ABSTRACT

In one sentence the history of maritime simulation applied to teaching future sailors is primarily that simulators filled a vacuum left by the severe reduction in opportunities for on board training as a primary resource. Of course, simulators are in any case a valuable educational tool, but though the maritime instructor would consider them worth any expense for pedagogical uses alone, many administrators may be said to appreciate the added benefit of simulators for research purposes. These two uses merge most fortuitously when a news-making accident occurs, especially if the simulators are of a high quality and integrated. 6 February, 2008, “M/V Und Adriyatik” caught fire off the coast of Istria, in Croatian waters about three hours short of the Bay of Piran. Given the proximity to Slovene waters, we were immediately called upon to assess the dangers to the environment. Yet as classes were in session we were able to involve students in the process. This paper will describe the process and the results, emphasizing the interplay between faculty and students in a complex integrated simulator facility at which a potentially urgent current maritime event is occurring. A distillation of the thesis could be that partnership between student and professor during a news-making event provides both added stimulation for the student and elevates the simulator a degree toward a vehicle for practical training.

Keywords: Oil Spill Crisis Management, Integrated Maritime Simulator, Maritime Education
1. INTRODUCTION
Normally such a paper as this would start out by stating that maritime transport is of fundamental importance to Europe and the rest of the world and that to put this in perspective over 90% of European Union external trade goes by sea and more than 1 billion tons of freight a year are loaded and unloaded in EU ports, meaning that shipping is the most important mode of transport in terms of volume, and that, furthermore, as a result of its geography, its history and the effects of globalization, maritime transport will continue to be the most important transport mode in developing EU trade for the foreseeable future. But more important in the present paper is the need to both attract more students to maritime education and to provide them the incentive to study as intensively as possible using the best combination of educational tools and ideas. It is well known that students respond with more interest to real events than abstractions [Harsch, co-author, numerous studies and personal experience, which is actually more convincing], which is why in this paper we use the abstractions inherent in simulation in direct connection with real and real time events to ignite the deepest latent intellect in students and provide them the opportunity to learn while grasping the import of their studies to the world as it exists (in crisis) today.

Now, to guarantee the proper safety level of a vessel, cargo, crew and the environment, the main company personnel must have the appropriate qualifications. In the process of acquiring knowledge, all personnel should be exposed to the crucial multi-dimensional question "What happens if...” However, this paper also suggests the possibilities offered when this question can be altered to “What happens [or is happening or happened] when….” Proper simulation training provides an accessible introduction to background theories through the realistic operations of the simulator and at the same time provides a means to introduce students to applications to current crises.

Work with ship handling, cargo handling, engine room, vessel traffic service, oil spill and communication simulators demonstrably reduces the likelihood of human error - operational failures and miscommunications commonly cause major accidents and expensive breakdowns with severe economic, environmental, and health consequences. To perform high-quality training, especially for imparting management skills, an integrated simulator center that works with values computed physically and mathematically in real time is necessary. Different scenarios involving various malfunctions can be illustrated through such a system, even, and importantly, those unlikely to occur – and when students observe the use of simulation applied to real events they are clearly, in our experience, better able to understand the importance of this latter stipulation. Without simulation added training even good operators are relatively poorly trained for such situations (we,
Simulator centers may be configured on different levels. The complex integrated simulator center at the Faculty of Maritime Studies is linked through the secure Virtual Private Network (VPN) to external traffic sources such as the Automatic Identification System based VTS system at the Slovenian Maritime Administration office, the RADAR based VTS system at the Slovene littoral marine police station and the oceanographic and meteorological source at the marine biology station. This configuration enables effective training and competency assessment of shipmasters and deck officers. The center is also invaluable for research and investigation into port development, ship maneuvering and improving ship and port safety and efficiency. And it should be added that even such well known acronyms as RADAR remain abstractions until the student is afforded the opportunity to witness its utility.

During recent years our center supported several activities. First it was used for preparing a new national contingency plan, then for an exercise on the salvage procedure of a grounded tanker in which stakeholders from different governmental institutions (more than 70 participants) from Italy and Slovenia were trained for a week. Subsequently, it was used for studies on optimal allocation and resource acquisition for a new Slovenian oil spill public cleaning service. Last year it was used for collision risk assessment of the LNG terminal planned for Trieste bay in the precautionary area between traffic lanes and about 80 meters from the Slovenian border. Using the ship handling simulator (together with the students during their lab work) and designing scenarios based on the real AIS archives we demonstrated the unsuitability of the proposed LNG location - as a consequence, plans are being made to build the terminal at a new location outside the PA area. Meanwhile the center has always been used for the voluntary AESOP [Hata! Başvuru kayanızı bulunamadı.] research project, the goal of which is to use simulation to identify illicit polluters by combining satellite imagery, hindcast simulation, Automatic Identification System archive data and the recent history of weather/sea conditions. This was an important project with enormous added value for students. The first goal for the student was to acquire and monitor ship traffic in the northern Adriatic and as far as possible toward the south. For that purpose they themselves chose locations (mountains with optimal position and altitude), appropriate antenna, cabling, power mechanisms and the means to acquire more technology and later analyze shipping. The second goal was monitoring the environmental situation, mostly wind stress and surface current for the area and time planned for satellite overpass. The final goal was to identify potential illicit polluters. Of course, meanwhile a lot of discussion took place about pollution at sea and traffic incidents discovered during monitoring. The project has succeeded in identifying several illicit polluters, one of which was inspected by the Italian Coastguard in Venice.

