Maritime University Curriculum and Technology Planning for the 21st Century

Part I: Projecting Maritime Education and Training Technology Needs Using Quantitative Technology Forecasting

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ABSTRACT

Throughout the maritime industry, success follows those who stay ahead of the curve, technologically speaking. This truism applies to the Maritime Universities as well, where maritime education and training continuously changes to adopt new technology in industry. But what does a technology curve look like? How do you know where you stand, or what's coming next? How can you tell *when* technology change will happen?

As a method of predicting the future, technology forecasting is unique in its use of quantitative time-based information to arrive at reliable projections of the technological future. Many methods have been developed to project in time technology diffusion, performance envelopes, and substitution rates. Technology precursor relationships have also been identified, wherein fixed time-lag relationships that emerged during technological transitions in the past provide projections of time-lag relationships of future technological and curriculum change. With just such a critical piece of information, maritime university educators can plan new curricula and learning technology investment with confidence.

This paper, Part I of a series, introduces quantitative technology forecasting, the focus of research and applications at the Center for Technology Forecasting at Maine Maritime Academy. Important methodologies, sample forecasts, and implications for projecting the future of maritime education are presented.

1. Introduction: Working Definitions

The term "technology" defines a lot of things to a lot of people. The worldwide popular media assume we all understand technology as something related to computers, communication, television, or the Internet. Yet, to the anthropologist, historian, engineer, or mariner, technology means much more. Technology is *all* the methods, materials, and systems that enable, displace, or amplify human activity. At the largest scale, to capture the greatest meaning, technology can be defined as any human creation that provides a compelling advantage to continue to use or improve that creation.

"Technology forecasting" is a term used also to define a lot of different things people do. Much of what is cast as technology forecasting is simply the dreaming up of prognostications or scenarios, many times the fanciful thinking of a "futurist". Typically, the accuracy of such predictions falls rapidly with distance in time. The definition used by those practicing quantitative technology forecasting is given as: the process of using quantitative methods to project in time the intersection of human needs and technological capabilities.

2. Quantitative Technology Forecasting

2.1. Quantitative Technology Forecasting Methodologies

Quantitative technology forecasting has been applied successfully across a broad range of technologies including communications, energy, medicine, transportation, and many other areas. A quantitative technology forecast will include the study of historic data to identify one of or a combination of several recognized universal technology diffusion or substitution trends. Rates of new technology adoption and rates of change of technology performance characteristics take on common patterns. The discovery of such a pattern indicates that a fundamental trajectory or envelope curve has been found and that reliable forecasts then can be made. These quantitative methods have proven accurate in predicting technology change in thousands of applications across technologies as diverse as carbon-based primary fuels to consumer electronics, on time scales spanning centuries or only months. Technology diffusion patterns and the driving social needs can be identified through study of historic, time-referenced data, from which the projection in time of new technology adoption can be determined reliably and accurately.

The quantitative forecasting techniques are, to use the words of mathematician and theorist Gregory Bateson (Bateson 1977) "explanatory principles", that is, their applicability is sufficient for the purposes of explaining technology diffusion patterns and forecasting technology adoption. Many researchers have attempted to substantiate the commonly found patterns through application of thermodynamics and other advanced systems theories, to varying success and acceptance in the field.

Several of the many techniques in quantitative technology forecasting are ideally suitable for projecting technological change in maritime education and training, and are introduced in more detail and illustrated with examples here.

