 1 subchapter B Part 10* ed. Code of Federal Regulations (Washignton D.C.2015, Current).
[110] William McKinney and Peter Kemper Jr., eds., *The Federal Statutes, Annotated*, vol. 5 (Northport, Long Island, NY: 1905), 399.

one the Nation's busy ports, or shore facilities, where some 55,000 plus ocean going vessel calls take place annually.[111] When a seafaring individual is questioned regarding their employment and the response is, "I'm in the merchant marine," the questioner says, "Oh, you're in the marines." When the seafarer says, "No, I sail on cargo ships for a living," the inquirer typically says, "Oh, you're in the Navy." The seafarer then responds, "No!", "Like the Exxon Valdez." "Oh", the other person says with a slight look of bewilderment and suspicion. Such is the cultural standing of the merchant mariner. Their labor remains hidden from sight and the only anchoring (pun intended) in the minds of the consuming public is related to ecological disasters, or pop media: The Love Boat, Poseidon Adventure, Titanic or Edmund Fitzgerald. Public perception of merchant seaman has been also blemished generally in films such as Lord Jim and The Wreck of the Mary Deare, in which the main character, a merchant marine officer, is viewed as a tragic hero. The surefooted qualities of the merchant sailor seem only consistently illustrated in "Popeye the Sailor". This animation; however, was created at a time when the merchant seamen numbered in the hundreds of thousands in the U.S. alone. None of these cultural references is reflective of the world's ocean seafarers, including the current 33,000 U.S. active seafaring individuals in particular.[112]

3.3 Some Views of Commercial Maritime Economic Value

A proxy measure with regard to the value of seafarers to U.S. society's economic production is most likely best measured by the incomes that they command. The mean salary for U.S. sea-going deck personnel in 2009 was $56,000, with a high of $70,700 for Ship's masters (captains). The lowest salaries are paid to unlicensed personnel with a

[111] MARAD, " U.S. Water Transportation Statistical Snapshot," ed. Office of Policy and Plans (2011), 1.
[112] Ibid., 25.

mean of $37,300.[113] These statistics reflect all sea-going personnel whether on tugs, ferries or ships, and whether their work is done on rivers, bays, the Great Lakes, or the world's oceans. Salaries for ship's masters on U.S ocean-going ships are in excess of $150,000, with correspondingly higher salaries being paid for unlicensed personnel as well, but at somewhat less of a percentage increase over non-oceangoing counterparts. The mean salary for all U.S. occupations in 2009 was $43,500.[114] While the seafarer's labor remains hidden, it is highly valued in economic terms.

When the U.S. Government considers the economic maritime environment, it considers the amount of cargo tonnage imported and exported at the U.S. borders and its considerable dollar value. In 2009, the number of tons for waterborne trade equaled 2 billion metric tons (a metric ton equals 1000 kilograms).[115] Sixty-one percent (61%) of that tonnage, or 1.2 billion tons, was in foreign trade and that foreign trade amounted to sixteen percent (16%) of all global waterborne trade.[116] The value of this foreign trade tonnage equals 1.12 trillion US dollars, which is 44% of all U.S. foreign commerce that includes air and land transportation modes.[117] U.S. policy decides whether the safety and value of U.S. maritime trade at some level is of importance to the Country at any given moment in history. Favorable policy designed to support the U.S. maritime industry has taken the form of Acts from Congress.

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113 Ibid., 26.
114 Ibid.
115 Ibid., 1.
116 Ibid.
117 Ibid., 28.

3.4 Oversight of Shipboard Labor

The merchant mariner has had to deal principally with steamship companies, hereafter called ocean carriers, with regards to their labor employment. The Merchant Marine Act of 1936 included provisions that would enable the Government to investigate crew manning and wage practices. This capability was in addition to the Seaman's Act of 1915 that set U.S nationality restrictions on U.S. carriers in order to protect the U.S. seaman's wage basis, protection against corporal punishment and shipboard living standards principally. Organized labor strength waxes and wanes with economic standards and governmental socio-economic and national-interest policies. U.S. seagoing maritime labor continued to be effective in negotiations with the carriers until the early 1980's when the number of seagoing jobs began to contract significantly as a number of major U.S. carriers filed for bankruptcy due to political, economic and technical conditions.

The oversight of manning levels for vessels, as well as training for personnel passed into the hands of the IMO, and out of the hands of the unions and the ship owners. The incentive for this consensual program has grown out of world governments' desire to limit seagoing casualties (vessel, cargo and life loss), especially those that negatively impact the environment. Manning requirements for oceangoing vessels are now set forth by the aforementioned IMO. The manning requirements of the IMO are set forth in their SOLAS (Safety of Life at Sea) Convention Regulation 14, Ship's Manning as amended from time to time.

The current minimum manning requirements are more fully defined in IMO Resolution A.890(21) adopted on 25 November 1999 as amended, as a set of guidelines that must be taken into consideration by a ship operator when determining a vessel's minimum manning requirement. Such guidelines include: watch-keeping, hours of work or rest, safety management, certification of seafarers, training of seafarers, occupational health and hygiene and crew accommodation. Part of SOLAS is in effect a global enrollment of what U.S. seaman labor achieved in the Seaman Act of 1915.

Seafaring is among the most regulated professions in the world. Like vessel crew manning, the global training standards for sea-going personnel are also set currently by the IMO. The IMO now has judgment authority over the training, examination and certificating practices of countries in its membership, which number 169 countries. The IMO's publishes their standard requirements in its International Convention on Standards of Training, Certification and Watch-keeping for Seafarers (STCW). The IMO's STCW requirements seek to ensure that a required task has a training standard associated with it.

3.5 Shipboard Labor Power Structure

The organization of a merchant ship's labor is hierarchical in fashion. Since the mid-1800's it split into two general contingents, deck and engineering. The deck department consists of licensed officers and unlicensed seaman. The captain sits atop the ship's hierarchy with senior responsibility for the ship and the safety of crew and cargo, as well as being the head deck officer. The rest of the deck officer compliment consists of the 1st officer (chief mate), the 2nd mate and the 3rd mate aboard U.S. ships. Other nations may have additional numbers of mates to fill out their watch standing operations. The bosun's-mate oversees the unlicensed deck crew that includes able-bodied seaman and the ordinary seamen. Some vessels have stewards and radio departments, and these departments fall under the deck department generally, with many ships today doing without them. The engineering department is similarly manned, but with the chief engineer at its head. The technology of a ship's construction parallels this personnel social hierarchy. Officers' staterooms are higher up in the superstructure of the ship, and in most cases they have larger staterooms than the staterooms for unlicensed personnel.

The ship's captain has been the historical disciplinary head and the representative of the shipping company's management, whether he belonged to a labor union or not. Discipline has been a key component in the efficient operation of a ship at sea. Part of the training that maritime academies provided students in the 20th century was military drill. "Military drills are performed, as much as anything else, to inculcate the habit of obedience. When the habit of obedience is acquired, there will be efficiency".[118] In the latter half of the 20th century, military drill has given way to technological efficiency in a ship's system.

3.6 How They Know What They Know

In 1940, 80% of all the officers in the U.S. merchant marine had received no "systematic training," and that only 10% trained at U.S. state nautical schools/maritime academies.[119] It can be assumed from this statistic, that maritime technical knowledge was, in effect, a result of on-the-job-training (OJT), and that maritime academy graduates were the exception. The OJT aspect of maritime labor at that time makes it similar to shore-side

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118 "General Catelog," ed. California Maritime Academy (Vallejo1940), 9.
119 Ibid., 6.

shop floor labor being supervised by more experienced shop floor craftsmen. As the U.S. merchant marine has dwindled in the number of its ships, so have the opportunities to learn on the job. Working one's way through the unlicensed ratings while self-studying is not as common practice today as it was in the past. The principle method by which U.S. ship's officers are trained is by attending one of the nation's maritime academies. The nation has a Federal school called the U.S. Merchant Marine Academy located on Long Island, NY. This school was founded at part of the Merchant Marine Act of 1936. There are six state maritime academies and these are located in Maine (circa 1941), Massachusetts (circa 1891), New York (circa 1874), Michigan (circa 1969), Texas (circa 1962) and California (circa 1929). Other states have had academies in the past such as Pennsylvania. Maritime academies were instituted to provide manning based on U.S. shipping policy. The first such act of Congress and the basis for the entire maritime academy system was approved June 20, 1874 and entitled "An Act to encourage the establishment of Public Marine Schools."[120] Each academy mentions the 1874 act at some point in their historical catalogs. New York created their school in that year. Subsequent schools were created by their state governments over time as funding and economic need provided. A quote from California Maritime Academy's 1932 catalog is typical of the verbiage touting such schools.

> "The enormous increase in the size of modern steamships, the advances in the marine and nautical engineering, the applications on shipboard of new apparatus and scientific devices call for a high degree of scholastic and technical knowledge, which with the increasingly exacting social and intellectual requirements of those responsible for the operation of

[120] 43 U.S. Congress, "Statutes of the United States of America Pased at the First Seesion of the Forty-Third Congress 1873-1874," (Washington D.C.: Government Printing Office, 1874), 121.

ships, makes desirable, if not mandatory, sound preliminary training."[121]

The required curriculum for meeting the licensing requirements for an introductory offer's license (3rd Mate) is set by the U.S. Maritime Administration. MARAD currently receives its guidance on curriculum from the IMO and it audits the Federal and State maritime academies for the IMO's STCW compliance.

Training for practicing merchant officers beyond entry level has been OJT generally. Even today, training is done OJT, since competing companies build shipboard systems that meet a requirement, but that technology's operation might differ across manufacturers. Today's U.S. Coast Guard merchant officer's licensing examinations do not specify any technology brands.

At one time in history, ship's officers, and especially the captain, were paid a percentage of the ship's cargo receipts. Many times the ship's captain was a part owner of the ship, or a relative or local friend of the owner. This period in time corresponds to when the New England coast was dotted with many small shipyards. Over time, this became less common and being paid a salary is the norm. The period of transition to a salary basis for paying all the crew members corresponds to the rise of maritime academies as a source of officers for U.S. ships. No comparable research for foreign merchant shipping has been done in this paper.

3.7 The Business of Ocean Shipping

Carriers can be characterized as being driven by the economic demands of international shipping in order to survive. A firm's practices are heavily influenced by the regulatory

121 "General Information," ed. California Maritime Academy (San Francisco1932), 6.

and economic policies placed upon them by the nations under which their ships are registered. Carriers stand to benefit if that nation has few formal policies or enforcement of their policies. Most cargo that moves across the world's oceans can't be sheltered or controlled by the cargo's loading country or the cargo's discharging country, because such arrangements are not economically stable for any lengthy period of time, meaning that a carrier can't expect to go between any two countries and consistently have cargo available at the time a ship is ready to receive it. Therefore, carriers design routes on which there is an expectation of generating cargos consistently between multiple ports in multiple countries. Preferential shipping policy where a country regulates that a certain percentage of their import and export cargo be carried on vessels that fly that country's flag isn't sustainable for the logistical difficulty stated above. Such policies also tend to drive up costs for consumers and therefore becomes politically undesirable. A carrier must seek ways to lower a ship's operating costs without shipping preference policies if it is to continue to be able to adjust to market fluctuations in revenue and cost.

The business of shipping is a layer of commercial entities connected to the ultimate voyage production product; however, many of them have no direct relationship with the operating costs of the vessel on a day-to-day basis. Operating costs include such items as crewing, fuel, ships stores, and even regulatory maintenance of the ship. Regulatory costs are administrative and maintenance work done to keep the ship within compliance to international safety standards. Choosing in which country to register a ship and choosing what classification society will monitor safety standards compliance can affect the overall cost of operating a ship. Flagging a vessel where income taxes are less, and where there is minimal oversight for continued safety requirements, because such requirements whether in ship systems or in ship crew training/manning tends to be expensive is called using flags of convenience (FOC). This is an attractive way to try to lower shipping costs. A second method used to lower costs is to attract crew members from countries with lower standards of living, because these crew members are willing to work for much less. This kind of situation resulted in the desire for the Seaman's Act of 1915. This is called using crews of convenience (COC). Technology notwithstanding, a carrier's operating cost can't be minimized without both of these methods in use at the same time.

A third way in which a carrier might lower operating costs in through using innovative technologies that use operating resources more efficiently or enable an operation to be performed more quickly. Technological innovation, which includes automation, requires more time to implement and typically includes capital expenditure that a carrier may not otherwise have at any given moment. A carrier will use FOC and COC in order to gain time to implement innovative technologies. Carriers will implement innovative technologies that lower their operating costs when the present-value returns are greater than the capital costs under the prevailing economic conditions. Implementing innovative technologies however, does not stop a carrier from using FOC and COC cost cutting methods.

A for-profit business model for shipping means that carriers might be motivated to try to operate ships at the lowest possible cost. Acting on this motivation can have side effects. Vessels operating under FOC tend to have lower safety standards.[122] Vessels using COC

[122] Martin Stopford, *Maritime Economics* (Abingdon: Routledge, 1997).

tend to have less formally trained crewmembers.[123] The likelihood of a marine casualty would seem to be higher when combining FOC and COC on a vessel. The IMO's member governments have ratified SOLAS and STCW in order to counter loosening vessel operating standards that tend to come with FOC and COC. Oversight is a challenge. The International Labor Organization (ILO) created in 1919, but now a UN agency, manages the labor framework for international mariners. Since 1959, the IMO has had oversight for maritime labor, vessel and environmental safety, and training since 1980. The IMO is reliant on its member states to oversee and police its Conventions.

3.8 Views on Technology and Work Processes on the Bridge of Ships

Regulated safety can be a motivation for new bridge technologies, but deciding on technological form and the implementation of innovative technologies generally can't be classified so easily. Technological form and implementation are at any time contentious issues between international and nationalistic policy requirements, the ship owning capitalist and shipboard labor, and in some cases the within the technological solution itself.

Automation or technological change aboard a vessel might improve the performance of some process. Such automation may enhance the labor of a crewmember or might displace a crewmember. For example, automatic steering while at sea can result in a straighter course being steered. A straighter course means less time at sea.[124] A straighter course also provides an opportunity for greater ship propulsion efficiency. Automatic steering doesn't remove the need for a helmsman however, because

[123] Ibid.
[124] R.O. Goss, *Studies in Maritime Economics*, 3rd ed. (Cambridge Univerity Press, 1976). 100.

maneuvering in close quarter conditions such as in harbors and heavy seas is still required. It could however, lower the number of crew required for a voyage generally.

Another example of technological innovation is to allow the ship's bridge watch officers to control the ship's diesel propulsion from the ship's bridge. This removes the human bridge to engine room link. Whether this removes an engineer crewmember from the ship isn't always the case, since the engineer's experiential knowledge is applicable to many other shipboard engineering tasks. What such automation does achieve is better coordination of the ship's movement through lower time delays. The fact that the engineer isn't reacting to an engine telegraph command from the ship's bridge means that their reacting experiential knowledge associated with that task is no longer required. The deck officer now mimics this task. This means that the engineer has lost the engine control task related to this process. The fact that the deck officer on the bridge now controls the ship's propulsion directly means that the deck officer has gained a task. The deck officer is now the focal point of the ship's speed in relation to any time delay between the desire to alter a ship's speed and the alteration of the ship's propulsion system to achieve such a speed alteration, as opposed to the engineer on watch changing the ship's propulsion system via commands from the ship's bridge.

With such innovation, the old process lies dormant until a need arises in the future. The ability to awaken the task lies in the situational awareness of the ship's crewmembers and any structural impediments placed in the way to such an awakening however inconceivable such impediments might seem, such as less training, no voice communication device in existence for communicating speed orders, or no close-at-hand throttling device available to the engineer.

Automation or technological change in the maritime environment tends to lessen the use of a particular process or set of processes in preference to another. For example, containerization has removed the deck officer from oversight of the processes of cargo stowage generally, though the chief mate is still required to approve the stow plan. The ability to take cargos of various sizes and weights and place them in the hold of a ship so that they survive the ocean transit is not generally well understood by a majority of the world's ship's officers. Today, most consumer goods make their ocean transits in uniform sized containers that are individually stowed (packed) at some location on land.

A deck officer's celestial navigation task has become dormant due to technological change. Most ships utilize the Global Positioning System (GPS) in order to locate its position on the ocean. With ECDIS, the plotting task for a GPS position is automated, with the GPS position plot showing up automatically on an electronic chart. The potentially less accurate previous ship positioning technique of celestial navigation required timekeeping, attention to correct sextant usage, mathematical calculation, and manual chart plotting precision in order to achieve results that ECDIS achieves quickly and automatically. Additionally, the celestial practice required the deck officer to manage time in order to balance the need for attention to other bridge duties. Today, the manual practice of navigation is still taught; however, its use changes with the technological change/choice of using ECDIS. Individuals that were expertly proficient at celestial navigation can still practice it freely, however under the terms of the current bridge operation requirements, GPS positions are tacitly mandated for the ship's navigation. Those that never practiced celestial navigation to the same extent as those in previous generations are likely not to become experts. Onboard ship, the processes for celestial navigation lie dormant, becoming more of a hobby to new generations of ship's officers. Celestial navigation experiential technical knowledge has lost its value. Similar loss of experiential knowledge value takes place with the use of automated radar and plotting aids also known as ARPA. Prior to ARPA, deck officers manually plotted radar contacts on their radar plotting screens using geometry and knowledge of relative motion and time in order to determine if a risk of collision existed with other ships around them. APRA automates this process entirely. The effects on deck officer's watch-keeping and collision avoidance experiential knowledge has yet to be fully understood, since both plotting and visual queuing worked hand in hand in the determination of collision. In acknowledgment though, deck officers must still pass a manual radar plotting exercise every five years in order to qualify for bridge watch-standing duties.

Aside from technical training as insurance against maritime casualties, since the 1990's the IMO requires that ship's deck officers participate in bridge team management courses. This training seeks to ensure consideration of all points of view and consensual decisions making with regard to operations on the bridge of a ship. This means not only integrating the technology into the decisions, but also ensuring that all personnel's knowledge of a bridge evolution is taken into account so that information that might have prevented a casualty is used in the decision making process. This is highly novel in the maritime environment where a hierarchical society exists, with the ship's captain at the top. Acceptance of bridge team management means that leadership styles must evolve from one of direct command on the part of the senior watch officer, to active involvement from lower ranking officers. Numerous maritime casualties have occurred because lower ranking officers would not speak up for fear of overstepping their place in the hierarchy.

3.9 Catastrophes and The Appearance of New Technology on Ships

New technology implementation aboard ships without accompanying regulatory oversight can occur such as with GPS, but there seems to be a high correlation between new regulatory oversight or rulemaking, a major maritime casualty, and an existing innovative technology thought to have been able to forego such casualty. The first wireless station placed aboard an ocean-going commercial vessel for other than testing purposes was in 1901 on the S.S. Lake Champlain.[125] The momentum for installation aboard ships seems to have increased directly with the size of the publicity of events in which wireless telegraphy was a factor in a successful rescue operation or some other event of public interest. Much has been written of the sinking of the Titanic on April 14, 1912.[126] The closest vessel to the Titanic's sinking was the California, whose wireless operator had shut down that ship's station for the night. Other vessels in the vicinity responded to the emergency radio distress call, with the Carpathia arriving first to the rescue. A hastily setup inquiry by the US Government in that same month culminated in the Radio Acts of 1912 in July and again in August. The most important clauses of these acts included a mandatory requirement for at least 2 radio operators for 24-hour operation of an efficient radio apparatus for vessels licensed to carrying 50 or more persons. Cargo

[125] "Norway-Heritage," http://www.norwayheritage.com/p_ship.asp?sh=lachb.
[126] William Henry Flayhart III, "The Extraordinary Story of the White Star Liner Titanic," Scientific American, http://www.scientificamerican.com/article/the-extraordinary-story-of-the-titanic/#.

vessels could carry one operator, but must in lieu of the second have personnel qualified to monitor the radio apparatus.

Forty-two years after the Titanic casualty, in 1954, another highly publicized maritime casualty occurred, the collision of the steamship Andrea Doria and the motor vessel Stockholm off the U.S. East Coast between Nantucket and Ambrose Light.[127] The formal inquiry into the collision found that amongst other contributing factors, poor use of the relatively new commercial shipboard technology, radar, contributed to the casualty. The failure by the officers on watch on both vessels to assess accurately their radar instrument's data output created a situation whereby radar assisted in the vessel's collision. The Andrea Doria's Master broke several of the navigation rules of the road, including running at an unsafe speed in fog and turning to port when meeting a vessel head-on. However, the Stockholm's deck watch officer's failure to correctly use the radar equipment, his lack of understanding of the principles of relative motion, and his failure to plot radar contacts accurately, contributed to these vessels' collision.[128]

At 2121 on March 27, 1989, the Exxon Valdez cleared its berth at Alyeska Marine Terminal at Valdez, Alaska after loading crude oil and headed toward the Port of Valdez harbor entrance known as Valdez Narrow, and from there into the channel known as Valdez Arm. Subsequent events described below taken from the National Transportation Safety Board's (NTSB) accident report describes the final seventeen minutes of the Exxon Valdez prior to its grounding on Bligh Reef in Prince William Sound.

[127] "SS Andrea Doria," https://en.wikipedia.org/wiki/SS_Andrea_Doria.
[128] U.S. Maritime Adminstration, "Radar Instruction Manual," ed. U.S. Maritime Adminstration (Washington, D.C.: U.S. Maritime Adminstration, 1978).

> “The master asked the third mate whether he felt "comfortable" about what he was supposed to do, and the third mate replied that he did. The third mate testified that he had determined by radar that there was a distance of about 0.9 mile between Bligh Reef and the ice floe across the channel and that it would be possible to pass around the ice once Busby Island Light was abeam. The master left the bridge about 2352.”[129]

> “According to the third mate, the radar indicated that the ship was still following a 180-degree track, although the vessel's heading was swinging right. The third mate then ordered hard right rudder. He estimated that Bligh Reef buoy was about 2 points (22 ½ degrees) on the port bow by this time that about 2 minutes had elapsed from the time of his order for right 20 degrees rudder until he ordered hard right rudder.”[130]

After several seconds at the radar, following an order for hard right rudder, the third mate telephoned the master and said, ‘I think we are in serious trouble.’ At the end of the telephone conversation, the third mate felt the vessel contact the bottom.”[131]

[129] NTSB, "Marine Accident Report-· Grounding of the U.S. Tankship EXXON VALDEZ on Bligh Reef, Prince William Sound, near Valdez, Alaska, March 24, 1989," (Washington D.C.1990), 8.
[130] Ibid., 10.
[131] Ibid., 11.

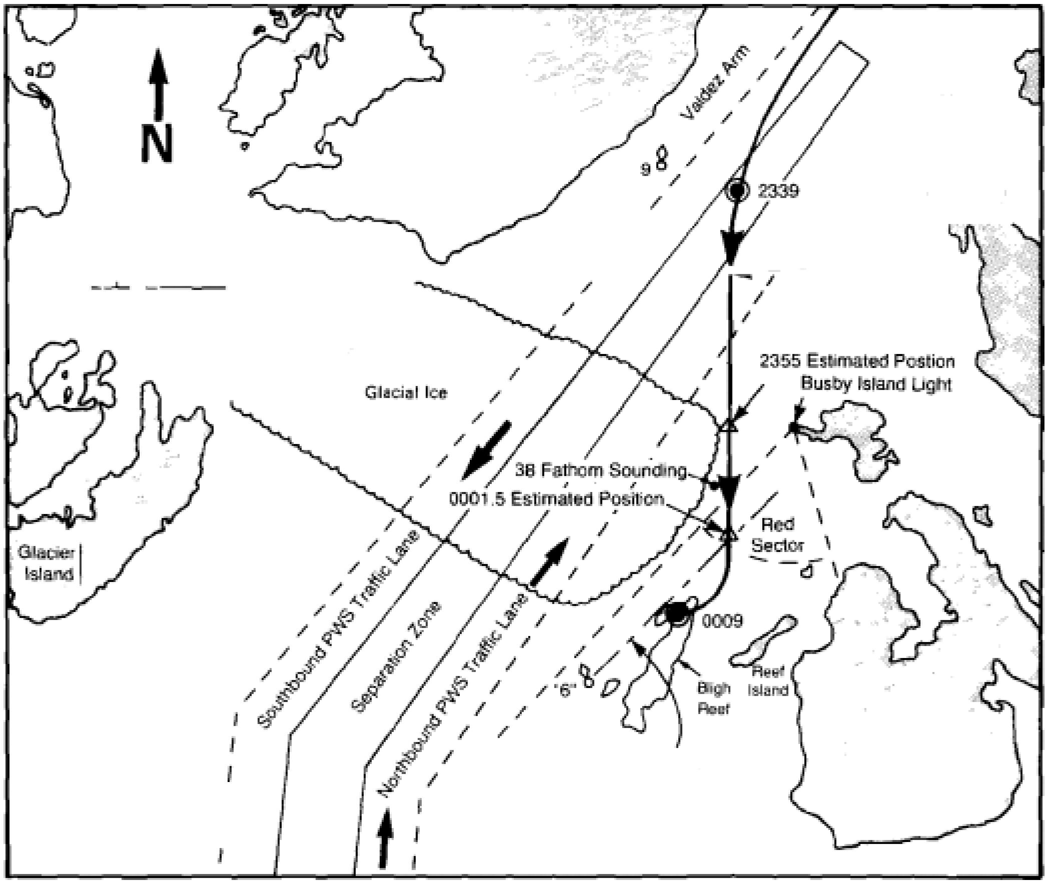

Figure 4 – The last 30 minutes of the Exxon Valdez's trackline to Bligh Reef[132]

It was 0009 on March 28, 1989. While not highly publicized, a global ECDIS research program was in full swing by this time, but timing of the Exxon Valdez grounding and the beginning U.S. Government research program correlate highly. In fact, the Wood's Hole Oceanographic Institute's Evaluation report of their ECDIS Test Bed Program explicitly calls out this incident, "heightened attention in 1989 to maritime safety and environmental pollution following the Prince William Sound oil spill …"[133] About 20 years earlier, an incident took place that began a lifelong interest in navigation safety on

[132] Ibid.

[133] Maritime Policy Center, "ECDIS Test Bed Project - Evaluation of Proposed IMO Perfornace Standard for ECDIS HGE draft version 2, September 1992," 5.

the part of an individual and whose future actions help in the translations moments for safer navigation with ECDIS.

3.10 A Social History of ECDIS

Witnessing a boating accident in the East River from his apartment in Manhattan, Mortimer Rogoff set to work on a technical means for helping boaters ply the waters in and around Manhattan Island safely. Knowing one's location is helpful in good weather and it is even more important in reduced visibility. The gist of the problem is being able to know one's whereabouts in the least amount of time, thus enabling one to keep a look out above and below water for dangers while steering one's vessel. For the navigator, the issues to be surmounted if one is to steer safely, is the time it takes to gather navigational position data and then plot an accurate position on a chart; data for which visual interpolation is necessary, and on a chart that doesn't always endear itself due to its bulky size and paper composition. For small boaters and coastal fishermen alike, on whose vessels space is at a premium, and who generally operate in sailable waters dense with traffic, Rogoff's envisioned device seems highly useful. In 1983, Rogoff's work on creating and integrating technologies in pursuit of navigational safety came to fruition in the form of VIEWNAV which received patent number 4,590,569, in 1986. The description for the patent reads:

> "navigation system particularly adapted for ships making a passing within a harbor or the like, utilizing signal inputs from on-board vessel position determining equipment… whereupon the computer causes a predetermined electronic chart to be displayed in color on the screen of a cathode ray tube, being generated by a plurality of electronic charts stored in the form of digital files in memory… The selected chart, together with the present position of the ship, is displayed …"[134]

[134] Rogoff, *Mortimer Rogoff - Man of the Future* 83.

Navigation charts capable of being displayed graphically on a display screen did not exist, so Rogoff set about creating them by painstakingly extracting latitudes and longitudes off of paper charts and inputting the data into files to be read and then displayed on a screen. The late 1970's was a pre-GPS era, but other electromagnetic wave devices were in use for navigation with highly accurate results and Rogoff set to work integrating one of them, Loran-C (a radio navigation technology that uses received signal time differentials between a principle station and a set of subordinate stations). With such integration came the ability to provide automatic positional updates. Rogoff integrated the reception of Loran-C time-differential values so that when received, they would enable the plotting of the exact position of a vessel. In order to achieve accurate position plots on the screen, Rogoff had to calibrate his chart data with the Loran-C time-differentials by sailing around the areas for the charts he created all the while taking Loran reading. Using this method of chart development with Loran-C integration, Rogoff's device could plot positions accurate to within 15 feet.[135] He began to market his VIEWNAV device to a class of users who needed to revisit precise locations; fishermen who set traps. His Navigation Sciences company begun in 1981 with the help of investors, had its first customer for VIEWNAV, Tallmadge Brothers, a fishing firm harvesting clams and oysters on offshore sea-bottoms leased from the state of Connecticut. VIEWNAV was used by Tallmadge Brothers for almost 20 years to manage their underwater inventories and stay clear of other fishermen's fields Additional customers followed, including the US Coast Guard, who used VIEWNAV to

[135] Ibid., 65.

position buoys in New York and Baltimore harbors, and the New York Pilot Association, who used it identify ships who were dragging their anchors within anchorage areas.

Other electronic navigation device makers were emerging within the maritime market place in the early 1980's, but Navigation Sciences' innovation was to put a radar overlay onto the display, which enabled a navigator to steer under conditions of restricted visibility. "The electronic chart becomes your window on the world – clear even on days of zero visibility."[136]

Navigation Science would bring the lab out to nature through onsite demonstrations of its technology and then ask for sales. One of the most notable demonstrations was in Tampa Bay in 1984, just after Tampa Bay's Skyline Bridge reopened after reconstructed due to a ship, the M/V Summit Venture, collision during a thunderstorm downpour in 1980 that took the lives of 34 motorists who plunged into Tampa Bay's depths when the bridge's center span collapsed. The demonstration placed a US Coast Guard captain's head under a hooded covering with only the VIEWNAV display visible to him for his navigation and piloting decisions. He piloted the vessel to within a yard of the center of the new bridge. This process was repeated several times during the day and all present felt that no bridge collision would have occurred had the M/V Summit Venture had such a device in 1980. One firm present at the demonstration was Exxon Corporation. Exxon forwent any purchase stating that they, "yet felt no pressing need to give up pencil and paper." [137] Exxon had some experience with a somewhat similar technological capability using radar overlays in their Collision Avoidance System (CAS) developed in conjunction with

[136] Mortimer Rogoff, "Electronic Charting," *Yachting* 1985, 54.
[137] Rogoff, *Mortimer Rogoff - Man of the Future* 87.

Sperry Corp in the late 1970's. However, it was not a real-time navigation positioning system. The Exxon Valdez's Third-Mate was at the chart table trying to figure out his position as the Valdez settle upon Bligh Reef in March of 1989. You can almost hear the cry from the Exxon's corporate boardroom in 1989, an ECDIS, an ECDIS, my kingdom for an ECDIS. Save $30,000 in ECDIS expense and pay billions in remedy, not to mention the environmental impacts.

After the Tampa Bay demonstration, the State of Florida wanted the device for all their harbor pilots with the caveat that Navigation Sciences was to be held liable for any mishap due to any fault of the device. Navigation Sciences saw no way to accept such liability and the sale didn't take place. While sales did materialize, there was no strong incentive to buy VIEWNAV's and Navigation Sciences' investors decided to no longer support the business.[138] Navigation Sciences dissolved in 1986, the same year the VIEWNAV patent was awarded, with the departing investors taking control of the VIEWNAV patent.[139]

With Navigation Sciences having been dissolved, Rogoff decided use to his expertise to assist ECDIS manufacturers in their efforts to develop and promote ECIDS and he formed Digital Directions Co., a consultancy as the vehicle to do so. From 1986 onwards, Rogoff tirelessly worked to make electronic charting technology the solution for all future navigation. He became of member of the IMO sub-committee on Safety of Navigation, a US representative to the International Electro-Technical Commission (IEC) devising ECDIS test standards and became the longtime chairman of the Radio Technical

[138] Ibid.
[139] Ibid., 88.

Commission for Maritime Services (RTCM) Special Committee 109 on Electronic Charts. Rogoff's role surrounding early ECDIS development was as the obligatory passage point for expert information regarding ECDIS.[140] He laid out the arguments in favor of ECDIS and at the same time laid out the impediments to ECDIS. Being the obligatory passage point has the effect of defining actors and identities. Rogoff ultimately served as a member of a number of organizations working on translation moments for safe navigation with ECDIS. These entities, some of whom inherit regulatory oversight, some of whom are directed as part of their jobs, some jump in to participate in research, some see a profitable opportunity, and still others, like Rogoff, make a mandatory ECDIS a lifetime pursuit, seek to work ECDIS into their sphere of control.

Rogoff noted during a conference at the University of Maryland in 1985, "My hypothesis is that what's holding it (ECDIS usage) back is the absence of legality and the presence of liability.[141] Electronic charts are not legal charts yet. Without that standing, there's no incentive to make them or buy them."[142] Giuseppe Carnevali the co-founder of another independently developed ECDIS manufacturer, Navionics in Italy, stated at the time that

[140] Callon, "Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay," 6.
[141] The subject of liability and worker competency with regards to shipping is not explored in this dissertation; however, it is a subject in need of exploration with regard to the actor-networks that seek power over maritime deck officer work. For many years, ship owners enjoyed a limitation of liability with regard to vessel casualties typically tied to the value of the ship owner's loss since cargo shipping was seen as a joint venture and the ship owners had little control over what goes on while a ship is at sea. See:"Maritime Limitations of Liability: A Study in Conflict of Laws," *Duke Law Journal* 1962, no. 2 (Spring 1962) (1962). Recent vessel casualties such as that of the Exxon Valdez have seen liability costs above those sustained by the ship owner, thus it seems that ship owners have or should have an interest in having knowledgeable and competent navigators.
[142] Rogoff, *Mortimer Rogoff - Man of the Future* 91.

electronic chart data had to be created by the manufacturers since there was no chart data supply from governments.[143]

The IMO, having in 1959 been given oversight for developing a safety framework for ships at sea, published their International Convention for the Safety of Life at Sea (SOLAS) in 1974. SOLAS covers all aspects of ship safety such as vessel construction, lifesaving equipment, cargo carriage, radio communications and safety of navigation. This is the international instrument to which member governments align themselves through national ratification of IMO conventions and by which member states regulate international shipping that comes to their ports. During what are termed port state inspections, a country can inspect a ship and determine its compliance with SOLAS. If found not to be compliant with SOLAS regulations, a state can fine and even impound a vessel until it complies with SOLAS. One such regulation is 19.2.1.4, under Chapter 5, Safety of Navigation, covers navigation equipment carriage requirements, including nautical charts and nautical publications for planning and displaying a ship's voyage. With no legal status for an electronic chart, a vessel choosing to use an ECDIS or ECDIS type device in lieu of paper charts prior to 1995 could be fined or worse, held in port until such time the proper paper charts are procured and onboard the vessel.