This year we took on an extensive project related to finding possibilities for safe berthing in the proposed new layout of the Port of Koper. This was a great experience for all of us - faculty staff, students, real pilots and captains, tug masters, terminal staff and inspectors from the Slovène maritime administration (Because it is beyond the aspect of the pedagogical theme of this paper, we hope it is self-evident that the simulation centre provides beneficial training to stakeholders, as is directly evident here. What has derived the moniker ‘life-long learning’, which we believe to be a rather mundane pedagogical concept in that it is actually nothing but the natural project of the human brain to continue seeking, learning, solving, is such a natural use of the simulation centre that we take no credit for providing for it. At any rate, this group of students, regular and irregular (stakeholders) spent three weeks on the simulator repeating berthing procedures with different ships using three bridges simulating tugs which were steered by the students. The fortunate circumstance of university simulators being of import to a local and national project allowed for a rather unique experience—students working side by side with professionals.

Another employment of the center occurred last summer, a national exercise on oil spill combating, search and rescue, and fire fighting at sea. The agreed upon scenario was first reviewed using the simulators (accident prepared during lab work together with students) and later the optimal response was determined by using the simulator center.

During the real scope exercise students were onboard a fast rescue boat connected with the command center through a VHF radio station. Their task was to help us locate actual positions of the ship in distress, participating rescue ships (without AIS transponders - and the exercise was in the area outside radar coverage), oil at sea and booms. By sailing around the slick and alongside booms they automatically transmitted to the command centre the exact crisis spot layout through AIS transponders. In one intensive exercise students gained experience with and learned a great deal about the limitations and need of communication and communication devices, electronic navigation (its limitations as well in crisis situations), of course, understand that extensive practical training does develop excellent operators, but for lack of opportunity practical training no longer is available for enough students).
and, obviously SAR, including fire rescue procedures and oil spills along with contingencies involved (when might a boom just as well be a floating calamari cartilage…).

A very significant experience using our simulator occurred during the Israel-Lebanon war of summer 2006, when the Israelis bombed a refinery on the Lebanese coast south of Beirut. Though political explication is normally outside our province, as the theme of this paper is the general effectiveness of teaching in connection with reality, as soon as the incident occurred we discussed a very obvious question with our students; i.e., if the Israelis share a coast with Lebanon would they intentionally strike a refinery near the shore? The answer helps students to begin understanding the basics of oil at sea: as the wind and currents are definitively northeaster bound there was virtually no chance that the oil would drift down to Israeli beaches. The discussion led as far as to the question of war-time environmental assault. At any rate, the center was called by EC JRC to provide professional support for reading the progression of spilled heavy fuel oil from the bombed storage tank and the students were exposed to the importance of the center’s work by witnessing its efficacy on the international stage: results from that simulation were presented to the EU as well as at a NATO - CMS workshop in Halifax, and the paper for NATO is now a chapter in a book.

The subject of this paper, the burning of the RoRo ship “Und Adriyatik” was publicly significant in its own right, for obvious reasons, including the fact that the Ro-Ro ship is one of the most financially successful types operating today. Its flexibility, ability to integrate with other transport systems and speed of operation have made it extremely popular on many shipping routes. Although Ro-Ro’s have proved very successful commercially, some concern has been expressed about their safety - virtually since the first Ro-Ro ships were introduced. The whole design concept is different from that of traditional ships because of the introduction of a number of elements which make Ro-Ro ships unique [2]. One of the structural characteristics which of course enable fast cargo manipulation is that that ship is without transversal bulkheads which in case of water intrusion or fire can prevent spreading along the deck. This was the case onboard the Und Adriyatik, where fire spread from truck to truck and deck to deck so rapidly over all the ship that the crew didn’t have enough time to deploy the life boat - they saved their lives by jumping into the cold northern Adriatic early in the morning on the 6th of February 2008. They didn’t drop the anchor and thus the ship was allowed to drift while burning intensely towards the Istrian national park Brijoni. After that, we the maritime department stuff who run the crisis management simulator were enlisted to support the Slovenian crisis team with relevant information regarding the drift of a foreseen oil spill and the possible implantation of a booming procedure. Immediately, the working group occupied the crisis center and some tasks were delegated to the students; such as finding on the web the news and pictures from surveillance planes, providing meteorological and oceanographic data from the accident location (Croatian EEZ area 60 miles south from Slovenian waters), scanning the radio frequencies, searching for the ship’s particulars; and later constructing together the ship’s drifting scenario on the ship handling simulator and using the crisis management application Pisces to model potential oil spill transport over the water and corresponding booming.