2.1.1. Logistic Growth Projection

Forecasters had their first significant successes in predicting technological change when they used exponential models to project new technology diffusion. It was deemed only logical that a new technology would at first be selected by one, than perhaps two others, and these people in turn, two others each, and son on, in a pattern of exponential growth. Ultimately, as in any natural system, a limit or bound on total would be reached, leading early researchers next to the logistic (or sigmoid, or so-called s-shaped curve) to model technology diffusion. Some of the earliest published works in this regard were by the American demographer Raymond Pearl and the English actuary Benjamin Gompertz. In the 1950's and 1960's, researchers in the United States such as Lenz, Martino, and Vanston, and others around the world [e.g., the very prolific Marchetti (Marchetti 1977)] refined the methods and showed that the logistic model was an excellent construct for forecasting technological change with virtually universal application across technologies and other individual and social human behavior. Figure 1 illustrates the idealized logistic curve of technology adoption or diffusion. Figure 2 shows the logistic growth of the supertanker of maritime fleets presented in a format that renders the logistic curve linear. (Note the scaling of percentage). A further example, Figure 3, shows the logistic pattern of discovery voyages of the Western Hemisphere. (Note the earliest voyages have been lost from history. Figure 4 shows the growth pattern of a recent computer virus that infected computers on networks worldwide.

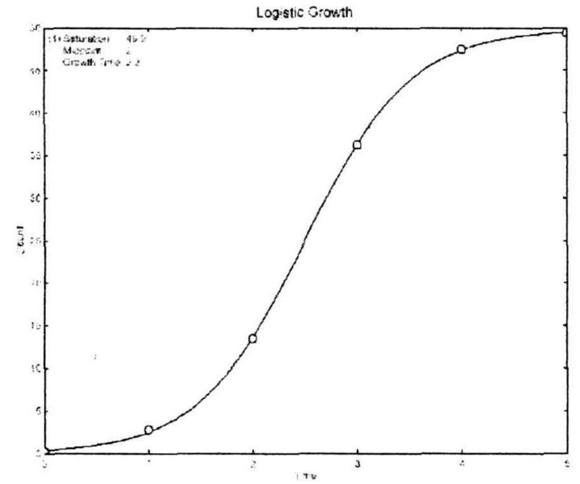

Figure 1. Ideal logistic growth curve (Adapted from Meyer et al, 1992).

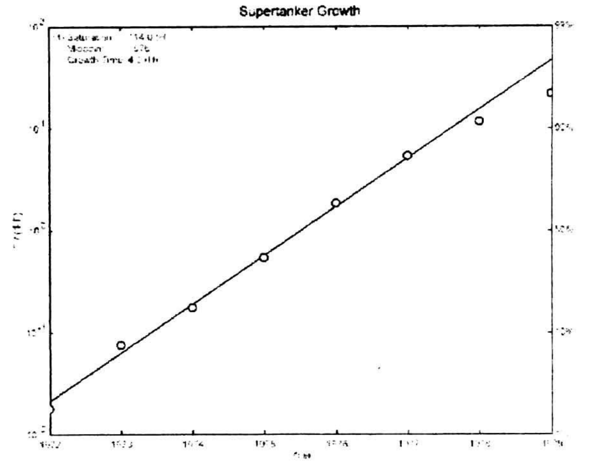

Figure 2. Logistic growth of the supertanker (Adapted from Modis 1992).

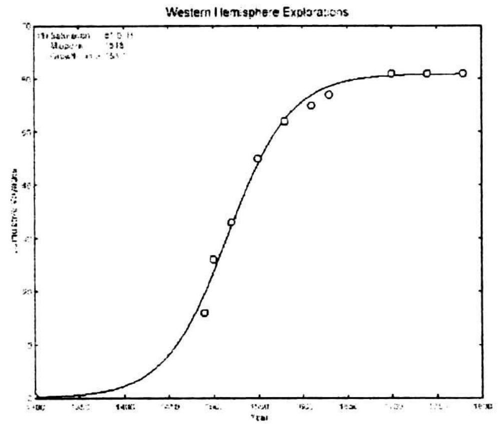

Figure 3. Logistic pattern of discovery voyages of the Western Hemisphere (Adapted from Modis 1992).