SOLAS Chapter 5 also requires that nautical charts and nautical publications be issued by and derived from official, or authorized by a Government, authorized Hydrographic Office, or other relevant government institution. Therefore, ECDIS and ECDIS type devices used before 1995 utilized non-government issued charts because no government was issuing electronic charts. After 1995, the charts may have been official, but the

[143] Ibid., 84.

hydrographic data upon which they were based was the same as that used for commercially generated electronic charts. Regulation 27 states that:

> "Nautical charts and nautical publications, such as sailing directions, lists of lights, notices to mariners, tide tables and all other nautical publications necessary for the intended voyage, shall be adequate and up to date."[144]

ECDIS providers, if they desired to try to comply with SOLAS needed to enable methods to update their non-hydrographic office produced charts, either through manual updates by the crew or file updates through some medium of data exchange.

A ship's record keeping requirements also impacted early ECDIS adoption. Regulation 28 of SOLAS requires that all ships engaged on international voyages keep on board a full record of "navigational activities and incidents which are of importance to safety of navigation and which must contain sufficient detail to restore a complete record of the voyage."[145] A ship's paper chart is, along with the ship's logbook and the ship's radar plotting cover, the principle tools for reconstructing a ship's casualty. Early ECDISs did not necessarily have a built in capability to store voyage transit history. After all, ECDIS manufacturers of that time in their advertising professed that any position noted after the fact of real-time was inaccurate. Even if an ECDIS did have this capability, its charts were not official.

SOLAS, as it existed in the 1980's, had impediments with long standing precedent due to previous translation moments in support of safe navigation. To navigation innovators who believed that their product should be made mandatory because its benefits are so compelling, these impediments needed to be reconciled to favor their cause of safer

[144] IMO, "International Convention for the Safety of Life at Sea."
[145] Ibid.

navigation with ECDIS. Though no identifiable first instance or communication for the beginning of the ECDIS translation moments is identifiable, the collective voices within the maritime domain began to be heard in the late 1980's. In 1989 the IMO proposed a draft specification for ECIDS performance standards based partly on recommendations from the International Hydrographic Organization (IHO) and from sea-trial IHO/IMO experiments held in the North Sea during the winter of 1988. The sea-trial project was an outcome of the previous year's integration of IMO and IHO ECDIS efforts through the IMO/IHO Harmonization Group on ECDIS, and this can be seen as a first official step to make ECDIS use a legal equivalent of paper nautical chart use. In 1990, the IHO in Appendix 1 to the IHO Special Publication 52 (Updating the Electronic Chart) stated:

> "Only time and the law will ultimately decide what type of ECDIS display constitutes 'the legal equivalent to the paper chart.' … Since so few even rudimentary ECDIS exist today and it will be many years before their role progresses from Navigation Aid toward something approaching 'the legal equivalent of the paper chart', it is probably best for the next few years to (a) encourage a continuation of the discussions among the mariners, hydrographers and manufacturers that are presently taking place, and (b) continue the experimentation and field testing that is going on in various parts of the world."[146]

My research hasn't been able to uncover reliable documentation of the discussions that took place among the mariners, hydrographers, and manufacturers prior to 1988, but much has been found regarding the experimentation and field testing that took place after 1989 in the U.S.

By the 1990's ECDIS technology was seen as feasible because of advances in computer technology including powerful graphics processing software capabilities, precise and continuous electronic navigation systems with wide geographic coverage, and advances

[146] IHO, "S-52 Specifications for the Chart Content and Display Aspects of ECDIS," (Monaco: International Hydrographic Organization, 1994 (2010)).

in micro-electronics. The U.S. ECDIS Test Bed Project overseen by Woods Hole Oceanographic Institute stated that electronic navigation adoption,

> "by the maritime transportation industry seems inevitable (it was adopted by the aeronautical industry many years ago) there remains a need for the setting of uniform, safe performance standards for ECDIS, as well as eventual introduction of national carriage requirements."[147]

The implied technological determination within this statement aside, what can be said is that the statement is a mechanism for translating unsafe maritime navigation to the realm of what is likely considered a more visible and thought to be safer transportation environment, commercial air transportation, if for no other reason than it uses electronic navigation.

The Test Bed Project would go on to inform the USCG on the ECDIS specification and make recommendations toward a final IMO specification published in 1995, IMO Performance Standards for ECDIS, IMO Resolution A817, November 1995. A key figure in the development of the Test Bed Plan and its execution and analysis is Mortimer Rogoff, the creator of the first truly integrated electronic charting system. He personally penned the following Test Bed Project documents:

1. The ECDIS Test and Demonstration Project in the Unite States, Aug 9, 1990,
2. Provisional Test Plan for the Unite States ECDIS Test and Demonstration Project, Dec 1990
3. Statement of Work for ECDIS Test and Demonstration Project, Jan 29, 1990
4. U.S. ECDIS Test Bed Project Guidance Document, Jan 1991

[147] Maritime Policy Center, "ECDIS Test Bed Project - Evaluation of Proposed IMO Perfornace Standard for ECDIS HGE draft version 2, September 1992," 4.

5. System Requirements Specification (SRS) Comments on "TO BE RESOLVED" (TR) items", Memorandum July 1, 1991

In addition to those documents, as the RTCM chairman of Special Committee 109 on Electronic Charts, he had direct oversight of RTCM documents used as referenced by the Test Bed Project,

a) RTCM Provisional Standard For Electronic Chart Display and Information Systems, RTCM Paper 120-89/SC 109-71/BD-190, undated,
b) RTCM Recommended Standard for Updating Electronic Char, First Draft, June 17, and
c) Updating for the Electronic Chart Display System created for Special Committee 109 Of RTCM by the Working Group on Updating, undated, 1988.

Based on his broad participation history with the ECDIS technology, Rogoff is the "primum moven and later the master translator for ECDIS."[148]

3.11 ECDIS Group Formation and Open Enrollment

For all its intrinsic features, ECDIS in the 1980's was not a commercial success or a viable navigation technological alternative to traditional navigation due to the IMO's SOLAS requirements. The IMO had revised SOLAS in the past. IMO resolutions are the means for altering IMO regulations. An ECDIS navigation solution came about by first problematizing traditional navigation against a navigation world with ECDIS. Problematization of traditional navigation comes in the following forms:

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[148] Callon, "Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay," 6.

1) The traditional maritime navigation process is a time consuming process.
2) Electronic navigation is faster, more accurate, and therefore safer.
3) It is impossible to advance to an era of safer navigation because electronic charts are not the legal equivalent to paper charts
4) Electronic charts made with hydrographic data from new surveys will produce safer navigation.

Each of the above statements begins to help identify an obligatory passage point[149] or rather, the spokesperson/group that speaks on behalf of ECDIS. The IMO, tasked with overseeing the framework for the safety on the high seas, is this point. Traces from the IMO's past activities contain artifacts that are useful for producing a navigation world that includes ECDIS. The principle artifact is the IMO's Convention for SOLAS. SOLAS would need amending if ECDIS is to prosper. The IMO as a regulatory body oversees maritime safety frameworks. If a change in SOLAS is the correct path, then an action by IMO is necessary. The IMO's first action was their publishing a Provisional Performance Standards for ECDIS, MSC/Cir. 515, 13 Apr 89. This provisional performance standard provides ECDIS with the legality sponsorship it needs in order to be the legal equivalent of paper nautical charts as outlined in SOLAS. Within the standard is a provision asking IMO member states to assess and test the provisions through trials. The publishing of this provisional standard served to enroll the first set of entities, its membership's governments, into the ECDIS group. Another set of entities were the commercial producers of ECDIS devices.

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[149] Ibid.

Concerns of the commercial producers of ECDIS devices were the carriage of ECDIS aboard vessels of ECDIS as a legal equivalent to paper charts, product liability, and commercial access to government chart data for the creation of electronic navigation charts (ENC). They needed these issues to be resolved for their market success. These issues were not priorities for the actors first enrolled by the IMO. The ECDIS Test Bed Project, which was a funded principally through U.S. Government funds, though supplemented by some commercial funds, expressed that the project's objectives were to validate the IMO provisional standard, support the development of a national capability for producing ENC's, and demonstrate and assess ECDIS capabilities and applications.[150] Commercially driven issues were recognized, but given a low priority. The Test Bed Project distanced themselves from commercial ECDIS providers by developing their test bed independently and away from commercial vendors. Their stated priorities were driven by the need to support their Government sponsor, the USCG, who is the U.S. Government's chosen delegate for representing US interests at the IMO. The USCG through their role as the U.S delegate to the IMO, proposed, funded and participated in the evaluation of the IMO ECDIS performance standard.

3.12 Controversy A and Transformation – Equate Navigation Safety to ECDIS

In order for ECDIS to displace paper chart navigation, ECDIS and safe navigation must be synonymous. The deck officer figures into any discussion regarding safe navigation, because their position as watch-standers on the bridges of commercial vessels places them at the forefront of safe navigation. As stated previously, the USCG oversees

[150] Maritime Policy Center, "ECDIS Test Bed Project - Evaluation of Proposed IMO Perfornace Standard for ECDIS HGE draft version 2, September 1992," 6-7.

merchant mariner licensing. They are the same entity that oversees U.S. IMO membership relations. If merchant mariners are not navigating safely, then the USCG is implicated. One can see the difficulty in mariner enrollment and its solution came in the form of regulatory power. The mariner identity needed transforming in order to replace traditional navigation practice with the progress of ECDIS. Mariner work isn't a low paying, repetitious, or a low decision making assembly line job. Characterizing it as so by translation -- transforming mariner work into something simple, repeatable and not situated -- is advantageous to ECDIS. From the standpoint of ECDIS and safe navigation, there can be no safe navigation without mariner enrollment. To work with mariners is to work with their situated actions. Predetermine the situated actions and the mariners must follow. Over the course of 4 years, the USCG managed to involve subsets of deck officers in ECDIS testing, and during such testing, the USCG altered the deck officer identity, flattening out its experiential expertise in the face of navigation with ECDIS. They also managed to displace the mariners' task performance location from the oceans to a bridge simulator location where their research staff controlled:

a) Weather - visibility
b) Currents, tides
c) Terrestrial contours, sea and channel bottoms
d) Hull design
e) Schedules
f) Traffic
g) Equipment failure
h) Exhaustion/fatigue

i) Familiarity with gear

j) Info on new dangers to navigation

In 1990 and apart from their ECDIS Test Bed project sponsorship, the US Coast Guard entered into an ECDIS research program that spanned 4 years consisting of 4 experiments, three that were sea-trial experiments and one in a computer simulated marine environment. The U.S. Coast Guard research program's goal was to provide U.S. input to the 1989 IMO draft ECDIS specification, but an additional reasoning qualification was given relative to their on-going human factors research program that has studied integrated display devices over the previous 10 years, though not ECDIS type.[151]

The following were the goals of U.S. ECDIS research program:

1. "Determine the capabilities and limitations of current and prototype ECDIS devices for improving safety of navigation.
2. Evaluate the adequacy of proposed ECDIS design and performance standards.
3. Ensure that human factors considerations are incorporated into the design, operation, and performance of ECDIS. "[152]

These goals are somewhat in contrast to the one question needing resolution and only stated in the research project's conclusion, "Is ECDIS an aid to navigation?"[153] Their

[151] Irene M. Gonin, Marylouise K. Dowd, and Lee Alexander, "Electronic Chart Display and Information System (ECDIS) Test and Evaluation, Summary Report," (US Coast Guard, 1996), 2.
[152] Ibid., 1.
[153] Ibid., 26-27.

answer is in the affirmative and based directly on the answers to two other questions also only stated in their conclusion.

1. "Does ECDIS have an impact on overall track keeping performance?"
2. What are the effects of ECDIS on the navigational performance of mariners with different experience levels?"[154]

The USCG notes that advances in disparate technologies like GPS, data models, microprocessors, sensor and geographic information systems (GIS) when integrated into an ECDIS device, implies that ECDIS is a real-time vessel positioning system for navigating within the proximity of land, seen and unseen hazards, and aids to navigation (AtoN). They explicitly call out the following potential capabilities: "improved navigation accuracy, improved mariners' awareness of potentially dangerous situations, and reduce the workload on the bridge."[155]

After noting ECDIS potential in their final evaluation report, the USCG makes very bold statements as if ECDIS's potential has already been achieved and it is only a matter of some backend detail to get it on track.

> "With these services, mariners will increasingly rely on automated radio-navigation positioning and electronic chart displays. These new technologies will give mariners accurate, timely, and dependable data. The challenge lies in developing standards which will provide a clear and easy to understand display, on a system which is user friendly."[156]

[154] Ibid., 26.
[155] Ibid., 2.
[156] Ibid.

The following USCG ECDIS experimental tests took place and included between 2 to 20 test subjects with bridge watch-standing experience varying between just trained to in excess of 20 years:[157]

1. Sea trials aboard the Training Vessel (T/V) Kings Pointer on October 1990
    a. Determine minimal requirements that increase safety
2. Sea trials aboard the T/V Kings Pointer on October 1991
    a. Performance standards testing and effects on navigational safety and mariner workload
3. Bridge simulator testing at the Marine Safety International/Computer Aided Operations Research Facility (MSI/CAORF) in Kings Point, NY in September – October 1992
    a. Route monitoring under controlled conditions of effect on navigation safety, workload, chart features, and radar integration
4. Sea trials aboard the M/V Kings Pointer and USCG Cutter Bittersweet between Jan and April 1993.
    a. At sea verification of simulator results

In each experiment set, the principle objective measure of navigation safety was cross track distance from the planned vessel track-line.[158] The planned vessel track is the plot on a navigation chart of the intended progress of a ship in a particular direction(s) called a course(s). Cross track distance is the perpendicular distance that a vessel is at any time

[157] Ibid.

[158] Research & Development Center US Coast Guard, "Human Factors Evaluation of Electronic Chart Display and Information Systems (ECDIS)," ed. US Coast Guard (Washington D.C.: U.S. Department of Transportation, 1995), 4..

from a given planned track-line. The USCG's research program's principle findings state:

> "ECDIS has the potential to improve upon the safety of navigation, compared to conventional procedures. There was strong evidence that the use of ECDIS increased the accuracy of navigation, as measured by a smaller cross-track distance of the ship from the planned track-line, and reduced the proportion of time spent on navigation, with a corresponding increase in the proportion of time spent on the higher risk collision avoidance task. In addition, ECDIS was shown to improve geographic 'situational awareness,' and to reduce navigation 'error.'"
>
> "The strongest and most consistent finding was that the availability of ECDIS on the bridge substantially reduces the mariner's workload for navigation."[159]

Additional data gathering included the mariners' recommendations on what chart information is most necessary for their navigation, and these comments became a part of the USCG report.

The value to the mariner of ECDIS is anecdotally stated in the report as follows: "Using ECDIS is like playing a video game, just keep the vessel icon on the track-line,"[160] from the least experienced mariner, to "The units are more than replacements for the chart – they are replacements for human activity",[161] and "Navigation goes away as a task."[162] Final qualification of the mariners' acceptance of ECDIS is made in the report based on a summation of the mariners' comments into the following statement:

> "The most commonly mentioned positive aspects of ECDIS use during high-stress events was that it provided quick and continuous confidence in own ship's position relative to charted objects such as channels and bridges."[163]

159 Ibid., ix.
160 Ibid., 4.
161 Ibid., x.
162 Ibid., viii.
163 Ibid., 5.3.

Interestingly, within the experimental research, no one experiment replicated exactly what occurred in previous experimental scenarios and this is a clue to the situated nature of deck officer work, even in simulation.

The USCG makes an important statement with implications for the value of deck officer experiential technical knowledge,

> "no significant differences were found in navigational performance between varying experience levels of mariners while navigating with ECDIS,"[164]

see chart below. ECDIS levels the experiential knowledge curve. The statement regarding cross track performance by the USCG effectively states that safe navigation is ECDIS and ECDIS is safe navigation. All classes of mariners are transformed into a single class, their navigation is made safe by the cross track numbers, and the numbers are turned into curves.[165] Navigation safety, which is really an action, is displaced from the oceans and into conference rooms of government regulators, politicians, and corporations. Most mariners are wholly unaware of ECDIS during these research projects. The few mariner test subjects involved in the research help to enroll the entire US deck officer population as a single class. Given the USCG's influence at the IMO, they help to enroll a global population of deck officers.

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[164] Gonin, Dowd, and Alexander, "Electronic Chart Display and Information System (ECDIS) Test and Evaluation, Summary Report," 9.

[165] Bruno Latour, "Visualisation and Cognition: Drawing Things Together," in *Knowledge and Society Studies in the Sociology of Culture Past and Present*, ed. H. Kuklick (Jai Press Inc., 1986).

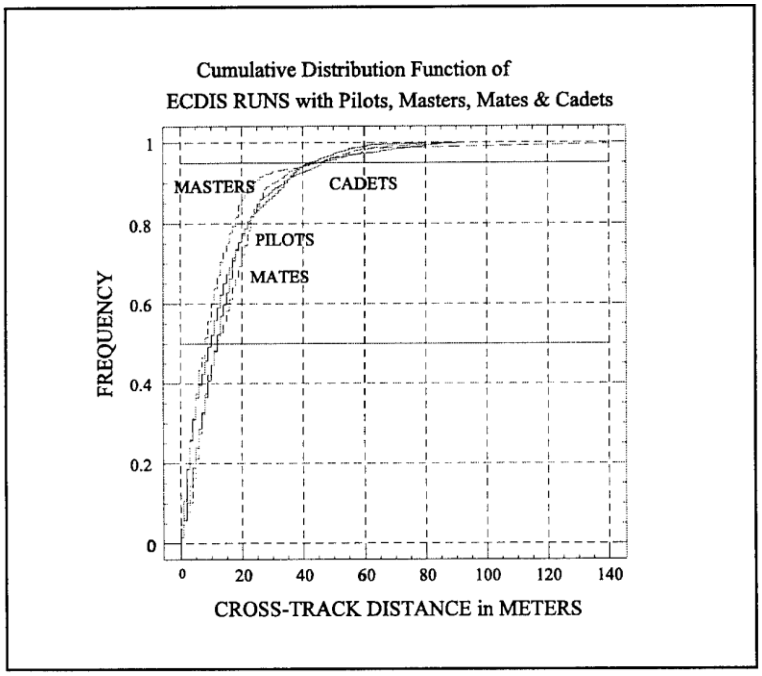

Figure 5 – Cumulative Distribution Function (CDF) of ECDIS Runs[166]

During shipboard tests it was noted that Masters and pilots, typically the most expert of mariners, were comfortable with their off track positions when navigating with traditional methods such that they didn't give many steering orders to helmsmen to get back perfectly on the planned track. Also noted in the test results was a registered sense of negative feeling in the necessity to keep a tight track, such that ECDIS provided no more accurate track keeping in coastal environments than did conventional navigation methods. The researches postulated that,

> "the mariners considered it less critical to stay close to the planned trackline and did not take advantage of the accurate position information that ECDIS offered."[167] (US Coast Guard, 1995, p. 5.5) (US Coast Guard, 1995, p. 5.5) (US Coast Guard, 1995, p. 5.5)

[166] Gonin, Dowd, and Alexander, "Electronic Chart Display and Information System (ECDIS) Test and Evaluation, Summary Report," 9.
[167] US Coast Guard, "Human Factors Evaluation of Electronic Chart Display and Information Systems (ECDIS)," 5.5.

Alternatively stated, the mariners' environment of situated action and their experiential technical knowledge allows for this kind of variation. In Callon terms, the mariners, like his scallops, weren't attaching themselves to the ECDIS provided to them.[168]

The Woods Hole ECDIS Test Bed evaluation speaks of "revenge theory."[169] The Woods Hole context posits that mariner operational behavior will adjust to ECDIS such that no improvement in safety occurs. By example, radar is introduced on board commercial vessels as a means for them to determine if risk of collision exists between one's vessel and other vessel traffic. The 'radar-assisted collision' is the term coined by maritime casualty investigators after reconstructing collisions at sea in which they found incorrect radar use.[170] This revenge theory is similar to Tenner's more recently articulated revenge effect or theory.[171] This theory considers that new technologies never fully solve the problem stated in their functional requirements, but instead often create and hide other greater problems that may surface as unintended consequences. Revenge theory seems to detract from an analysis that seeks to discover whether actual group enrollment occurs: in the above case, the safety of navigation with radar. The purpose of positing of a revenge theory scenario can only be to detract from deck officer identity with respect to their commitment to safe navigation. The Woods Hole evaluation reports that ECDIS can prevent some accidents, but it isn't a cure-all for maritime safety. What they have identified is a failure to fully enroll mariners. Enrollment is the process by which actor's roles and relationships are defined by those seeking to influence a network's activities

[168] Callon, "Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay," 16.
[169] Maritime Policy Center, "ECDIS Test Bed Project - Evaluation of Proposed IMO Perfornace Standard for ECDIS HGE draft version 2, September 1992," 37.
[170] Ibid.
[171] Edward Tenner, *Why things bite back : technology and the revenge of unintended consequences*, 1st ed. (New York: Knopf, 1996).

and goals. Their solution is to provide increased "operator training and safety-conscious operating procedures."[172]

Many observers and participants in ECDIS research and development believed that ECDIS success was at hand when the IMO issued Resolution A817 on November 1995, which is the agreed-to ECDIS performance specification that modifies SOLAS to allow ECDIS to be a legal replacement for paper charts. Mariners on many occasions during research and testing of ECDIS performance standards had expressed concern regarding the potential loss of manual navigating skills and this could affect the safety of navigation. [173] Such commentators could now point to the Performance Standard that states the need for a sufficient back up to ECDIS should it fail. Such a backup can be another system or paper charts. From a SOLAS perspective, if you use paper charts as the backup for ECDIS then you must use them in parallel with ECDIS, doubling the bridge watch navigation plotting effort. If not, how will you be prepared if ECDIS fails? The standard goes on to specify that should electronic charts of sufficient detail not exist for the intended voyage, that a full complement of paper charts shall be available on board for that portion of the voyage. The standard doesn't say to go back to unsafe navigation. This leads to the next controversy requiring more translations of ECDIS.

3.13 Controversy B and Transformation – Raster versus Vector

Maps and charts dot walls of homes and businesses as works of art. In this sense, cartography is art and in a technological world this challenges paper charts to continue to

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[172] Maritime Policy Center, "ECDIS Test Bed Project - Evaluation of Proposed IMO Perfornace Standard for ECDIS HGE draft version 2, September 1992," 37.

[173] US Coast Guard, "Human Factors Evaluation of Electronic Chart Display and Information Systems (ECDIS)," Sec 8 p.10.

be relevant tools for marine navigation. The technology exists and continues to expand for converting databases/data-files into data objects accessible by programs that both use the objects as input for algorithms and for display to a user. Two-dimensional paper charts have no such capability when taken from the present-to-hand bridge environment of a deck officer. There is no research and development plan working to impute information from a two-dimensional chart, even one scanned into or drawn within a digital environment. Paper nautical charts are the roller skates of the marine navigation technological world. They work fine when used by individuals from an earlier era; current era individuals can use them with some training, but they will likely hang on garage or restaurant walls as objects of interest, and watch the next new technological device replace that which replaced them. The ECDIS research project denigrated paper charts and propelled the use of digitized charts to the forefront of marine navigation.

Throughout the USCG's testing period, cross track distance and workload were the consistent measures for navigation safety. From a navigation perspective, and more specifically from navigation genre called piloting, the USCG tests showed that deck officers were able to better maintain their planned track positions and this allowed them the ability to concentrate more of their time on collision avoidance. Technologically speaking, all this is easily achieved by having an up-to-date digital picture of a chart on the monitor, along with a program that takes latitudes and longitudes from interfaced external positioning devices, and plots positions as they are received based on the chart parameters (what latitudes and longitudes are represented on the digital picture of a chart). The deck officer now knows the ship's position, the plot is done automatically saving time, and that time can be used toward other high-risk bridge-work such as collision avoidance. Based on the IMO specification, ECDIS seeks to do much more.

ECDIS can provide alarms based on chart data if the chart data is readable in code, e.g. contains aids to navigation (AtoN), ship track, hydrographic, and geographic characteristics.[174] Without such data access, the deck officer would need to manually preset alarm criteria for whatever digital chart picture is chosen for display and use. If ECDIS seeks to create a new navigation paradigm, then it must not provide only the trivial capability of paper chart replacement. ECDIS begins to enter the paradigm shifting domain by enabling chart data to be interactive with a programmed decision support capability.

The Woods Hole evaluation of the IMO's preliminary ECDIS standards tries to set a realistic expectation of ECDIS near-term impact on the safety of navigation by pointing out that the dearth of available official government hydrographic data sets. The evaluation suggests that ECDIS use be sanctioned with the use of public or private data sets instead of the provision in the standards stating equivalency to paper charts. The IMO made no such adjustment in the provisional standard's provision. However, the lack of digital data sets at the time of the IMO standard's publication for official chart creation directly affected ECDIS's ability to provide better navigation safety over paper charts. Woods Hole wanted to ensure that ECDIS use was encouraged and that its use

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[174] Hecht et al., *The Electronic Chart - Fundamentals, Functions, Data and other Essentials - A Textbook for ECDIS Training*: 40.

would not be delayed due to “unattainable requirements.”[175] In 1993, little digitized data existed for manufacturing digital charts, thus ECDIS could not be a reality.

Woods Hole recommended,

> “National hydrographic offices and IHO should work with IMO to ensure that the interim ENC specification is suitable, and hydrographic offices should continue and expand their efforts to provide interim data sets (vector or raster based) for use by ECDIS vendors and data suppliers.”[176]

There was no other choice short of leaving ECDIS on the shelf until sufficient hydrographic data sets became available.

Each nation has sovereign control of their nation’s hydrographic data for their sovereign waters and in the case of safe navigation, in production and dissemination of charts for their coasts and ports. The International Hydrographic Office (IHO) located in Monaco and founded in Sept. 1921 originally as the International Hydrographic Bureau, is responsible for coordinating global hydrographic data and nautical chart dissemination of member states.[177] The IHO came under the League of Nations oversight in Oct. 1921 and is now under the United Nations.[178] An individual nation’s hydrographic office has the responsibility to validate its nation’s hydrographic data such that its charts are an accurate depiction of hydrographic facts. For nautical charts and from the perspective of safe navigation, a chart derived from a nation’s hydrographic data must provide information regarding the dangers and limitations inherent in the use of that chart due to the

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[175] Maritime Policy Center, "ECDIS Test Bed Project - Evaluation of Proposed IMO Perfornace Standard for ECDIS HGE draft version 2, September 1992," 37.
[176] Ibid.
[177] CAPTAIN FEDERICO BERMEJO, "THE HISTORY OF THE INTERNATIONAL HYDROGRAPHIC BUREAU," ed. International Hydrographic Organization (Monaco: International Hydrographic Organization, 2005), 7.
[178] Ibid., 8.

hydrographic data used in its construction. For proper and safe usage of a chart, knowledge of a chart's survey data, its scale and its accuracy are all factors that a mariner must consider when using a particular chart in a particular area for a particular navigation purpose.

Recognition of the accuracy of navigation charts was at issue in a Resolution adopted in 1983 by the IMO, whereby its members were informed of the fact that many of the world's charts were based on surveys that did not meet modern standards, and that member governments work to conduct new surveys and coordinate as necessary with other member governments.[179] A 1985 Resolution asking member governments to help establish regional hydrographic commissions to support the IHO, and the IHO's already established regional commissions in the preparation of accurate charts soon followed.[180]

Digital hydrographic data existed in the 1980's as raw data taken during hydrographic surveys, but not as chart data available for the building of electronic charts. At the time, access to, or whether such data was stored, could be adapted, and made available were open questions. The IHO's first meeting to discuss electronic chart data standards took place in 1986. Subsequent meetings produced the data standards specification IHO S-52, and IHO S-57 being officially published in 1994 and 1996 respectively. IHO S-52 Specifications for Chart Content and Display Aspects of ECDIS essentially defines what is viewable within an electronic navigation chart (ENC) and IHO S-57 Transfer Standard for Digital Hydrographic Data defines the data specification requirements for all the objects found on ENCs. The IHO coordinated the acquisition and definition of

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[179] IMO, "Charts," http://www.imo.org/en/OurWork/Safety/Navigation/Pages/Charts.aspx.
[180] Ibid.

hydrographic data. It is the IMO that drives the requirements for such data's use in commercial shipping.

The IMO oversees hydrographic requirements from the standpoint of safety of navigation and these requirements are promulgated via SOLAS. Chapter 5 of SOLAS Regulation 9 – Hydrographic services reads: "Contracting Governments undertake to arrange for the collection and compilation of hydrographic data and the publication, dissemination and keeping up to date of all nautical information necessary for safe navigation."[181] Since IMO's member Governments are entities enrolled for the promotion of ECDIS, individually, they need to enroll their hydrographic offices in order for the ECDIS goal to succeed. This enrollment is not quick due principally to a lack of monetary and human resources.

In the U.S., the National Oceanic and Atmospheric Administration (NOAA) requested that the National Research Council (NRC) form a committee in order to study the needs of mariners for NOAA's nautical products. The NRC accepted the study and reported as guidance to NOAA the priorities for their chart product work. Within the report was wording that expanded NOAA's chart scope, such that creating vector type charts, in lieu of their current course of action for producing raster charts, serves a greater marine geographic information services community. Enlargement of the charting community can be seen as a method to increase the government's desire to fund NOAA projects. This expanded community includes those interested in information systems for land use planning, and environmental research and management purposes, and includes engineers,

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[181] *CODE OF THE INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES FOR A SAFETY INVESTIGATION INTO A MARINE CASUALTY OR MARINE INCIDENT (Casualty Investigation Code)* (London: International Maritime Organization - Publishing Service, 2008).

scientists, planners, managers, decision makers, and the public needing "timely access to understandable information in making difficult choices."[182] There is no emphasis of the requirements for NOAA's principle chart users, commercial maritime and the U.S. Navy, in the NRC report.

The draft performance standards and the final standards for ECDIS to be the legal equivalent to a paper chart required vector type charts. Data for this type of chart must be topographically readable so that a ship's position would automatically associate hydrographic and geographic information about its surrounding position. A digital picture of a chart does not meet the IMO specification for a digital chart for ECDIS. Only vector type charts meet the specification. Raster type charts is the term used to describe digital pictures of charts. ECDIS can use them, but ECDIS isn't considered to be operating in ECDIS mode, but instead in what is called Raster Chart Display System (RCDS) mode.

Raster chart characteristics are virtually identical to its paper chart original. From the standpoint of a vector chart, raster charts, like their paper chart originals are viewed as an artwork-like cartographic view.[183] Raster type chart data is stored as pixels and therefore its data is implicit, only understandable in relation to other pixels within the same picture. The black pixel could be part of a line, lettering on the chart, part of a black can buoy, or other chart feature. Raster charts can't be interrogated for additional information relative to their display content. Zooming in or out distorts information, with the chart becoming

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[182] National Research Council, *Charting a Course into the Era - Guidance for NOAA's Nautical Charting Mission* (Washignton, D.C.: National Academy Press, 1994). 38.
[183] M. Bergmann, "A Harmonized ENC Database as a Foundation of Electronic Navigation," in *Marine Technology and Sustainable Development: Green Innovations*, ed. Olanrewaju Oladokun Sulaiman, et al. (Hershey, PA, USA: IGI Global, 2014).

block pixels when zooming in or a picture clod upon zooming way out. As a vessel transits from one ocean area to another, the raster type chart for the next area might be of a different scale and therefore navigation assumptions might need to be adjusted.

Vector chart characteristics lend themselves to ECDIS's navigation safety functions. Geometric data elements are what makes up vector charts. Chart objects exist independently of the chart, in that they contain characteristics for their display and positioning, as well as additional information helpful to the navigator such as its duration of existence. Consider that a picture of a house is similar to a raster chart. When you make a doll house with all its objects inside that make it a home, this is similar to a vector chart. Vector charts enable rendering of dynamic content such as tides and weather in real-time. The vector chart data is stored information as opposed to raster chart data, which is just pixel size, color, and brightness data.

ECDIS device sales were not strong in the mid to late 1990's and therefore even its base navigational safety capabilities of automatic positioning weren't realizable. In 1998, the IMO in the IMO RDCS Performance Standard, made operating ECDIS with raster type charts, (RCDS mode) acceptable and thus created an interim step for full ECDIS compliance until such time that more vector type charts are produced. Since December 2000, raster chart use is no longer sanctioned as a primary form of marine navigation and raster type chart use has been limited under SOLAS to just gap-filling for geographic areas in which no vector type chart is available.

Sailing with raster charts is no different from sailing with paper charts beyond automatic position plotting. The argued benefits of ECDIS due to embedded programming logic interacting with hydrographic data and ship position data do not materialize with raster charts. Vector charts materialize from the view that hydrographic offices will digitize their data as their resources allow. The interesting thing is that the digitized chart data is from the very data on which the paper charts (therefore also raster charts) are based – the same data that the IHO informed the IMO on in 1983 based on surveys that didn't meet modern standards. In some cases, the digitized data for vector charts is nothing more than data taken from a paper chart.[184] Therefore, the vector chart data is only as accurate as its latest survey, which for most of the world's oceans is from surveys that took place in the early 20th century. The SOLAS requirement for raster charts as gap fillers only ensures that the majority of the world's ECDISs must now operate in a SOLAS compliant mode and thus fully compliant with the performance standards. The goal for ECDIS succeeds; navigation is safer; by design. ECDIS can interact with chart data. On the surface, and on the surface view of a vector chart, the vector chart looks more or less the same as a raster chart. Underneath is where the difference lies, in layered data that is actionable by the systems algorithms and viewable on demand by the deck watch officer. It is just generally older hydrographic survey data.

3.14 Assumed and Forced Mariner Enrollment

Mort Rogoff's witnessing of the calamity in the East River spurred him to develop a capability that enables safe transit with no loss of life. Effective deck officer ECDIS practice is the key to meeting the ECDIS goals of safer navigation and increases in efficiency that reduce costs. ECDIS development assumes from the start that the mariner is part of the technology. Participants in the ECDIS research project included ocean

[184] Ibid.

carrier managers who employ mariners and maritime union leadership who represent mariners. The mariners themselves participate in at-sea tests, simulator research, as committee/panel members, and as proselytes in magazine and journal articles. An assumption of implicit enrollment of mariners by researchers and program managers occurred by using them in research and testing, and reporting their responses to questionnaires on ECDIS and electronic charts. The small number of mariners involved acted as proxies for all mariners. After all, the reports' results, as interpreted by researchers, speak for the mariners.

The trend in vessel casualties since the IMO specification was approved and implemented by manufacturers doesn't reflect a downward trend with regard to collisions and groundings. Between 1994 and 2006 there has been a 4 to 5% increase in such occurrences and in roughly half of the occurrences, the bridge watch officer was not aware of any danger until the incident occurred.[185] The UK P&I club advises that,

> "It is becoming increasingly evident that far from reducing risk, ineffective operation of complex ECDIS systems resulting from poor management practice or training can actually increase the risk of incidents such as collision and grounding with the interface between computers extenuating the so called 'human element'."[186]

The Nautical Institute, an organization that supports mariners' interest through information sharing, policy representation and forums for support, shares that in order to harness the power of ECDIS and avoid catastrophe due to incompetence, training and familiarization is key.[187] One has to ask, that with all the new technology available to mariners, driven by validated performance specifications, why these advanced systems,

[185] Filipkowski, "See More- Analysis of Possibilities of Implementiaton AR Solutions During Bridge Watchkeeping," 225.
[186] UK P&I Club, "ECDIS Need to Know," *Seaways - The International Journal of The Nautical Institute*, no. March 2012 (2012): 8.
[187] Nautical Institute, "ECDIS - Industry Recommnedations for ECDIS Training," (2012).

