The success of business, industry and military relies heavily on efficient air and sea transportation systems (Goldsman, Pernet & Kang, 2002). Efficient transportation using standard sized containers generates logistical savings for businesses through economies of scale and flexibility in production and distribution. At the same time, cargo flow places significant stress on the U.S. transportation network. Major coastal container ports are currently operating near their maximum capacity, suffering from bottlenecks and delays in container movements. In the interim, the U.S. Department of Transportation (DOT) forecasts that by 2020, even at moderate rates of domestic growth, the international container trade will double from its current levels (Maritime Transportation System Task Force, 1999). Meanwhile, there is concern about the diminishing availability of skilled personnel that can operate in the wide variety of disciplines associated with port operations. Increasing cargo volume combined with a shrinking workforce can create alarming situations in the future, hence the motivation to publicize to current students the breadth and benefits of port-related careers in the hope that these students will become tomorrow’s skilled workforce. One possible first step to feed the pipeline of the port logistics profession is exposing young individuals to the world of port logistics and associated career opportunities.

According to Clark and Mathews (2000), visual technology enhances learning by providing a better understanding of the topic as well as motivating students. Visualization methods are widely credited for simplifying the presentation of difficult subjects as well as aiding cognition. Their use in the power engineering education is enjoying significant growth by ...(Idowu, Brinton, Hartmann, Nehard, Abraham, Boyer, 2006). To achieve efficient knowledge transmission
and understanding of port careers, a team of researchers from Old Dominion University created a web-based tool that simplifies complex port logistics topics and strives to motivate students to become engaged in related careers. Resolving an issue such as containerization, it can easily be solved on a screen with the use of virtual maps and arrows instead of confusing directions on a piece of paper.

The VisPort tool combines a high fidelity simulation of port operations with a rich, multimedia visualization of modern port careers aimed at promoting cognition of port logistics, improving higher order thinking and problem solving skills, and enhancing understanding of science, technology, engineering and mathematics (STEM) topics related to port logistics, sustainability and transportation disciplines (see Figure 4). The project emphasizes modeling and simulation of port logistics in order to provide a platform for introducing complex port logistics principles and problems that converse topics found in the Standards for Technological Literacy (STL) and national mathematics and science standards and engineering concepts. The project has the following specific goals:

- Provide a multimedia environment that allows students to learn about port careers, career ladders, required education, and most importantly, get a realistic sense for the day-to-day activities associated with each career.
- Provide a virtual-reality, first-hand experience associated with operating equipment and scheduling decisions associated with port operations.
- Provide a simulation of port logistics that can be used under instructor guidance, to experiment with alternative equipment, operations and algorithm selection while following the Engineering Design Process Model.
• Provide a tool that is usable to as wide range of students as possible through a web-based interface.

In addition to the educational goal, we envision students in the future using the tool to identify potential problems found in port operations and use the engineering design process, depicted in Figure 4, to recommend improvements to port operations in instructional scenarios.

![Figure 1 – Engineering Design Process Model.](adopted-from-www.nasa.gov/...)
The crane agent must move the boom on top of the container, latch it, then move the crane to the destination, lower it and unlatch, all of it in continuous time. While the simulation is executing, it is possible to switch the Artificial Intelligence (AI) that controls the crane with the program’s user so that the simulation can run autonomously or via the student's control. An opposing simulation methodology would be an event-based simulation in which the process of unloading a container would be an instantaneous event that takes place after a specific delay. In such a case, selectively replacing portions of the simulation to allow first person participation is not possible.

In an agent-based simulation, the fidelity of the AI algorithms used by each agent in the simulation governs the realism of the overall simulation. It is also possible to run the simulation in real-time or accelerated time modes. The accelerated mode is similar to time-lapse photography in which a two-hour period can be observed in a few minutes. This is particularly useful for learning the concepts of throughput and the impact of logistical delays.

Separate autonomous agents were designed for the ship captain, harbor pilot, crane operator, loading and unloading workers, container movement operators, truck drivers, security workers, and journeymen responsible for coordinating container movement. Subject matter experts were interviewed as to the process they use to implement their job. The results were then programmed into each agent. The containers and equipment were programmed to behave according to realistic physics. For example, container handling equipment speeds are programmed according to the actual equipment specifications, thus yielding realistic times for travel throughout the yard.

**Logistics of Container Movement**

The yard layout is depicted in Figure 1. A series of cranes transfer containers between the ship and the ground on the dockside, an area consisting of four lanes within which container movement equipment can travel to deliver/pick up containers. In order to minimize the time the
ship remains in berth, containers are quickly moved between the dock-side and the transfer yard, a portion of the overall port that acts as short-term storage for containers that have just been offloaded from the ship or are just about ready to be loaded onto the ship.