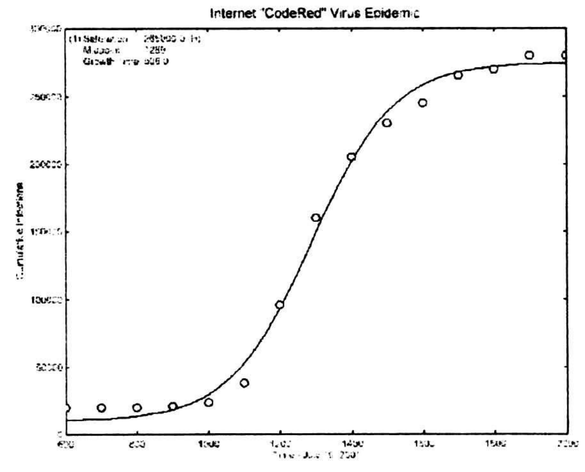

Figure 4. Logistic growth of a recent network computer virus (Data from Danyliw and Householder, 2001).

2.1.2. Constant Rate of Change (Performance Envelopes)

Technology change occurs within dynamic and complex systems of human behavior. The growth and diffusion of technology impacts and is impacted by the activities of humans as individuals and groups of varying scale. The adoption of new technology requires intellectual, material, energy, and other resources to be redirected, increased, and otherwise managed as required in the implementation of the new technology. When a new technology comes along having the substantive compelling advantage such that it will successfully substitute for the incumbent technology, humans tend to go about the changeover in a methodical way, seemingly to maintain equilibrium in the vast array of a culture's interacting and interdependent social, material, and economic systems. The result is that the adoption and change of substitute technologies is far from random and rarely sudden, and usually follows a smooth transition, at a rate either consciously or unconsciously maintained by the forces for equilibrium in society. Forecasters call the sequential performance levels of adopted technology that follow along an identifiable curve a *performance characteristic curve*, and search for its telltale shape in the history and projection of a technological area. Figure 5 shows an example of the performance characteristic curve for transistor density on a microprocessor chip, the popular "Moore's Law". Figure 6 shows the performance envelope of industrial energy substitution, pointing to the fuel cell as the next leading energy conversion technology.

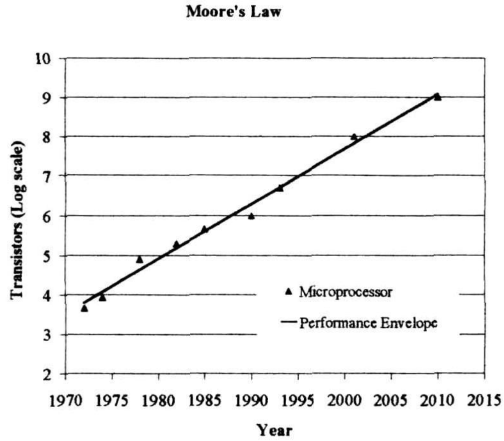

Figure 5. Moore's Law - Performance envelope of microchip transistor density (Data from Intel Corp. 2001)

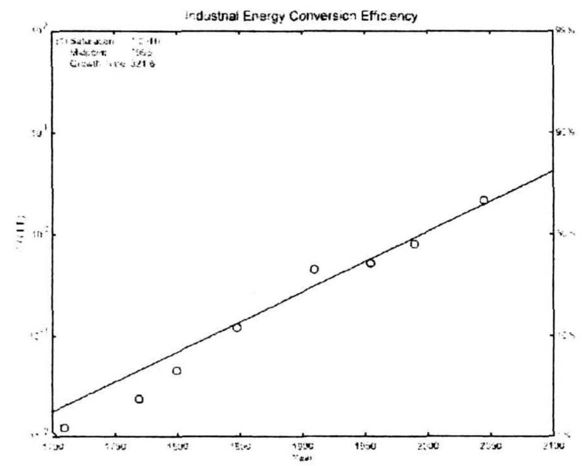

Figure 6. Performance envelope of industrial energy conversion technology (Adapted from Ausubel and Marchetti, 1997).