ECDIS included, have not removed, or even reduced the "potential for failure in the systems in which they were introduced."[188] Perrow believes that maritime industry induces safety errors: "an error inducing system: the configuration of its many components induces errors and defeats attempts at error reduction."[189]

Industry experts in risk are the P&I clubs. The UK P&I Club views risk relative to ECDIS as follows:

> 1. "The equipment itself may suffer from failure from any cause.
>
> 2. The chart issues intrinsic to their dissemination, upkeep, availability.
>
> 3. The operation of the ECDIS system onboard carried out by poorly trained crew following poor navigational practices and operational procedures …"[190]

The IMO and IHO specifications addressed the equipment and the charts risks. The mariner, thought to be 'onboard' with ECDIS is not enrolled. Equating ECDIS with paper chart navigation, and then making ECDIS a mandatory carriage requirement onboard ships, didn't further enroll the mariner. No doubt there are cases even today, where a mariner makes his way onboard a ship that has only ECDIS and no paper charts, and the mariner doesn't have ECDIS training. The curiosity in the corner of the bridge is now front and center. To reduce the chance that marine casualty events will occur, mariners will be required to have ECDIS training by January 2017 that conforms to IMO standards, or else they cannot sail. Forced enrollment of mariners, through certification via training is occurring. ECDIS certification ensures mariner enrollment or their re-education by defining reasons why mariners need certification. These reasons stand as a

[188] Club, "ECDIS Need to Know," 11.
[189] Charles Perrow, *Normal Accidents* (Princeton: Princeton University Press, 1999). 172.
[190] Club, "ECDIS Need to Know," 11.

barrier to other groups who may be courting mariners to some anti-ECDIS group or other innovative or competing technology.[191]

ECDIS can't be a success without the mariner. It isn't surprising that forced enrollment is considered the most likely avenue to ECDIS success. Concomitant with the USCG studies have been other research projects and recommendation reports that generalize the deck officer class in order to argue for ECDIS. The NRF funded the "Who's Minding the Helm" with broad participation from US Government agencies, academia and commerce, in which various recommendations are made in the pursuit of safer navigation. Mariners and their culture are framed in the report, which seems an attempt to only facilitate their forced enrollment into the ECDIS project.

"… well publicized shipping disasters in which navigation contributing factors. Ship handling, positioning, work practices, and communications in piloting waters have been identified as 'key causal factors' calling into question the professional qualifications of merchant mariners and marine pilots and the effectiveness of marine navigation technology, shipboard navigation and piloting, and safety oversight."[192]

This quotes sets up the opportunity to peel the onion that is the mariner layer by layer, and show that forced enrollment will be the only answer. Mariners are shown as familiar with the risks of their environment, but "not in probabilistic terms," and therefore, their complex environment "isn't well understood, even by those who operate in it."[193] They have "no practical means … to fully assess all the factors that could affect the safety of vessel movements other than their professional judgments." Mariner responses to their

[191] Latour, *Reassembling the Social*: 32.
[192] NRC, *Minding the Helm - Marine Navigation and Piloting* (Washington, D.C.: National Academy Press, 1994). ix.
[193] Ibid., 159.

environment "reflect their accumulated experience and professional competence …"[194] The report offers a way ahead out of a reliance on mariners situated actions.

"The probabilities based on accidents incidence data are epistemic, that is, they represent a state of knowledge relative to a reference class. The reference class is the set of past occurrences reflected in the knowledge base from which the statistics derive. Therefore, the probabilistic risk is an estimate of actual risk, just as is perceived risk. The difference is that probabilistic risk is quantitative, based on a widespread acceptance in recent years in the nuclear, aerospace, and process-control industries."[195]

Mariner operational estimates of risk are "based on experience and may or may not be effective as measures of probability or cost." "Statistics and methods for formal analysis to determine the probability for success are not available at sea, nor do mariners have the means to develop such measures."[196] The mariner is viewed as traditional and conservative in the face of change. As a class, they "tend to cling to proven traditional methods."[197] Their approach to change is understandable due to legitimate concerns over the need to establish confidence in a system, but proponents of ECDIS argue for the need for accelerated introduction of high technology. ECDIS has been available since the mid-1980's. Its performance specification and testing specifications were approved in the mid-1990's. Its foundation, the vector chart remains somewhat elusive in exactitude. All the while demonstrations, promotions, arguments in support of and accommodations for ECDIS occur. The initiative for solutions for perceived gaps in navigation safety, something that ECDIS was to have solved, is already well under way with the IMO's e-Navigation framework.[198] In mariner terms, ECDIS is what it is, a tool for consideration in their pursuit of 'good seamanship'. Mariners' interview responses for this paper's

[194] Ibid.
[195] Ibid., 163.
[196] Ibid., 166.
[197] Ibid., 262.
[198] Hecht et al., *The Electronic Chart - Fundamentals, Functions, Data and other Essentials - A Textbook for ECDIS Training*: 340. For a discussion on IMO e-Navigation Framework.

research states as much. In ECDIS group terms, the mariner is misusing or not using ECDIS and needs to be forcibly enrolled.

The IMO's STCW-2010 ECDIS training standards vetted through many of shipping's leading international organizations and approved in 2012 will come into full force in 2016. Mariners without the training credential by January 2017 will be unable to work aboard ships in international trade. This move is similar to current radar/ARPA certification, which has been in existence for over 40 years. There is a slight difference and it is subtle. Radar/APRA are tools required for use in order to determine if risk of collision exists between vessels. The science and engineering of radar is well understood and proven. It didn't replace anything upon its arrival to the ship's bridge. For example, watch lookouts are still required. For ECDIS, there is no regulatory mandate that ECDIS be the sole navigation capability, only that it is a mandatory capability aboard ship. Its use isn't required. Companies can choose to have it as the only means by which bridge watch standers can navigate. When I say navigate, I am saying that the practice of plotting positions and understanding one's situational awareness with reference to a chart is done solely with ECDIS. This doesn't include looking out of the bridge windows to ascertain additional situational awareness. It also doesn't include the use of what is termed good seamanship, the catch all that ensures a mariner uses due diligence in the pursuit of one's job. Good seamanship is akin to the term 'safety culture' first coined during the International Atomic Energy Agency's (IAEA) investigation of the Chernobyl disaster.[199] The IAEA used the term to cover such things as organizational, culture, and

[199] H.P. Berg, "Human Factors and Safety Culture in Maritime Safety," in *Marine Navigation and Safety of Sea Transportation: STCW, Maritime Education and Training (MET), Human Resources and Crew Manning,*

managerial issues. The IMO implemented the International Safety Management Code in 2008 to begin to address to safety culture aboard ships with more training.

Mariner concerns regarding the technology aren't without substance. The IHO's website contains a section with links to ECDIS related issues that can affect its performance as a navigation tool.[200] The website contains what amounts to advisories, much like a Notice to Mariners. The advisories are not enough to counter ECDIS promotion. No one is saying that the ECDIS promoters have created a tool for unsafe navigation, for loss of life, and for polluting the environment. Each IHO advisory has an acknowledgement regarding the shortcoming issue and therefore all is well. ECDIS promotions is indeed strong.

As with mariner concerns, ECDIS promoter concerns about mariners are not without basis. Crewing ships engaged in international trade is multi-national and multi-cultural, and the practice brings with it complicating issues of communication and interaction within and between ships, as well as between those ashore working in the trade practice. The multi-cultural aspects of the ship's bridge environment need emphasis when compared to safety cultures in other technical fields.[201] Good seamanship as a practice isn't the sole purview of some dominant mariner class or culture. Mariners are supposed to practice it all the time. Incident investigations prove that it isn't practiced as such. While the majority of voyages take place with no incidents, when an incident does occur,

Maritime Policy, Logistics and Economic Matters, ed. Adam Weintrit and Tomasz Neumann (London, UK: CRC Press, 2013).

[200] IHO, "CONSIDERATION OF ECDIS MATTERS RELATED TO THE IMPLEMENTATION OF THE CARRIAGE REQUIREMENTS IN SOLAS REGULATIONS V/19.2.10 AND V/19.2.11," in *Report on monitoring of ECDIS issues by IHO* (London2013).

[201] Berg, "Human Factors and Safety Culture in Maritime Safety."

there is an eight in ten chance that the mariner contributed significantly to its occurrence.[202] The recent grounding of the M/V Ovit in the straits of Dover in 2014 is one such recent case. The ship's ECDIS wasn't properly setup and its use was improper. Even if such use is proper, research shows that humans are poor monitors of automated systems, tending to rely more on system alarms instead of manually checking their environment.[203] This is especially true for systems that have proven reliability track records. Many investigations show that bridge watch officer reliance on automation can create an 'operational bias's for reliance on the automated systems instead of taking in other "salient cues provided visually through the bridge window,"[204] Rearranging the marine navigation world from one of reliance on situated action to planned and automated action has consequences. Good seamanship should preclude such reliance.

One must consider that the need to forcibly enroll deck officers means that what ECDIS is held out to be isn't necessarily so in the eyes of deck officers. Their intransigence suggests a lack of a fortified definition for ECDIS. Looking at local practice gives an understanding of what ECDIS may lack in its definition. In this case, pre and post-ECDIS implementation bridge work practices.

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[202] A. Rothblum, "Human Error and Marine Safety," in *Maritime Human Factors Confernece* (Linthicum, MD2000).
[203] Club, "ECDIS Need to Know."
[204] Ibid., 11.

Chapter 4 – Comparative Navigation Traditions – Pre and Post ECDIS

4.1 Deck Officer Action through the Embodied Notion of Good Seamanship

The deck officer on watch brings to the bridge of a ship experiential technical knowledge to perform navigation tasks with a view to performing them to meet the expectation of 'good seamanship.' Rule 2[205] in the IMO COLREGS[206] (the 'Nautical Rules of the Road)' defines good seamanship as follows:

> "a) Nothing in these Rules shall exonerate any vessel, or the owner, master, or crew thereof, from the consequences of any neglect to comply with these Rules or of the neglect of any precaution which may be required by the ordinary practice of seaman, or by the special circumstances of the case.
>
> b) In construing and complying with these Rules due regard shall be had to all dangers of navigation and collision and to any special circumstances, including the limitations of the vessels involved, which may make a departure from these Rules necessary to avoid immediate danger."[207]

Rule 2 is a catchall rule that can be interpreted simply as, if a casualty happens and the officer(s) didn't use some available capability (knowledge, tool, process), then fault will be found with deck officer performance at some level. Now that ECDIS is a mandatory device on the bridge of ships, and even though it may not be the primary tool for navigation on a ship, its capability becomes mandatory if it can avert a casualty in any particular circumstance. Good seamanship demands the use of, if available, a properly setup and properly operating ECDIS while on watch. If there is a possibility of a casualty occurring and an ECDIS could or should provide a timely alert or alarm, then good

[205] Rule 1 of the COLREGS discusses the Rules legal application.
[206] IMO, "Articles of the Convention on the International Regulations for Preventing Collisions at Sea, 1972 ", ed. International Maritime Organization (London: The Lloyds Register, 2005).
[207] Ibid.

seamanship demands ECDIS use during the deck officer's bridge navigation routine. Good seamanship is as mandatory as ECDIS, and even more so, since proper ECDIS use derives from good seamanship performance.

The opposite of good seamanship is poor seamanship. The easy definition for poor seamanship is the occurrence of a vessel casualty that is due to deck officer error. The statistic that 80% of the casualties are due to poor seamanship is based on fault assessment studies analyzing ship casualties. [208] This statistic is typically interpreted by lay-people in society, as deck officers aren't very safe. Just ask people how they interpreted the Exxon Valdez incident. A more objective perspective of the 80% statistic occurs if one accounts for all successful voyages in which no casualty occurred. Consider 70,374[209] as the average number of vessels in the World's merchant fleet between 2005 and 2014 and the 987[210] vessel casualties of all kinds in the same period. That is just 1.3 percent of the total vessel population between 2005 and 2014. This compares favorably with commercial airline operation that had 1.9[211] percent of its world fleet involved in some accident between 2005 and 2014. When one begins to consider the multiple number of voyages for all vessels when a casualty didn't occur when in a narrow channel, when in the presence of other vessels, or while in inclement weather, one appreciates that good seamanship is by far the norm.

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[208] Rothblum, "Human Error and Marine Safety."

[209] European Maritime Safety Agency, "Equasis Statistics - The world fleet 2005," (Lisbon, Portugal: EMSA - An Agency of the European Union, 2006).
EMSA, "equasis statistics - the world fleet 2014," (Lisbon, Portugal: European Maritime Safety Agency, 2015).

[210] Allianz Global Corporate & Specialty SE, "Safety and Shipping Review 2015," ed. Greg Dobie (Munich,: Allianz Global Corporate & Specialty SE, 2015).

[211] Aviation Safety - Boeing Commercial Airplanes, "Statistical Summary of Commercial Jet Airplane Accidents Worldwide Operations 1959 – 2014," (Seattle2015).

While it is up to the authority investigators to determine fault in the case of a casualty, such an investigation already has precedent on its side for 80% of grounding/collision casualties being some form of human fault. The form that such a fault takes in the report may not be accurate or authentic, simply because the whys of not doing something are hard to document. What was that deck officer thinking at that key moment in time? Casualty fact finding normally begins with interviews that are subject to accurate and honest memory recall.[212] What is most easily documentable is that something wasn't done or was done incorrectly. What procedure wasn't followed that influenced the causal chain? What evidence, log or trace exists or is missing? Examples of such evidence are a radar plot on the radar's plotting screen, or a transfer plot on a piece of radar plotting paper, or the system event log in an ECDIS that shows what alarms or alerts occurred, what charts were viewed, and what voyage track was planned and then followed. With new voyage data recording devices, much like the ubiquitous black boxes on airliners, now being installed on ships' bridges, additional evidence can be gathered, viewed, and listened to that may provide more accurate accounts of casualties.

It is impossible to account for every navigation situation that a deck officer may encounter in the construction of a technological device like ECDIS. This fact is apparent by the need to enroll the deck officer into the ECDIS technology. ECDIS's technological success has nothing to do with its actual use. Its material existence is its success. ECDIS's research study material justification is that it saves deck officer time, and tasks more critical to a voyage's success use the time savings, namely the collision

[212] See for casualty guide: IMO, *CODE OF THE INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES FOR A SAFETY INVESTIGATION INTO A MARINE CASUALTY OR MARINE INCIDENT (Casualty Investigation Code)*.

avoidance task and any related sub-tasks. Successful voyages are due to the application of good seamanship principles throughout the voyage, and good seamanship principles may or may not include ECDIS use. The shipping casualty statistics noted earlier during the post-ECDIS period aren't considerably different from the pre-ECDIS period decade earlier.

4.2 Understanding of Work Process Flexibility, Variability, and Luck

ECDIS's implementation based on a wide variety of standards, programmed procedures, user settings, and algorithms, means that ECDIS use could remove some amount of variation or tolerance within the marine navigation task when compared with traditional marine navigation methods. For example, if all ships planned exactly the same routes between the exact port pairs and adhered to the exact cross-track limitations. Variation here is defined within a deck officer's navigation process, such that a task can be accurately accomplished when its accomplishment is within some parametric boundaries that don't materially affect the navigation process's outcome; e.g. choosing one method of navigation over another. The definition of tolerance used here is an event, error or inaction unaccounted for within a deck officer's navigation process, but which doesn't materially affect the navigation process's outcome.

What role does variation and or chance play in a good seamanship performance? Given the vast number of variables existing during any navigation situation, do we consider all the instances of successful navigation to be dependent on or partially due to luck; that is process variation or process tolerance? This is a difficult subject matter, and not one analyzable in a direct manner without having detailed data on may navigation evolutions.

The answer is likely, yes, variation and tolerance do play a role. What is variation is that part of a work performance that is good based on deck officer's judgment. The deck officer has a choice of many navigation methods and not every navigation method has the same exactitude. In traditional navigation, every time a deck officer picks up a sextant and brings the celestial body to the horizon there is some variation due to any number of factors. Each time a deck officer plots a navigation fix on a chart, some variation in the plot will occur because there are no mechanically precise devices in use. What can be considered tolerance is likely understood as that part of a performance that is poor, but within the context of the overall performance, that part of the performance isn't critical such that it impacts its success. In 2004, I went to work at sea on a merchant ship. As part of my normal practice, I documented all my bridge watch activities, including all my navigation work. In 2006, I utilized my 2004 navigation work in preparation for going to sea again, working out each celestial navigation sight and plotting the results for practice. I found multiple instances of errors in calculations and in chart plots. In each case, that part of the navigation work was only a proportionally small part of the overall operation. My plot was within tolerance of the estimated position as plotted on the chart. This is an example of tolerance. The benefit of such tolerance is in its later use for feedback and learning.

4.3 Deck Officers and Tacit Knowledge Types

Deck officers are using their technical knowledge to perform their jobs to the standards of good seamanship. Their resource repertoires are a make-up of usage processes incorporating explicit and tacit knowledge. Explicit knowledge communicates through explanation, elaboration, transformation or mechanization[213]. From the standpoint of a deck officer, explanation and elaboration is in their navigation books. Transformation occurs when a GPS signal is received, then processed over some time period, and the ship's position and speed is determined, the resultant of which is sent to a recording and display device; for example, an ECDIS. Mechanization occurs when an automatic plotting and route tracking tool replaces manual chart plotting, such as an ECDIS. Mechanization is the explication of some form of tacit knowledge. That part of a deck officer's technical knowledge that isn't explicit and therefore not easily documentable is their tacit knowledge.

Recalling Collin's model of tacit knowledge,[214] tacit knowledge comes in three sub-types: relational tacit knowledge (RTK), somatic tacit knowledge (STK), and collective tacit knowledge (CTK). A deck officer's relational tacit knowledge includes, for example, knowing but not mentioning to the oncoming deck watch officer that the vessel traffic system (VTS) operator tends to forget to get back to a vessel with information once the (VTS) operator asks the vessel to wait due to conflicting communication priorities. RTK is knowledge that can be communicated to others, but the ability to do so is elusive at that moment in time.

An example of STK is a deck officer's ability to quickly and accurately take bearings on terrestrial landmarks; being able to steadily sight the landmark, accurately read the bearing and almost instantaneously note the time, and then move quickly to the chart

[213] Collins, *Tacit & Explicit Knowledge*: p.81.
[214] Ibid., pp. 85-138.

table, accurately measuring direction and distance on the chart and then plotting the bearing. This is seemingly physical prowess at some task.

A deck officer's collective tacit knowledge is that which is only useful in the situational presence of some social context. Recalling the role that variation plays in the performance of good seamanship, and those navigation judgments that didn't impact the overall success of the performance being of an acceptable level; it is their presence as social judgments, which is a social context, based on training and the experience of working on the bridge, that is representative of deck officer collective tacit knowledge.[215] They decide on the acceptable margins of error based on their bridge watch experiences. The standards for good seamanship are tacit social judgments. Codified standards for good seamanship are just plans. Good seamanship standards are the result of experience in situated actions across a collective of deck officers. That collective can be local to a ship, a sea-lane trade or other class grouping of deck officers. The constitution of the maritime social domain is the basis for social judgments that have variation.[216] This is true also for the work process tolerances that aren't apparent at the time of action.

I argue that deck officers exhibit collective tacit knowledge as evidenced by their ability to adopt and use new bridge technologies. They are collectively in touch with changing circumstances and recognize what are appropriate adjustments in technology use and adoption.[217] This idea can help explain why deck officers have been difficult to enroll into the immature ECDIS technology. They don't get together to explicate technology

[215] Harry Collins and Rodrigo Ribeiro, "The Bread-Making Machine: Tacit Knowledge and Two Types of Action," *Organization Studies* 28, no. 09 (2007): p.1424. "… she needed the master baker to teach her how to make 'correct judgments' …"
[216] Collins, *Tacit & Explicit Knowledge*: p.85.
[217] Ibid., p.124.

adoption amongst themselves, they do it under situations of improvisation because they are trained deck officers. If they weren't so trained (socialized), the idea of good seamanship could/would have a very different meaning.

4.4 Communication, Duty, and Understanding

The merits of responsibility aside for a moment, the good seamanship rule does not exonerate either the Master or any officer of the neglect to use good seamanship regardless of the ship's management structure. There is an ongoing commentary regarding the typical merchant ship management hierarchy and its being the traditional top down model in which the ship's Master has the final word.[218] Management structure is a separate issue that has and does impact work performances in some instances of vessel casualties. You won't find published anywhere that the Exxon Valdez ran aground because of corporate greed. After hearing Captain Hazelwood state that he wasn't going to sail the Exxon Valdez's on time because the ship's crew was exhausted and the reports of a large amount of glacial ice in the channel will make navigating in the dark dangerous, Exxon Shipping's main office threatened to replace Captain Hazelwood if he didn't sail the ship on schedule. If you knew Captain Hazelwood, you wouldn't say that to him.[219] What is in the reports is that Hazelwood was drunk and didn't help the Third Mate. The deck watch officers were tired and the Master was not a watch stander. Exxon had just a short time earlier removed an additional Third Mate watch stander from the ship's crew and forced the Chief Mate to stand watch. The Chief Mate's primary responsibility up to that point was cargo operations, the loading, unloading of the ship. The Chief Mate was to be on watch on the night of the grounding, but the Third Mate

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[218] Perrow, *Normal Accidents*: 177.
[219] Interview with Exxon mariner.

who had been up for only 24 hours agreed to stay on bridge watch longer in order to allow the Chief Mate, who hadn't slept for 36 hours, some time to sleep. The third officer lost his situational awareness for a critical three minutes trying to clear the ice field, that if he had acted three minutes earlier, deck officers generally would have a better environmentally friendly reputation.

The concept of bridge team management[220] has come about after reviewing multiple ship's casualties and the study of the air-line industry's FAA report of the 1972 Eastern Airlines crash in Florida that prompted the implementation of Crew/Cockpit Resource Management.[221] It is now a part of deck officer training within IMO's STCW convention. Bridge team management allows deck officers the ability to collaborate, ensuring that a good seamanship approach happens in all situations. It stands to reason that such bridge watch styles will promote learning and interpersonal sensitivity at all the officer levels, but none of this training acknowledges the role of shore-side management's role in ship casualties. There is no Sarbanes-Oxley for maritime shore-side management practice.[222]

It is conceivable to consider instances where junior officers take their lead from more senior officers regarding which technologies to utilize or accept, and when to use them. The following is an account of a situation where a Third-Mate's acceptance of the Master's technology preference would have been deemed an instance of poor seamanship had a casualty occurred.[223]

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220 AJ Capt. Swift, *Bridge Team Management* (London: The Nautical Institute, 1993).
221 Capt. Rexford Penn, *Bridge Resource Management* (Wilmington: The Rexford Penn group, 2012). p.9.
222 U.S. Government, "Public Law 107–204 107th Congress - 'SarbanesOxley
Act of 2002," (2002).
223 Donald F Clark, "Self interview - Recollections from Aboard the MV Lord Fleur D'Epee," (1985).

> “We are steering 190 on the gyro,” says the outgoing mate on watch.
>
> “Are there any targets out there that I shall have to concern myself with in the next 20 minutes?”
>
> ‘No,” he says.
>
> “I relieve you.”
>
> “I stand relieved,” he says.
>
> “Hey, the radar is off,” Ned says as the off-going Mate turns to enter the chartroom to finish filling out his ship’s log entries for his watch.
>
> “The Master wants to save the tubes, so he says we should turn it off when we don’t need it.”
>
> “Darn it. At least you could have put the radar in ‘Standby’ and kept it warmed up and ready for use. This ship has only one radar, so I’m blind should the ship run into one of the nearby rain squalls. If there is a collision and the radar wasn’t on, I’ll be held responsible regardless of whose fault it really is.”

An assessment of the ECDIS technology leads one to believe that the forced enrollment of deck officers occurred to meet the timeline expectations of the maintainers of maritime standards, maritime regulators, academics, and ECDIS product manufacturers. Forced enrollment, which includes acquiring the mandatory ECDIS training certification, isn’t true technology adoption. ECDIS is a new materialization of navigation. Deck officers must understand what ECDIS conveys, and must, in some way, physically transform themselves in order to do so. This transformation process is a negotiation with ECDIS by the deck officer. Forced enrollment fails for the majority of deck officers, much like forced piano lessons/practice has for the majority of piano students. A form of physical transformation takes place in the deck officer during negotiation that can lead to ECDIS use adoption. Understanding of ECDIS adoption or lack thereof by deck officers happens with an analysis of ECDIS in terms of a mariner’s use of tacit knowledge, so that one can see if the deck officers that are the target of ECDIS meet the conditions of communication embedded in ECDIS for the navigation process.[224] Conditions of communication means that a communication takes place because of the closing of some gap in communication. Collins defines five conditions, from a simple transmission of a string closes the gap, to some physical change in the human receiver closes the communication gap.

Collins says that someone only gains tacit knowledge when in direct contact in society.[225] The explicit can be conveyed by intermediaries (persons/things) with strings inscribed on them. Strings are the facilitating factor in a communication, for example a single word, a longer explanation, or a physical change such that a receiving person achieves some fluency and understanding due to contextual change. If they appear to transmit tacit knowledge, then they are not intermediaries, but are end persons (owners). When a technology is said to gain tacit knowledge one must consider how that process could have occurred or if it did indeed occur. Collins argues that such a claim is misleading if not outright wrong.

> "It is not a matter of the explication or incorporation of tacit knowledge, but of fitting a social prosthesis into a rearranged world."[226]

A social prosthesis mimics and substitutes action, giving the appearance of knowing.[227] One finds that a social prosthesis still requires human tacit knowledge, but its source may come from new contributors. The technology's output may or may not be the same, since it is now a part of a rearranged world.

[224] Collins, *Tacit & Explicit Knowledge*: p. 23. See condition 4
[225] Ibid., p. 87. Communicating with and without intermediaries.
[226] Collins and Ribeiro, "The Bread-Making Machine: Tacit Knowledge and Two Types of Action," p. 1417.
[227] Ibid.

4.5 Action Types and Their Relationship to Types of Knowledge

Actions based on a decision with some intention in mind come with some knowledge that is either explicit or tacit. Technologies come with embedded explicit knowledge, not tacit knowledge, since that hasn't become explicit yet. Stepping away for a moment from this research paper's maritime theme, take for example a doorstop used to hold a door open. One design is weighted enough to hold open a door and another is an angle piece of material that is jammed under a door using friction to hold the door through redirecting the doors weight into the floor. In these cases, the doorstop has been embedded with explicit knowledge concerning that weight can hold the door either by using a lot of weight or by using the concept of friction and force redirection. The weight mimics a human holding a door open. People manually open doors in a uniform manner. Some people open doors quickly, especially when one is in a hurry. Some open doors slowly. Door opening requires some use of somatic tacit knowledge, for example children learn how much force to use in order to open a door. An automatic electronic door opener/closer mimics opening and closing a door using some kind of presence sensing device. It uses what Collins calls mimeomorphic action to accomplish its task.[228] Mimeomorphic actions take place in the same manner with some allowable amount of variation. The door opens when a person is within the zone of the proximity sensor. A gentleman in some cultures opens a door for his female companion. An electronic door opener embedded in this culture doesn't know not to open if the gentleman forgets his manners and enters first. The only way the door opener can be enculturated is by providing some additional explicit biometric device. The door now mimics the social convention. If this is accomplished, how will the door know to let the male enter first in

[228] Collins and Kusch, *The Shape of Actions - What Humans and Machines Can Do*: p.36.

the case of a brother and sister, who due to sibling rivalry, don't follow the gentleman scenario? Either the sibling must break the rivalry convention and be controlled by the door, or the door now needs more explicit knowledge. Social context defines who opens and then enters the door first and these types of actions are polimorphic actions.[229] Polimorphic actions have the ability to execute differently depending on the social circumstances. A polimorphic action is socially contextual. Building an automatic electronic door opener and providing rules and biometrics for every conceivable opening scenario doesn't instill social context. However unlikely, there would be no flexibility should the brother have a change of mind and let his sister enter first.

Many machines use technology to mimic mimeomorphic actions to some tolerance allowed by their designers. For example, a ship's autopilot can steer a set course. Collins cautions us that technology can only mimic action and not reproduce human action, since reproduction presumes intention and technologies don't have intentions, their designers do.[230] Polimorphic actions can't be mimicked, but they can be accomplished through substitution, and that substitution is only successful in a rearranged world. Re-arranging the world means that some task disappears because it is purposeless. The job to hold the reins of horses whose job is to pull artillery goes away with motor driven vehicles. The decision to rearrange a world is a high-level polimorphic action.

What follows are a set of short vignettes to document the processes of chart correcting, voyage planning, and navigating/tracking a voyage using pre-ECDIS methods derived from interviews with merchant officers and this researcher's direct experience. Vignettes

[229] Ibid., p.32.
[230] Collins and Ribeiro, "The Bread-Making Machine: Tacit Knowledge and Two Types of Action," p.1419.

of post-ECDIS implementation versions of chart correcting, voyage planning, and navigating/tracking a voyage then follows that are derived from merchant officer interviews, ECDIS operation manuals, ECDIS literature, and this researcher's personal training on ECDIS.[231] Presented afterward is what Collins calls an 'action survey' that helps to assess what types of actions, polimorphic or mimeomorphic, are being performed during the navigation tasks.[232] Recall that polimorphic actions are actions that can be performed differently depending on social context, while mimeomorphic actions are actions that are repetitions within some bandwidth of variation. An analysis of the action survey will help to express deck officer technology adoption in terms other than deskilling, ECDIS's ramifications on deck officer work performance improvisation, and the value of experiential technical skill.

4.6 Work Process Vignettes

The inspiration for creating work process vignettes and a follow on vignette analysis comes from its very effective by Julian Orr in his work, Talking About Machines.[233] The vignettes in this chapter are composites derived from the interviews with deck officers who remain anonymous, as well as incorporating nautical reference material where necessary for the purposes of clarity.

4.6.1 Pre-ECDIS Nautical Chart Correcting and Updating

As the Second Mate, Ned has bridge work to do even when the ship is not at sea or when he is not on watch, in this case, it is chart work.

[231] Hecht et al., *The Electronic Chart - Fundamentals, Functions, Data and other Essentials - A Textbook for ECDIS Training*: pp.16-22.
[232] Collins, *Tacit & Explicit Knowledge*: p.173.
[233] Orr, *Talking About Machines*.

While familiarizing himself with the chart room located to the rear of the bridge, Ned noticed a nice stack of Notice to Mariners located in an inbox on top of a small cabinet located just behind the chart table. As Second Mate, Ned has the responsibility to maintain the ship's navigation equipment, including the charts.[234] A chart's accuracy can change for any number of reasons such as a buoy disappearing, a point of land changing characteristics, a new obstruction to navigation, or some new aid to navigation becoming available. Charts do cost money, so instead of constantly buying new charts, they are updated regularly using Government publications called Notice to Mariners and Local Notice to Mariners.

An index card file box is next to the inbox where the Notice to Mariners pile sits. Ned opens the card box and expectedly sees that the cards are each marked with a chart number at the top and columns of dates going across each card. The date column corresponds to the latest Notice to Mariners updates that some previous Second Mate has applied to the chart to which the index card belongs. Ned sets to work, pulling the first card out and systematically going through each Notice to Mariners to see if any chart updates are required. The first 3 cards yield no updates, but the third card's number is found in the top most Notice to Mariners. Ned opens the top drawer beneath the chart table and removes a set of navigation triangles, a navigation divider, a vial of typing correction fluid, a set of color pencils, a regular pencil and a black pen, and lays them on the chart table. He's ready to begin.

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[234] Captain Dempsey states the traditional tasks of the Second Mate in Capt. Deborah Dempsey and Joanne Foster, *The Captain's a Woman, Tales of a Merchant Mariner* (Annapolis, MD: Naval Institue Press, 1998). p. 73.

The navigation charts are stowed in a set of six drawers underneath the chart table. Each drawer label starts and ends with numbers that corresponds to the chart numbers in that drawer. Ned finds the number sequence of interest and opens the drawer. In the draws are charts folded in half so that the chart portion faces itself. The charts have large numbers written on their backsides that faces up. He flips through the charts in the drawer pulling the appropriate chart from the drawer. Laying the chart on the chart table and unfolding it, he begins the correcting process. The first correction is to remove a buoy marking a wreck just off an island on the chart. This is an easy correction, not requiring Ned to draw in a buoy or even to measure the latitude and longitude before making the correction. The wreck and the buoy are obvious on the chart and a little correction fluid does the job. On to the next chart.

4.6.1.1 Vignette Discussion and Action Analysis

Charts are the principle purveyor of information for navigation. They are procured and corrected, then sequenced by a voyage plan, and enacted through navigation production during a voyage. They are a central input material to the manufacturing of a voyage.

In this vignette, the deck officer decides to reduce the backlog of Notice to Mariners updates. Generally, this task is tedious, requiring detailed measuring and careful drawing and marking on the chart. It can be onerous if the work is undone for some time, but normally each Second Mate shoulders the burden willingly. In most instances, no one is going to measure Ned's success or failure as a deck officer if he doesn't go through the publication stack. The Master might grunt, saying it is the Second Mate's job. They may argue about overtime pay for the work. Chart correcting is a community effort. The community benefits from the completed task. In this case, two overlapping communities exist. The Second Mate community shares the burden of correcting charts. The Second Mate community is mostly anonymous and transient, with many Seconds coming and going aboard ship over time. The trace that they've been chart correcting is their initials and the Notice to Mariners date on the chart correction index card, or on some ships an initial and Notice to Mariners date in the lower right corner of the chart, which are correction tracking tools found on many ships. The community stays connected through the correction tracking tools for chart and publication corrections. If the previous Second didn't feel compelled to make corrections, then the other community, that being the entire ship's crew, will feel pain if an incident occurs. Any number of tragedies can befall a ship if it's deck officers do not have access to the most up to date charts. It is possible, though not likely, that a stack of Notice to Mariners will not require any corrects to any of the onboard ship's charts or other navigation publications to which they apply. The Second Mate won't know this without going through the publication stack top to bottom.

Chart correcting is not an art because an ugly drawing sends the same information as a beautiful one and therefore it requires no special somatic knowledge for guiding one's hand in a design. It requires having knowledge of charting symbols, knowledge of geographic standards of measure, and the ability to manipulate manual tools in order to accurately locate a position on the chart and make the correction however unsightly. The chart corrector is dependent on whatever authority is authorizing the correction from the standpoint of stating their correction location accurately in the correction publication. It is a case of chart correctors following orders. Following the Notice to Mariners information doesn't guarantee an accurate chart. It guarantees that if the corrector does an accurate job interpreting the correction guide, and does an accurate job on the actual chart correction, that following the process of correction occurred based on the information in the given Notice to Mariners publication. The chart correction information is inherited from the authority publishing the correction material.