To further illustrate our theme, as we write news is leaking out about an oil spill in the Mississippi river near New Orleans, the result of a collision between a tanker and a barge. Over 419,000 Gallons’ of fuel oil (about 1500 tons) and an undisclosed amount of other toxic substances went into the water. The immediacy of the event is a natural pedagogical tool, as is the case we describe in the paper. If school were in session at the moment, we would ask the students the obvious question: How does this case differ from the case of the Turkey ship that burst into flames off Istra? One student would quickly say ‘There is no fire this time’. Another would point out that this crisis was caused by a collision, and perhaps therefore require a very different respond with oil spill consigning. But the answer we would be waiting for is that responding to oil spill in a river poses a very different task from that of a burning ship. (High current, narrow sailing area, shipping problem…) Regardless, the point we wish to make is that as long as crises occur, actual crises present an exceptional didactic tool, especially if one has the means to study their circumstances and effects - in this case to teach from the centrifugal point of modeling via simulation.

2. SETTING THE SCENE – FIRE ON BOARD THE RO-RO “UND ADRIYATIK”

In the early morning on the 6th of February 2008, the Und Adriyatik was sailing on its regular route between Istanbul and Trieste. As with her three sister ships of the same company her usual cargo is trucks and trailers and some passengers (truck drivers). The ship was sailing on the course 334° inside TSS with a speed of 20.6 kt. At 04:51 local time the AIS system showed a ship slowly reducing speed. At 04:57 the speed was 6 kt. At 05:04 LT Croatian, Italian and Slovenian Maritime Rescue Centers received a mayday on channel 16 from the ship in distress - Und Adriyatik, situated at 44°56.7’ North and 013°21’ East. The ship was just outside Croatian territorial waters - 12.74 Nm from the islands before the city of Rovinj inside the EEZ area; thus it was their responsibility to conduct SAR operations. At 05:09 the ship’s speed was reduced down to 4 kt. At
05:15 the ship was almost stopped and oriented to the west. At 05:20 the last communication came from the ship: that they could not control the fire and that 22 crew members and 9 passengers were abandoning the ship. At 05:24 the Croatian MRCC decided to send three ships to take care of castaways: cargo ship “RIK”, platform supplier “Brodospas Sun” and a passing Greek ferry, “Ikarus Palace”, which replayed at 05:30 that they could see smoke. At the same time Und Adriyatik was floating still at the position 44°57.49′N 013°20.69′E, from where they slowly began drifting on the course 180° at a speed of 0.5 kt before slowly changing heading from west to SWS, at the same time increasing her drift speed to as much as 1.5 kt. At 06:10 AIS information from the ship vanished. Ikarus Palace probably arrived to the distress area about 06:30 – but this cannot be clear because this ship, though quite large, was without an AIS signal the entire time. RIK arrived on the spot at 05:45. At 07:06 the message was received that all crew members and passengers’ were save onboard Ikarus Palace and that three crew members and two passengers needed medical care, which it was decided would be provided in Venice. At 07:15 “RIK” left the scene and at 07:45 the supplier vessel Brodospas Sun arrived to the burning ship, leaving at 09:30. That is the complete timeline for the activities beginning with the first indication from AIS that something may be wrong until the last potential rescue vessel left the burning ship.

Later it was learned that two tugs arrived voluntary (around 8 and 10), one from a platform and the other from the Pula shipyard. They began pouring water over the aft and starboard side of the sip as much as the circumstances allowed given to the severe heat release. The large tug boats specially built for rescuing waited in Rijeka until almost noon, when the Croatian command center finally decided to send them. They arrived alongside the ship around 19:30, by which time the ship had already drifted more than 10 nautical miles towards the Istrian coast and was just 7 miles from Brijuni national park.

Another attempt to gain control over the blaze was made by aircraft (decided at 12:10)[3], but the first eight flights were ineffective, as the fire was below deck. The following afternoon, the burning was reduced somewhat by this method as breaches on deck allowed some water to reach the fire below.