2.1.3. Logistic Substitution

The transition from one technology or performance level to the next tends to follow a neat, managed pattern. In the 1960's, Fisher and Pry (Fisher and Pry 1971) analyzed hundreds of technological substitutions in history and devised a method to graph the substitution patterns in linear fashion, thus giving us the popularly applied Fisher-Pry projection of technology substitution. Figure 7 illustrates the typical logistic substitution pattern. Studies have shown this remarkable logistic substitution pattern in technologies as diverse as the substitution of automobiles for horses in personal travel and the substitution of latex for oil based paints. In the maritime industry, published reports show the logistic substitution of motor-over-steam-over-sail in ship propulsion technology (see Figure 8), and, with possible implications for the maritime education and training, the substitution of simulators for real-time flight experience in aviation training.

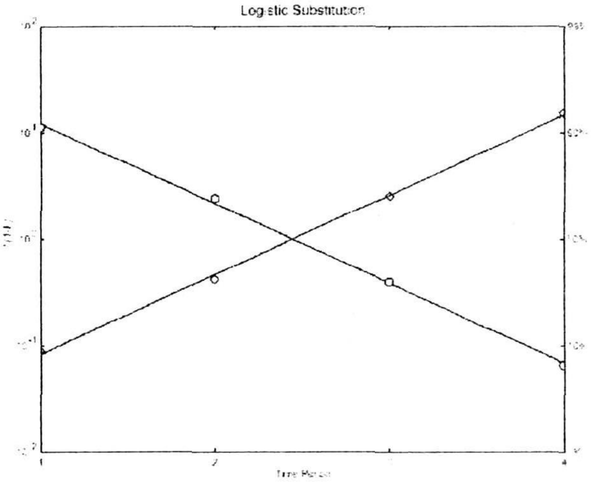

Figure 7. Typical logistic technology substitution (Fisher-Pry display).

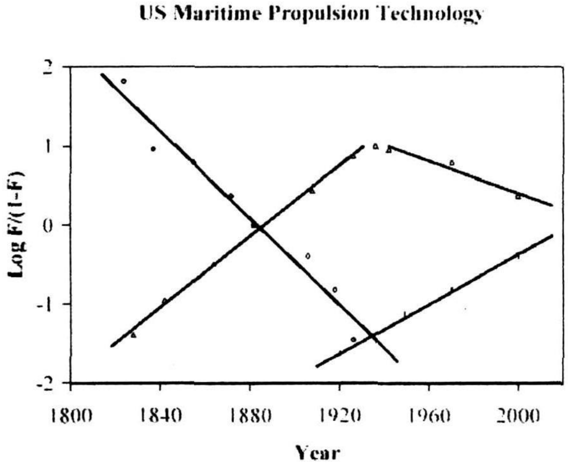

Figure 8. Substitution of US maritime propulsion technology (Adapted from Modis 1992).

2.1.4. Precursor (Lead-Lag) Growth Trajectories

The implementation or adoption of a technology has been shown to vary logistically. When one technology is dependent on or otherwise closely related to a previous development, the two trajectories are usually linked in a steady lead-lag relationship (see Figure 9). Studies have shown that the worldwide discovery of petroleum resources has led the production of oil by a fixed period of time over many decades. Studies have shown also that the diffusion in USA industry of networked desktop personal computers followed the same shape logistic trajectory as the precursor technology, stand-alone PCs.

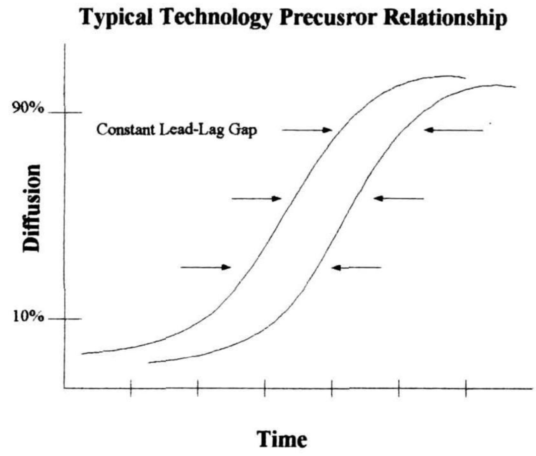

Figure 9. Constant lead-lag logistic relationship.