At the highest level, and this goes for all deck officer work that involves reading; chart correcting is a polimorphic action, since language use dominates reading and requires immersion in order to become contextually proficient in its use. At the highest level of action, the chart room exists due to polimorphic actions where contextual social interpretations of human factors, engineering trade-offs, engineering standards, and ideas of efficiency take place. That said, mimeomorphic action dominates the time-consuming chart correcting process. The design of the chart table space defines the process for gathering and deploying the navigation implements, the charts, index cards, and Notice to Mariners publications and therefore those actions are more or less the same each time chart correcting takes place. The lookup and choosing of corrections is done in a mechanical way. Finding the location on the chart is done over and over again with little variation. Chart corrections and new data additions require no special interpretation actions. What action that is polimorphic as one corrects the chart is judging which corrections to make and the level of accuracy standard one is willing to apply. This includes whether or not to look carefully through all the Notice to Mariners, drawing with thick or thin lines or letters, making notations on the index cards, or folding the charts carefully. The Second Mate makes a determination what level of accuracy is acceptable personally for oneself, and socially for the profession. In a sense, all of a deck officer's work can be said to be bound by some level of accuracy, which may be forced upon them (standards), learned through training (peer pressure), or accepted based on context. It isn't fixed. It isn't the same across deck officers, across ships, and an officer may adopt or adapt a new level.

4.6.2 Voyage Planning Using Traditional pre-ECDIS Methods

The Second Mate sets to work by first deciding that the season has meandered expectedly from winter to spring and the consideration of a shorter more northerly westbound route versus a more southerly route used during winter. A weather forecast service provides the ship with weather forecasts, including sea states via an IMARSAT service satellite communication feed. The Second lays out a great circle voyage track, the shortest route possible, which takes the northern route; because the North Atlantic looks free of winter storm features. This ship has a gnomonic projection chart for the North Atlantic simplifying the Second's task from the standpoint of not having to do a large number of mathematic calculations in order to determine the course to steer from waypoint to waypoint along the voyage track.

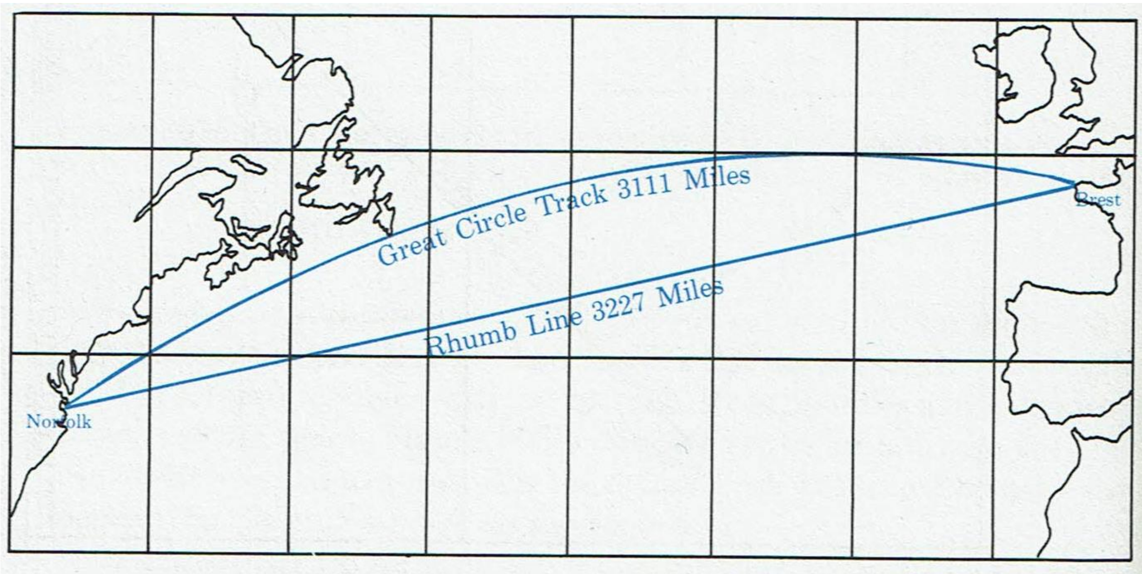
309b. Rhumb line and great circle on a gnomonic chart.

Figure 6[235]

The Second draws a straight line from the initial trans-Atlantic point of departure, Norfolk, VA to the first European port of call, Brest, FR on the gnomonic chart, and

[235] Elbert S Maloney, *Dutton's Navigation & Piloting*, 13th ed. (Annapolis, MD: Naval Institute Press, 1978). 38.

notes the latitude at points that cross the meridians. The Second intends to transfers these points to the mercator charts that will be used to measure the courses to steer, and to follow the ship's voyage via navigational plots. When the Second pulls out the North Atlantic mercator chart from the chart table drawer, he finds that it already has his intended routings drawn onto it, and the penciled in voyage track has been covered with clear tape so that it is preserved over time.



Great circle and rhumb line on a Mercator chart.

Figure 7[236]

The tape enables one to plot actual ship positions and make erases without erasing the intended track or risk tearing the chart. The Second's workload is the beneficiary of some forward thinking second mate previously aboard the ship and a smile comes to the Second's face. The constancy of voyage tracks for vessels in a liner service is different

[236] Ibid., 36.

from that of other shipping trades that don't have fixed voyage schedules between a set of ports.

The upcoming voyage's waypoints (those noted from the gnomonic chart) now need entering into the principle GPS receiver, so that it will track the voyage electronically and serve as a reference guide to the various course changes during the voyage. The Second has work to do here, since no one has stored this voyage plan into the GPS. Having just come aboard and being new to this vessel, the Second pulls the manual for this GPS, and follows the cookbook instructions for entering a voyage's waypoints into the device.

In addition to the small-scale North Atlantic mercator chart that will be used to plan and follow the entire voyage, the Second Mate pulls all the associated larger-scale navigation charts to be used on the voyage from the chart drawers. Each of the plotting charts has also been prepared previously with tracks and notations covered with clear tape. The Second Mate lays them in order of use one on top of the other, and places them in the top chart table drawer. These charts include those used for piloting the ship out of and into the various ports, as well as large plotting sheets for plotting positions while out of sight of land. The Second Mate handles the charts carefully, so that they aren't damaged and become unfit for use.

The final result (see figure 5) of the voyage plan is a sequence of charts marked with a primary and maybe alternative routes, with track deviation alliances, courses, wheel-over locations, parallel index marks and distance, and notations for the deck officer on watch regarding the navigation aids best suited for use during each route leg.

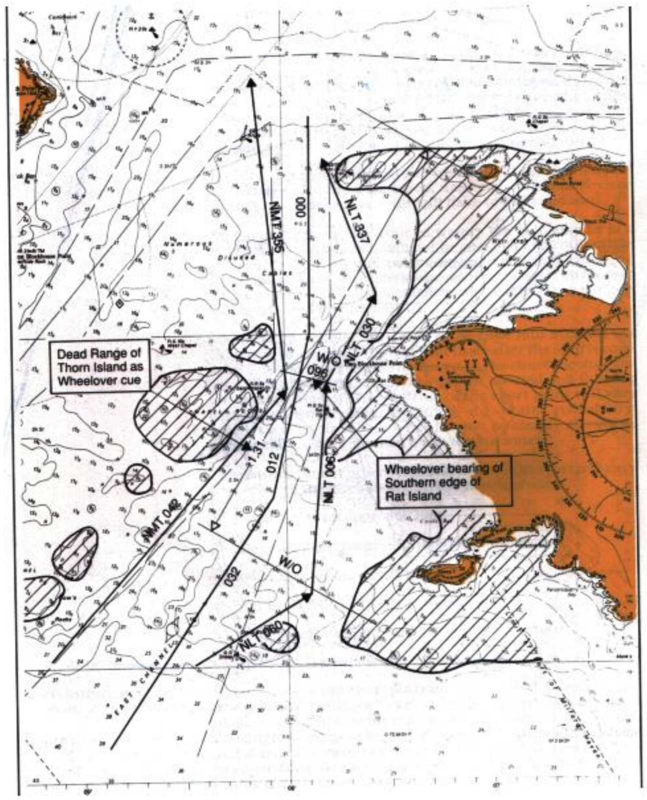


Figure 8 – Portion of Trackline Plotted on a Paper Chart[237]

4.6.2.1 Vignette Discussion and Action Analysis

Planning the voyage is the process of deciding the vessel routing from each outbound sea-buoy to the sea-buoy of each destination. By tradition, the deck officer who is the Second Mate plans the ship's voyage and then lays out (draws the route and makes any necessary notations) the routes for the voyage on the ship's charts. The voyage plan requires not only nautical chart information but also other nautical detail gathered from hopefully up-to-date nautical publications.

Commercial vessels generally require the shortest routes for it voyage, since the shortest is fastest and uses the least fuel. The routes should also not expose the ship to any

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[237] Penn, *Bridge Resource Management*: 29.

unnecessary risk. Voyage planning requires information as to port call sequence, typically from the Master, and examining nautical publications for relevant information for each route leg. What is relevant is the deck officer experiential technical knowledge, learned in a formal educational environment and through on-the-job experience. While the IMO STCW requirements are training standards, how the training is accomplished, the environment in which it is accomplished, and the quality of the teachers, trainers, mentors, etc. is highly variable and subject to social, cultural, political, and economic influences.

The interpersonal style for approaching the Master is a polimorphic action, since the approach could be different based on for example, approaching leaders in a particular culture or how a particular leader wants to be approached in the course of normal work duties. Voyage planning has very little leeway in terms of process and those processes are done and redone over and over again. This fact makes the voyage planning process principally an assemblage of mimeomorphic actions. The navigation officer's social maritime domain knowledge represented by the officer's judgment determines any variation in the process. The tools at hand, personal preference, and training determines the actions of the navigation officer.

4.6.3 Open Ocean Navigation Using Traditional pre-ECDIS Methods

It is 0340 ship's time when Chris enters the ship's chartroom from the aft stairwell in the rear of the ship's bridge. It is common practice, and really tradition, to relieve the off-going watch 15 minutes before the official start of the next watch, so Chris arrives early enough to assess all factors relating to her upcoming watch. First things first. In the chartroom, Chris reads the Captain's night orders in the "night order book," signs them in the space provided in order to show an understanding of them, and also to provide an official record that they have been read. Completing what by all accounts will be the most important item during this night watch, she then glances at the last ship's position placed on the chart by the current Mate on watch. She walks to the left of the chart table and turning right, takes two steps through the chartroom door and onto the ship's bridge. Chris turns and walks to the right to the starboard bridge wing, and then back across the bridge to the port bridge wing, glancing at both radar's plan position indicator (PPI) while in the transit from wing to wing. She is building up her situational awareness before relieving the current mate on watch as she digests the latest chart position, the weather, the sea state, depth sounding on the doppler speed log, radar targets, and the running lights on the silhouettes of vessels on the horizon. She's now ready to meet with the current mate on watch to get any watch pass-down information.

> "We are on course 345 degrees true, steering 345.5 degrees by the gyro. We're running 110 RPM's, and making 20 knots. Only one target on the radars, 12 miles off the port bow bearing 325 degrees. It seems to be moving on a parallel course, and at the same speed as us," says the current Mate on watch.
>
> He continues as Chris glances about, "All bridge equipment is working properly and there are no engineering issues or requests that I am aware of."
>
> Chris states, "I am ready to relieve you.
>
> The off-going Mate says, "I stand relieved," and walks off like a zombie to bed.

It is 0400, and with no vessel traffic posing any issues, Chris proceeds back into the chartroom. She writes the GPS's current latitude and longitude reading of 21 degrees 20.7 minutes North / 109 degrees 22.5 minutes West into her rough log, which is a notebook that she brings to each watch in which she writes down watch notations that will be entered into the official ship's smooth log or that she wants to remember for later reference. She also enters these coordinates into the ship's GPS watch logbook. Per the Master's standing orders, she must plot a GPS position on the chart hourly.

Figure 9 – Navigation Implements - Dividers[238]

Picking up the available pencil on the chart table in one hand and the navigational dividers in the other, Chris readies to plot the 0400 GPS position. She decides that the pencil point isn't sharp enough for accurate chart work, so she sticks the pencil tip into the electric pencil sharpener located on the shelf just above the chart table. With a sharp

[238] Maloney, *Dutton's Navigation & Piloting*: 181.

pencil in her left hand, Chris manipulates the navigation dividers in the other, and measures off the minutes of latitude from the legend along the side of the chart nearest her presumed chart position. In this case, she places one tip of the dividers on 21 degrees North latitude on the left edge of the chart and extends the other tip of the dividers up the chart to 20.7 minutes of latitude. Keeping this spread on the dividers, she places one point of the dividers on the intersection of 21 degrees' latitude and the meridian nearest to the expected plotted position, in this case 109 West longitude. The other tip she touches softly at 20.7 minutes, making a slight mark with the pencil at that point. She then measures the minutes of longitude using the longitude scale on the top of the chart, beginning at the 109 W meridian, and measuring 22.5 minutes westward. Keeping this spread on the dividers, she sets one tip at the same intersection of 21 degrees N latitude and 109 degrees West longitude. The other tip she touches softly westward on the parallel of latitude, making a slight mark with her pencil at 22.5 minutes west of 109 degrees.

Chris picks up a clear plastic navigation triangle (an isosceles right triangle / 45,45,90) and places it on the chart, hypotenuse up, along the 21 North latitude so that it is bisected by 109 West longitude.

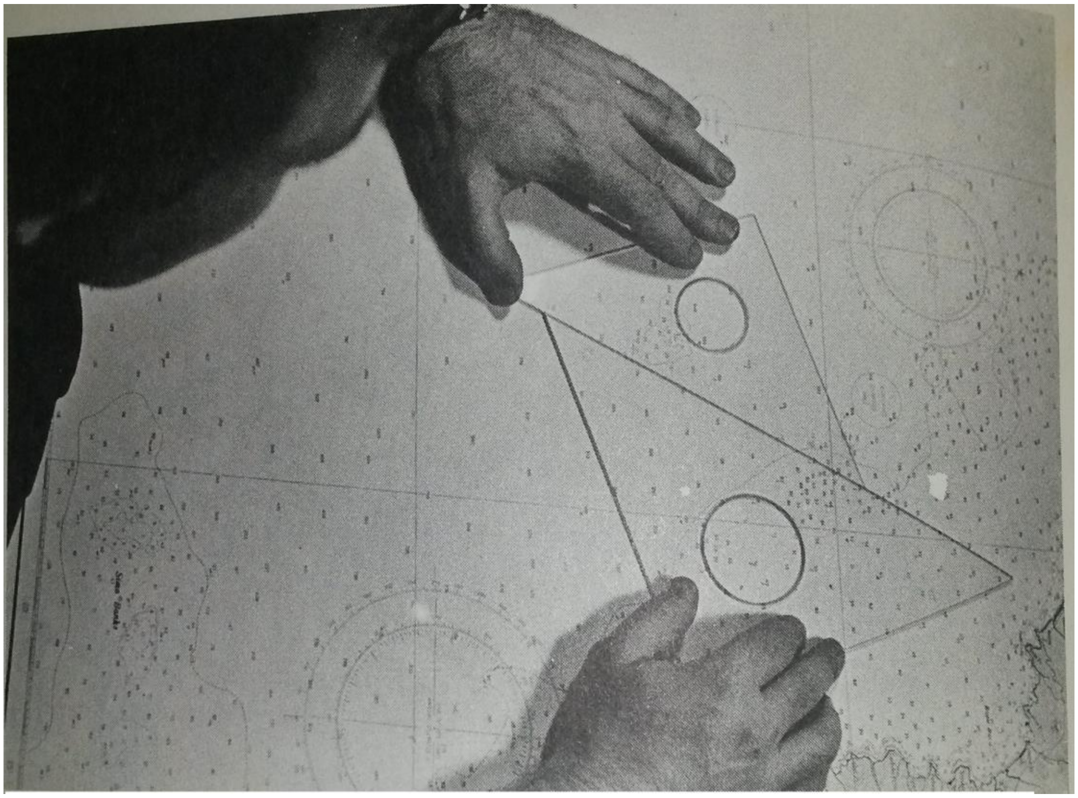

Figure 10 – Navigation Implements - Triangles[239]

She then places the hypotenuse of another navigation triangle against the left leg of the triangle on the chart and slides the first triangle up to where it just touches the tiny latitude measure dot she made on the meridian. She draws a small line with her pencil that is perpendicular to the meridian in the vicinity of the as yet

unplotted GPS longitude. Next, she places the hypotenuse of a navigation triangle parallel with the meridian on which she made the latitude dot and faces it westward. She places another triangle against the lower leg of the first triangle now on the meridian, and slides the first triangle down and to the left until it just touches the longitude mark made on the

[239] Ibid., 184.

parallel of latitude. Chris draws another line, this time perpendicular to the parallel of latitude. She draws this second line so that it just crosses the first line that she drew. Their intersection on the chart is the ship's 0400 plotted GPS position and she draws a small triangle around the point to show that it is an electronic fix, i.e. determined by electronic means. She quickly erases the extraneous markings she made on the chart before leaving the table.

According to this ship's Master's standing orders, morning and evening stars will be shot and plotted on the chart twice daily, unless there is ship traffic that needs monitoring or the vessel is maneuvering. The sun will rise during this 0400 to 0800 watch, so morning stars are her responsibility. The celestial phenomenon called civil twilight is the optimum time to take stars because the horizon is visible enough for using a marine sextant, and it is still dark enough for navigational stars to be visible in the heavens.[240] Chris has to calculate when this phenomenon occurs. At the chart table, she opens the Nautical Almanac to the page that corresponds to today's date. The Almanac contains tabulated times for civil twilight for each day, but these times are only good for the selected range of whole degree latitudes, and also only if the observer is located on one's time zone's meridian from which Local Mean Time is calculated.[241] This is no hindrance to Chris, since the Almanac contains an interpolation table called Table I for correcting the time for civil twilight based on one's true latitude, and also a handy table called Conversion of Arc to Time, for time corrections to one's true longitude (see below).

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[240] Navigational stars are generally considered to be the 19 first magnitude and 38 second magnitude stars found in the Nautical Almanac.

[241] Local Mean Time is similar to Greenwich or Universal Time, but with reference to a local meridian (longitude).

Chris thumbs to today's pages in the Almanac and notes that her latitude falls between the tabulated values of 20 degrees and 30 degrees North latitude.

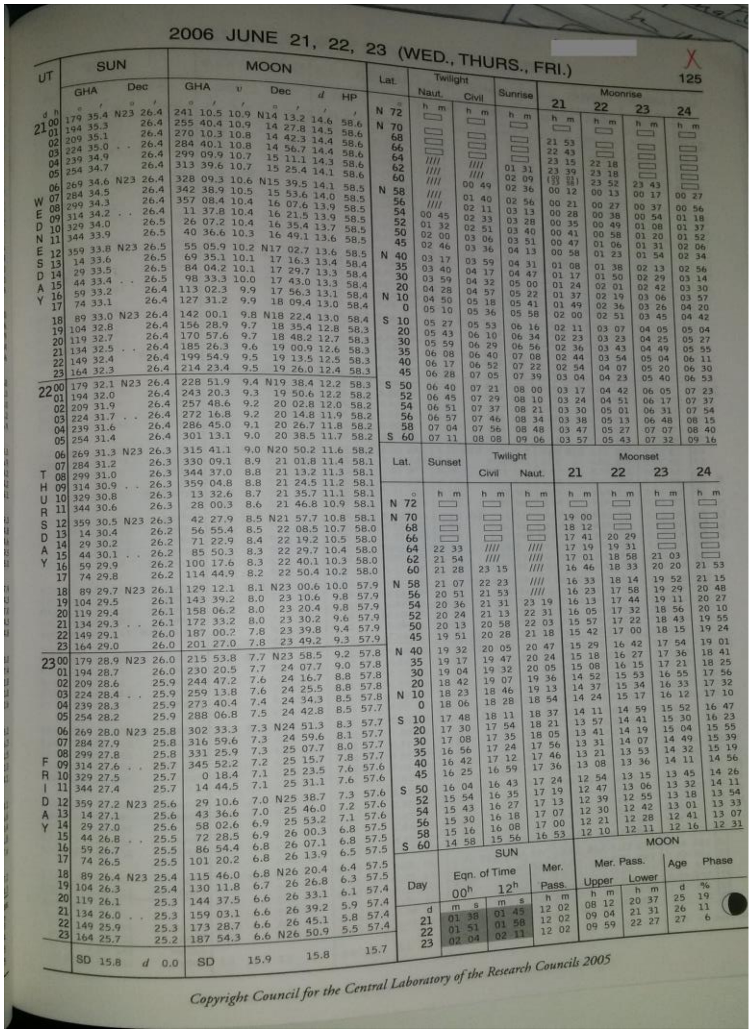
2006 JUNE 21, 22, 23 (WED., THURS., FRI.)

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Figure 11 – Almanac Daily Page[242]

Civil twilight at 20 degrees North is 0457 and 0432 for 30 degrees. Relative to these times, Chris estimates that the ship will be at approximately 24 degrees 48 minutes North latitude.

[242] *Nautical Almanac 2006 Commercial Edition, Jan 1 2006 through Jan 1 2007*, (Arcata, CA: Paradise Cap Publications Inc. & Celestauire, Inc., 2005). 125.

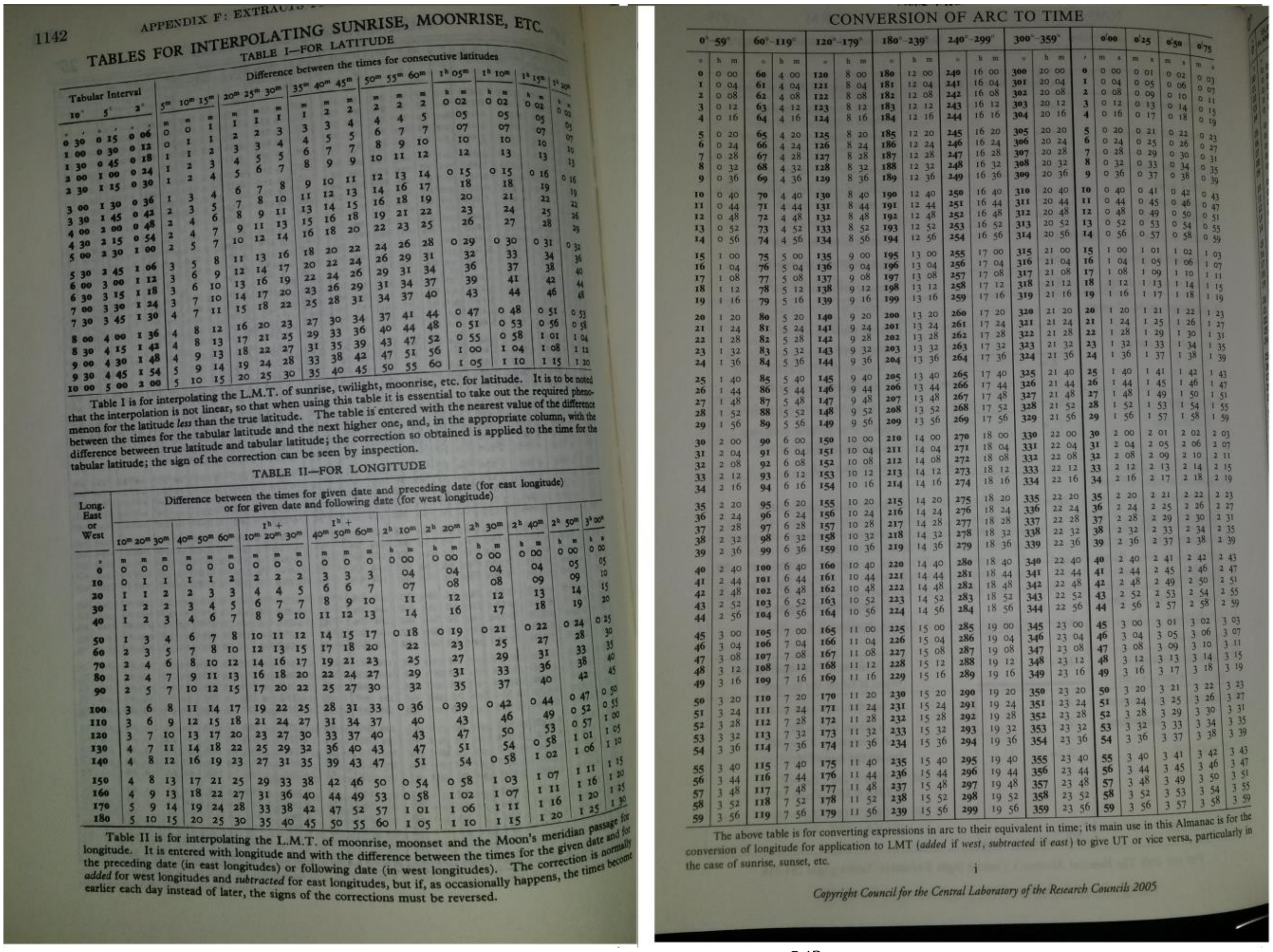
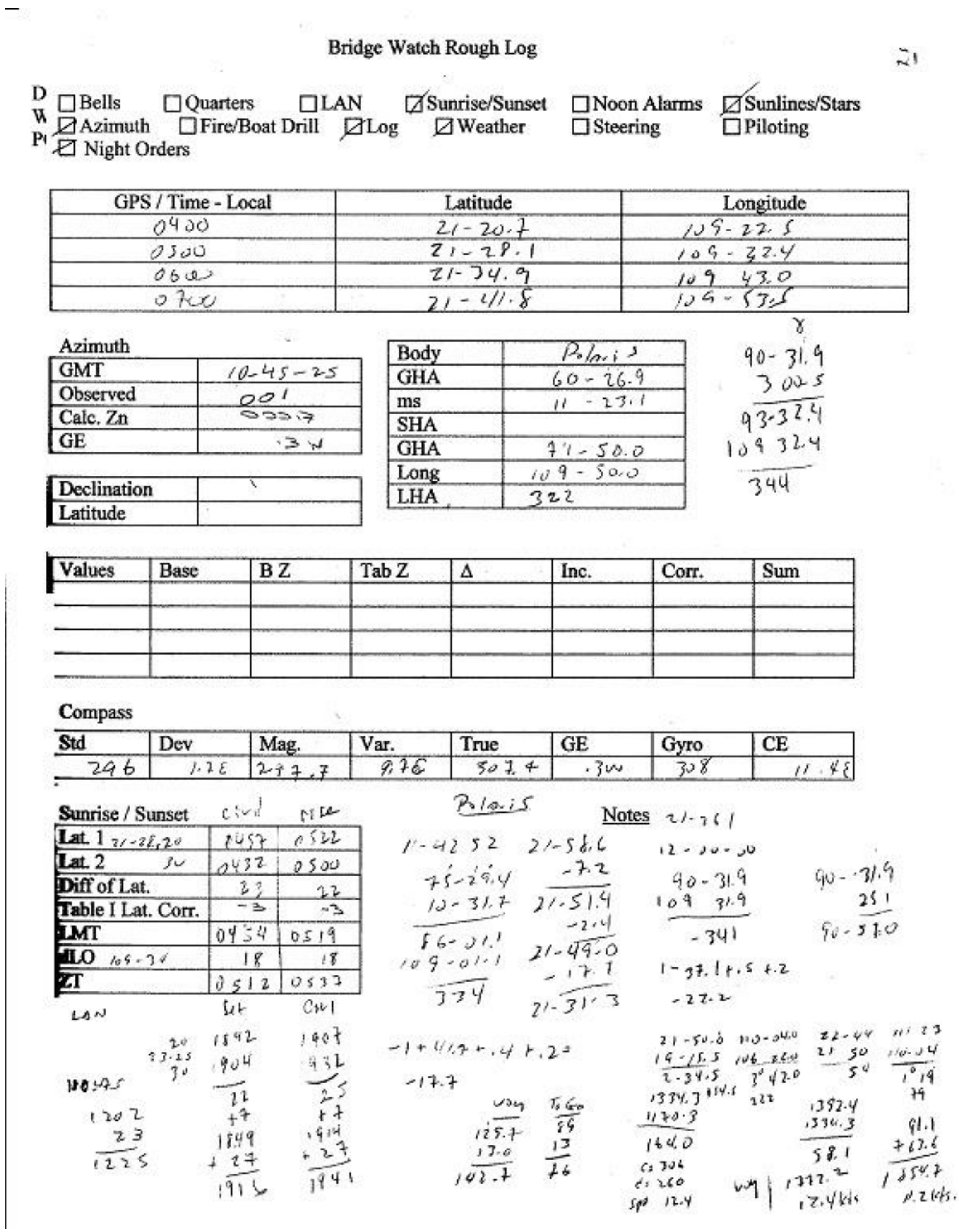


Figure 12 – Almanac Support Tables[243]

She enters Table I from the top left of the table in the area with the heading "Tabular Interval." Below this heading are three columns, one for an interval of 10 degrees, one for 5 degrees, and one for 2 degrees. Chris uses the 10 degree column in this case, since her latitude falls between the tabulated values of 20 and 30 degrees North. She scans down that column until she comes to a value closest to the difference between her estimated latitude of 21 degrees 28 minutes and the next lowest tabulated latitude of 20 degrees, so 1 degrees 28 minutes. The closest tabulated value is 1 degree 30 minutes. She re-enters Table I on the top but to the right of the tabular value heading. She looks

[243] Nathaniel Bowditch, "American Practical Navigator An Epitome of Navigation Volume 1," ed. Defense Mapping Agency Hydrographic Center (Washington, D.C.: Defense Mapping Agency Hydrographic Center, 1977).

for a value in the heading that is closest to the difference between the two tabulated civil twilight times of 0457 and 0432, or 25 minutes. Finding the exact value of 25 minutes, no interpolation between successive columns being in this case required, she scans down the column until she comes to the value that is in the same row as the 1 degree 30 minutes value from her first table entry to the left. The extracted table value is 3 minutes and she subtracts this value from the tabulated time of civil twilight for 20 degrees, since twilight occurs sooner as latitude increases within the tabulated values, and gets a time of 0454. The ship's local mean time (LMT) is based on being 7 hours behind Greenwich and the reference longitude for this time zone is 105 degrees West. Chris estimates that at 0454, her civil twilight time corrected for latitude, the ship will be at 109 degrees 34 minutes West longitude. The difference between her longitude and the LMT meridian is 4 degrees and 34 minutes of arc. This converts to 18 minutes and 16 seconds of time, which means that civil twilight for the ship will be approximately 18 minutes later, or 0512 when added to the value corrected for latitude. For the benefit of the ship's crew, Chris uses the same methodology to calculate the sunrise and sunset times for the day.



Bridge Watch Rough Log

☐ Bells ☐ Quarters ☐ LAN ☑ Sunrise/Sunset ☐ Noon Alarms ☑ Sunlines/Stars
☑ Azimuth ☐ Fire/Boat Drill ☑ Log ☑ Weather ☐ Steering ☐ Piloting
☑ Night Orders

GPS / Time - Local	Latitude	Longitude
0400	21-20.7	109-22.5
0500	21-28.1	109-32.4
0600	21-34.9	109 43.0
0700	21-41.8	109-53.5

Azimuth

GMT	10-45-25
Observed	001
Calc. Zn	[illegible]
GE	.3 W

Declination	
Latitude	

Body	Polaris
GHA	60-26.9
ms	11-23.1
SHA	
GHA	71-50.0
Long	109-50.0
LHA	322

Values	Base	B Z	Tab Z	Δ	Inc.	Corr.	Sum

Compass

Std	Dev	Mag.	Var.	True	GE	Gyro	CE
296	1.2E	297.7	9.7E	307.4	.3W	308	11.4E

Sunrise / Sunset	Civil	Naut
Lat. 1 21-28.20	1057	0522
Lat. 2 30	0432	0500
Diff of Lat.	23	22
Table I Lat. Corr.	-3	-3
LMT	0454	0519
LO 109-34	18	18
ZT	0512	0537

Notes

Figure 13 – Rough log showing hourly GPS positions and Azimuth Calculations[244]

244 Don Clark, "FY 06 Cruise Rough Log," (2006).

Preparation for shooting stars follows the calculation of civil twilight. Chris brought her own sextant aboard ship, because she likes to keep in practice even if the Master doesn't require stars or sun lines as part of the watches' routine. Chris reaches into the shelf above the chart table where she placed it prior to vessel departure, and lifts then grasps the handle of the sextant's storage box. She lifts the box up and over the shelf lip that protects against shelf contents spilling out in bad weather. The sextant box is made of polished wood. It has two brass hinges and a tensioned brass clasp with keyed lock that keeps the box lid from opening. She unlocks the clasps and carefully lifts the lid into its fully opened position. In the red lighted chartroom, Chris peers down onto the sextant cradled in a bed of foam. The sextant lays handle first, so Chris grasps its frame and lifts it out, all the while inspecting it for any damage.

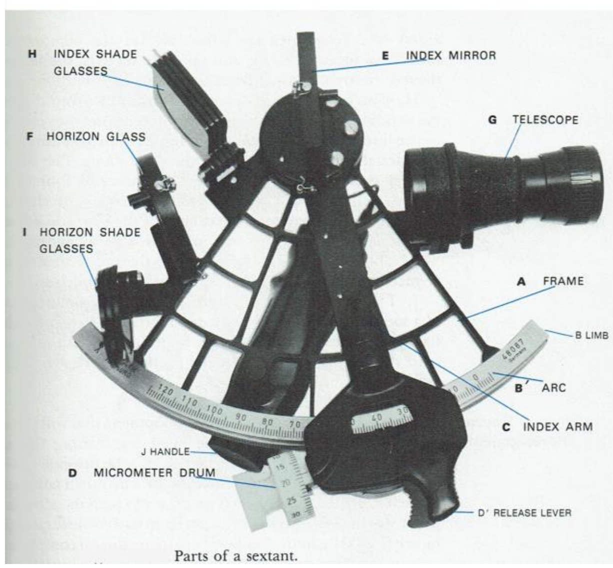


Figure 14 – Marine Sextant[245]

[245] Maloney, *Dutton's Navigation & Piloting*: 465.

Secure that its mirrors, shades, eye telescope are in good order, she pulls the release lever on its index arm and checks for any binding or play in its arc. She gives the micrometer drum a few turns to check it for binding. She walks the sextant out onto the starboard bridge wing, sets it on deck out of the way of any walking traffic, allowing it to come to the same temperature as the outside.

Returning to the chartroom, Chris takes a celestial navigation calculating sheet out of her rough log. The calculating sheet is a tool that Chris created for her convenience after many hours of using a blank sheet of paper and trying to remember each component of each celestial calculation. Many navigators create similar work sheets, preprinting them with their preferred celestial navigation methodology in mind. Chris likes to use the DMAHC publication number 249 (Pub. 249), for star sights because of its ease of use.