From the first the morning it was not clear whether there was any dangerous cargo onboard the vessel, despite the fact that all 202 trucks and trailers being transported would naturally be classified dangerous due to the fact that each of track had two full reservoirs of diesel oil (up to 500 liters, or all together close to 40 tons). Additionally, there was about 8 tons of different oil, some chemicals, and about two tons of matches. According to the mandatory ship reporting system in the Adriatic sea, such a ship should send such information to the relevant authorities about the dangerous goods classified in the IMDG Code, Chapter 17 of the IBC Code and in Chapter 19 of the IGC Code, as well about polluting goods as defined in MARPOL Annex I, noxious liquid substances as defined in MARPOL Annex II, harmful substances as defined in MARPOL Annex III. Regulation applies to any oil tanker of 150 gross tonnage and above and all ships of 300 gross tonnage and above, carrying on board, as cargo, dangerous or polluting goods, in bulk or in packages. The operational area of the mandatory ship reporting system covers the whole Adriatic Sea, north from the latitude 40° 25′.00 N. This area is divided into five sectors, each of them assigned to a competent authority, operating on a VHF channel. So this ship passed 4 controlling sectors without sending any report to the competent authority (in Brindisi, Bar, Rijeka and Ancona). (For the professor this actually quite common disregard of regulations fits into the extremely important theme regarding the difference between theory and practice, which any seaman discerns quite quickly is an issue once at work at sea, yet is possible to convey with some gravidity in a real crisis situation such as this – there should have been no doubt from the beginning of the incident that this ship was to be treated as one hauling dangerous cargo.)

Missing information about the type of burning cargo can be disastrous; and this probably explains why the Croatian crisis team waited so long before initiating any fire fighting response. Nonetheless, they did make an unnecessary mistake by not sending a fast rescue boat from any or several ports in the vicinity of the accident to collect the crew and passengers from the cold sea. Such a boat could have arrived to the distress location in less than 30 minutes from Pula. Another mistake was not accepting help from the Italian Coast Guard air surveillance division – they asked for this later so that a plane arrived on the spot as the rescue boat from the Ikarus Palace was returning to that vessel. When a seaman/passerenger is in the water it is always good to have air support in order to help in locating the potential lost.

Back ‘onboard’, the first expectation regarding the Und Adriyatik was that due to the intensive burning and visible hull degradation and deformation was that it would be a total loss. Slovenia thus quickly offered booms. This support was also rejected; the Croatian team was able to provide sufficient booms of their own - yet only on the following day. This was quite risky given the rapidity with which the burning vessel was approaching shallow waters. Though it may appear humorous in retrospect, the staff in charge was waiting
for the onset of an imminent bora (a strong, gusty but steady northeast wind) to blow the ship away from the shore [4]. At 18:00 we heard on channel 24 that the position of the ship was 44°56.6’ N 013°32.4’ E. The ship was still drifting freely towards shore but the speed was reduced and the course was slightly toward ENE. Around this time, an intuitive student asked whether it would not be possible to approach to make the ship fast, as the stern the ship had been extensively cooled by the two tug boats - since 19:30 when the two specialized tug boats arrived from Rijeka (both equipped with AIS transponders) it was again possible to continue monitoring the ship’s position; at 22:00 the ship at 44°58.3’ N 013°32.9’ E, having drifted north, and then, after midnight, beginning to move south: to 44°52.5’ N 013°37.5’ E by 07:30 the next day - on that next morning Italian tugs arrived and indeed made fast the ship at 11:00. The ship was still burning but now the drifting was under control, just on time before the onset of the Bora.

Figure 1: “Und Adriyat” distress location and respond with MV “RIK” and “Brodospas Sun” [05:30]

Clearly a number of factors contributed to a dangerous situation becoming potentially more dangerous in numerous ways. For instance, making the ship fast was necessary because the anchor was not dropped, and thus the tug pilots who accomplished the task may have been risking their lives unnecessarily, for an explosion may have been possible (of course, other dangers are presented by a drifting, burning ship as well). Yet part of the didactic process includes making a leap into the mind of the captain of a ship in distress, who is faced not only with a Mayday situation, but a number of unexpected instances of bad luck: the fire was between the crew and their main life raft; the sprinkler system failed; the alarms didn’t go off; no pumps worked; the fire heated the deck to an unbearable degree very rapidly. Not only that several of his crew were seriously injured (mostly broken bones, though the captain himself suffered burns). He had literally but seconds to make a decision about dropping the anchor, which he could easily have managed as the safest place on the ship was at the bow. Quite likely he abandoned ship more rapidly than he might have if he had not feared explosion, and this may be the very reason he did not drop the anchor, for an anchored burning ship is an invitation to tugs that may have been annihilated by a large blast.