2.1.5. Anthropological Invariants

In the grand history of the progression of technological change, one of the striking results is evidence of the invariance of human behavior in many areas. While technologies offer many and perhaps infinite variety of how to get things done, the things humans do want to get done, generally, have remained the same for hundreds and thousands, perhaps millions of years. For example, travel and communication patterns, depicted in broad averages of commuting or foraging times, or in numbers of human exchanges, have been shown to be constant across time and cultures. The anthropological benefits in applications of technologies can be viewed as artifacts of unchanging human behavioral preferences. As an example, Figure 10 shows the more or less constant accepted (and, by implication, engineered and designed) risk of death by automobile in the United States over nearly an entire century.

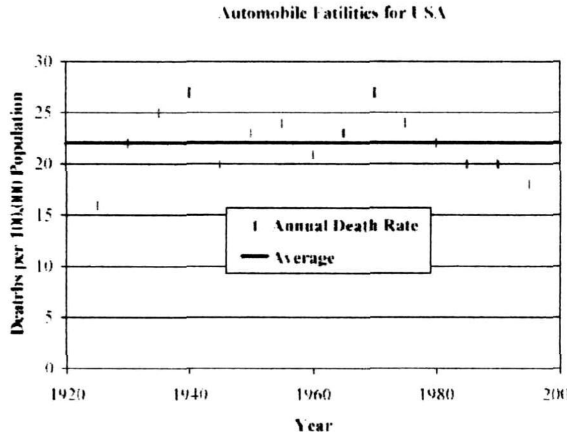

Figure 10. Risk of having a fatal automobile accident in the US (Adapted from Marchetti 1994).

3. The Center for Technology Forecasting at Maine Maritime Academy

3.1 Mission of the Center for Technology Forecasting

The mission of the Center for Technology Forecasting is to advance the art and science of technology forecasting, performing technology forecasts in maritime and other technologies to support the learning outcomes of students, the decision-making effectiveness of industry, government, and other institution leaders, and the enlightened understanding of human progress for the 21st century. The Center is undertaking primary research in advanced areas of system modeling, through theories of complex adaptive systems, evolutionary systems, theories of swarm behavior, etc., that show promise of extending our understanding of technology change and diffusion. The Center is interested in performing both broad and narrow studies of technology change in the maritime industry and maritime education and training.

3.2. Projecting Maritime Education and Training Technology Needs

The sample technology forecasts given in this paper point to new ways to understand the future needs of the maritime university. Table 1 lists suggested technology forecasts with references to the forecast samples above to illustrate the advantages and possible outcomes of the forecasts in the future of MET. The C4TF is looking for collaboration and support in these and similar areas of inquiry.

Inquiry	Forecast Technique (Sample)	Application in MET
How quickly will a new maritime technology be adopted?	Logistic Curve (Figures 1-4)	Timing the adoption of new training curriculum needs
Is our lab equipment obsolete?	Substitution (Figures 7-8) and Precursor (Figure 9)	Timing and amount of lab investment decisions
Can I reduce staff and offerings in certain degree programs?	Substitution (Figures 7-8)	Timing of course and curriculum change
Should we invest in new education technology?	Logistic Curve (Figures 1-4) and Substitution (Figures 7-8)	Timing and investment in education technology
What is the life expectancy of our PC network hardware?	Precursor (Figure 9) and Performance Envelope (Figure 5)	Timing and investment in technology infrastructure
Are the technology topics in this technical textbook appropriate?	Logistic Curve (Figures 1-4) and Substitution (Figures 7-8)	Optimize education value for students
What will be the typical crew size in the future?	Logistic Curve (Figures 1-4) and Invariants (Figure 10)	Appropriately sized training teams
Is there a custom-training opportunity for the future pleasure cruise industry?	Logistic Curve (Figures 1-4) and Substitution (Figures 7-8) and Performance Envelope (Figure 5)	Successful investment in new curriculum offerings

Table 1. Suggested technology forecasts for maritime university planning

4. Technological Challenges for Maritime University Leadership

4.1. Key Areas of Technology Change in MET

The general accelerated diffusion of technology change in most societies over the last several decades, and continuing today, poses serious challenges to the Maritime university administration and academic leaders. The areas of technology of most significance to the maritime education and training are found in three arenas: maritime, personal, and education technologies. The response, or preferably, the strategic plan to meet these challenges takes the forms equivalent to production, marketing, and new product development.