LAT 20°N

LHA ♈	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn
	Schedar		CAPELLA		◆ALDEBARAN		Diphda		◆FOMALHAUT		ALTAIR		◆DENEB	
0	52 39	009	21 34	047	24 48	080	50 33	163	38 12	197	29 02	269	42 11	314
1	52 48	008	22 16	047	25 43	081	50 48	165	37 55	198	28 05	270	41 30	313
2	52 56	007	22 57	047	26 39	081	51 02	166	37 37	199	27 09	270	40 49	313
3	53 03	007	23 39	047	27 35	081	51 15	168	37 17	200	26 12	270	40 08	313
4	53 09	006	24 20	048	28 30	082	51 26	169	36 57	201	25 16	271	39 27	313
5	53 14	005	25 02	048	29 26	082	51 36	171	36 36	202	24 20	271	38 45	313
6	53 18	004	25 43	048	30 22	082	51 44	172	36 15	203	23 23	271	38 04	313
7	53 21	003	26 25	048	31 18	082	51 51	174	35 52	204	22 27	272	37 22	312
8	53 24	002	27 07	048	32 14	083	51 56	175	35 28	205	21 31	272	36 41	312
9	53 25	001	27 48	048	33 10	083	52 00	177	35 04	206	20 34	272	35 59	312
10	53 26	000	28 30	048	34 06	083	52 02	179	34 39	207	19 38	273	35 17	312
11	53 26	359	29 12	048	35 02	083	52 02	180	34 13	208	18 42	273	34 35	312
12	53 25	358	29 53	048	35 58	084	52 02	182	33 46	209	17 45	273	33 53	312
13	53 23	357	30 35	048	36 54	084	51 59	183	33 18	210	16 49	274	33 11	312
14	53 20	356	31 17	048	37 50	084	51 55	185	32 50	211	15 53	274	32 29	312
	CAPELLA		◆ALDEBARAN		RIGEL		ACHERNAR		◆FOMALHAUT		Enif		◆DENEB	
15	31 58	048	38 46	085	21 19	108	12 23	175	32 21	212	41 52	265	31 47	312
16	32 40	047	39 42	085	22 12	108	12 28	175	31 51	212	40 56	266	31 05	312
17	33 21	047	40 38	085	23 06	109	12 32	176	31 20	213	40 00	266	30 22	312
18	34 03	047	41 34	085	23 59	109	12 36	176	30 49	214	39 03	267	29 40	312
19	34 44	047	42 31	086	24 52	110	12 39	177	30 17	215	38 07	267	28 58	312
20	35 25	047	43 27	086	25 45	110	12 42	178	29 45	216	37 11	267	28 16	312
21	36 07	047	44 23	086	26 38	111	12 44	178	29 12	216	36 14	268	27 34	312
22	36 48	047	45 19	086	27 31	111	12 46	179	28 38	217	35 18	268	26 51	312
23	37 29	047	46 16	087	28 23	112	12 47	179	28 04	218	34 22	268	26 09	312
24	38 10	047	47 12	087	29 16	112	12 47	180	27 29	219	33 25	269	25 27	312
25	38 51	046	48 08	087	30 08	113	12 47	180	26 53	219	32 29	269	24 45	312
26	39 32	046	49 05	088	31 00	113	12 47	181	26 17	220	31 33	269	24 03	312
27	40 12	046	50 01	088	31 51	114	12 46	181	25 41	221	30 36	270	23 21	312
28	40 53	046	50 57	088	32 43	114	12 44	182	25 04	221	29 40	270	22 39	312
29	41 33	046	51 54	088	33 34	115	12 42	183	24 26	222	28 43	271	21 57	312
	Mirfak		CAPELLA		◆ALDEBARAN		RIGEL		ACHERNAR		◆FOMALHAUT		◆DENEB	
30	55 43	024	42 13	045	52 50	089	34 25	116	12 39	183	23 48	223	21 15	312
31	56 06	023	42 53	045	53 46	089	35 16	116	12 36	184	23 10	223	20 33	312
32	56 28	023	43 33	045	54 43	089	36 06	117	12 32	184	22 31	224	19 51	312
33	56 49	022	44 13	044	55 39	090	36 56	118	12 28	185	21 51	225	19 10	312
34	57 09	021	44 52	044	56 35	090	37 46	118	12 23	185	21 12	225	18 28	313
35	57 28	019	45 31	044	57 32	090	38 35	119	12 17	186	20 32	226	17 47	313
36	57 47	018	46 10	043	58 28	091	39 24	120	12 11	186	19 51	226	17 05	313
37	58 04	017	46 49	043	59 25	091	40 13	120	12 05	187	19 10	227	16 24	313
38	58 20	016	47 27	043	60 21	092	41 02	121	11 58	187	18 29	227	15 43	313
39	58 35	015	48 05	042	61 17	092	41 50	122	11 50	188	17 47	228	15 02	313
40	58 50	014	48 43	042	62 14	092	42 37	123	11 42	189	17 05	229	14 21	313
41	59 03	013	49 20	041	63 10	093	43 25	124	11 33	189	16 22	229	13 40	314
42	59 15	012	49 57	041	64 06	093	44 11	124	11 24	190	15 39	230	12 59	314
43	59 25	010	50 34	040	65 03	094	44 58	125	11 15	190	14 56	230	12 18	314
44	59 35	009	51 10	040	65 59	094	45 43	126	11 04	191	14 13	231	11 38	314

Figure 15 – Excerpt from Pub. 249[246]

[246] *Pub. No. 249 Vol. 1 Sight Reduction Tables for Air Navigation (Selected Stars) Epoch 2005*, (Celestaire Inc, 2005). 120.

The altitudes and azimuths for seven navigation stars for a given latitude and local hour angle (LHA) of Aries are pre-calculated. Chris calculates the LHA of Aries in the same way as she did for her Polaris azimuth but for the time she calculated for civil twilight. She uses this value and the whole degree latitude value closest to her estimated position as entry values for the Pub. 249 tables. She writes down the altitudes and azimuths for five of the seven stars on a piece of folded over notepad paper. These will be the stars that she will try and shoot. This paper acts as a cheat sheet, giving Chris the approximate altitude of the star and its azimuth.

She pre-populates the navigation calculation sheet with the name of each star at the top of each column. She continues on, filling in row values that aren't dependent on her sextant sight values and time of star sighting values: Date, GHA of Aries, assumed Longitude, and Dip.

At 0500 Chris quickly writes down the 0500 GPS position, walks onto the bridge glancing at the radars, and then walks out to the starboard bridge wing. At 0501 she lifts the sextant off the deck. While holding it by its handle in her right hand. She pulls her star cheat sheet from her pocket and peers at it in the dim light of the gyro repeater, noting the altitude and azimuth of Mirfak, then stuffs the sheet back into her pocket. She chooses Mirfak because it is the dimmest star she will try to shoot and the one most likely to disappear as civil twilight gives way to dawn. She pre-sets the star's altitude on her sextant's arc, degrees on the arc and minutes and seconds on the micrometer drum. Looking down at the gyro repeater to align herself with the star's azimuth, she begins to look through the sextant's eye piece straining a bit to make out the horizon.

Chris spares herself much of the sighting process by pre-setting her sextant to the star's altitude as calculated in Pub. 249. Mirfak is found quickly, but the horizon isn't quite defined enough for a good site, so Chris relieves some eye strain by lowering the sextant to her side. A minute later Chris raises the sextant and relocates Mirfak. Its bearing is 044 degrees and she finds it a bit higher in the sky, as she sees it slightly above the horizon as she peers through the scope. She rotates the micrometer drum and at the same time swings the star back and forth on the horizon until it is just touching it. She looks at her digital watch and notes the time. Kneeling down on one knee, she sets the sextant down on the deck carefully, takes out her cheat sheet and writes down the noted time, picks the sextant back up, reads the degrees, minutes, seconds, and writes these down. She notes the altitude and azimuth of Fomalhaut on her cheat sheet and puts the paper back in her pocket. Picking up the sextant, she dials in the pre-calculated altitude. Rising up from the deck, she walks over to the gyro repeater and begins to sight this next star, and then the next, until she has sights for all five stars.

Chris feels that five of seven stars are sufficient for a good star fix, confidant that her sights are good. She proceeds back to the chart room where she wipes the sextant clean of any salt and moisture, places it back in its case and stores it back in the shelf. Taking the cheat sheet from her pocket she begins the process of sight reduction.

She goes into the Almanac and extracts the time adjustments to the GHA (Greenwich Hour Angle) of Aries for each star's actual sighting time. Chris writes the sextant sight values into the row labeled Hs and the appropriate column for the star. She writes each sighting's time correction into the calculation sheet and uses these values along with her assumed longitude in order to calculate the LHA of Aries for each sighting. She enters Pub. 249 using these LHA values and the whole number assumed latitude, and she extracts the calculated altitude and azimuth for each star, writing these down on her calculation sheet in the appropriate columns and rows.

Celestial Body	Mirfak	Fomalhaut	Vega	Altair	Deneb
DR Latitude NS					
DR Longitude EW					
Date (Local)	6-22-06	6/22/06	6/22/06	6/22/06	6/22/06
Watch Time	05-03-03	05-08-50	05-06-21	05-10-54	05-12-40
Watch Error F–, S+					
Corr.					
GMT	12-03-03	12-08-50	12-06-21	12-10-54	12-12-40
GHA (hrs)	90-31.9	90-31.9	90-31.9	90-31.9	90-31.9
GHA increment (m:s)	0-45.9	2-12.9	1 35.5	2 43.9	3-10.5
v corr. / SHA	360 91-17.8	92 44.8	92-07.4	97-15.8	93 42.4
GHA	451	452	452	453	453
Asmd Longitude E+, W–	109	109	109	109	109
LHA	342	343	343	344	344
T					
Asmd Latitude NS	21	21	21	21	21
Dec. (hrs) NS					
d corr. +–			33-24.5		
Dec.			33 48.7		
HT (Table)			12.2		
Corr. +–		39-22.8			
Hc (Comp. Alt.)	29-12.0	39 27.0	33-08.0	43-53.0	53 18.0
Ho (Obs. Alt.)	29-19.1	38-55.1	33-46.7	44-08.8	53-36.8
a (Alt. Int.) A T	7.1 T	35.1A 27.9 A	38.7 T	15.8 T	18.8 T
Z (Table)					
Corr. +–					
AZ					
Zn	044	178	303	262	319
Hs (Sext. Alt.)	29-28.6	39-03.5	33-55.3	44-17.0	53-44.7
Dip Corr.	7.2	-7.2	7.2	7.2	-7.2
App. Alt.	29-20.8	38-56.3	33-48.1	44-09.8	53-37.5
Alt. Corr. +–	-1.7	1.2	1.4	1.0	.7
Ho (Obs. Alt.)	29-19.1	38-55.1	33-46.7	44-08.8	53-36.8
Δ					

Figure 16 – Navigation Calculating Worksheet[247]

[247] Clark, "FY 06 Cruise Rough Log."

Her observed altitude values must be adjusted for any uncorrected sextant error, for the fact that she wasn't standing at sea level, and for refraction in the atmosphere. Once these adjustments are made she is ready to calculate her intercepts. The intercept for each star sight is the difference between the observed altitude and the calculated altitude. Since she wasn't at the exact spot of her assumed position used in calculating the calculated altitudes she must adjust her plotted position by their absolute value difference. Each star's line of position is plotted either in the direction of the azimuth or 180 degrees away from the calculated azimuth. "HoMoTo," Chris says to herself. If Ho (the acronym for the observed altitude) is more (Mo) than the calculated altitude, then the adjustment is in the same direction (To) as the azimuth (the adjustment is toward the sighted body), otherwise it is away.

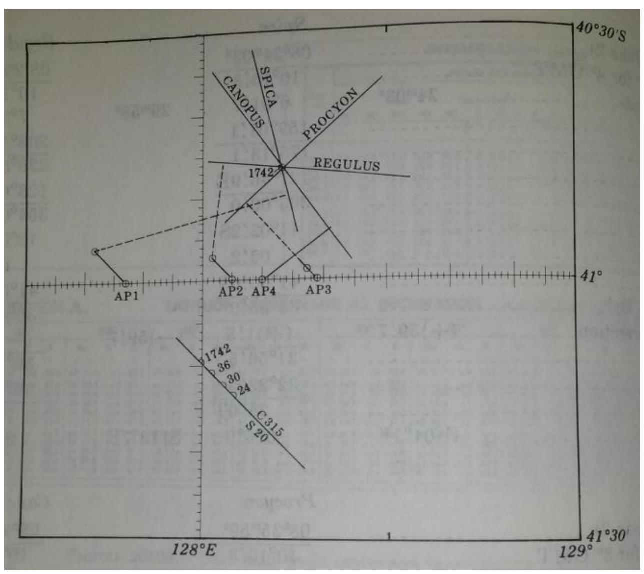


Figure 17 – Sample of Star Fix on Plotting Sheet[248]

[248] Nathaniel Bowditch, "American Practical Navigator An Epitome of Navigation Volume 2," ed. Defense Mapping Agency Hydrographic / Topographic Center (Washington, D.C.: Defense Mapping Agency Hydrographic / Topographic Center, 1975), 530.

Chris places a small mark on the navigation chart for the ship's assumed position at the time of Mirfak's sighting. Laying a triangle on the chart, she aligns it so that she can move the mark toward or away from the body's azimuth. Mirfak's adjustment is 7.1 miles toward or in the direction of its azimuth. She measures 7.1 miles off the latitude scale with her dividers. She sets on divider point on the mark for the assumed position and in the direction of the azimuth she lays the other divider point. She makes a small mark and then draws a line perpendicular to the azimuth. This is her line-of-position (LOP) for Mirfak. Chris continues her sight reductions and plots the other four star's LOPs (Fomalhaut, Vega, Altair, and Deneb). Of these, three stars adjust toward the sighted body's azimuth and one away.

The process of shooting stars took nine minutes, so Chris advances the first four observed LOPs in the direction of the ship's course by the amount of distance the ship traveled during the interval between the time of each star's observation to the time of the last star's observation. Where these LOPs cross gives Chris her star fix. She marks it on the chart with a dot and a small circle around the dot. She plots the 0500 GPS position, marking the position with a dot within a triangle and notes that it is within a mile of her star fix. She smiles, pats herself on the back and walks out onto the bridge to check for vessel traffic and to change course to 000 degrees.

4.6.3.1 Vignette Discussion and Action Analysis

Chris is constantly measuring, interpreting, interpolating, and calculating throughout this vignette. Her watch is guided by the Master's explicated "standing" and "night" orders, but she chooses the means to achieve the watches goals. She constantly creates coherent accounts for her watch through a bricolage of methods and inputs, judgments, interpolations and adjustments.[249] She will ultimately pass along these watch accounts as a written narrative in the ship's log, and in verbal form during the traditional verbal pass-down between successive bridge watch personnel. The next watch's account will supersede her narrative. Revisiting her narrative only happens if an incident occurs that traces itself back to Chris's account of her watch.

Chris recreates her coherent accounts during each watch. Similar watch situations will typically generate the same coherent account, but the path to reach coherence can differ due to some desired change within her bricolage repertoire.[250] For example, she may choose to sight Venus for a daytime line-of-position instead of using the Sun. Difficulty arises when a coherent account is unclear or wrong. Such occasions do arise, but hopefully, the account is remedied before an incident occurs. Involvement in a ship casualty and having an incoherent log entry will cause the officer of the watch to come under scrutiny.

In this vignette as in the previous one, the chart table plays an important role for bridge watch personnel. Chris uses the chart table during her celestial computations and the figuring of her weather data. Not only does it serve as a tool for the practice of navigation, chart placement, and navigation material storage, it is a social gathering point for discussing voyage production at the changing of watches and is somewhat akin to the office water cooler. Like a water cooler though, it isn't a place to dally. Too much time at that the chart table means that the watch officer isn't keeping a good look-out and

[249] In, Orr, *Talking About Machines*: p. 127., Orr talks of coherent representation.
[250] Claude Levi-Strauss, *The Savage Mind* (Chicago: University of Chicago Press, 1966). pp. 17-19.

situational awareness. At night, a red light is directed over the chart table in order to make it available for use in the dark, while the rest of the bridge is dark except for the backlights of some switches and knobs on the consoles of various bridge technologies. The chartroom is the hearth of the ship's bridge, even though the chartroom can be in its own segregated room.[251] Typically, if it is in its own room, it has an opening for direct viewing into the ship's bridge. It remains a focal place on the bridge even with the introduction of new bridge technologies.

Chris's somatic knowledge becomes a part of the bridge navigation technology when she manipulates her navigation tools like her sextant. She makes physical adjustments to coordinate her eyes for sighting the celestial body, her hands and arms for adjusting the navigation tool, and making body weight adjustments in order to counter the ship's movement. These physical mechanics are very similar to riding a bicycle. Chris practiced these mechanics in order to be proficient in taking celestial altitudes. She notes that she typically practices these procedures in order to stay proficient in them regardless of whether there is a shipboard requirement to use them. When she says that she practices them, she is probably saying that she practices the complete celestial navigation process that includes its concomitant planning, calculations, and plotting. What she is doing is staying proficient in host of knowledge bases, one of which is remaining proficient with her celestial navigation tool the sextant.

Correct use of a sextant for celestial sights requires that the celestial body be on the horizon. The optics and mechanics of the sextant produce most of this effect. The

[251] Albert Borgmann, *Technology and the character of contemporary life : a philosophical inquiry* (Chicago: University of Chicago Press, 1984). 73.

navigator must put into action these mechanics. The navigator locates the celestial body through the telescope by looking up in the sky and with the index arm set to zero on the sextant's arc. Once found, the navigator moves the index arm forward maintaining a reflection of the celestial body in the telescope's field of vision, while at the same time lowering the sextant toward in the horizontal until one can view both the celestial body and the horizon through the telescope. Once the body is brought down to the horizon, the navigator rocks the sextant slightly from side to side creating the effect of a swinging arc of the celestial body relative to the horizon. The sextant is adjusted to find the bottom of this arc, where the star just touches the horizon, using both the release lever for large movements and the micrometer drum for very small adjustments.

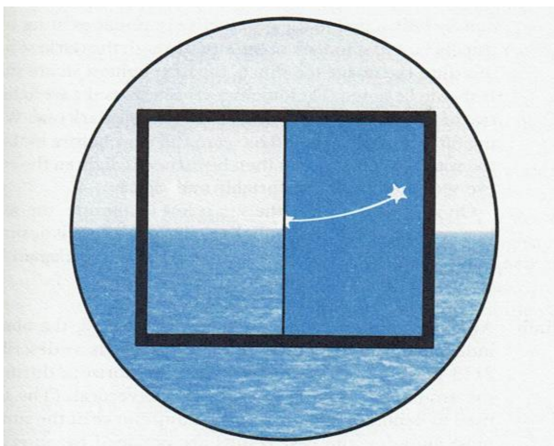

Swinging the arc.

Figure 18 – Swinging the arc as seen through a sextant telescope[252]

Once the bottom of the arc is found to be just on the horizon, the navigator notes both the time on the chronometer, and the value of the body's observed altitude by reading the degrees indicated on the sextant's arc and the minutes and seconds on the micrometer drum.

[252] Maloney, *Dutton's Navigation & Piloting*: 477.

She has great leeway in determining her methods and inputs for the work practices during her watch. She chooses five navigation stars for her celestial star plot. The reasons for her choices aren't overt. Outwardly, one can see that she is taking advantage of the pre-calculations done by the publishers of Pub. 249. The full benefit of Pub. 249 is realized because not only does it significantly reduce the time for sight reduction calculations; it also assists in finding the stars with minimal additional work. Celestial sights are done very quickly by creating a pre-calculated cheat sheet to pre-set the altitude on the sextant and also to provide the direction of the star in terms of its azimuths. This procedure is much faster than using a star finder tool in order to estimate altitudes and azimuths, even if one had all the navigational stars memorized through night-sky recognition.

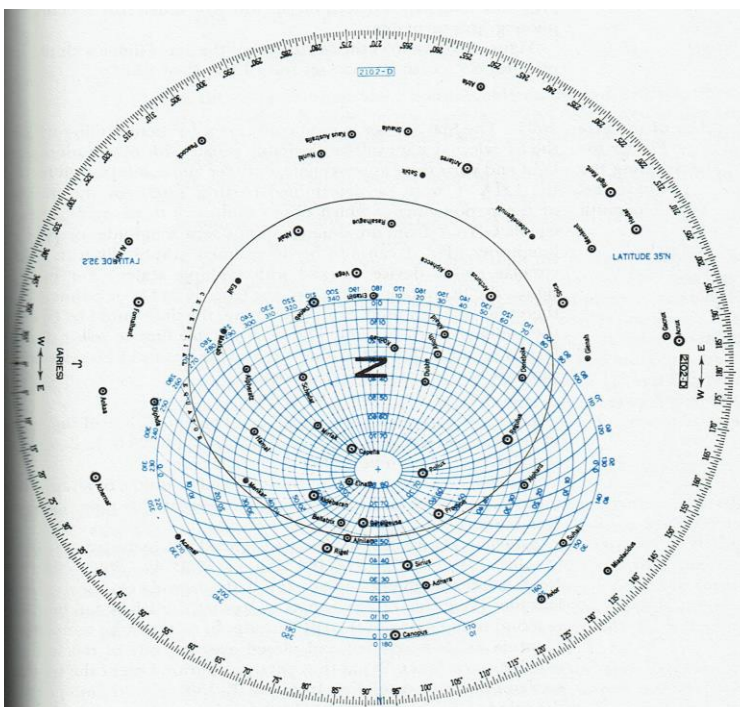


Figure 2002b. Star Finder; base with template for 35°N latitude in place.

Figure 19 – Star finder[253]

[253] Ibid., 443.

There is significant time-savings to her chosen method. She is the only deck officer on watch and she has to balance her time spent on the navigation with all the other necessary bridge work. There is nothing to guarantee that these time-savings are necessary on any given watch and there is no banking the time. Surely, there are instances where the time saved is utilized for another priority, but that isn't evident in this vignette. It is likely that Chris uses these methods all of the time. She has her reasons, but we can't discover them by watching her produce the navigation product.

As noted before, Chris is constantly interpreting and interpolating within her methods and practices. During her weather information-gathering task, she eye-balls the apparent wind direction and speed prior to calculating its true values. No one is standing over her shoulder to discern if she reads the wind direction gauge and anemometer accurately. She chooses the method used to calculate their true values. She sends her results out to the global community of interest via the ship's satellite email system.

When she sights Mirfak with her sextant and brings the star down to what she saw as her horizon, and she rocked the star back and forth to determine that it was just on that horizon. She walks away confident in what she saw. We can't see what she saw. On the job, no one is verifying her prowess at the task. It is just as likely that no one is reviewing her celestial computations. There aren't any shipboard deck officer navigation competitions going on. There is no navigation instructor to grade her efforts and reverse engineer her sights for accuracy. In fact, accuracy may not even be important in bridge watch production except in a relative way during a watch. With miles of ocean around on all sides of the ship, utilizing Pub. 249 for stars is perfectly acceptable. It is not as exact as other methods of site reduction. You wouldn't use it as a navigation tool when transiting within a bay or river and Chris knows this. Other navigation inputs and methods and other relative accuracies come in to play.

In this vignette as in the last, judgments of acceptable accuracy are social judgements. The determination of what sight reduction methodology to use is left to the deck officer on watch. The deck officer uses judgments that are based on training and the training has a large situational component. Therefore, I believe that uses of judgment are polimorphic actions, and these decisions are mostly hidden unless one is similarly trained and located within the situational boundaries, i.e. aboard the ship and on watch at the same time as the officer on watch, much like a shadow. It is the situational aspect of judgment, where actions might differ not because of how the social maritime domain is organized, but due to how the social maritime is socially constituted that the action might be different.[254] Deck officers are drawing on training, relating it to situational context and taking action, where such action could be different due to differences in for example, training cultures. Intention and human interaction in the past marries up with the deck officer's situated action in the present and that is when the social context is acted out. It is similar to reading a travel guide that states Brazilians all drive like formula-one drivers, and when you arrive and begin to drive aggressively, you fit into traffic nicely. This, however, is action based on what Collins calls interactional expertise.[255] In this vignette's case, the deck officer isn't applying collective tacit knowledge through interactional expertise, but making a polimorphic action of judgment based on the acquisition of explicit technical

[254] Collins, *Tacit & Explicit Knowledge*: pp. 85-86. CTK based on how societies are constituted. RTK based on how societies are organized.
[255] Collins and Evans, *Rethinking Expertise*: p.14.

domain knowledge, relational, somatic or collective tacit knowledge, and the ephemeral situation or context. The judgment is deck officer improvisation. The resultant can be different each time she makes a judgment.

The mechanics of navigating and tracking a voyage are repetitious. Once the methodology and judgment of accuracy is determined, the actions follow more or less the same procedure: balancing oneself with the movement of the ship, decide on the stars, chart work, use of the navigation tools, planning the watch evolution (can be a tool like the rough log that includes all the things to accomplish while on watch).

4.6.4 Navigation in Pilotage Waters Using Traditional pre-ECDIS Methods

Sailing up Yangtze River to Shanghai is when we really earn our pay. It's pretty incredible. You must always be on your toes. The open ocean voyage is a piece of cake compared to the stress of transiting up the river. The amount of traffic is phenomenal, total chaos, with fishing boats, river ferries, small river cargo ships and barges, and a host of ocean going ships all making their way up, down, and across the river. The weather is hazy and we must keep a good lookout for small craft that scurry around the river amongst the larger vessels.

When the Master gets to the bridge and joins me, the Third Mate, we'll have what is called a 1, 2 watch. The Chief Mate (Mate) will come to the bridge soon to help with the collision avoidance task and they'll have what is termed a 1, 2, 3 watch. The 1, 2, 3 station watch is based on what commercial airline cockpit crews do. You put multiple eyes on that blinking light or anything else for that matter. It is called bridge team management in the maritime domain.[256] When the local river pilot is taken aboard at the sea buoy, then technically, the ship will have a 1,2,3,4 station watch.

I prepared the ship for arrival prior to entering the congested waters of the Yangtze. This includes calculating tides and currents along the river, placing bearing circles on the bridge wing gyro repeaters, preparing the very high frequency (VHF) radios by setting them to the correct frequencies for local communication, and pulling out the appropriate charts and nautical publications like the "List of Lights" for the river transit.

The Shanghai pilot is aboard as the local expert. The pilot is taken aboard ship at the pilot station in the estuary of Yangtze River at the North Deepwater Channel. The vessel is obliged to carry the pilot for his local knowledge and in most ports taking on a pilot is mandatory. Ships will take on a pilot even if an officer onboard were to have pilotage for a particular port. Should the vessel not have one and something goes wrong due to a navigational or communication error, then the ship's liability for the incident would increase. The ship's Master is always held accountable for the ship's safe passage even in the face of pilot error.

The Master, Chief Mate and I are all working on the ship's bridge in conjunction with the pilot. The Chief Mate is handling the collision avoidance using the Radar, automatic radar plotting aid (ARPA) and just looking out the bridge windows. I am taking bearings on known landmarks using the aids to navigation found in the List of Lights and on the chart, and in some cases taking ranges (distances to identifiable landmasses or land marks) using the radar as well. I look at the chart for charted dangers to navigation, as

[256] See Penn, *Bridge Resource Management*. for a good explanation of BTM.

well as comparing the chart's soundings to that shown on this vessel's depth sounding instrument, adjusting for tide and current information that the I've calculated prior arriving outside the port at the sea-buoy. I also plot a GPS position, so that I can compare it with my terrestrial navigation work. I can then assess, communicate, and adjust for any discrepancies with regard to the ship's actual location. This whole process is giving the bridge team situational awareness of our position and other vessel's positions, so we can execute our port arrival plan effectively.

The chatter on the multiple VHF radios is constant and it is mostly in Chinese.

> "Right 15 degrees," says the pilot to the helmsman.
>
> "Right 15 degrees," says the helmsman.
>
> "The helm is right 15 degrees," says the helmsman once he moves the helm over.
>
> "Helm amidships," the Master calls out.
>
> "Helm amidships," the helmsman replies.
>
> "The helm is amidships," states the helmsman.
>
> "Right 15 degrees rudder," the Master states.
>
> "Right 15 degrees," the helmsman replies.
>
> "The rudder is right 15 degrees," states the helmsman.
>
> "Sorry sir," he offers.
>
> "No problem. We handled it," says the Master.
>
> "Steer 230," says the pilot, as the ship's swinging brings its heading toward its next intended course.

We've now made a radical ninety (90) degree turn to port in order to cross the whole of the river to get into the berth at Zhendong Container Terminal; however, the last occupant of the berth is just now easing into the channel for departure. We must wait a few moments, but we aren't drifting much, having arrived at slack tide and having a tug idling on our starboard side near amidships keeping us steady in the channel.

The pilot has his head buried in the radar cowl. The Master decides to take a quick look about, since we are broadside to the main flow of river traffic. The Master moves from the starboard bridge wing to the port wing. It would be jaw dropping moment for him if he were to wait that long, but turning around and rushing back to the bridge control console he throws the bridge-control throttles for the main engine to full ahead. The vessel gains momentum and the tanker that was about to T-bone our vessel on the portside misses them by a mere by 20 meters. The vessel a quarter mile up-river from them isn't so lucky.

4.6.4.1 Vignette Discussion and Action Analysis

Communications, local waterway knowledge, and social practice on the waterways are key points in this vignette. Since the 1990's the IMO has seen to it that deck officers are formally trained in what is called "bridge team management." Its precept is that deck officers form a team when entering congested and or hazardous waters, that each team member is assigned a role in the team, and that no points of view be suppressed when it comes to determining risk. This vignette's team consisting of the Third Mate, the Chief Mate and the Master go about their assigned duties with little in the way of non-work related discussion. There is little time to focus on anything but the next planned waypoint, and all the surface movement on the river. The preponderance of this vessel's transoceanic voyage has been in open oceans. Congested waters such as the Yangtze are dizzying by comparison. All of the deck officers aboard may or may not have been to this port before. Learning all the ins and outs of transiting the river is something that requires a great amount of experience. Maritime nations know this and they train and provide local experts called pilots to assist ships through their inland waters. The local pilot knows the waterway's terrain, the structures along and across its banks, the hazards under its surface, the effects of currents and tides, and the maritime social practices along the route that may not conform wholly or in part with international standard practices. The pilot becomes the fourth member of the bridge team working to bring the vessel safely to berth. Most nations require the use of their pilots by vessels that have no deck officer aboard trained for its local waters. Some nations still require such pilot presence, and in most cases, commercial firms will still require their ships to pick up a pilot to limit liability regardless of the vessel's onboard expertise.

Having a pilot aboard in no way relieves the ship's Master of the overall responsibility for the safety of the ship. Repeatedly, vessels have come to harm under the guidance of a local pilot. This vignette's ship Master is active in the awareness of what is going on moment to moment. Like a tourist from the country who has travelled to a city full of bicycle riders, cars, trucks and trolleys, the Master tries to successfully negotiate each vessel meeting, all the while ensuring that the ship is where it is supposed to be, and that everyone on the bridge is communicating and monitoring their workspace. The Master doesn't know the schedules for the ferries that are encountered throughout this river transit, nor does he have knowledge about the local sailing club's regatta. The Master doesn't know that channel dredging is taking place in one of the traffic lanes of the traffic separation scheme the ship will be following, and the Master doesn't know that the berth for the ship will not be vacant upon their scheduled arrival.

The Master of the ship in this vignette overcomes two potentially catastrophic situations. In one case, the Master corrects a communication error and in the other overcomes a technological gap. In the first case, the pilot has given a correct rudder order, but the helmsmen, while repeating the correct order, has inadvertently placed the helm in the opposite direction. The Master observes the helmsman's physical action of turning the ship's wheel at the helms console and provides correcting orders. This Master's style is calming. No yelling takes place toward the helmsman for the error, nor is there alarm in the voice of the Master. Instead, the Master's command is direct and clear. The Master clears the helmsman's error through a direct helm order adjustment versus just telling the helmsman of the error and to correct it. The Master then reintroduces the correct helm order and the helmsman complies without confusion or anxiety. Such interaction between a deck officer and unlicensed crewmember isn't always the case. Many officers are apt to bark out an order and berate the seaman as part a normal course of action. A ship's crew isn't chosen by matching personalities across the crew or through some scoring of interpersonal skills. Availability and certification are the principle means by which crewmembers qualify themselves for sea-duty.

Clearly, the sooner errors or omissions in navigation and collision avoidance duties are noticed and corrected the better. There is little room for error in congested waters. Unplanned situations that arise when working in these waters that typically also involve currents, shallow bottoms, strong winds, and tight traffic schemes many times are hard to overcome for large vessels whose hydrodynamics won't support quick reaction times. This is where deck officers must remember Rule 2 of the Rules of the Road.[257]

Rule 2 exists because there is no guarantee that all the other vessels' deck crews are competent, that the local pilot is well trained, or that some chance situation will occur that makes a good situation or decision turn poor.

The Master avoids a collision with another ship while this vignette's ship is waiting for a berth and lying across the river channel. Knowledge of the factors that affect detecting contacts on the radar due to shadowing and blind spots prompts the Master to do an eyeball scan of the river around the ship. What isn't apparent is how or why the Master chose to consider these factors given the large amount of other bridge work being done and the fact that a team is working on just such situations. The same knowledge used by the Master isn't used by the bridge officers on an upstream ship that ultimately collides with the tanker that just missed colliding with this vignette's ship.

Transiting along coasts and within inland waters requires the execution of terrestrial navigation actions. Terrestrial navigation actions are repetitive, except for the judgment of accuracy of a range and bearing, and the decision of which terrestrial aids to navigation to use for ranges and bearings. The action of sighting the bearing circle on a terrestrial landmark or aid to navigation and plotting the results on the chart is done repeatedly as a ship progresses on its route.

Communication style with the helmsman is a socially contextual action, but the action of moving the ship's rudder by turning the ships wheel or other steering device is repetitive.

[257] *Navigation Rules International - Inland*, (Arcata: Paradise Cay Publishing, 2005). p. 6.

The helmsman's job is to keep the ship on its designated heading by making adjustments to the ship's rudder by turning the helm. The helmsman's action of determining when to adjust the helm is a mimeomorphic action, because that action is done over and over again in the same manner with little variation. This action differs from the polimorphic action of the deck officer with the con giving the helmsman orders for an alteration of course due to local context.[258]

Ships do not stay on course by themselves. A helmsman, given a course to steer, will steer the course until told differently. The helmsman will apply left or right rudder to keep on course between helm commands from the watch officer. The helmsman is the memory of the course to steer that originates from the watch officer. The course to steer and the course required to keep the ship on track can be different for many reasons, most of which have to do with set and drift through the water caused by environmental factors. The watch officer adjusts the course to steer in order to keep the vessel making good the voyage plan's course. The watch officer may make an adjustment to the auto-pilot's course to steer while at sea, since most open ocean transits are steered by the auto-pilot. When close to land or in confined waters a helmsman is likely to be steering the ship. The helmsman is an extension of the watch officer and an extension of the ship's rudder system. The ship's auto-pilot is a mechanical helmsman, but without the ability to take verbal commands from the watch officer.

The interaction with the local pilot is polimorphic because it is contingent on local customs. They will have to come to some agreement on how they are going to communicate and determine in a very short time where their individual competencies lie,

[258] Con refers to the position of responsibility to guiding the ship's steering.

even given the fact that the ship's master has ultimate responsibility for the ship's safety. Miscommunication can have dire consequences, because even small gaps in communication can have large consequences.[259] In the late fall of 1980, Energy Transportation Company's (ETC) LNG Taurus ran atop of a submerged rock near the harbor of Tobata at the mouth of the Shimonoseki Straits. The ship had onboard a local pilot as required by Japanese law and it was he who was directing the ship to the berth. The ship was carrying a full load of liquefied natural gas from Indonesia. The ship's hull sustained only minor damaged in the grounding with some ballast tanks being breached, but the liquid gas containment vessels it carried lost no integrity. What was lost was a career. After floating off the rock with the help of nature's tide and some tug boats, berthing the ship, and clearing Japanese Customs, the Master of the ship, a US citizen, shot himself dead.[260] Such is the stigma of a seagoing incident that some feel that they can't live it down or change their deck officer identity. The Masters of ETC's LNG fleet were extremely well trained. Local knowledge and the ship's deck officer crew were not enough to avert an accident. There was a failure in the bridge communications, a polimorphic action.