2.1. Fire Onboard

We feel it is worth stating that fire is one of the most dangerous situations a ship and the people it carries on board might experience because for the student this is counter-intuitive – ships run aground, collide with other vessels, run afoul of bad weather, etc.; in other words, they risk sinking. But of course a fire can sink a ship as well. Still, the main goal of everybody involved in fire-fighting is to avoid the loss of both the ship and the lives of those onboard. A survey of total loss accidents in merchant shipping over a period of 25 years shows that these can be arranged in the following order: stranding, fire, water-leaks, gales and collision
It is shown that fire together with explosion amounts to 25% of maritime casualty returns in the total loss lists. It is also a fact that a fire aboard a ship often starts in the engine room. From the research carried out by project PHOENIX [6] (during the 6-year period from 1990 to 1996, when 955 fire casualty vessels were examined), negligence is suspected to be the main cause for fire accidents, the majority of which started in the engine rooms, “Figure 2”. The situation in this sense reflects a great need for education and training. The consequences of the accidents studied, in the majority of cases, were not significant. General cargo vessels would seem to be those most prone to developing a fire on board. Vessels over 15 years of age show a tendency toward high risk. On the other hand, vessels to which the most recent amendments to SOLAS Chapter II-2 apply tend towards a lesser risk of fire on board. Vessels with a tonnage above 10,000 but less than 50,000 also show a tendency toward high risk. As might be expected, the risk of accidents is higher when the vessel is under way. In this situation, the majority of fires start in the engine room.

The Und Adryatik was registered by Det Norske VERITAS classification house and according to them [0] enclosed Ro-Ro decks and special category spaces on ro-ro ships are in many ways ‘fire-protected’ to a standard equivalent to that for engine rooms. The boundaries are enclosed by A-class divisions, fire hoses and portable equipment is provided in adequate numbers and a fixed fire extinguishing system, typically CO2 on cargo ships and deluge (water spray) on ferries shall be provided for enclosed spaces. Such spaces shall also be provided with a smoke detection system. Fire patrol is required for special category space and good ISM practice for Ro-Ro spaces on cargo ships. Compliance with Dangerous Goods Regulations will add somewhat, basically more fire hoses. Open cargo decks have in general no fixed fire extinguishing system (even when carrying dangerous goods). Furthermore according to DNV the degree of fire hazard where in this case it actually occurred, among the cargo, can be said to be lower than that expected for an engine room.

The combustibles may be notable, like gasoline and goods of various kinds; however there are no obvious fire sources - parked cars and trucks, statistically, are very infrequently the cause of fires that resulted in significant damage. Appropriate enclosure or ex standard (as applicable) for the ship’s electrical system together with an effective ventilation system geared toward preventing flammable gases and any leakages from being ignited should help ensure the safety of the Ro-Ro.

This is naturally the prevailing situation only until a fire actually does occur, and furthermore, fire (or explosion, the two being inseparable for statistical purposes) is the most likely reason for the total loss of a Ro-Ro (Dimitris, 2005). (Table 1.)

Figure 2: Casualties starting place and relationship between cause and casualties
Table 1: Percentage of Accident Cases with Total Ship Loss for Different Types of Accidents [8]

<table>
<thead>
<tr>
<th>Accident type</th>
<th>Description</th>
<th>Percentage of accident cases with total ship loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grounding</td>
<td>Touching of the sea bottom or underwater wrecks for a significant period of time</td>
<td>9.50%</td>
</tr>
<tr>
<td>Contact</td>
<td>Striking an external surface substance (not another ship) such as drilling rigs or platforms, etc.</td>
<td>2.60%</td>
</tr>
<tr>
<td>Collision</td>
<td>Striking another ship, regardless of whether underway, anchored, or moored</td>
<td>7.40%</td>
</tr>
<tr>
<td>Fire/explosion</td>
<td>Fire or explosion, regardless of the cause</td>
<td>14.20%</td>
</tr>
<tr>
<td>Hull/machinery damage</td>
<td>Any case of hull/machinery damage or failure</td>
<td>6.40%</td>
</tr>
</tbody>
</table>

3. TOOLS - MARITIME TRAINING CENTER
Yearly over 5000 ships sail into the gulf of Trieste destined to ports in Koper, Trieste, Monfalcone and Portorož. These include a great deal of dangerous cargo, such as crude oil, crude oil derivatives and various chemicals. The dangerous cargo transport exceeds 40 million tons a year. For the sensitive area of the Slovene coastal region the danger is not represented only by the ships that transport dangerous cargo: every ship signifies danger whether from the point of view of intentional discharge of oily water, noxious organisms in the ballast water, or within the ship’s hull or a discharge of bunker fuel caused by collision or grounding.

The most sensitive part of the Slovenian coast is the western, where the salt pans and the regional park are situated. For insuring such areas, the reinstatement of instruments of international cooperation for the joint arrangements on sea and the vessel traffic management system are very important. As part of preparing the National Oil and Chemical Spill Contingency Plan for Slovenia (NOCSCP), in which the Faculty of Maritime Studies and Transportation has taken active part, the Potential Incident Simulation, Control and Evaluation System (PISCES) is a response simulator intended for preparing and conducting command centre exercises and area drills in oil spill response [9]. PISCES is oriented to the accomplishment of tasks required by the Oil Pollution Act 1990 (OPA 90) to provide improved training for spill response managers. PISCES provides exercise participants with an interactive informational environment based on the mathematical modeling of an oil spill interacting with surroundings and combat facilities. The program uses vector-based nautical charts to provide a geographic description of the incident area. Vessel traffic and positions of response resources are shown on the chart. The system also includes information-collecting facilities to enable the assessment of the participants’ performance.