Terrestrial technology change has a history of inevitably transiting to sea. That is to say, advances in land transportation, communications, and other technologies, find their way aboard ship once proven sufficiently reliable and deemed seaworthy within the risks and bounds of maritime safety. Maritime education and training must be current with maritime industry technology skills requirements. Personal technology, from wireless communication devices to palmtop organizers, is changing the classroom (and extra-classroom) learning expectations and study habits of new students. Education technology, such as advanced turbine simulators, asynchronous distance learning technology, as well as tailored academic support systems for accounting, admissions, etc., is advancing in installations, complexity, and of course, cost.

4.2. Meeting the Challenges of Technology Change with Technology Forecasting

The maritime university executive is wise to trace the future trajectory of all these technologies, as they will impact the future operation and success of the school. Using analogies from industry, there are three areas where technology change will impact school decision-making: production, marketing, and product development.

The executive should ask, for example: When will I need to make investments in my curriculum to include training in a new technology undergoing adoption in industry (such as, say, fuel cell power plants)? A technology forecast will show the logistic growth of the technology and indicate when and to what degree the technology is being or will be utilized in the marketplace. Further, a historic perspective gained from precursor relationships of curriculum adoption versus industry adoption will tell the executive when to begin training in a new technology, very likely ahead of, and better able to help define, new education and training standards.

Having the teaching (by business analogy, "production") resources in place in a timely fashion will provide the competitive, relevant course content that attracts new students (the "marketing" parallel in business). Finally, the new graduating cadet, by analogy the "product" of the school, trained in skills not too far in advance of the technology adoption so as to be unusable, nor too far behind so as to be obsolete, is better prepared to serve society or to add value for the customer's of his or her company's business. All these positive results for the maritime university are reflected in the reputation of the university leadership.

4.3. Experience at Maine Maritime Academy

4.3.1. Electric Machines Laboratory

Projections of technology change were used in at least two strategic decisions regarding curriculum planning at MMA. A decision was made to relocate the electric power laboratory to make room for more classrooms in one of the campus academic buildings. Some consideration was given at first to reduce the overall size of the laboratory by eliminating floor space not utilized in the original lab room. However, arguments presented showing trends in maritime propulsion toward greater use of electric rather than steam energy, such as the US Navy's "all-electric ship" strategy, the continued diffusion of solid state drive technologies, and the highly distributed power on board cruise vessels, led to a decision for a larger electric power laboratory.

4.3.2. Fuel Cell Power Plant Research

An opportunity arose where MMA could partner with US government agencies, a key US shipbuilder, and other education institutions to explore the adoption of fuel cell power plant technology for both terrestrial power generation and ship's power. The performance envelope (Figure 6) of energy conversion, stretching over three centuries and forecasting fuel cell technologies to lead the energy conversion, was instrumental in securing Academy approvals to participate in the multi-million dollar research proposal.

5. Strategic Education Technology Planning

Part II of this series of papers on Maritime University Curriculum and Technology Planning for the 21st Century (see Walk 2001) provides specific procedures to include technology forecasting in a comprehensive strategic technology planning program for the maritime university.

6. Conclusion

Quantitative technology forecasting has a remarkable record in predicting change in technological performance and the timing and adoption of new technology. Various techniques of technology forecasting can be used to analyze trajectories of technologies influencing the maritime and education industries to improve maritime university curriculum and technology planning for the 21st century.

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