Figure 1 – Sample Port Layout.

Beyond the dockside, containers are moved between the transfer yard and the main storage yard, where they can remain for longer periods as necessary. The outgoing yard serves a purpose similar to the transfer yard, i.e., acts as a short term buffer for containers that are to be loaded to or have been delivered from trucks. Trucks from outside the yard drive onto the truck loading area where they can be loaded and/or unloaded and then depart without having to be exposed to drive through the rest of the yard. This layout is just one of the many possible ways to organize a port yard and was picked for this project because of its relative simplicity which nevertheless requires a wide range of realistic equipment, personnel and container handling.

Agent logic was programmed using state machines. For each agent, a series of states are defined. While in a state, an agent performs a specific task; completion of the task or messages from other agents cause state transitions, which allow sequential task execution. As an example
of this approach to programming agent behaviors, consider the straddle carrier, a flexible piece of equipment that is used to move containers from the dockside to the storage yard, rail or trucks. Figure 2 depicts a picture of a straddle carrier on the left and the visual model used to represent it in the Figure 3 simulation. The software architecture simulates the mechanical operation of the straddle carrier and the operator as two different agents. The straddle carrier operation is primarily a physics-based simulation that requires control inputs (throttle, steering, latch/unlatch commands) and simulates the movement of the equipment accordingly. The agent representing the human operator is programmed to act according to a series of task-driven states, as illustrated by the state transition diagram shown in Figure 2. This state diagram was generated by consulting with subject matter experts and converting the procedural description of the operator into a series of states that are amenable to programming in a computer.

**Figure 2 – Straddle Carrier**

Specifically, during port operations, a straddle carrier operator is first assigned a specific job, which may involve working the dockside to transfer yard loop, or the outgoing yard to truck loading area loop.
Figure 3 – Straddle Operator State Diagram.

The straddle carrier operator starts at the idle state, during which they do nothing until a task is received. In the actual port, this is done through a radio or similar equipment that displays the task on a dash-board inside the cab. The task includes the container location, typically specified as a row, column and layer. Once the task has been received, the operator drives the straddle carrier to the destination row by using any of the routes situated among the yard blocks. Once they arrive near the row, they will maneuver to line up the straddle carrier so it can straddle the row and reach the specific column, at which point they will latch the container (here for simplicity we assume it is the top container). Once the container is latched, the operator exits the row then travels to a specific row in the truck loading area. Straddle carrier operators typically perform a similar lining up maneuver and straddle the truck at which point the container is lowered on the truck bed. Finally, the operator advances past the track and then goes back to the yard entry point to wait for another task.

While at each state, the software simulating the agent generates control commands that are sent to the straddle carrier simulation which in turn causes the vehicle to move accordingly. When a user requests that they take over, the simulation simply removes the operator agent from the simulation and instead uses the commands from the human operator for guiding the vehicle.
The same approach is used for all autonomous agents involved in the simulation, although the only agents that can be replaced by the user in first person mode are the gantry crane operator, and drivers for three different types of container handling equipment (straddle carrier, reach stacker and port truck). The user can also choose to take on a role of a task scheduler and affect the assignment of resources or even micro-manage equipment assignments sent to other agents in the simulation. This mode is further described in the following section. This design provides maximum exposure to the challenges involved in each career associated with employment within the port.

**Scientific and Technical Visualization Curriculum**

Based on visual learning, the Scientific and Technical Visualization Curriculum designed to increase interest and understanding of geometry and science concepts; enhanced capabilities to visualize in both two (2-D) and three (3-D) dimensions; improved presentation skills as applied to mathematical and scientific concepts; higher competency in using the internet for accessing, processing, and sharing information (Clark and Mathews, 2000). According to Clark and Wiebe (2000) the scientific visualization courses, with which the scientific and visualization curriculum is created, expose students to all of the major and conceptual areas associated with visualization and give them experience in a broad range of graphic techniques. Also through this curriculum, students use analytical and communication tools to gain better understanding and appreciation and the advantage of being able to apply the new acquired skill – visualization — to further study the sciences enter the workforce or continue their study in multiple professions (Clark and Mathews, 2000).

The primary areas covered in the scientific and visualization curriculum courses
include: basic design process, graphing, image processing, animation, simulation, presentation, and publication (Clark and Mathews, 2000). Although the Scientific and Technical Visualization Curriculum is developed as a vocational track, it could be integrated with other academic subjects. The concepts and information used throughout the curriculum can be integrated easily into mathematics, science, and technology education classes (Clark & Wiebe, 2000). By using simple and complex visualization tools, students can conduct research, analyze phenomena, solve problems and communicate major topics identified in the Standards for Technology Literacy (STL) as well as topics aligned with national science and mathematics standards (Wiebe, Clark, Petlick & Ferzli, 2004).