3.1. PISCES 2 - Oil Spill drifting and weathering application
The PISCES model reflects the common understanding of the behavior of oil spills on the sea surface (we learned in the Lebanon case that sometimes the behavior of oil beneath the surface is definitive). The model describes oil spills on the water surface in the first days of release when response operations are carried out. The initial amount of spilled oil varies from 10 to thousands of tons. For the description of an oil slick the PISCES model uses the Lagrangian approach, which is an effective technique of oil spill numerical simulation. The oil spill is represented by an ensemble of particles moving under the effect of wind and current. The distinctive feature of the model is the extension of the Lagrangian approach by introducing interactions between oil particles [10]. This innovation allows compensation for some essential deficits of the traditional Lagrangian methods and to describe in a satisfactory manner oil interaction with different kinds of natural and artificial barriers.

The processes occurring in the oil slick are also taken into account and include evaporation, natural dispersion, emulsification, and viscosity variations. Simulations are carried out with regard to the environment representation, including complex coastline descriptions and a variable field of currents and weather conditions. In addition, models of response operations such as burning, booming and skimming are implemented. The movement of an oil slick is assumed to be two-dimensional and resulting from transport by currents and wind, spreading and stochastic diffusion. According to the generally accepted approximation oil particles move 100% with a stream and 3% downwind. Diffusion adds to this movement a random component. The spreading of the oil slick is adjusted in order to match the well known approximation of Fay
with corrections introduced by Lehr to take into account downwind elongation. For the description of weathering processes the oil product is represented in the same way as in the ADIOS (National Oceanic and Atmospheric Administration) oil library and characterized by a common product name, type (e.g.; crude or refined), specific gravity, surface tension, viscosity, distillation curve, emulsification constant, pour and flash points. The evaporation process is simulated by using a pseudo-component approach and uses the evaporative algorithm proposed by Stiver [12] and Mackay [13].

This method calculates the evaporation rate as a function of wind, slick area and oil properties such as the distillation curve.

Processes of emulsification and natural dispersion are described with empirical dependencies proposed by Mackey. Both dependencies take into account strength of wind and oil properties. The emulsification process starts as soon as a fraction of evaporated oil reaches the emulsification constant, which is determined by derivation from the experimental data. Emulsification stops when water content in the floating emulsion mixture reaches its maximum. The maximum is an empirical value. It is usually about 75% for crude oils and 25% for refined products. The algorithm for natural dispersion takes into account oil-water surface tension, oil viscosity and slick thickness. Viscosity variation due to emulsion formation is defined by the Mooney (Mooney, 1951) equation, and the evaporation effect is taken into account according to the Mackey solution.

Figure 3: Interference of model components

3.2. Integration in the Frame of Contingency Training and Major Crisis Response

The configuration of the customized installed crisis equipment is quite unique. The PISCES simulator is connected to three ship handling simulators of which one is Full Mission on a floating platform. Besides the navigational simulator, which has Vessel Traffic Component (VTS) and Search and Rescue (SAR) module with helicopter console is integrated with eight communicating GMDSS stations. There is a full mission engine room simulator which is also connected to the ship handling simulator. A cargo handling simulator (CHS) as part of the ERS simulator is located on the main bridge. The PISCES simulator is also equipped with five operative stations, designed for Civil Protection, Port Authority, Marine Police, Navy and Researchers from the Faculty or the Environmental Agency. The simulator can work not only as educational equipment, but also for actual assistance on the occasion of an oil spill (Perkovic et al., 2006). PISCES can receive on-line data from the Automatic Identification System receiver, which is located on Mt. Slavnik and directed by the Port Authority. Because of the ideal height of the receiving antenna it is possible to supervise ships as far as the city of Split (200 nautical miles) [14].

Besides the abovementioned, traffic data is acquired and relayed to the simulator center with RADAR based VTS located at the marine police station. Meteorological and oceanographic parameters are integrated into the GIS on near real time from the marine biological station. Chemical processes in the combustion of the stain are also presented on PISCES GIS. The process is calculated with ALOHA software made by the National Oceanic and Atmospheric Administration. The simulator center is further equipped with an AIS receiver, Marine VHF transceiver, HF/MF receiver and digital decoder, phones and fax machine.