4.6.5 Nautical Chart Correction and Updating in a Post ECDIS Maritime World

The Master removes a CD case from the mail pouch and hands it to the Second Mate. The Second Mate leaves the Master's office and proceeds to the ship's bridge. The

[259] IMO, "THE INTERNATIONAL CONVENTION ON STANDARDS OF TRAINING, CERTIFICATION, AND WATCHKEEPING (STCW)," ed. International Maritime Organization (2011). The 2011 edition of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), and the STCW Code, including the 2010 Manila Amendments.

[260] "Salvage teams battle to save $160m tanker," *The Times (London)*, 16 December 1980 1980.

Second goes to the chartroom and sits opposite the backup ECDIS. The second opens the CD case, extracts the CD and places it into the ECDIS CD drive. Invoking the ECDIS chart tool from the ECDIS tool bar menu, the Second clicks OK to the system message that says, “Would you like to update all the charts?” Five minutes later the system asks, “Accept chart updates?” Clicking the mouse on the selection for “Yes” satisfies both the system and the Second Mate that the chart updates and new charts are in and available to the ECDIS. The charts are automatically available to both the primary and backup ECDIS.

4.6.5.1 Vignette Discussion and Action Analysis

Chart correction when utilizing ECDIS corresponds to ensuring that the ECDIS has a commercial chart updating service and that the onboard ECDIS has licenses for charts that cover the voyages that the ship intends to pursue. A chart updating service is the responsibility of the ship’s shore management contingent, those entities that pay the ship’s bills. The ship’s Master and Chief-mate must be competent at installing and maintaining the ECDIS’s charts per IMO STCW 2010. A major part of the competency for installing and maintaining ECDIS charts lies in being be competent in utilizing a Microsoft Windows like interface and correct interpretation of ECDIS’s manual instructions and system messages as one proceeds through the install and update process.

Some raster charts are available for no fee from chart providers. For example, the U.S.’s NOAA provides vector and raster charts at no cost to users. The U.S. is an anomaly. Generally, vector charts or ENCs (electronic navigation charts), which are the charts that ensure that ECDIS operates in an official manner, are provided for a fee. ENCs are provided in what are called base cell files, and these are typically provided on an annual subscription basis. Having the subscription service entitles the subscriber to chart updates for subscription's period of time. The ENC's are encrypted per IHO standard S-63 and they can only be unencrypted for use with a valid permit. If a particular chart/base cell is not authorized, the user can create a purchase request key to be sent to the chart supplier, who will then supply a valid permit for the base cell area and provide the ENC data if it isn't already onboard on one of the ENC CD's. Base ENC data and updates are provided via CD; chart updates are required to be provided on a weekly basis. Electronic delivery of chart updates is possible, but it is costly and therefore chart updating usually waits until a vessel is in port in order to take possession of an update CD.

Upon loading of the subscribed ENC into an ENC database in the ECDIS system, the ECDIS will be converted it to a SENC. ECDIS uses the proprietary system electronic navigation chart (SENC) for determining what chart information is available for display. The creation of the SENC is done by a particular ECDIS's manufacturer's proprietary system process in which the ECDIS manufacturer programmatically interprets the ENC data in the IHO S-57 format, which is the standard for transferring digital hydrographic data. The ECDIS manufacturer also can provide value added data content during the conversion process. Such content might be in the form of additional nautical information and objects input by the mariner such as course lines and waypoints. Some conversion processes may not interpret an ENC quite the same and error messages are provided during the conversion process to alert the user of any discrepancies including the magnitude of the error, which may require additional action by the mariner. Discrepancies, however, cannot result in loss of ENC data.

Manual updates to a chart are possible and required if an ENC update isn't available. Manual updates create what are called Mariner Objects. Mariner Objects are created using a set of dialog boxes where the Latitude/Longitude and chart object types are input. Object types are chosen from a menu of marine object types. The Mariner Objects are stored in its own database, and this database is accessed by ECDIS programming logic during the chart presentation process for displaying a chart on the ECDIS display monitor.

What the watch officer sees on ECDIS's display monitor is a combination of what is in a SENC database file for the desired chart area and rules for the display of ENC data per IHO S-52, the chart content and display aspects specification. The data in the SENC and the chart presentation standard are brought together only at the time of chart display on the ECDIS monitor.

Clearly, the chart correcting and updating actions in a post-ECDIS world reflects a rearrangement of the marine navigation practice that is a consequence of a redefinition of what is considered safe navigation under the revised SOLAS 20. Notice to Mariners are still are published, but their contents need not find their way to ships directly, only indirectly as a consequence of being part of a file update to an ENC. An entire substitution of one set of chart correcting actions for another set of chart correction action has taken place. The need to understand chart meanings, a subset of cartographic language learned by deck officers, has been taken back by the cartographers and given to data and software developers. These workers create the charts, chart updates, and navigation publication updates.

The use of computer keyboard and mouse are substitutes for the use of navigation dividers, triangles and parallel rulers. The chart is no longer viewed or even accessible during the chart correcting and updating process. The deck officer task has become an orchestrated arrangement of MS Windows like point and click routines, the reading of pop-up messages, file accessing and message reading within some scroll window. Windows type process control the task of creating a Mariner Object, the one real touch point for mariner chart updating.

Deck officer polimorphic action associated with accuracy is now in the action realm of those charged with software and ENC file creation. These entities abide by the IHO standards for ECDIS, but they also have their own social domain standards in the same vein as that deck officer who went about the actions required when updating and correcting charts manually.

An entirely new concept in the ECDIS era is the SENC. The ENC is like a cola product. The SENC is Coca Cola, Pepsi, and Royal Crown. This chart type is a by-product of the commercial nature of ECDIS, which allows manufacturers the ability to provide value added features to chart displays beyond that provided by the government hydrographic offices gathering and making available the official ENC data.

Deck officer actions for chart correcting and updating are entirely mimeomorphic, with all polimorphic actions now done by entities higher up the action hierarchy.

4.6.6 Voyage Planning in a Post ECDIS Maritime World

Fresh from ECDIS training, the Second Mate is dismayed that the ECDIS that's been aboard the ship for 5 months hasn't been set up completely so that voyage plans can be automatically analyzed for safety factors along a plan's route legs. The initial installation of ECDIS aboard a vessel requires inputting dimensional information for that vessel into an ECDIS dialog box. This installation has none input. The lacking data includes the length overall, the widest beam, and the highest vertical height. The Second Mate selects ship info dialog box and adds the correct vessel dimension data, then clicks the dialog box closed.

The ship's draft during the voyage is an important value to note before voyage planning and since the ship is still loading cargo and not at its departing draft, the Second looks at the log book and checks the drafts for the previous voyages. Next, the Second checks the under-the-keel data values in ECDIS in order to input the draft value. The Second opens the Safety Contour dialog (Figure 20) that shows the Deep, Safety and Shallow Contour settings, as well as the vessel's Safety Depth setting. The under-the-keel data values are important factors used in displaying safe and unsafe waters, for sounding alarms, and for automatically checking a voyage's routes for dangers to navigation.

"My gosh! These are the default values!"

The ship has been in serious danger during the last 5 month's voyages. The "Shallow Contour" is set to 2 meters. The 'Shallow Contour" should be set to the ship's draft for the intended voyage. That would tell ECDIS that the ship's draft was less than or equal to 2 meters, when in fact the ship usually has a deep draft of 12 meters. The ECDIS would allow the ship to ground without providing any visual indicators or sounding any alarm.

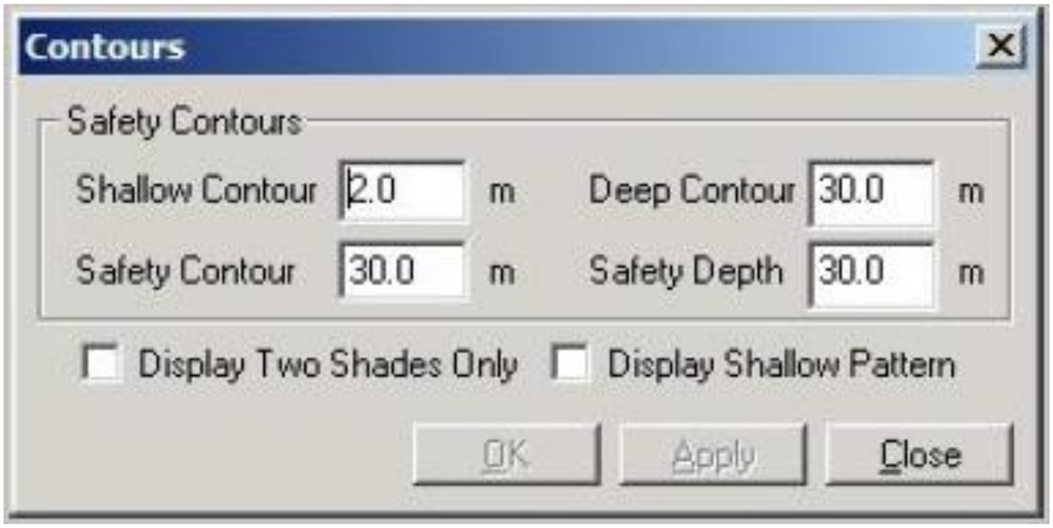


Figure 20 – An ECDIS Safety Contour Dialogue Box[261]

The Second sets the Shallow contour, water not navigable, to 8 m. The Safety contour, the boundary between safe and unsafe navigable water, is set to 12 m. The Deep contour, navigable water, is set to 16 m. The Safety depth is set to 12 m, and any objects on the chart that are within the 12 m depth or shallower, like a sea mound or wreck, will be emphasized on the chart in black. These values are based on rules of thumb learned in ECDIS class; the ratios (1, 1.5, 1.5, 2) times the draft for shallow contour, safety contour, safety depth, deep contour respectively.

The Second Mate closes the Contour dialog box after setting the values judged to adequate for the upcoming voyage.

[261] PC Maritime, *Navmaster User Guide* (Plymouth: PC Maritime, 2009). 120.

The Second Mate opens the Route dialog box (Figure 21), selects the Waypoint tab using the mouse. Using the keyboard, the Second types in the origin and destination

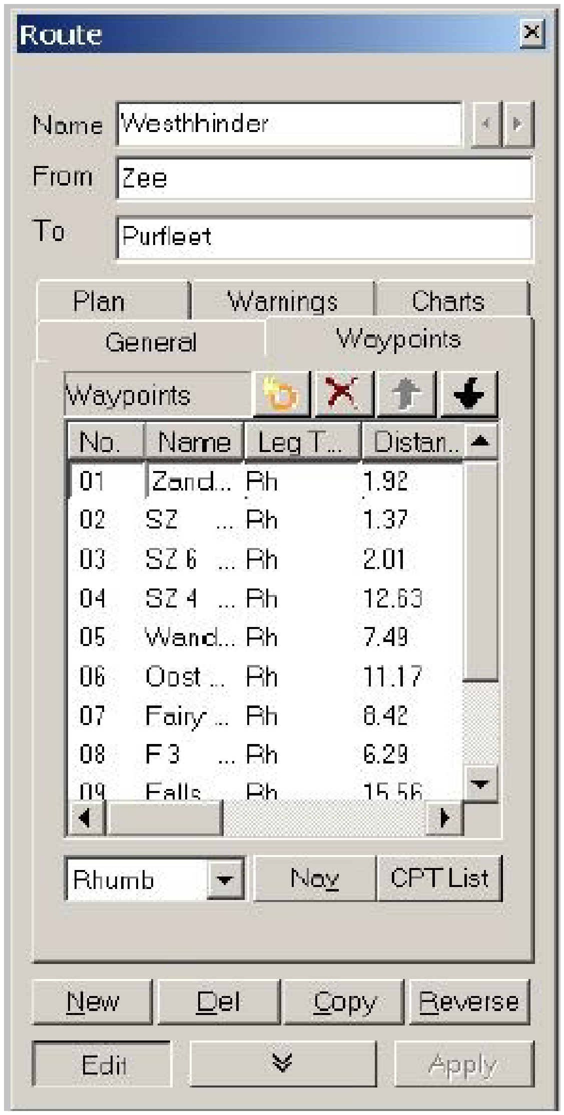


Figure 21 – An ECDIS Route Dialogue Box [262]

waypoints; the pilot station outside of Tacoma, WA, US to the entrance to Yokohama, JP. The Second could have just as easily left clicked the mouse on the chart location that corresponds to these two location's Latitude/Longitude. This tells ECDIS the end-points

[262] Ibid., 149.

between which it should generate a route. Choosing “Options” in the “Route” menu, the Second Mate then clicks on the Composite Great Circle square that places a check in it (Figure 22). A composite route is a route that contains both great circle and rhumb-line legs. The reason for a composite route is that some pure great circle routes may bring a ship into waters that harbor ice hazards or because land or groups of island may be encountered and maneuvering around these would be operationally inefficient. Clicking the corresponding check box, the Second types a limiting a latitude of 45 degrees North latitude into the North Latitude Limit editing space, so that ECDIS will not go beyond the specified latitude when generating the route. The number of great circle waypoints is set by setting the “Intercept every” counter to 5 degrees. Clicking “Apply” at the bottom of the Route dialog box has ECDIS generate the route with its associated waypoints.

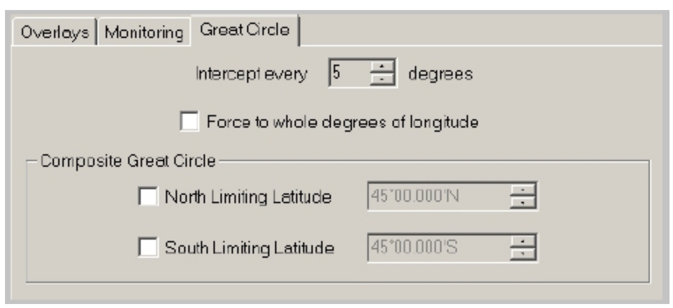


Figure 22 – An ECDIS Great Circle tab[263]

Selecting the Waypoints tab in the dialog box, the Second Mate applies cross-track limits that cover individual route legs where required, as well as cross-track limits on groups of legs. Cross-track values are like bumpers. When a hazard is within the cross-track values used for a route, ECDIS generates a warning or alarm. During the voyage, ECDIS uses the cross-track values to alert the deck officer on watch that the ship is off its

[263] Ibid., 166.

intended planned route. The Second Mate adds some mariner notes regarding a derelict fishing vessel floating in an area crossed by the planned track. These notes will be visible to the watch officer when entering the noted area.

The Second Mate clicks the Warning tab in the Route dialog box (Figure 23) which invokes ECDIS to show detected hazards to navigation along the proposed route. ECDIS generates a set of warning messages while checking each route leg in the voyage. These messages correspond to dangers due to objects at the surface or below the water's surface that have been detected in the ECDIS's SENCs that are within the cross-track boundary limits, safety depth, or vessel height parameters set up in the ECDIS. In this case, the Route Check generated several hazard messages. The Second opens the route leg table, clicks on the route, which then takes him to the route leg on the electronic chart. Making adjustments on each route leg for each danger message, by moving the route around an object and thus placing the vessel's route in safer water, the Second ensures that the planned route is safe. The Second selects the Accept button accepting the route and closes the dialog box.

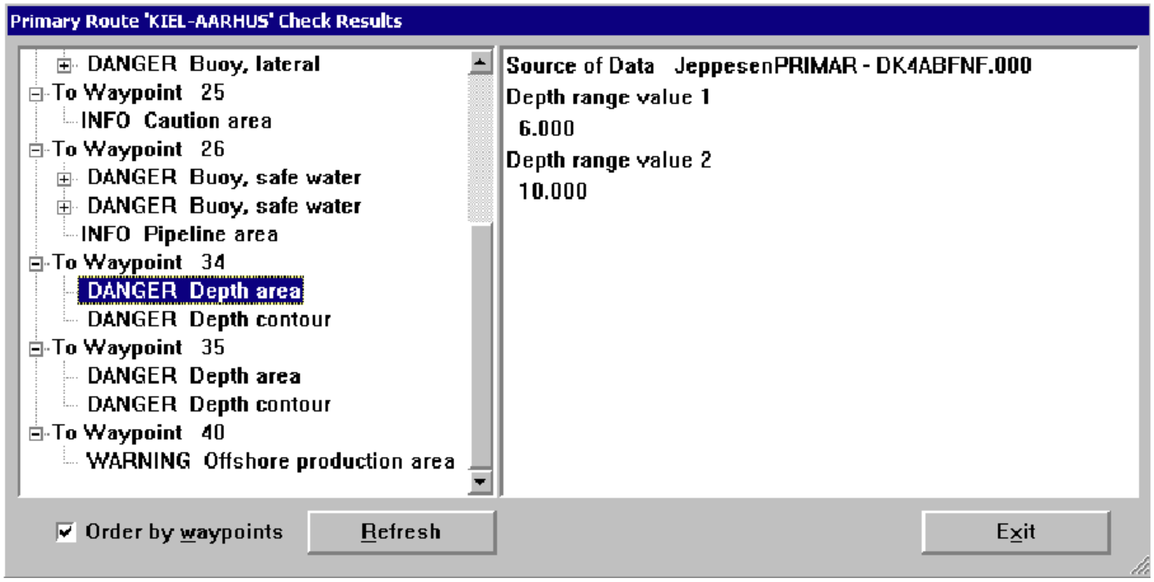


Figure 23 – Route Hazards Warnings Dialogue Box[264]

The routes from the vessel's current berth to this harbor's sea buoy and from the destination's sea buoy to the vessel's next berth in Yokohama have been standardized and previously set and stored in ECDIS, so no route creation is necessary. The Second calls up each of these saved routes from the route database and invokes the Route Check capability. New and updated charts may have delivered new data that may require an adjustment in a route due to a new hazard. The Second Mate finds no new hazards that might require an adjustment in these routes and closes the Route database dialog.

[264] Raytheon Anschütz GmbH, *ECDIS 24 Operating Manual* (Kiel: Raytheon Anschütz GmbH, 2014). 8-47.

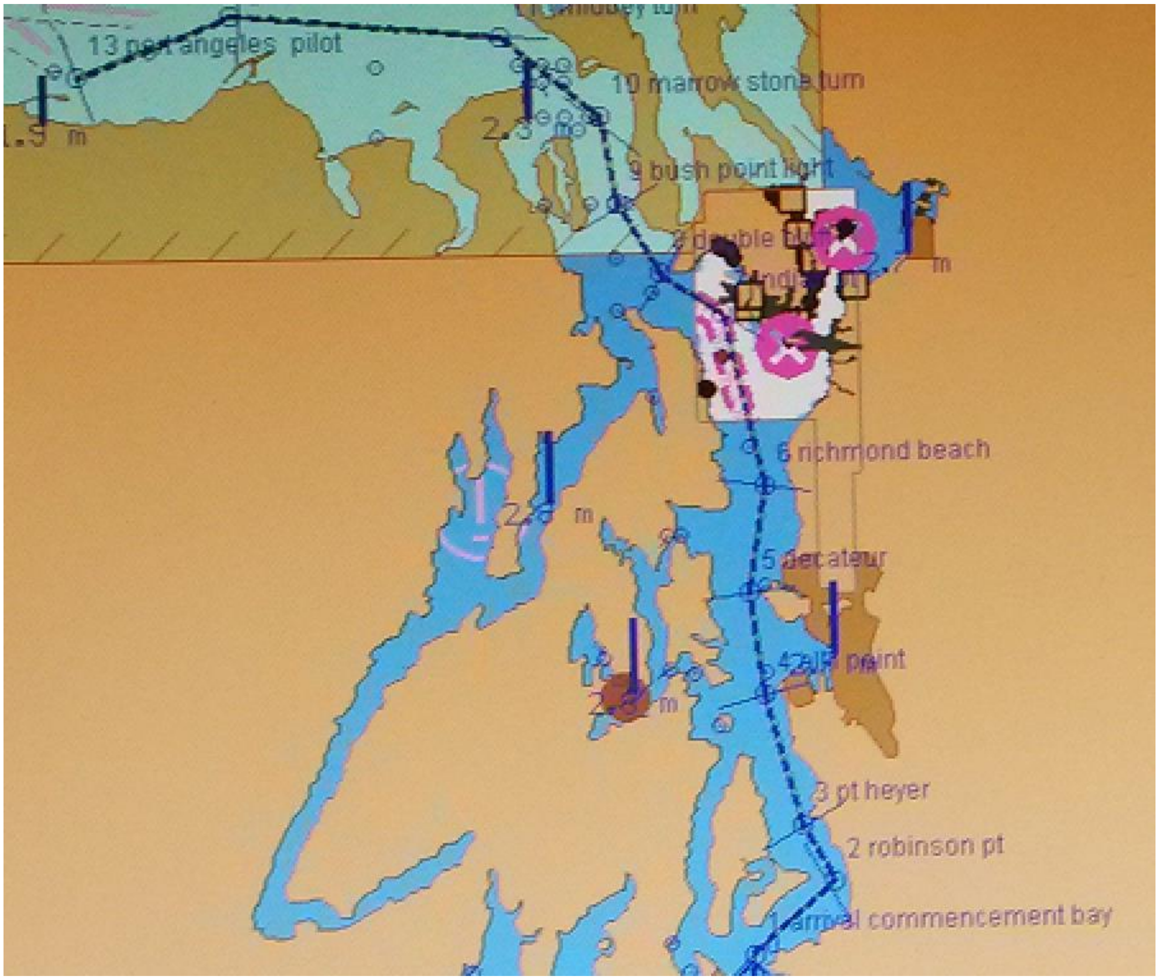


Figure 24 - A portion of the route plan, Northbound from Tacoma[265]

4.6.6.1 Vignette Discussion and Action Analysis

Route planning begins with actions similar to pre-ECDIS route planning; data collection relevant to the upcoming voyage. A sharp departure from pre-ECDIS planning immediately ensues after data gathering. The use of a computer keyboard and mouse dominate the route planning actions as it did in chart correcting and updating. The planner has the option of interacting with an electronic chart when specifying waypoints, or just entering in Latitude/Longitude in the dialog box.

[265] Donald Clark, *Photo of ECDIS Display During Training Class*, (2016).

The multiple ways of setting waypoints is similar to the multiple ways in which waypoints can be determined in the pre-ECDIS era. The concepts of rhumb line and great circle routing exist to the extent that the planner can check a box and have ECDIS adjust for these types of routes. The planner need not necessarily know what they mean. If the planner needed the shortest route, then the planner could iterate through route type choices, choosing the shortest. Adjusting for route restrictions given in terms of Latitude/Longitude due to weather or ice is a matter of moving a route line without any knowledge of the kind of trigonometric route line. Route calculation has been embedded into a computer program to either connect waypoints into a route track or create waypoints and the route track from two end-point locations. The planner can make variations in route legs by inserting or adjusting waypoints via the GUI.

The planner can re-use routes by saving the route in question and recalling it from the database at some future time. This re-use is in contrast to placing tape over a track on a paper chart in the pre-ECDIS era.

The navigation officer reviews automated warning messages instead of manually reviewing a route for hazards. ECDIS does the tedious work of checking the route and identifying dangers. The automatic route checking function checks a route for hazards based on vessel dimension, vessel draft, and any charted hazards in the chart database. The deck officer reviews the stored warning messages instead of visually checking the chart using nautical knowledge of chart information. The navigation officer must review the messages first and then enter the ENC environment using Windows like processes in order to resolve the issues with the routes.

ECDIS is firstly about the charts. If the chart data is wrong, then bad things can happen. (reference for Navy ship aground).

When correcting charts and when creating voyage plans with charts, the Second Mate learns about the area in which one will be sailing. This is somewhat akin to learning to be a pilot in one of the many harbors in the U.S. that requires pilotage. In the U.S. at least, pilots take an exam in order to qualify for pilotage. Part of the exam is to draw the harbor from memory. Chart correction and voyage planning is a start towards this in depth local knowledge. If standing watch is partly situational awareness, then better awareness must correlate with knowledge of one's geographic area as other variables begin to overlay themselves onto the geographic area like ferries, sailboats, fishing boats, tides, current, and other cargo ships.

In the paperless chart work of ECDIS, local hydrographic/geographic knowledge is expendable. ECIDIS will give an indication (a visual warning light in ECDIS speak) and or an alarm that relates to what one needs to know at the moment one needs to know it. This is all possible because of the ECDIS specification standard. Remember that ECDIS is all about the charts. If the voyage planner doesn't set up the vessel's dimensional information or set the contours or depth values correctly, ECDIS will run you aground. It is happy to do so. It doesn't know danger, it interprets data objects, and its algorithms act accordingly. The ECDIS will tirelessly churn out positional information on the chart. It will tirelessly churn out projected positions. Its algorithms will check for correlations between data elements that require it to churn out an indicator or an alarm. An incorrectly set data element by the voyage planner such as shallow contour will cause

ECDIS to do nothing more than it would do if the element were set correctly, though the consequences to the mariner and ship can be quite different.

Historically, charts come with contour lines. Contours come from sets of like soundings and form a continuous line along the coasts on marine navigation charts. In the U.S., and maybe for most maritime nations, those contours come from sounding standards of sailing ships when drafts were quite shallow. One sees contours ranging from 1, 2, 3, 5 fathoms, then 10 fathoms and maybe no more contours until the 100 fathom contour. These contours equate to 1.8, 3.6, 5.4, 9.1, and 18.3 meters; meters being the current chart measurement for depth. Going from 9.1 meters to 18.3 meters is quite a jump. Many modern ship's drafts fall in between these two contours. For the vessel in this vignette, its draft is 8 meters and the safety contour is set to 12 meters. There is no 12-meter contour, so ECDIS will default to the next deepest contour on the display, so it will send an indicator warning when the ship is in 18.3 meters (10 fathoms), which is also greater than the deep contour setting of 16 meters, but of course that is safe water. The display will show dangerous waters and flash indicator warnings continuously. A depth sounder input to ECDIS with an alarm depth set to 12 meters can give the mariner more information.

If ECDIS indicators and alarms work based on contours, how will a watch officer know if it is heading into dangerous waters? It will have to use its depth sounder and hope that there is no steep change in depth. Hydrographic surveys and changing chart data in a database are expensive. Many modern ships will have to wait for vector charts to catch up to ECDIS's ability to inform watch officers of dangers to navigation. Experienced mariners with local knowledge have the advantage over new mariners who only know navigation via ECDIS. One is not necessarily safer over the other.

Using rules of thumb for contour and depth settings is a polimorphic action because it is subject to change based on maritime domain social context, e.g. are rules of thumb acceptable. All other actions to create an initial route plan when using ECDIS are mimeomorphic. Each action is repeatable without much variation. Variation in process is due largely to the geographic parameters used for creating the route plan, such as what portion is open-ocean and what portion is coastwise or within inland waters. Adjusting planned routes during voyage planning can be essentially a manual process requiring human polimorphic action, i.e. judgment. Stringently adhering to cross-track parameters makes route adjustments mimeomorphic, since following the cross-track widths, once established by some edict requires nothing more than an adjustment of the track to the parameter.

4.6.7 Navigation in a Post ECDIS Maritime World[266]

After a successful ocean transit that was speedy thanks to the automated route planning, which took into account ocean currents, as well as wind and wave forecasts, the ship approaches the coastline. The ocean route taken was safe and efficient and steered for the most part by the autopilot along the route legs connecting the planned waypoints. The vessel was able to travel a half-knot faster than on past voyages, consuming about the same amount of bunkers (heavy fuel oil). The ECDIS planned route itself went via email to the chart supplier ashore before departure, and they emailed the vessel the newest

[266] Hecht et al., *The Electronic Chart - Fundamentals, Functions, Data and other Essentials - A Textbook for ECDIS Training*. (Provided a template for this unproblematic navigation with ECDIS vignette that then incorporated input from interviews and ECDIS training.)

digital charts and updates which might be required along the planned track. All navigation related information needed for the voyage has been available instantly on request via 'Pick Reports' in ECDIS.

ECDIS is steering the ship. The ECDIS is in track control mode, giving steering signals to the autopilot via an electronic interface in order to keep the vessel on the planned route as the vessel approaches the coast. This is the first time that this ship is entering this port. The inland water route segments require careful inland navigation and inbound and outbound traffic is heavy. In addition, the weather is deteriorating. Visibility is impaired by rain squalls and the radar display is affected by rain and sea clutter. The watch officer gives his full attention to the navigation task, including keeping a sharp lookout for other vessels. At the central conning station, alongside the radar console and other navigation devices, is the high-resolution color monitor of the ECDIS. Using the ECDIS as an integrated navigation system, the watch officer is able to focus his attentions on overall situational awareness without having to spend time running between the chart table, position-fixing devices, and the radar/APRA.

Time 1400: The watch officer sits behind the ECDIS console with the display screen facing him. The console sits at the front of the bridge along the ship's center-line. The watch officer can view both the screen and the area in front of the ship in almost the same glance. The monitor displays a color chart image of the area showing the coastline, safe and shallow water areas, and aids to navigation. The safety contour line of 18 m, which is based on the current draft of vessel, is clearly emphasized on own ship's safety contour. The ECDIS display is free from unnecessary clutter and information. The ECDIS shows the waypoints and planned route for this coastal navigation task. Own-ship (the ship one is on currently) is a small symbol on the display. The GPS receiver data provides positional data to ECDIS, which ECDIS plots on the screen; the automatically displayed ship symbol in relative motion. This means that the ship is stationary on the screen and the chart objects pass by the ship as if one were looking out the ship's bridge window. The ship's position refreshes on the chart every second, automatically. There is no need to change charts, since the ECDIS seamlessly adds to the screen what is beyond the current screen view. There is no manipulation of traditional navigation tools like triangles and dividers for the purposes of marking a position on a paper chart. The able-bodied seaman brings the watch officer a fresh cup of coffee. The watch officer takes a sip and sets the coffee in the holder attached to the ECDIS console.

Time 1500: The Look-Ahead function alarm (alarm time 10 minutes to point of interest) is activated in ECDIS by a virtual buoy that is located at a geographic location where earlier in the day a ship lost a cargo container over the side. The virtual buoy exists due to a continuing AIS transmission by local authorities and it will continue to show up on ECDIS while the danger persists. The ECDIS has previously set standard guard zones for hazards as defined by the Master. The 'Safety Box' setting provide alerts based on the distance to and the time to hazards. Time and distance alerts have also been set up for all waypoints and turns.

Figure 25 – ECDIS Ship Display with Safety Box[267]

Time 1520: The ship now enters the traffic separation scheme marked by several real buoys now showing on the ECDIS. The ECDIS now shows the vessel is passing a nun buoy on the starboard beam. Glancing to starboard, the watch officer confirms via the bridge windows what is on ECDIS. The electronic and real world overlap in the officer's mind and they are one.

[267] Maritime, *Navmaster User Guide*: 276.

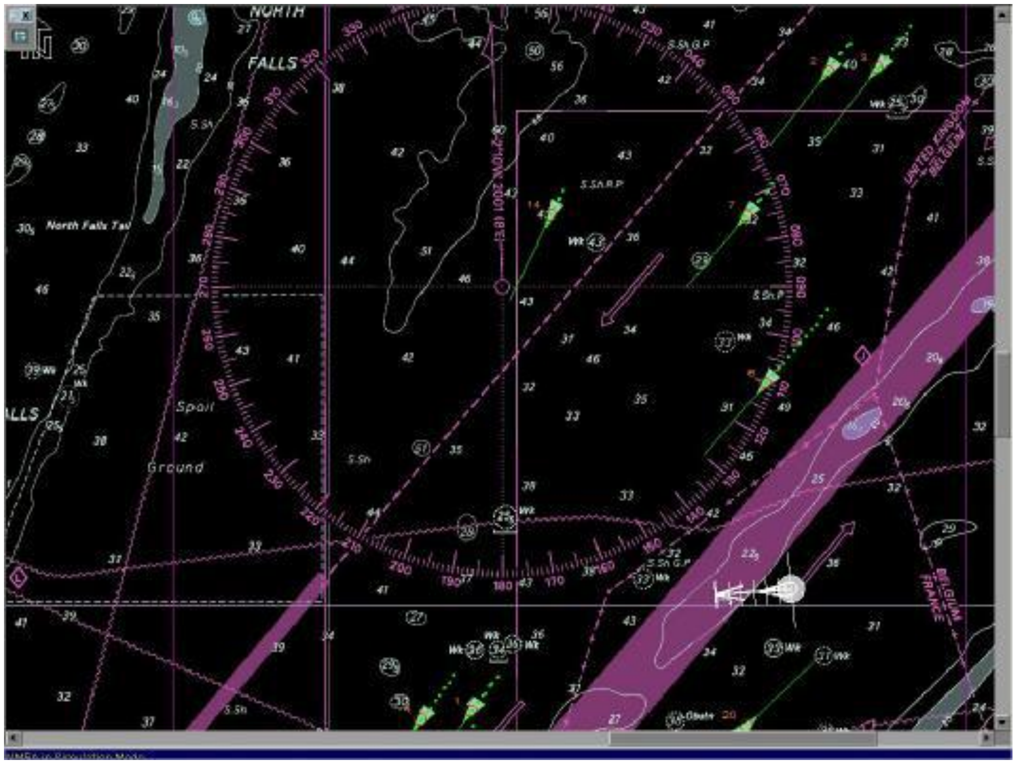


Figure 26 – ECDSI in Night Mode[268]

Time 1545: As dusk approaches, the watch officer places the ECDIS into "Dusk" display mode. This is done so as to not affect one's night vision. "To get a better feeling of the how well the surveyed depth soundings on the chart are, the watch officer calls the function which provides the sea survey category of the ENC in use. The system indicates significant seafloor features are detected and the charted soundings were precisely measured by a recent hydrographic survey.

Time 1550: As the vessel approaches the channel into the port, the watch officer chooses the next larger scale of the chart corresponding to a four nautical mile range scale. The new display appears instantly. A symbol of a tower, not yet detectable visually is shown ahead of the ship. Placing the cursor point on the object, the information window called a

[268] Ibid., 239.

'Pick Report' opens to show details of the tower (white; Fl(3) WG 15s 21m 15nm; radar-conspicuous)[269], because there is not check in the checkbox in the ECDIS configuration page for names of buoys and aids to navigation . However, this is faster than spending time paging through the "List of Lights" publication to see which tower it is.

Time 1600: The channel begins to narrow and vessel traffic is increasing, so the watch officer reduces the speed of the ship. Without warning, the vessel ahead to port in the outbound lane begins to veer toward ownship's port bow, apparently trying to avoid a shallow area. There is no time to call that ship on the VHF radio and ask for its intentions. The watch officer switches from autopilot to manual steering and issues a command.

"Helmsman, 20 degrees to starboard."

"20 degrees to starboard. The helm is 20 degrees to starboard."

One minute later the watch officer issues another command.

"Steer 240 degrees."

"Steer 240 degrees ay." Steering 240 degrees."

The ship responds and turns to starboard. The watch officer uses the Safety Contour (previously set to 12 m, but showing 18.3 m) and Look-Ahead functions to verify that the ship will remain in safe water.

The officer feels that the ship is out of danger of collision and wants to return to the planned course, but not so soon as to place the ship in danger again.

"Helmsman 10 degrees to port."

"10 degrees to port. The helm is 10 degrees to port."

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[269] **F**lashing **3** times **W**hite and **G**reen light every **15 s**econds. The tower is **21 m**eters high and the lights should be visible at **15 n**autical **m**iles.

Feeling that the ship is getting close to its base course the watch officer tells the helmsman to return to the base course.