Ernst and Clark (2006), state that a technologically literate person understands and effectively communicates basic technological concepts, processes, and interrelationships with engineering, mathematics, science, and society. Communication technology is an integral component of technological literacy; therefore, modeling, visualizations, and presentations enforce communication technology concepts (Ernst & Clark, 2006). Having strong communication concepts strengthens individual’s technological and scientific knowledge and abilities while providing students with an opportunity to gain a firm grasp of engineering principles behind the technologies (Newhagen, 1996).

Visual and technical literacy maintains a significant role in successful knowledge and skill development in engineering and technology career paths (Wiebe, Clark, Ferzli & McBroom, 2003).
Design Initiative for Students

The activity described below will emphasize modeling; simulation and application of port logistics in order to familiarize individuals and promote the persuasion of STEM related careers.

The project will emphasize modeling and simulation of physical systems in the port environments in order to bring real world problems closer to students interested in pursuing STEM related careers. The activity will include modeling and simulation of typical port logistics.

As a part of this activity, students will simulate port logistic applications, according to
specifications and under guidance of the instructor, which in this case will serve as the head of the port authority. To be able to complete this activity students need to be able to read technical specifications to determine different types of cranes and other types of transportation vehicles required in a port environment, therefore the use of the VisPort software is necessary. Starting this activity the students will receive instructions from the port authority including the number and type of cargo ships that will be visiting the port. As a second step they will lay out and mark a plan necessary to be distributed to crane and transportation vehicles operators. Once plan layouts are made students will simulate the arrival of a cargo ship and coordinate the different applications under specific time and space constraints. Logistic materials consisted of timers, sings, communication devices can also be used so students can better communicate and correspond with each other, during the loading and unloading process. Once operation is complete the students should prepare a report identifying glitches during the operation process and suggesting alternative ways of operation for future applications. Students should use at least one type of port logistics software during the plan layout process. At the end of the activity the instructor should evaluate the operation and specify positive and negative components.

Upon the observation of several complex port logistic systems and by using the engineering design process (see Figure 1), students will identify potential problems found on the port site. Following the second step of the engineering design process students will generate potential ideas and then using modeling and simulation techniques (M&S) all potential ideas will be analyzed and tested for the best one to be chosen. According to the results, the best idea will be chosen and executed during the port logistics activity. Upon completion of the activity an evaluation will take place for the students to draw conclusions and identify design flaws to be encountered.
Activities such as the one described above are easy to correlate with the standards for technological literacy created by the International Technology Education Association in 2000. See Table 1 for correlations with ITEA’s standards.

Table 1.

<table>
<thead>
<tr>
<th>The Nature of Technology</th>
<th>Technology and Society</th>
<th>Design</th>
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<tbody>
<tr>
<td><strong>Std. 1:</strong> Students will develop an understanding of the characteristics and scope of technology.</td>
<td><strong>Std. 4:</strong> Students will develop an understanding of the cultural, social, economic, and political effects of technology.</td>
<td><strong>Std. 8:</strong> Students will develop an understanding of the attributes of design.</td>
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<tr>
<td><strong>Std. 2:</strong> Students will develop an understanding of the core concepts of technology.</td>
<td><strong>Std. 5:</strong> Students will develop an understanding of the effects of technology on the environment.</td>
<td><strong>Std. 9:</strong> Students will develop an understanding of engineering design.</td>
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<tr>
<td><strong>Std. 3:</strong> Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.</td>
<td><strong>Std. 6:</strong> Students will develop an understanding of the role of society in the development and use of technology.</td>
<td><strong>Std. 10:</strong> Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.</td>
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<tr>
<td><strong>Std. 7:</strong> Students will develop an understanding of the influence of technology on</td>
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Summary

A standards-based project, Visualization in Port Logistics (VisPort), is designed to promote the use of visualization and simulation among grade 10-16 students to improve their higher order thinking, problem solving skills, and understanding of science, technology, engineering and mathematics (STEM) topics as it relates to the port logistics, sustainability and transportation disciplines. By experiencing the use of visualization tools along with related content knowledge the students gain a better understanding on complex port logistics principles, analyze, solve problems and converse topics found in the Standards for Technological Literacy (STL), national mathematics and science standards and engineering concepts. Within the end of the 2010 fiscal year the project team will create 4 units that will embrace areas such as transportation, sustainability, power and energy. Since not many existing curriculums specialize in the field of port logistics through the use of visualization tools it is anticipated that the new created units will embrace students learning and understanding in the STEM fields.
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