Such configuration provides feasibility to use simulator also for real crisis management at sea. It is also possible to use the simulator for different research work similar to identifying illicit oil spill polluters and to use the simulator for replying spillage processes. Detail structure of Crisis System is described in figure 4.
4. METHODS AND RESULTS - SIMULATION BASED DECISION MAKING

Four hours after the distress call from the burning “Und Adriyatik” was released we were asked to support the Regional Civil Protection unit by preparing a forecast for drift of a potential oil spill and to make the plans for deploying boom. During the early morning the available information was obtained from the Slovenian Maritime Administration, such as; distress time, position, the ship’s name, information regarding the lost AIS signal from the ship in distress and some news about the crew who had already. In the first year of their nautical education, the students are taught the importance of such basic, at times obvious, though in the abstract mundane information. A degree of disconnect is always discernable [Harsch], and though we do not advocate the burning of ships, when the Und Adriyatik was on fire our students experienced that which they had been taught, and were no longer functioning on pure memory. Our first step was to start the oil spill crisis application PISCES 2 and to acquire on-line AIS data. We were surprised to find that four hours after the “mayday” there was no single ship equipped with an AIS transponder, so it was not possible do determine the ship’s position that time. From the VHF radio we heard about very intensive fires and that total loss with sinking was to be expected. Another step was to contact Maritime Administration for the list of dangerous cargo on board – the reply was that no single report had been issued from this ship to any costal station during her sailing through the Adriatic Sea (our students needed no explanation of the seriousness of this lapse).

One of our students was instructed to begin checking Croatian web pages for any news about the cargo on board the ship and about the fuel which could be spilled into the sea. He was also looking for photos of the burning ships and any video recorded by planes. Another checked the web and Equasis database for any ship particulars focusing on bunker tank quantities.

4.1. Preliminary Simulation

Meanwhile we prepared the first oil spill simulation based on the daily average forecast from the Adriatic Forecasting System and the Mediterranean Forecasting System “Adricsom” [15] managed by GNOO-INGV (Gruppo Nazionale di Oceanografia Operativa - Istituto Nazionale di Geofisica e Vulcanologia), which had already been used successfully several times during our previous research work on detecting illicit oil slicks and identifying polluters at sea. At that moment (due to the some administrative work on their server) we were without high resolution data of surface currents (which are very important during the initial oil release stage), so we used freely available data from the web. Figure 5 shows Wind Stress and Field of Surface Current Velocity for the first two days. The oil releasing scenario was based on the presumption that oil IFO 300 was spilled on 06/02 at 13:00 from the last known position (44°57.6’N 013°20.8’E) (The Maritime Administration provided this position as it was just before the termination of the ship’s AIS signal at 06:10).
with the ratio of 50 t/h for the first two hours and later with the ratio of 10 t/h over the next 22 h. The top frame on the next illustration (Figure 6) describes our preliminary simulation with the oil position on 08/02 at 18:00 (after two days and 5 h). It is clearly visible that the slick is oriented towards Italy – another reason for establishing immediate contact with GNOO - to inform them about the seriousness of the situation as well as to ask them for more accurate data and of course to get a second opinion. We gave them all available information about the accident and the contact with the Italian Coast Guard in Rome - but they didn’t provide us high resolution wind and current data. Nevertheless their simulations were similar to our preliminary one. The middle and bottom frames on the left side of Figure 6 is the result of the forecast of the evolution of the slick (two days after the instant oil release according to the scenario at 06/02 at 00:00, taking into account only its advection due to the surface current fields coming from an ocean circulation model with approximately 2.2 km of horizontal resolution, without considering the weathering of the oil [16]. The black lines represent the trajectory of the oil particles. Colours in the background represent the bathymetry.

Figure 5: Average daily forecast for the Wind Stress and Surface Currents Velocity for the first two days.
Frames on the right side are the results of the forecast of the evolution of the slick considering its advection due to the surface current fields coming from an ocean circulation model with approximately 6.5 km of horizontal resolution, and also considering the weathering of the oil. The black arrows represent the intensity and direction of the current, while the white arrow represents the intensity and direction of the wind [16]. The oil spill is represented by the coloured cloud of dots and shows the condition after two days after an initial spill of 800 tons of heavy fuel oil occurring momentarily on 06/02 at 04:00. This simulation is quite similar to our work; the difference in progress can be justified by considering different starting times and the simulation period which is in our case longer by 5 hours and shifted towards next day (when according to the forecast a strong NE wind would be blowing) for 9 hours.

Figure 6: Preliminary oil spill drifting simulation; top by using PISCES 2, left with advection due to the surface current and without weathering, right by using MEDSLICK application.
Just after finalizing our first report, we heard on the radio that the new position which was at 13:40, 13°28’ E. This position is exactly 6.9 nautical miles away from the last known position at 06:10, and it means that the ship was drifting on the course of 130° at the speed of 0.92 kt. The ship’s drift clearly depicted that something was wrong with our input parameters regarding the wind and currents. We knew that we could find a more accurate wind reading from the coast, but finding readings of conditions for the ship’s location without establishing contact with an on-scene unit is always difficult, especially for the current and waves conditions.