"Steer 225 degrees."

"Steer 225 degrees. Steering 225 degrees."

Regaining the track, the watch officer places the helm back into autopilot with ECDIS still in track control. The able-bodied seaman brings the watch officer a fresh cup of coffee. The watch officer takes a sip and sets the coffee in the holder attached to the ECDIS console.

Time 1635: During a quiet moment, the watch officer ensures that the ECDIS has the most recent ENC updates. The latest updates arrived automatically this evening via satellite email with updates for the planned route. Two update messages wait to be automatically applied pending ECDIS user acceptance. The watch officer asks the Master if he can accept them. With the Master's concurrence, the watch officer accepts them.

Time 1652: The watch officer knows that good seamanship demands that the watch officer uses some ECDIS independent means for checking the system's navigation position accuracy. The watch officer double-checks the ECDIS's primary position-fixing system data feed. Since the own-ship symbol does not blink to indicate a warning and since the position-fixing status bar indicates DGPS (differential-GPS which is a locally enhance GPS signal) he is confident that the ship is receiving the DGPS broadcast service. The secondary positioning system Loran C indicates a good signal as well. To ensure the systems accuracy, the officer takes a bearing with the port gyro-repeater's bearing circle off of a lighthouse to port and notes the time. Next, the watch officer takes a radar range and bearing of an aid to navigation to starboard, and notes the time as well.

The officer inputs these navigation values and corresponding times into the ECDIS. ECDIS uses the inputs to calculate and plot a fix, advancing the lines of positions to a common time, and also placing a DGPS fix on the chart for the same time. This confirms system accuracy, both that the DGPS and Loran-C signals are accurate enough for navigation and that the chart is accurate when compared to real land surrounding the ship.

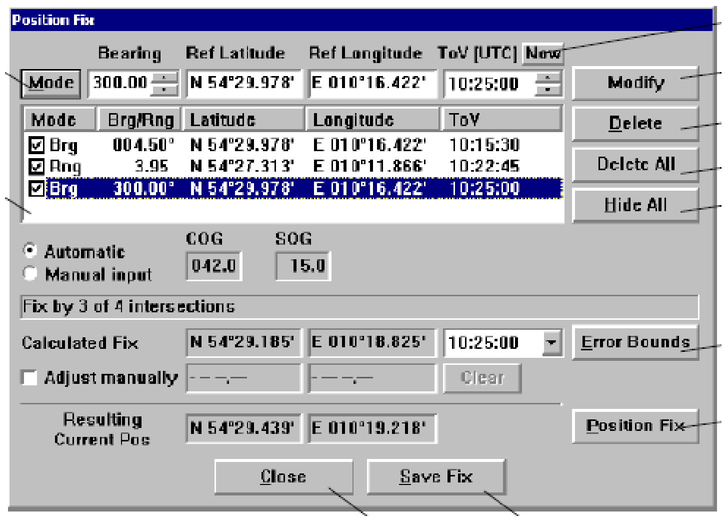

Figure 27 – ECDIS Manual Plotting Dialogue Box[270]

Time 1730: With the pilot now aboard the vessel proceeds into port. The pilot brings with him a PPU. The PPU is a handheld type of electronic chart device that is not subject to IMO standards or certification. It contains notes for his local pilotage work and data feeds from the local vessel traffic service. The pilot communicates with the local vessel traffic center (VTC) asking for a three-hour weather forecast. The pilot tells the watch officer to expect more rainsqualls.

Heavy rain clutter continues to cause the radar echoes of the buoys to be difficult to see. The most important of them are equipped with AIS transponders so they can be identified

[270] GmbH, *ECDIS 24 Operating Manual*: 9-11.

on the ECDIS display by means of their dedicated symbolization. This watch officer hasn't encountered this use of AIS technology before.

"Wow, AIS integrates with the ECDIS and it makes it possible to see the buoys on ECDIS," remarks the watch office to the Master and pilot. "I don't have to move and check the ARPA screen and then plot their positions on the chart."

The Master orders the helm into manual steering. The watch officer keeps a watchful eye on the ship's track, comparing the planned route to the ship's actual position. Even the smallest deviation from the planned track is quickly (in real-time) shown on the ECDIS. The able-bodied seaman brings the watch officer a fresh cup of coffee. The watch officer takes a sip and sets the coffee in the holder attached to the ECDIS console.

Time 1930: The Master asks the watch officer to take the con and the watch officer verbally announces to the bridge that he has the con. Having the con means that the watch officer will gain valuable vessel handling experience and will be giving all helm and engine speed commands.

Before coming alongside, the ship must turn ninety degrees (90°) in order to reach its berth across the channel. The ship is now displayed on the ECDIS screen as a True to Scale symbol that shows the ship's length (190 m) and beam, as well as its actual position and heading in real-time. The watch officer closely follows the distance readings from the ship's port side to its berth with ECDIS is prediction mode. Without having to leave his workstation, he issues the necessary commands for steering and engine control. On the

ECDIS, he monitors the vessel's maneuver in a confined waterway without viewing either the bow or stern.

4.6.7.1 Vignette Discussion and Action Analysis

The deck watch officer-only perspective in this vignette is intentional. The Master and pilots are onlookers, providing guidance only if their expertise would add value. They are silent with regards to the navigation task at hand. ECDIS is in the starring role in this port arrival drama. The watch officer's praises ECDIS as each navigation event transpires are like piano music to a silent picture. This ECDIS is a full feature unit, able to show not only the chart features and ownship's position, but also the radar targets, AIS data, and make hazard alerts and sound alarms.

From 1400 to 1930, the watch officer sits at the ECDIS console drinking coffee ensuring that the vessel remains on track by viewing the ECDIS screen and comparing it to what he sees through the bridge windows. No hazards to navigation occur needlessly so long as the ECDIS has been set to identify them based on its setup by the Second Mate and none of them changed by someone clicking about. The adage, "if it can be clicked, it will be clicked," applies. Each new watch officer must double check the ECDIS settings before taking the watch and it must become second nature in order to get it done in a timely fashion. ECDIS won't do this for the watch officer.

The ECDIS does a number of real-time self-tests like ensuring that it is receiving GPS data or that the gyrocompass data is being received. In addition to these kinds of tests, the watch officer must periodically check that the ECDIS is fully operational. A compliant ECDIS requires up-to-date ENC charts, and that it has been set up with accurate vessel information, guard zones, appropriate cross-track parameters, and route warnings do not exist when the route check runs.

It seems like the watch officer is an observer for the most part, but he is also monitoring. Using ECDIS means also monitoring ECDIS. You can't separate observing and monitoring. Monitoring the ECDIS is part of the full-time job. New technologies bring with them new tasks, that of the care and feeding of the new technology. One must maintain the new technology making navigation safer. If it isn't fed charts and chart updates regularly, if its sensor feeds are not operational, if setup data and guard zones aren't set and re-verified, if the warnings on the routes it generates aren't viewed and warnings mitigated, then it can't do its simple job of replicating a paper chart and automatically plotting the vessel's position. In a sense, because the ECDIS is so dependent on setup features, data feeds, and up-to-date charts, and because the deck officer is responsible for these while on watch, the monitoring of the ECIDS entails a new level of vigilance on the part of the watch officer. Being extra vigilant is not a poor trait for a watch officer to have, since double-checking virtually everything on watch is a necessity when there are so many variables beyond what the watch officer can control or have direct knowledge about. It remains to be seen if the care and feeding of ECDIS is only short-lived or it remains as the technology matures. The dependency for care means that the deck officer is a part of the technology equation. But being a part of the equation doesn't necessarily mean that the deck officer is a valued part of the equation.

The dependency, ECDIS on the watch officer and the watch officer on ECDIS isn't new from a bridge watch perspective. Each time a deck officer takes the watch, the oncoming watch meets with the off-going watch and a pass-down question and answer session ensues, along with a review of the off-going watch's log entries. This is what deck officers do and how they make coherent sense of what is going on. It sets their expectations for what will occur in the future. The difference is that ECDIS must be monitored all the time, given that it has so many entry points as dependencies in its ability to function. There is no accounting for the monitoring function in the ECDIS research and this clearly impacts its value as a time saver. Deck officers state that their companies have added other work, believing that ECDIS is a time saver. Monitoring subtracts even more of any real time-savings achieved due to ECDIS.

There is the chance that the mutual dependency can turn into a co-dependency ending in many different forms of destructive behavior such as watch officers developing Mate's neck (elongated necks from starring down into an ECDIS display instead of looking out the bridge windows) and forgetting to look out of their bridge windows, thus leading to a casualty in the real world. Worse yet, deck watch officers could destroy themselves, as individuals and as a worker class by not taking a more active role in ECDIS development and application, for example with regard to ECDIS training. Despite arguments for more training time, the IMO sets ECDIS training to just a 40 hour course, but one is only able to scratch the surface of ECDIS functionality in 40 hours. Additionally, ECDIS is taught with groups of individuals gathered around a single display monitor. Learning isn't occurring under such circumstances, observing is occurring. If you don't learn ECDIS during your 40 hour training, when will you learn it? When you join a ship as a deck officer you should immediately go to the bridge and open every drawer there to see what is there and where things are stored. Why would you not do the same thing for an

ECDIS? But if you haven't been fully trained, you may end up doing more harm than good by accidentally changing an ECDIS parameter. The mouse can be your friend in ECDIS or it can be your worst enemy or worse, the enemy of your fellow watch officers who don't check all the ECDIS settings because their training didn't provide the time to do it, so they don't even know what to check.

One hopes that one finds time before watch or through some creative method to learn ECDIS fully. One also hopes that looking out of the bridge windows frequently remains a part of the watch officer's routine activity. Not looking out the window seems to be the most common comment by pre-ECDIS watch officers of post-ECDIS watch officers. No technology has been implemented that can give a full and accurate picture of the vessel surroundings, such as identifying small craft or low lying/floating obstructions in the vessel's path. The vignette is trying to emphasize ECDIS features in comparison to pre-ECDIS navigation work. The watch officer hasn't forgotten about good seamanship. In this vignette, good seamanship of the watch officer occurs with the checking of the accuracy of the chart's sounding datum in the database and when plotting the terrestrial position on the ECDIS. Good seamanship is not set aside just because a new technology has made it way to the bridge. The application of good seamanship will evolve to include the situated experiences of the officers using ECDIS.

Navigating and voyage tracking in the post-ECDIS era is mechanically different, using different technologies and technical artifacts almost exclusively. The ECDIS video screen replaces the chart table as the principle location from which to understand one's position and for socializing the on-coming watch. The main difference between the

ECDIS display and the paper chart is that the ship's position is displayed continuously. The watch officer doesn't have to plot and then interpret the plot in so far as what course heading must be followed to the next waypoint or when the next waypoint will be encountered, ECDIS does this all for you. You just need to know where to look on the ECDIS display or within its menu structure. As long as there is confidence that the monitoring of ECDIS is sufficient, ECDIS's outputs can be trusted. ECDIS monitoring is a mimeomorphic action, deciding whether to accept the monitoring results is a judgement and therefore a polimorphic action.

Polimorphic actions around communicating between officers and with the pilot still exist in the vignette, though they are mostly silent here. New mimeomorphic actions have been substituted in as the primary means of navigating in a rearranged world due to a redefinition of safe navigation. From the point of view of maritime regulators, judgment of accuracy has been removed in favor of standards of accuracy, system feedback loops, and system messages. From the point of view of the deck watch officer, judgment of accuracy is as it has always been, based on the experience of their collective situated actions. Whether or not deck officers acknowledge it, those judgments are also plans that may change based on context.

4.7 Action Survey Comparing Pre and Post ECDIS Implementation Actions

The function of the Action Survey is to document systematically a task's actions in a pre and post technology environment. This survey compares pre-ECDIS chart correcting with post-ECDIS implementation chart correcting, pre-ECDIS voyage planning with post-ECCIS implementation voyage planning, and pre-ECDIS navigation with post-ECDIS implementation navigation. The far left-hand column of the survey contains the tasks in bold and supporting actions directly under the tasks. The entries in the column labeled Deck Officer describe whether an action is polimorphic or mimeomorphic under the pre-ECDIS era. Recall that polimorphic actions are actions that can change depending on the context of the action, while mimeomorphic tasks are those that can be mimicked because they are typically repetitive with small variation. The remaining three columns to the right contain the entries for a post-ECDIS implementation era. Mimicked by ECDIS means that an action has moved to ECDIS and away from the deck officer. Substituted by Deck Officer means that in an ECDIS world the user of ECDIS performs the task. Substituted by Non-ship Based Person means that a human does this task, but the task is not done with ECDIS at the location of ECDIS use. A task may disappear and a new type of task may appear with the introduction of ECDIS.

Action	Pre-ECDIS	Post-ECDIS		
		Mimicked	Substituted	
	Deck Officer	by ECDIS	by deck officer	by non-ship based person
Chart Correcting				
Choose which charts / publications to update	polimorphic			mimeomorphic
Pull the charts from the chart drawer / publication from the book shelf	mimeomorphic			
Create database for new charts or updates			mimeomorphic	
Choose which Notice to Mariners to utilize	polimorphic			mimeomorphic
Read and interpret the Notice to Mariner item	polimorphic			mimeomorphic
Determine the location on the chart based on the Latitude/Longitude of the update entry	mimeomorphic	mimeomorphic		
Make the adjustment either drawing and/or writing on the chart, or deleting an item on the chart, or deleting then drawing and/or writing on the chart.	Mimeomorphic	mimeomorphic		
Update the chart correction tracking tool, such as index cards	mimeomorphic	mimeomorphic		
Put the charts in the chart drawer / publication back onto the book shelf	mimeomorphic	mimeomorphic		
Accept and Save new chart updates to the database			mimeomorphic	

	Pre-ECDIS	Post-ECDIS		
Action		Mimicked	Substituted	
	Deck Officer	by ECDIS	by deck officer	by non-ship based person
Voyage Planning				
Determine the origin and destination ports for the voyage	polimorphic		polimorphic	
Input or verify vessel dimensions, voyage depth parameters, and guard zone values			mimeomorphic	
Decide on the method to use for planning the voyage	mimeomorphic		mimeomorphic	
Execute the voyage planning methodology	mimeomorphic	mimeomorphic		
Transfer the planned voyage to the voyage tracking chart and the navigation charts to be used during the voyage	mimeomorphic	mimeomorphic		
Check for hazards along the planned route	mimeomorphic	mimeomorphic		
Adjust route for hazards	mimeomorphic		mimeomorphic	
Input the voyage plan to any electronic devices such as a GPS	mimeomorphic		mimeomorphic	
Layout the navigation charts in order of use during the voyage	mimeomorphic	mimeomorphic		

	Pre-ECDIS	Post-ECDIS		
Action		Mimicked	Substituted	
	Deck Officer	by ECDIS	by deck officer	by non-ship based person
Navigating and Voyage Tracking				
Decide when to take a navigation fix	polimorphic	mimeomorphic		
Monitor ECDIS accuracy and settings			polimorphic	
Decide the type of navigation fix to take	polimorphic	mimeomorphic		Polimorphic (a higher level decision determining GPS and DGPS as well as other automated feeds.
Do the procedure for the type of navigation fix decide upon	mimeomorphic	mimeomorphic		
Decide the navigation procedure was done accurately	polimorphic			
Determine if navigation signals are within acceptable limits/exist		polimorphic		
Plot the resultant of the procedure for the navigation fix decided upon	mimeomorphic	mimeomorphic		
Judge accuracy of navigation procedure	polimorphic			
Determine vessels position relative to the navigation fix	mimeomorphic	mimeomorphic		

4.7.1 Action Survey Analysis

The action table above reflects that the ECDIS device only substitutes its mimeomorphic actions for mimeomorphic actions the deck officer did in the pre-ECDIS era. Some judgment actions no longer exist in favor of some standard. Adhering to the standard requires only mimeomorphic actions on the part of the ECDIS, the user, or some human ashore. The interpretation of such a change is that there is some rearranging of the navigational world going on with the introduction of ECDIS. The research, development, testing, and decision to accept an ECDIS standard did away with some deck officer polimorphic actions. The testing and accepting of a new definition of safe navigation made some judgments of accuracy no longer relevant. The rearranged world of safe navigation takes place because of a switch in paradigm, from one where deck officers take navigation fixes using many different methodologies to one where ECDIS receives sensor data and plots it using a standard method.

In a pre-ECDIS era, deciding on when to take a navigation fix and which method to use is based on judgment that has its roots in the social maritime domain. Collins and Kusch call these types of actions formative actions, where "members share a common net of concepts and actions."[271] The deck officer knows that safe navigation is the goal. The deck officer knows how to do navigation. The deck officer has training that corresponds to a certain social decision-making judgment environment. That translates to an idea of what is good seamanship. How that deck officer translates that idea of good seamanship into action through behavior can vary depending on the situational context. The social knowledge of navigation fix and accuracy judgment is no longer part of the maritime

[271] Collins and Kusch, *The Shape of Actions - What Humans and Machines Can Do*: p.10.

domain's collective tacit knowledge in a rearranged world of marine navigation. It's now explicit in the various standards, and realized when implemented in ECDIS. Deck officers are to take training classes in ECDIS to acclimate them to ECDIS. This in essence gives them interactional expertise.[272] For a good seamanship performance, interactional expertise isn't enough from the deck officer's perspective. Their performative actions of judgment have not transferred to ECDIS. The judgment action has shifted focus to ECDIS the tool. They negotiate with the tool in the process of technology adoption. They monitor ECDIS and they look out the bridge windows seeking confirmation of the tool's properties.

Technology replacement isn't new. What has been done in this research is to document what actions were done under the past safe navigation paradigm and what actions take place in the new paradigm of safe navigation given ECDIS. The study of pre and post ECDIS actions and of ECDIS translations allows one to argue for a replacement of deskilling as a paradigm for ECDIS technology adoption with one of dialogue or negotiation with or in light of the technology. Deck officer judgment actions are left mostly untouched by ECDIS. They are still making navigation judgments. The lack of voluntary and full enrollment into the ECDIS technology of deck officers means that there is still negotiation going on between deck officers and ECDIS technology. The judgments are situated actions. These situated actions are performative and are the mechanism by which deck officers adopt the ECDIS technology.

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[272] Collins, *Tacit & Explicit Knowledge*: 178.

Chapter 5 – Performativity, ECDIS, and Deck Officer Identity Production

5.1 Locations of Deck Officer Identity Creation

Deck officers create individual identities during their bridge watches. The success or failure of those watches cling to them as an identity of sorts. More generally, the aggregation of many deck watch officers' acts become identities existing beyond the individual watch officers, lying in some social knowledge domain such as casualty reports, news media, ship's logs, pop culture referents, or sea stories. These collective identities contribute to or detract from the perception of the value of deck officers as a class. A deck officer can subscribe to these collective identities as the circumstances require every bit as much as those created by one's individual bridge watches. An example of such a subscription is the newly minted deck officer who has not held a deck officer job, but who wants to be associated with identities of deck officers generally.

Deck officers are not the sole creators of deck officer identities. The ECDIS researchers discussed earlier in Controversy A found it useful to create identities useful in pursuit of their goals through the process known as translation. The USCG, who represents the US at the IMO and therefore has a global impact on US mariner identity, translated marine navigation to a simulator and found little material differences in cross-track error between more experienced and less experienced navigators. The team at Woods Hole positing the possibility of a revenge theory pushback by mariners. The authors of the NRC' Who's Minding the Helm, felt it necessary to paint the mariner as traditional and conservative in the face of change and lacking formal risk assessment skills. Collectively, these entities create such identities as are useful in pursuit of ECDIS goals.

A constant determining of deck officer identities, hence their valuation, takes place in many locations, some local to the individual deck officer, some at arm's length. The mechanism by which this takes place is through performative acts.[273] The fact that performative acts are taking place constantly at multiple locations means that it isn't inconceivable that an individual identity can exist that is in opposition to other existing identities. Interviews with deck officers support such a possibility; that of a deck officer who doesn't feel deskilled due to the introduction of new bridge technologies. Deck officer identities put forth by non-deck officers are similar to gender identities created by "regimes of power/knowledge"[274] or "power/discourse."[275]

There is a process by which deck officers become sanctioned and regulated deck officers, that is by meeting the formal licensing requirements. These requirements include training at a traditional maritime school or the even the more traditional route of working one's way up through the ship's deck department. Common requirements for all deck officers, are passing the required examinations, acquiring the necessary 365 days of sea-time for a particular license level, and being healthy enough to pass the required medical examinations. Deck officers must also follow a set of career rules, regulations and requirements by maintaining a particular lifestyle that is free of illicit drug use, free of criminal acts, and lacking in alcohol abuse. If one is able to successfully, pardon the pun, navigate these processes, then one is designated a deck officer. This process repeats itself not only for every new individual, but iterates every five years thereafter for each officer

[273] Austin, *How To Do Things With Words*.
[274] Michel Foucault and Colin Gordon, *Power/knowledge : selected interviews and other writings, 1972-1977*, 1st American ed. (New York: Pantheon Books, 1980).
[275] Judith Butler, *Gender trouble : feminism and the subversion of identity*, Thinking gender (New York: Routledge, 1990).

for as long as one desires to stay a deck officer. The performative act making one a deck officer is the granting of a license from the licensing authority, which in the United States is the U.S. Coast Guard. One could not possibly be called a deck officer without a license.

5.2 Embodied Deck Officer Identity

There is a parallel state by which deck officers become deck officers in and among themselves, and that is by successfully standing their bridge watches. There are good watch officers and likely poor watch officers, but nonetheless, they are deck officers as seen by both themselves and their fellow deck officers. It isn't because they meet the regulatory definition of a deck officer. It is because they successfully stand watch. There is something in this parallel process that allows the deck officer an oppositional view to the concept of deskilling in the face of new technologies brought to the bridge to participate in their bridge watches. Deck officer enrollment into ECDIS technology is up for contention, even as their experiential knowledge is highly sought after. ECDIS stands for safer navigation, but the action survey shows that deck officers are safe navigation's linchpin. The system of systems that is ECDIS supplants what is historically quite a lengthy navigation curriculum, but the tasks associated with socially distributed deck officer tacit knowledge remain in place with the introduction of ECDIS. The lack of enrollment of pre-ECDIS deck officers into the ECDIS technology and the type of actions embedded in ECDIS are a foundation that allows support of their oppositional view of deskilling. Enrollment can only exist when a deck officer embodies the identity created by the ECDIS power regime and stops doing deck officer performatives.

5.3 The Social Identification of ECDIS Character

At the onset of ECDIS research and development, an assumption of technological determinism pervaded ECDIS. Essentialist thinking was successfully able to equate ECDIS to safe navigation. The IMO standards determined ECDIS's character as the purveyor of safe navigation through a bureaucratization of member state signatures. This character reproduces endlessly with each ECDIS boxed up at the end of the manufacturing assembly line, each installation aboard a ship, each time a deck officer participates in an ECDIS training class, at each installation of a vector chart, and with every moment that an ECDIS is in operation. Mobilized ECDIS supporting actors maintain ECDIS's character ceaselessly by re-emitting ECDIS's character with each supporting action, though they don't know it and are ancillary to it. The new e-Navigation architectural framework recently published by the IMO further enforces a view of technological determinism with regard to safe navigation. The technological determinism that pervades ECDIS runs up against, at the very least, the following features: the lack of current hydrographic data, effective ECDIS training, and the plethora of commercial ECDIS designs that make ECDIS information interpretation difficult. But, these issues seem to have little effect on the character of ECDIS. The fact of ECDIS comes about by performative actions of its functional support network, which also includes deck officers. Insofar as the IMO and those that oversee IMO policies through regulation are concerned, deck officers are seen to support their functional network. Acting, if you will, as "ventriloquists" for their policies, rules, and regulations.[276] There is a dilemma for the researcher in this idea. One must try to separate out deck officer acts that are due to a regulatory system from acts that are to good seamanship as defined

[276] Kira Hall, "Performativity," *Journal of Linguisitc Anthropolgy* 9, no. 1-2 (2000): 186.

through the deck officer social domain. SOLAS now requires ECDIS. Regulations specify that deck officers must train in the use of ECDIS. Ship owners, operators, or managers, depending on how the ship is outfitted and crewed, place ECDIS aboard in lieu of paper charts and traditional navigation tools (as a backup capability as well). This forces deck officers into ECDIS use, thus reinforcing that ECDIS is safe navigation. The good-seamanship navigation rule, Rule 2, is a regulation. It is also however, the mechanism by which deck officers constitute their performative acts. The good seamanship rule, Rule 2, demands all capability use while navigating. In a given situation, ECDIS use may be necessary to support a watch. Actual deck officer use is situational and largely hidden from any none shipboard person. ECDIS data files can only reconstruct deck officer perceived use after the fact. The situation and context must be inferred from interviews or the viewing of bridge video recordings if available. This creates a situation where there is no questioning by society of ECDIS's value to safe navigation when its information is ambiguous, its training substandard, and its installation faulty. Only its improvement is up for discussion.

Like Butler's gender, ECDIS is seen as natural.[277] One can't see where it begins or ends. ECDIS's character is an illusion built both discursively and recursively in such a manner that its character seems pre-discursive. Its very presence builds the reality for its justification. It becomes an object of belief.[278] One can't begin to unravel its true essence without unraveling the society in which it is embedded. Such an unraveling begins with the ECDIS entity power regime that brought ECDIS to the bridge of ships.

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[277] Jagger, *Judith Butler - Sexual Politics, Social Change and the Power of the Performative*: 18.
[278] Butler, "Performative Acts and Gender Constitution: An Essay in Phenomenology abd Feminist Theory," 520.

But, such an unraveling must go well beyond that power structure. Everyday people not touched by ECDIS participate in its discursive character building. No one is to blame. Everyone is to blame.

Existing normative commentary on ECDIS is not about ECDIS, the idea of safe navigation, but about the processes by which ECIDS is socially instantiated. For example, common to a number of obstacles to implementing ECDIS as safe navigation is funding: the social choice of where to put investment, current and future. For example, given the wealth disparities in the world and that most of the coast lines aren't within wealthy nations' borders, the allocation of funding for hydrographic surveying needs to be done as a kind of aid to the poorer nations, even if this means the wealthy nations do the surveying. With only so much funding available, do you provide food, medical, and infrastructure aid to the many such poorer nations, or survey their coast lines? If both are to be funded, which land bounded countries will not receive aid for food, medical, and infrastructure? There is no centralized entity making ECDIS social choices. There is no master translator role after the approval of the technical specifications for ECDIS. The constitution and organization of the global shipping society, and likely society at large, provides a sort of primordial fluid necessary for repetitive performative acts to naturalize ECDIS. The interesting aspect of this naturalization is its global nature. All countries that have merchant ships have a stake in ECDIS. One can posit that commerce subordinates much regardless of political and economic ideology. A complete resignification of wealth distribution by wealthy societies can only bring about ECDIS as safe navigation in any near-term timeframe. Safe navigation that is, insofar as an ECDIS implemented with full features, data, user training, and user experience.

Based on the post-ECDIS vignette discussed earlier, deck officer use of ECDIS during their bridge watches can be interpreted as some kind of forced performance script. Such a script enforces a deterministic ECDIS view of safe navigation, encompassing the deck officer and suppressing deck officer freedom of action. It is certain that safe navigation is the goal of deck officers in general for both pre and post-ECDIS eras. Whether navigation is safer under an ECDIS regime is open for debate, since only passing time could support such an interpretation. A positive view of technological determinism sustains ECDIS as a forced script, and such a view would be an incorrect interpretation of ECDIS. Such an interpretation assumes a predetermined successful outcome for each and every navigation action, or that the cause of a vessel casualty is due to something other than ECDIS. Reality in this case is that the bridge work processes aren't centered on ECDIS at all. Outwardly, it looks as though the deck officer is taking orders from ECDIS, but given the type of tacit knowledge embedded within ECDIS, ECDIS is just mimicking repetitive work processes and providing informational results. The performative bridge watch acts are due to the deck officer. Their work involves performative acts in the sense of Austin speech acts,[279]and I assert that these are achieved within a theatrical performance process sense. What follows is an analysis and explanation of deck officer actions interpreted as performative acts. Following the performative act analysis is a hypothesis of how such performative acts can be theoretically constructed using a specific theatrical genre's performance framework, and how this construction provides a basis for the value of deck officer experiential technical knowledge, and its place in bridge technology.

[279] Donald A. MacKenzie, Fabian Muniesa, and Lucia Siu, eds., *Do Economists Make Markets? On the Performativity of Economics* (Princeton: Princeton University Press, 2007), 2-3.

5.4 Deck Officer Performative Acts

"The ship is here," ECDIS sings out every second during a ship's voyage. It is a mostly silent song that ECDIS sings and it is actually a bit more complex. It goes something like this:

"The ship is here. The water depth is safe. Cross-track distance is XXX meters to port. Course over ground is in direction XXX degrees true. Speed over ground is at XX nautical miles per hour. The time to the next way-point is XX hrs., XX min, xx sec. The time to destination is XX hrs., XX min, xx sec. The time is XX hrs., XX min, xx sec."

There is no harmony in the song, as each individual fact sings out at the same time; and really, the song is more akin to a group chant. The chant is synched to its internal CPU clock, that is synched to some other convenient time source located somewhere off the ship. Of course ECDIS doesn't really sing out; it constantly displays.

Sometimes ECDIS's display screen flashes an alert or sounds an alarm of some preplanned upcoming way-point for maneuver, or to get the attention of the deck officer on watch for some preprogrammed reason that through some system logic triggers the flashing alert and or alarm sound system task. ECDIS makes a true sound utterance when its programmed-in logic, born of the IMO ECDIS standard, wants to direct the attention of the deck officer on watch to some data feature or unfolding set of data points on the ECDIS screen.

"So what," is the deck officer response to ECDIS's chant while the ship is out in the open-ocean. Barring any screen flashing or sound utterances, the deck officer of the watch may look at the ECDIS once an hour in that environment. When the ship is in constrained waters like harbor or river channels, ECDIS gets more of the watch's attention. However, whatever its chant, ECDIS is all very well established and factual as far as its programming logic and system inputs go. From this perspective, its navigation is constative.[280]

In what can be termed pre-ECDIS or traditional navigation, the deck officer undertook a multitude of tasks in order to get a single fixed position of the ship at a single moment in time. The ship's Master, the exigencies of the watch, and deck officer preference determined both the method and the iteration frequency of the position fixing tasks. The outcome of current ECDIS position fixing to the traditional navigation position fixing tasks of the past century is the same, a fact of where the ship is on a chart and by extension, on earth. It is the ship's material reality of place at a particular moment. When produced under ideal conditions, with a full accounting of all environmental dependencies, the traditional celestial and terrestrial navigation fixes are the equivalent of the ECDIS positions with its attendant GPS data feed, less the frequency of fixing position moments.

In this sense, navigation is just a component in a deck officer bridge watch. A deck watch officer is not navigation in the sense of knowing where the ships is. A deck watch officer is not a state of affairs, an individual who is licensed, trained and placed on board a ship. The deck watch officer is not observing the ship's voyage. It is the deck officer during a watch that brings the voyage, a state of affairs, into existence through the use of knowledge (some of it experiential in nature), practice, and instruments. The successful

[280] Hall, "Performativity," 185.

voyage is by far the norm, but its state of affairs is always in flux and its success always up for contention. It is the actions of a deck officer while on watch that iteratively brings forth the reality of a voyage. It is in this sense, that voyage production is a string of performatives of deck watch officers (not to play down the role of marine engineers).

5.4.1 Analysis of Deck Officer Bridge Work Performative Acts (1)

Some examples can help with this claim. Take for example the speech exchange from the Navigation, and Voyage Tracking in Pilotage Waters (Coastal, Inland, Ports and Harbors) Using Traditional pre-ECDIS Methods vignette:

> "Right 15 degrees of rudder," says the pilot to the helmsman.
>
> "Right 15 degrees of rudder," says the helmsman.
>
> "The rudder is right 15 degrees," says the helmsman once he moves the helm over.
>
> "Rudder amidships," the Master calls out.
>
> "Rudder amidships," the helmsman replies.
>
> "The rudder is amidships," states the helmsman.
>
> "Right 15 degrees rudder," the Master states.
>
> "Right 15 degrees rudder," the helmsman replies.
>
> "The rudder is right 15 degrees," states the helmsman.
>
> "Sorry sir," he offers.
>
> "No problem. We handled it," says the Master.

As stated before, the success of a ship's voyage is always in flux. The ship is arriving into port at the end of a voyage. The Pilot has directed the Helmsman by stating a rudder order. The Helmsman repeats the rudder order and then states that the rudder is actually at the ordered position, as is the custom and most probably a formal requirement on the bridge of most all merchant ships. Picking up in the dialogue above where the Helmsman says, "The rudder is right 15 degrees," one can see that the Helmsman is describing that the ship's helm is right 15 degrees. The fact that the Helmsman's description is in error regarding the direction of the helm is material for the next exchange because of its falsehood. The ship's Master's words, "Rudder amidships" is the action that precipitates the ship's helm being moved to amidships. These words are the leading incident for the Helmsman's subsequent action. Otherwise, there are no subsequent Helmsman actions. The Master's next words are "Right 15 degrees rudder," in response to the Helmsman describing that the helm is amidships. The Master could have asked for any amount of rudder necessary to achieve the goal of the course change. He didn't even have to initially ask for "Rudder amidships." The Master's helm orders are neither true nor false, so they are not descriptive (constative), but are performative. The timing of the Master's orders implies that the rudder was not at right 15 degrees as stated by the helmsman and from this perspective one could argue that the utterance was as constative as performative. However, the Master's words are not describing what he is doing. They are the act by which the ship's rudder moves. In this case, the Master's words are causal for the rudder's movement, but its success is contingent on more than just the Master's words.

The success of the action brought into being is dependent on many variables, such as the Master's training, knowledge, and experience, as well as the Helmsman's ability to follow the Master's command. The Master's goal for his speech commands guides the sequence of helmsman commands given to the helmsman. The Master is not stating or explaining the reasons for the sequencing of helmsman commands as they are given. The moment calls for action, not action, then a reason warranting the action, then action, on the part of the Master. That requires a narrator and no such position exists aboard ship. The organization of the Master's utterances is due to a performance production process. There is no direct truth in the Master's words. It is through the Master's speech acts or utterances in this speech exchange that the ship's voyage continues to be successful.

5.4.2 Analysis of Deck Officer Bridge Work Performative Acts (2)

The following speech exchange is between the Master of the ship the Charlotte Lykes, Captain Deborah Dempsey, and other deck officers and crew as the ship enters the port of Naples, Italy in order to anchor on 25 February, 1994.[281]

> Master: "Slow ahead." "355 … stop her… dead slow ahead … 357 … slow ahead …okay, mate, walk out your starboard anchor to one in the water … 359."
>
> Master: "Do you need lights on the bow?"
>
> Chief mate: "No, we've got enough from the moon."
>
> Chief mate: "We've got one in the water and it's back on the brake."
>
> Master: "Hard left," … "dead slow ahead." … "Slow ahead."
>
> Second mate: "We're smack in the middle now."
>
> Master: "Amidships … stop engine."
>
> Master: "142 … dead slow astern … let your anchor go, mate."
>
> Master: "We want seven on deck."
>
> Chief mate: "Five in the water now, broad on starboard … she's holding good now … seven on deck, putting the brake on."

The ship's progress is solely dependent on the Master's statements, which are in some cases dependent on descriptive information from crew members. The Master is

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[281] Dempsey and Foster, *The Captain's a Woman, Tales of a Merchant Mariner*: 186.

providing engine order telegraph commands, called bell commands, and rudder orders that when executed appropriately control the speed of the ship. Additional commands follow from the Master for dropping the anchor as feedback information arrives from crew members. The Master is manipulating the temporal aspect of where the anchoring evolution takes place, and the area or space in which it occurs. The goal to safely anchor becomes the ship's reality. In this case the sum of the Master's performatives is successful a anchoring of the ship in Naples harbor.

The Master's performatives would not materialize as a successful anchoring if the crew members were unresponsive or gave intentionally false information. Even with a responsive crew the anchoring's success is still up for contention. The environmental conditions of weather, wind, waves and currents have an effect on the anchoring evolution. Any one of these can act for a moment to constrain or upset the anchoring. The ship itself is a significant actor insofar as its correctly operating technical functions are concerned. The ship's engine responds accurately to the engine orders, the steering engine room operates as designed, the anchor windless brake holding at the correct time, the anchor chain in the chain locker isn't kinked and pays out smoothly, rust hasn't deteriorated any on-deck tool in use. The Master's performative acts must correspond to other actor's roles and timing. The Master achieves this by manipulating space and time, much like a theatrical performer on stage.

The deck watch officer is the sole body on the bridge during most commercial vessel ocean voyages in fair weather. Speech utterances are not the dominant form of bridge watch acts. The deck officer watch is mostly silent, with the deck officer taking action as required to meet the circumstances of the voyage. These acts are silent, but they are performative none-the-less.

5.4.3 Analysis of Deck Officer Bridge Work Performative Acts (3)

It is May 11, 2008. The CFL Performer, having sailed from Paramaribo, Suriname on April 28, now sails off the UK coast bound for the port of Grimsby with a load of bauxite in its cargo hold. The following account is adapted from the marine casualty report from the grounding of the CFL Performer on May 11.[282]

The weather is clear with 6 nautical miles of visibility, seas calm and a north-easterly wind of between force 2 and 3. The tidal current is south-easterly and the tide height is expected to be 2.5 meters above the chart datum. The second mate is the officer of the watch and is the only crew member on the bridge for the watch.

The Second Mate walks up to and peers into the 3cm radar that is set to the 3 nautical mile range scale. He repeats the action with the 10 cm radar that is set to the 12 nautical mile range scale. After checking for ship targets and checking the distance to the coastline, he returns to doing paper work for an upcoming ship security and safety management audit that will take place upon arrival at Grimsby.

> At 1403, the second mate alters the ships course to 321 degrees from the current 356 degrees.
>
> At 1550, the second mate alters the ships course to 331 degrees from the current 321 degrees.
>
> At 1616 the bridge phone rings. The second mate picks up the handset and hears the Master's voice.

[282] Marine Accident Investigation Branch, "report on the investigation of the grounding of the CFL Performer," (Southampton, UK: Marine Accident Investigation Branch, 2008).

> "I felt a vibration. Can you check the depth of the water?"
>
> The second mate analyzes the ECDIS display and answers, "there's no cause for concern, there's plenty of water."

At 1619, the second mate senses that something is wrong. The ECDIS shows that the ship's speed is just 1.1 knots, rather than the planned 9.5 knots. He immediately alters the ship's propeller's pitch to zero which removes all forward thrust on the ship. The ECDIS display is set on the 1:100000 scale. The second mate changes the display to the larger scale of 1:50000 and immediately sees that at the ship's current location the charted depth is less than the ship's draft. He sees that the depth sounder has been in the off position all watch. He switches it on and receives attendant confirmation of the grounding. He has grounded the ship onto the Haisborough Sand, just off the UK's East Coast.

The Master successfully refloated the vessel within 20 minutes of the grounding without sustaining any damage. Putting aside all the errors associated with the grounding, this case shows that deck officer bridge watches are generally mostly silent when at sea. The deck officer watch is performative nonetheless. Not all deck officer performative acts are successful as in this case of the CFL Performer's Second Mate's watch. Acts are left entirely undone in some cases. Why such acts go undone cannot be analyzed without a model for the production of performative acts.

5.5 Contingent Deck Officer Identities

A laymen's view of deck officer identity comes about through the same methodology of bureaucratic standardization as that of ECDIS: the levying of new training requirements, the passing of examinations, the issuing of licenses, and the revoking of licenses all contribute to this identity. The identity must show some social stability because deck officers are intrinsic to bridge work and because lack of stability would reflect poorly on regulators. Ship casualties and incidents are handle piecemeal and ad hoc as they occur, never across a class. This constructed identity of a deck officer proper doesn't even require that one go to sea for work. Credentials stand in for the deck officer and therefore credentials have a performative aspect. Their acceptance is in lieu of actual deck officer action aboard ship. Shipboard actions are hidden from the layman except when a ship casualty occurs.

ECDIS and deck officers appear as givens, but they are really roles within performances going on all about them. The general populace accepts these givens, for they have no reason to question them until a performative failure. Even then, the nebulous but highly connected constitutional nature of society shores up the givens. A failure of ECIDS provides opportunity for improvement. A failure of a deck officer is an opportunity for social admonishment and loss of agency. The fact that so few deck officers have to succumb to admonishment provides an opening to hypothesize a theoretical methodology by which deck officers create their own stability of character or identity through successful performative acts. Such a process is the theatrical genre Commedia Dell'Arte (CDA), employing flexible performance techniques similar to those used in everyday social transactions.

5.6 The Process of Constructing Deck Officer Actions

There are a number of parallels between CDA, a hybrid of oral and literate performance processes of the 16th century, and deck officer bridge watches.[283] The parallels exist not

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[283] See Fitzpatrick, *The relationship of oral and literate performance processes in the commedia dell'arte : beyond the improvisation/memorisation divide*. For a comprehensive analysis of CDA.

between the theatrical product of CDA and the finished deck officer bridge watches, but between the production processes used to create their finished products. Characterization of deck officer performances are likewise a hybrid of oral and literate performance processes. Recalling the pre-ECDIS vignettes, the deck officer comes to watch with nothing more than an idea of a watch and some guidelines in the form of the Master's standing and night orders. The deck officer has the flexibility to pursue the watch in any manner within the guidelines of these orders, as well as within any rules and regulations for good watch keeping. The IMO's COLREGS Rule 2 is such guidance for good watch keeping. A bridge watch only comes about as the deck officer performs the necessary tasks that ensure good seamanship and adherence to the Master's orders. It is not a fully scripted evolution, but unfolds as a set of many objects and many interacting variables that induce themselves into the watch and may require an accounting by the deck watch officer.

Captain Dempsey's bridge watch when anchoring in Naples can be analyzed with regard to the CDA performance production model discussed earlier on page 35. The goal is to anchor the ship safely in Naples harbor at night using only the ship's crew. This is the CDA scenario. The scenario outlines a set of schemas, arrival, anchoring, and safety. The arrival schema sets an ordering for the ship to arrive on its anchoring station; the ship must maneuver to the anchoring location and the ship must stop at the anchoring location. The anchoring schema includes: the deck crew must go out to the bow, the deck crew must ready the anchor for dropping (subschema of setting the brake, starting the windless, lifting the cat's paw, walking the anchor to the water line) the anchor needs to be dropped, a certain length of anchor chain needs to be deployed, the anchor must hold. The Captain and crew perform according to the needs of the scenario.

A subschema for vessel maneuvering is deployed, and formulaic speed and rudder orders are given that take into consideration the ship's current speed and direction, the ship's performance characteristics, and any current environmental factors such as wind, wave, and current.

The Captain deploys personal resources that impact the spatial and time elements of the anchoring evolution through the speed and rudder orders. The orders are based on feedback from the ship, the crew, and anticipation of environmental factors in conjunction with the ship's performance characteristics. Each order is improvised insofar as it isn't predetermined and the orders are based on the Captain's experience with anchoring this ship, as well as all anchoring evolutions done previously on her other ships, and everything she has been told and read about anchoring in Naples and at all other locations. In this way, everything that is the Captain and the whole of maritime culture is included in the anchoring evolution.

The Captain meets the needs of the safety schema by approaching the anchorage at a safe speed, and asking if light is needed on the bow.

The anchoring is deemed successful and the value in the form of Captain Dempsey's identity is asserted. The performance is both an event and a discursive practice, providing identity and thus agency. It is performative. Captain Dempsey holds a Master's license that allows her to assume the position of a ship's Master or Captain.

The idea of being a captain is an object of belief, an illusion of performative acts noted previously. It is Captain Dempsey's continuous constituting acts that act in opposition to her as 'Captain object of belief,' versus her as 'Captain in reality.' Her performative acts stand in contrast to the pre-discursive object of belief.

The anchoring event occurs without any memorized script. The performance takes place through improvisation of the anchoring scenario that outlines the entrances, actions and exits of the performance participants. This short analysis of the anchoring scenario just provides an understanding that construction of maritime deck officer performatives is highly similar to the CDA's composition in performance technique. If this is so, then it may be possible to model deck officer bridge watches for more concrete use by those interested in technology studies.

Working out the CFL Performer's grounding in a narrative model provides a more complete understanding of how such an incident can occur beyond the after action report filed by the Maritime Accident Investigation Branch in the U.K. Even more so, a successful modeling might act as a predictive tool in a more general sense to inform on the potential of such incidents or of human / technological orchestral composition and performance.

5.6.1 Deck Officer Action Production Model

The following is a general model using the CDA objects introduced earlier in this work, the scenario, the schema, the subschema, and the deployment of formulas. A voyage from A to B is the scenario. The safe navigation of a vessel from point A to point B is the overall goal for a vessel voyage. In CDA, schemas act to order the scenario's performance and serves as a measure of new experiences. Schemas form by induction based on experience.[284] The voyage schema implements the scenario goal. This schema is an ordering of voyage events, the departing from the origin port, sailing to the destination port, and then arriving at the destination port. Each of these order events requires a subschema of activities: navigation and collision avoidance. Navigation has four subschemas of its own: piloting, dead reckoning, celestial navigation, and radio navigation.[285] Piloting is the determination of a vessel's position and its direction, which involves frequent continuous references to landmarks, aids to navigation, and depth soundings. Dead reckoning is the projection of a vessel's present position, or future position from a previous position using known directions and distances. Celestial navigation is the determination of a vessel's position through observation of celestial bodies. Electronic navigation is the determination of a vessel's position through the analysis of information from electronic devices on board a vessel that receive and process raw and structured physical phenomena such as radio waves and sound. Whatever method or combination of methods the navigator uses, the procedures must furnish a solution to the three basic problems of navigation. The problems are to determine the position, the direction to proceed, and the distance in relation to the factors of time and speed to the next vessel-maneuvering, -notifying, or -documenting event. Collision avoidance has two subschemas: the analysis of vessel contact information, and the taking of prompt, early and substantial action in order minimize the risk of collision.[286] At the lowest level of CDA performance production is the deployment of formulas that actualize

[284] Ibid., 69.
[285] See Maloney, *Dutton's Navigation & Piloting*: 1-3. for a description of navigation techniques.
[286] Adminstration, "Radar Instruction Manual," 3.

the performance of "surface level action."[287] Formulas equate to the deployment of a performer's personal resources.

5.6.2 Using the Deck Officer Action Production Model

The above is a general modeling format of a deck officer's bridge watch. A specific model can be constructed for an individual's bridge watch. In this case, the scenario is the Second Mate's watch on the CFL Performer on May 12, 2008. The goal of the scenario is the safe navigation of the CFL Performer from Paramaribo, Suriname to Grimsby, U.K. The schema under which the watch takes place is the sailing to the destination port. The subschemas of navigation and collision avoidance are necessary for this sailing schema. The situated actions for this watch determine which navigation subschemas need deploying. The piloting and electronic subschemas are necessary in this case. When the Second Mate begins to deploy personal resources to actualize these two subschemas, this narrative model shows a break down in performance. The Second Mate fails to deploy the piloting subschema by not turning on the depth sounder at the beginning of the watch. Additionally, and more importantly, the Second Mate is unable to deploy electronic navigation resources because he is untrained on ECDIS. His working knowledge of ECDIS is to equate ECDIS use in terms of a paper chart, which is the ultimate cause of the grounding. The Second Mate's composition in performance causes the vessel grounding. His performative acts end in a failed performance.

A more formalized production performance model is possible, but this is beyond the scope of the current work. What this model narrative has achieved is to provide an

[287] Fitzpatrick, *The relationship of oral and literate performance processes in the commedia dell'arte : beyond the improvisation/memorisation divide*: 72.

understanding of and a singular example of an application of the CDA performance production genre to deck officer bridge watches.

It is evident from the previous two examples that the production of deck officer bridge watches can be closely related to the production of CDA theater. This form of theater clearly places a large amount of a performance's success on the individual's or bridge team's successful deployment of personal resources. Deck officers' ability to deploy personal resources successfully reaffirms the importance of deck officer experiential technical knowledge and establishes their agency in relation to bridge navigation technology. The fact of their agency means that they are not just a pass through for the technology to perform. In the case of deck officers, the method of performance production is every bit as important as the performative act, since it constitutes agency creation required for their oppositional identity that stands against a deskilling paradigm view of technology.

Chapter 6 – Conclusion

Deck officers may not be aware of their oppositional view to deskilling, but their performatives created through their flexible performance process stands in contrast to a discourse of deskilling reinforced by others' performative acts. To be deskilled is to have one's identity handed out as a label through other's performative actions. The other in this case refers to individuals and groups seeking to explain the effects of changes in modes of production on the worker. Adding the local voice of a worker or worker group adds symmetry to a skill / deskill discussion, in this case, the voice is the deck officer's, who works on the bridges of ocean going cargo ships. Deck officers have an oppositional view to deskilling because as they go about their duties on the ship's bridge, they create performative acts that recursively work to reinforce their valued identities within their maritime domain culture. Their performatives are the result of a flexible performance production process. The idea that deck officers use a flexible performance production technique is justified by fact that deck officer work processes are highly improvisational, possibly more an oral tradition than a literate one, and that the professional requirement for good seamanship demands situated actions that plans cannot accommodate. The plan in this case is the ship's voyage or navigation plan saved within the ship's bridge ECDIS.

Outwardly, ECDIS is a navigation system of systems that stores and presents to the deck officer user: a graphic representation of the voyage plan, a constantly updated ship's position relative to the voyage plan, warnings for dangers to navigation within the planned route, and alerts to navigation data gaps along that planned route. However, ECDIS is a technology that requires much care and feeding. Almost child-like, ECDIS technology isn't able to make decisions with regard to good seamanship, but only mimics navigation tasks once performed by deck officers. ECDIS is unable to perform tasks based on the tacit knowledge used by the deck officer community to negotiate the complexities of bridge watches. ECIDS performs tasks enacted by embedded programming logic based on explicit knowledge. Viewing this explicit knowledge enacted by embedded programming logic as a stand-in or standard for safe navigation wasn't the intent of the originators of ECIDS, but seems to have become so by subsequent innovators of ECDIS. One of the originators, Mort Rogoff, proposed to help navigators understand their ship's position for accurate and safe maneuvering of their ship, not to devalue their knowledge. The ship's position relative to its planned track (cross-track distance) became the focal point of ECIDS research. The more the cross-track distance was minimized during research and development, the greater the distance ECDIS seemed from the deck officer task of doing the actual maneuvering of the ship in order to minimize that cross-track distance. The regulators of ECDIS use translations, which are performative acts, to characterize deck officers in order to justify a change in technology. ECDIS research papers sprinkled with comments that either knowingly or unknowingly seek to minimize deck officer importance is an instance of performatives that seek to build a dominant and parallel or counter social identity of deck officers, that of being traditional and error prone. Succumbing to a form of technological determinism in arguing for ECDIS, while waving an identity of Exxon Valdez deck officers in hand, regulators of ECDIS forcibly enroll deck officers by making ECDIS a requirement on ships and forcing ECDIS certification onto deck officers. The aggregation of successful deck officer performative acts in a harsh and highly variable environment forces ECDIS regulators to try to enroll the deck officer to use ECDIS in order to shore up gaps in its safe navigation mantra. This counter identity creation process isn't keeping current and new deck officers from continuing to go to sea. Their own identity creation process will continue to produce many more successful voyages than failed ones.

Deck officers explain their transitions from work processes for which they are already qualified through certification and experience, to new work processes incorporating technologies that automate some or all aspects of those work processes by saying that they are, like ECDIS, a tool. They aren't making a distinction between ECDIS and traditional navigation apparatuses or methodologies. Rule 2, the good seamanship rule, requires them to use all the tools placed at their disposal. They desire to use ECDIS in the best way possible, so when deck officers speak regarding ECDIS's introduction onto the ship's bridge they emphasize training. They believe that ECDIS use is only as good as the training they receive. Until recently training wasn't standardized and much of the training was done on-the-job, because there is no standard commercial ECDIS device, only IMO ECDIS standards being implemented within ECDIS devices. Deck officers have no expectation that the ECDIS device one uses during training is going to be the one found onboard one's ship. Therefore, many transitions to ECDIS have been marked with the burdensome and time-consuming work of re-familiarization and re-learning while on watch, during which time the safety of the ship is at risk. There are even more transition instances of primary learning of ECDIS functionality on-the-job, where such learning competes directly with the safe navigation of the ship. Sometimes safe navigation has suffered due to ECDIS's introduction. ECDIS-assisted casualties mark the deck officer's transition to ECDIS. These incidents are the force behind the IMO's latest basic ECDIS training requirements. Deck officers will need to be both ECDIS certified in order to work on board vessels with ECDIS, and they will be required to have familiarization training for the ECDIS device aboard the vessel on which they work beginning in January 2017. This training becomes a control over a deck officer's ability to work since most ocean going vessels covered by the IMO's SOLAS convention will be required by that time to have ECDIS as the ship's primary means of navigation. This type of regulated work requirement or control is nothing new to the deck officer. Regulated training is a social feature that deck officers submit to knowingly in order to obtain and maintain their sailing license.

The deck officer license, known currently in the US as an officer credential, is the focal social feature for deck officers. It is a recognition of achievement, status, hierarchy, and the entre onto the bridge of ships. Non-on-the-job training is challenging the status of the deck officer license as the focal social feature for deck officers. ECDIS training is another in a long list of training requirements that deck officers must partake in order to maintain perceived proficiency in their work processes. To speak of perceived proficiency is to state that none of the training requirements tests judgment in a situated context. Situated judgments are what deck officers do. It is the application of their experiential technical knowledge, their value.

From the interviews for this research project, deck officers lament three things when discussing the transition from traditional navigation methods to ECDIS:

1. The pride one finds in the use of traditional navigation methods,

2. A fear that over-reliance on ECDIS will create myopic users who refrain from looking out the bridge windows,
3. If tradition methods aren't kept polished or taught to a high level of competency, what happens when ECDIS and its back up ECDIS fail?

Pride in a task-well-done comes in many ways and forms for deck officers. Deck officers can offset the loss of pride in their daily navigation work with their ability to use traditional methods as their watch situation allows. They can use traditional methods in their work, only that the primary means must be ECDIS. Additionally, some deck officers get greater self-satisfaction from other bridge work processes such as ship handling. Ship handling requires situation awareness, and if officers are not looking out of their bridge windows, but are instead fixated on the ECDIS screens, this is a problem. Some ECDIS-related casualties are the result of such inability to resolve ECDIS display information through supplemental awareness. The use of supplemental awareness is part of judgment that is not currently part of regulated ECDIS training.

All the ECDIS training is of no use if the ECDIS system aboard a vessel fails, forcing the deck watch officer to rely on traditional methods for one's navigation. This is problematic if that watch officer has never utilized such methods in a real-time environment. The ready-to-handness of ECDIS is then realized and lost in the same moment. It becomes truly present-to-hand because there is no fixing it. This is a challenging scenario, like dropping a person from the city into the wilderness. It will no doubt transpire that such a system failure occurs at the least opportune moment and only a god-machine can save the ship from distress. Such a machine is likely waiting in the rearranged navigation world stage-wing where constant innovation to preclude human error and machine error harbors. The question in such a re-arranging navigation world is what does knowing ECDIS get you? When the HMS Bounty's mutineers put Captain Bligh over the side of the ship and into the ship's boat in 1789, Captain Bligh was able to sail the boat roughly 3500 nautical miles to safety and rescue. In 2089, such an accomplishment is likely not possible. There are differences for the deck officer in knowing traditional navigation methods and knowing ECDIS. Likewise, from the perspective of a deck officer's watch, knowing Rule 2 and knowing ECDIS are two different things entirely. Society thus far sees fit to continue to instantiate Rule 2 into the deck officer domain. Rule 2 is the method by which the value of deck officer experiential technical knowledge, collective tacit knowledge, finds application during bridge watch processes, including its technology. Rule 2 is however a convention.

Aside from verbal statements from interviewed deck officers, evidence for their oppositional view to deskilling is the fact that their enrollment into the ECIDS technological network is continually in flux. Forced use and forced training still has not created an environment free of ship groundings. The societal entities that promote ECDIS proliferation find that the roles defined for deck officers aren't accepted readily and the ECDIS capability isn't the determinant for safe navigation. The determinant is as it has always been, in the hands of the deck officer on watch. Deck officers are still making the necessary judgements for navigating ships as they have in the pre-ECDIS era. ECDIS replaces repetitive chart work when electronic navigation charts are available for the ocean areas transited, thus saving deck officer time for other crucial tasks like collision avoidance. The time saved however is mostly lost to oversight of ECDIS functions, as well as new regulatory processes and paperwork imposed by governments and those passed down from shipping managements.

That ECDIS on the bridge of ships makes navigation safer is numerically incalculable. ECDIS made its way to the bridges of all commercial ships through regulation and not by virtue of its capability to make navigation safer. Performative acts on the part of ECDIS proponents create the convention and belief of safer navigation. There is no truth in ECDIS, only success or failure in its use. The IMO helped ensure ECDIS use by allowing raster type charts. Allowing raster charts puts to test the modernity of ECDIS, so raster charts are now only allowable where no vector charts are available, where no modern oceanographic surveys exist, where no modernity exists. This seems to be a postmodern state of rationality, where the traditional holds in reserve in order to support the goal or aim of a technology.

Twenty-five years after the approval of ECDIS, the fact that vector charts for ECDIS are based mostly on old surveys suggests that either the old surveys are as good for navigation charts as charts developed with new surveying techniques or that chart datum isn't the important factor when navigating. In both cases, the importance of safe navigation points to deck officer actions. In an era of mobile phones, tablets, PCs and social media, the idea of systematizing a process and making it interactive using computer technology could stand as good as an explanation of why ECDIS is on the bridges of ships as its ability to provide readily observable and accurate position plots for the officer on watch. Tablets and social media were in their infancies when ECDIS was in its infancy and therefore ECDIS is of similar technical interactive lineage, where there seems to be a fetish for system building beyond an initially scoped technology. The fact that ever more interaction and connectedness is developing in the IMO's e-navigation framework means that ECDIS is no more a safe way of doing navigation than was the pre-ECDIS methods. In this case, safe can mean both safe as in safety from a casualty at sea and safety from extinction.

Mariners don't need ECDIS to describe their maritime environment. ECDIS becomes a convention for describing their environment. It can't guarantee safety, for one deck officer will still see fit to ask another ship's deck officer for an allowance that acts against the rules of the road and ends up the cause of a ship casualty. ECDIS won't ensure greater cooperation because of the multiplicity and complexity of the commercial, environmental, governmental, and personal contexts within which it sits. No coordination and safety plan can come about even if every voyage plan on every ship across every route were somehow coordinated through a centralized ranking system. We now know that plans are not the means of enacting the world. It is through situated actions. Deck officers perform this work and they will continue to do so short of rescinding the good seamanship rule, Rule 2. Deck officer's valued identities are on the line. Commercial leadership, government regulators, and fellow mariners entrust the deck officer because of this value.

If one wants to find the value of experiential technological knowledge, one must look at the place and time of its use. It is through situated actions that experiential technical knowledge comes about. The value of such knowledge is only as good as the production process that puts it into use. The epistemological status of the value of maritime experiential knowledge is lost when embedded into a plan for execution. Such is the case when literate performance production processes replace more orally based ones. Literate production processes seek to determine value before action takes place. The author of a plan or idea takes preeminence instead of the plan's actors who must perform the action. More orally based production techniques are by their nature more flexible. This flexibility allows for the possibility of more experiential technical knowledge creation.

It has been shown how deck officers theoretically construct their performative acts. Within the context of ECDIS, one can say that the method by which deck officers deploy their technical knowledge is of value to the research and developers of ECDIS. Likewise, and for the same reasons, they are of value to ship operators. Nothing about how deck officers deploy their personal resources has changed with the introduction of ECDIS. ECDIS doesn't threaten deck officer value partly because the deck officers' performance production process is left untouched. This makes the deck officer performance production process interesting and worthy of further study. While an unusual application of theater performance production, using the CDA performance production process is potentially a very useful tool where work processes emphasize improvisation; the good seamanship rule, Rule 2 corresponds to such a domain. The overlaying of the CDA performance production genre onto deck officer work processes highlights the similarity between a deck officer's bridge watch interactions and those used in everyday social interactions. Is this similarity just coincidental? A historical study of deck officer performatives may provide better insight. Such a study might begin with the study of merchant ship logbooks going back several hundred years. The ship's logbook is the location of documentary evidence of a ship's deck officer performatives.

For symmetry, one should undertake a study using the same methodologies utilized in the above research to look at instances of the introduction of workplace automation that have displaced workers. The benefits of studies using the above methodology are to understand what similarities and differences exist in their pre and post-automation action and knowledge types, and their performance production processes. Building a taxonomy of references based on a number of such studies should help governments, commercial executives, and labor develop policies that take an accounting of potential knowledge and action gaps in the situated actions that make up the unfolding world in which we live.

This dissertation's fills a void in Science and Technology in Society research in what is taking place experientially when speaking of workers in conjunction with the introduction of automated technology into the workplace. Identity creation and maintenance, worker agency through performativity, situated action production, and experiential technical knowledge replaces the skill and deskilling debate.

We are not speaking about skilling or deskilling when we speak of workplace introduction of technologies automating current work processes, but about measuring pre and post technology implementation socially based experiential technical knowledge. Knowing this measure enables an understanding of the potential work process shaping that might take place; a shifting of repetitive work tasks to a technological system or a rearrangement of the world that does away with some socially based knowledge. There are implications for both of these outcomes. Over time, relying on technical solutions for repetitive tasks has a way of making pre-technological tasks evaporate with subsequent loss of competency. If documented, the pre-technology task knowledge survives.

Success on such an instantiation of technology is measured as probabilities against technological failure. When an ECDIS stops functioning regardless of why, and it will happen and at the least opportune time, the emergency replacement will need to include the repetitive tasks that ECDIS absorbed. The fallback to traditional navigation processes may be no better than not having ECDIS, since competency in doing the repetitive tasks has diminished over time.

Rearranging of the world has somewhat different implications, but no less important. Rearranging of the world is about prioritizing social values regardless of the technology. This rearranging can come about due to a reprioritization of social values such as has been occurring with regard to the earth's environment. In this case, it seems that over time, new technology introduction comes about by some process of social consensus building (not saying that this is a simple evolution), e.g. electrical power generation via other means than coal-fueled plants. Another kind of re-arranging of the world occurs when the new technology does away with polymorphic actions as its main effect. In such cases, we are dealing with the primacy of plans as the way the world should unfold verses the way in which it actually does unfold, by situated actions. The workers in this research's study are deck officers who have been guiding ships on the high seas and into ports for almost as long as recorded time. Their job deserves special study because of its longevity alone. Policymakers speak of creating jobs. The jobs that policymakers should promise and then follow through with are those with the potential for longevity, and these are jobs that value situated action over plans. Jobs with work processes driven by plans can only fall victim to the next technology that absorbs that work process's mimeomorphic actions. Society has seen fit to introduce policies that limit environmental impact, but human element policies seem to be without solution. The long-term impact of technology on humans needs considering in light of an analysis methodology that measures the potential for job longevity, ones that favors collective experiential technical knowledge applied in situated actions.

Appendix A – IRB Consent Form & Interview Questions

Interviewees for this dissertation's research came from three sources:

1. Contacted directly by this researcher from this researcher's own social network,
2. the Maritime Institute of Technology and Graduate Studies (MITAGS) in Linthicum Heights, MD allowed this researcher to address their students and to arrange for interviews while the researcher was a student at their school,
3. Christian Hempstead allowed the researcher to address his students and to arrange for interviews while the researcher was a student in his ECDIS certification class.

Each research interview participant signed a consent form before the interview. Each interview began with a standard set of interview questions; however, the interviewees were able to expand their area of comments beyond those directed toward the interview questions. Likewise, the interviewer upon receiving agreement from the interviewee was able to ask additional relevant questions within the subject matter domain of the dissertation.

IRB Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants
in Research Projects Involving Human Subjects

Title of Project: Situating Experiential Technical Skill – Dialogue between Maritime Deck Officers and Technology

Investigator(s):	**Donald F. Clark**	kes4845@vt.edu **/ 571-242-7015**
	Name	E-mail / Phone

number

IRB NUMBER: 13-805

I. Purpose of this Research Project

This research project is being conducted in order to gather raw data for my dissertation. The general area of study is called science and technology studies. The purpose of my dissertation is to explore and understand the relationship between laborer experiential technological skill and technology. It is a study of maritime labor and technology and it seeks to uncover new notions beyond the common deskilling paradigm for labor/technology adoption. Typical maritime labor / technology studies are about labor negotiating for labor's well being in light of proposed new technologies that seek to reduce jobs or skill levels; what can be classified as labor deskilling studies, and such works use impersonal wage / skill measures to record the labor disputes and resolutions. The merchant marine laborer is left without a voice. Not hearing labors' voices keeps one from knowing firsthand, the actual interaction of merchant mariners with technology. Without this knowledge, one can't understand the place of labors' experiential technical skill within technology, the personal dimensions of any struggle with skill replacement in light of automation, and how these two dimensions might relate. New technologies that increased the size of ships over the last 100 years haven't impacted the number of deck officers generally on a per ship basis. The incorporation of communication, navigation, and collision avoidance technologies into deck officer work processes over the last 100 years also shows little impact to their per ship numbers. The deck officer's job isn't disappearing any time soon. They have shown to be a resilient cadre in the face of new technologies. There must be reasons for their resilience and this study seeks to understand these reasons. I intend to interview at least 30 deck officers and have them explain their transitions from work processes for which they are already qualified through certification and experience, to new work processes incorporating technologies that automate some or all aspects of those work processes. I intend to analyze their explanations for the types of knowledge they apply during their interactions with these new technologies, as well as the social organizations that are included in their transition explanations. The resultant of my work hopes to bring insight to the relationship of experiential technical knowledge to technology, and by generalization other perspectives of skill replacement due to technical automation.

II. Procedures

As a participant in this research, you agree to an audio-recorded person to person interview session in which the researcher asks you a set of questions. Follow up interviews may be requested if the researcher requires clarification on any of your answers. The list of the research questions will be provided to you for your review. The interview may take place in person, over the telephone, or via some other method of audio communication. The actual duration in minutes or hours of the interview is undetermined; however, the researcher will ensure that you are comfortable and provided with any necessary relaxation breaks.

III. Risks

Should you feel any emotional or mental stress during the interview, you are asked to let the researcher know so that the research may try to mitigate the stress through a change in question or termination of the interview.

IV. Benefits

No promise or guarantee of benefits has been made to encourage you to participate. A larger societal benefit might accrue if the research leads to better understandings of laborer empowerment and coping strategies in the face of future new technologies whose perceived strategy for introduction is to weaken or replace the then current human labor capital.

V. Extent of Anonymity and Confidentiality

Your participation in the research will only be known to the researcher, and possibly to members of the researcher's dissertation committee. The researcher will only refer to you in the dissertation by an assigned serial number which shall be based on the sequence in which you are interviewed. The list of serial numbers and associated participants and their contact information and will not be shared with anyone without your written consent except as stated in the following paragraph. The resulting audio recordings from your interview for this research will remain in the possession of the researcher after the dissertation is completed and degree awarded and it will be maintained in accordance with Virginia Tech IRB policy. Your signed hard copy consent form and the participant serial number key will not be stored together, but will be stored in separate locked filing cabinets.

The Virginia Tech (VT) Institutional Review Board (IRB) may view the study's data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VI. Compensation

You agree to participate in this research without any promise of compensation.

VII. Subject's Consent

I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

____ Date__________

Subject signature

Subject printed name

VIII. Freedom to Withdraw

It is important for you to know that you are free to withdraw from this study at any time without penalty. You are free not to answer any questions that you choose or respond to what is being asked of you without penalty.

Please note that there may be circumstances under which the investigator may determine that a subject should not continue as a subject.

Should you withdraw or otherwise discontinue participation, you will be compensated for the portion of the project completed in accordance with the Compensation section of this document.

IX. Questions or Concerns

Should you have any questions about this study, you may contact one of the research investigators whose contact information is included at the beginning of this document.

Should you have any questions or concerns about the study's conduct or your rights as a research subject, or need to report a research-related injury or event, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu or (540) 231-4991.

Interview Questions:

1. How long have you been a merchant marine deck officer?
2. How did you obtain your first license?
3. What license do you hold currently?
4. What type of ships have you sailed aboard and have you specialized on one particular type of vessel or trade?
5. What are your principle goals when standing watch on the bridge of a ship?
6. Briefly summarize how you organize and pursue your bridge watch?
7. Do you pursue your watch any differently depending on the type of vessel you are sailing aboard or trade that you are in?
8. Are there particular bridge work processes that you enjoy the most?
9. Do have a special pride in an ability, skill, knack, or precision in any of the bridge work processes, if so which ones, and why might you feel that way?

10. What new technologies have been introduced onto the ship's bridge during your career?
11. Have any of these new technologies altered the work process by which you achieved your watch-standing goals, if so, which ones, and specifically how did each one alter your work processes?
12. How did you first encounter each new technology that did alter your work processes, and to your knowledge what entity decided that the technology was going to be place on the bridge?
13. Would you describe your interaction with each new technology, not from the perspective of what the manual or directive for it prescribes, but what you are thinking as you use it; and include any special personal rules you might apply when using the technology.
14. Were there any concerns or difficulties when integrating each new technology into your bridge watch routine, and if so, what were those concerns or difficulties and how did you resolve each concern or difficulty?
15. Can you relate any situations or incidents where you found any new technology's use problematic or beneficial from the standpoint of your seagoing experience?

Appendix B – Listing of Interviewees

Interview	License	Experience	Profile
1	3rd	>30	Maritime Instructor / Sailing
2	Master	>30	Maritime Instructor / Sailing
3	2nd	>10	Sailing
4	Master	>20	Sailing
5	2nd	>10	Sailing
6	3rd	>10	Sailing
7	2nd	>10	Sailing
8	3rd	>5	Maritime Instructor
9	Master	>40	Sailing
10	3rd	>5	Sailing
11	Master	>20	Sailing
12	CM	>5	Sailing
13	Master	>50	Maritime Instructor
14	Master	>30	ECDIS Instructor
15	Master	>20	Sailing

16	3rd	>30	Self / Sailing when time permits

<u>License</u>
3rd = Third Officer / Mate
2nd = Second Officer / Mate
CM = First Mate / Chief Mate
Master = Master

Experience is in years

The interviewees represented multiple genders, though this was not a feature captured for this research.

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