4.2. Improved Simulation
We rapidly made a second simulation based on another source of wind conditions. This time we decided to check the first wind forecast from the WindGuru source [17]. Their forecast is visible from the first frame of Figure 7, describing that there was a west wind during the morning and afternoon that would change to SE for a short period and after that quickly change from the NW to the forecasted and expected NE wind. The right frame on the same picture shows the ALADIN [18] forecast trajectories for an air particle released at 12:00 at altitude 10 m (blue line) and altitude approximately 800 m (red line). ALADIN shows that on that afternoon the west wind would turn to the NW and that particles would already be far from the original point and not be affected by the Bora. The last frame shows the wind field acquired by the morning overpass of the NOAA satellite and analyzed by the QSCAT [19]. The light blue color points to a NW wind with the speed of 5m/s. This was enough to prepare the second simulation based just on the wind force. A significant difference in the released oil footprint is evident from Figure 8. At that moment we could not find any appropriate clue regarding the surface currents and it is obvious that at the edge of the Istrian peninsula the currents field may become complex and can quickly change also due to tides. Further simulation would have to wait.

4.3. Postponing Simulation
After the crisis we decided to re-analyze this case to find a means for improvement. For this purpose we checked several resources to determine the evolution of the crisis through the first day. First we made a detailed analysis of the initial drift of the abandoned ship (Figure 9), the idea being to discover the currents from the drifting footprint provided through AIS. AIS retrieval clearly shows the ship’s position, speed, heading and course.
Figure 8: Oil spill simulation – initial release and continuous release from the drifting ship (Δt=20h)

From the series of pictures below we can note the drifting speed and course related to the ship’s heading. When the ship was directed towards the east her speed was almost zero; after that the ship slowly moved towards the south, her speed slowly increasing while the heading at that point didn’t change much – she was, let’s say, in a sort of state of equilibrium. After her speed increased to about 0.5 kt, her heading began changing towards the south with the Rate of Turning at -5°/min. The change in heading directly influenced the increase of drifting speed up to 1.5 kt in the direction about 110°, as the ship exposed herself at a position nearly perpendicular to the wind. This was probably not the steady-state situation, but after that the AIS signal was lost and it was only possible to have approximate locations in discrete times. One of the sources we used to find out the ship’s position and eventually the wind direction was from the smoke orientation (from illustrations from the MODIS optical satellite), (Figure 10), [20]. The figure shows smoke from the ship in distress. (The satellite picture is geo-referenced by the Google Earth system.)

Figure 9: Ship’s Inertia and drifting according to AIS
Figure 10: Smoke from the “Und Adriyatik” acquired by the optical satellite MODIS and geo-referenced on Google Earth (12:25 GMT).

The complete inertial trajectory and initial drifting loop is clearly shown by figure 11. From this loop it was possible to determine out the wind condition on the spot. For that purpose we decided to use our integrating simulator to reproduce the real scenario. Transas ship handling simulator (NTPro 4.62) was used as a tool for modeling the ship’s drift. From the object database we found that a similar Ro-Ro ship which was exposed to the NW wind and similar loop was easily reproduced without considering the currents field. Without considering currents – the ship’s ROT (Rate Of Turning) was faster – we were not able to get the same “equilibrium state” for the moment when the ship was heading west. This was a clear indication that we needed to consider the currents field. The question was how to get that information. Probably the only possibility was by analyzing the life raft drift. There are many studies and full scope experiments regarding life raft leeway\(^1\) [21, 22]. From those experiments we can determine that a heavily loaded life raft of the size 4-7 persons cannot drift in the wind of 20 kt with a speed greater than 0.7 kt. In this case a 6 person life raft was loaded with 19 crew members and passengers and a few more clinging to the life raft and actually acting on it as something of a drogue. Thanks to the Italian Coastguard who gave us photos from the first morning’s over-flight it was possible to determine the life raft’s position when it was reached by rescuers - about half a mile NNE from the ship. This means that the life raft drifted at least at the same speed as the ship, which drifted on average at a speed of 1.2 kt. This point to the state of the surface currents, which had a speed of some 0.5 kt directed to the E or ENE. Simulated drifts including surface currents and winds are shown by figure 12 together with the ship’s AIS trajectory. The simulated drift of the ship was transmitted through the AIS transponder to the VTS simulator called Navi Harbour. The oil spill application PISCES 2 can receive the traffic information from the VTS simulator or real VTS application and this enables the possibility to attach continuous oil release to any floating object. In our case the next figure (Figure 12) shows simulations of two hypothetical spills - one for the case of an instant spill of 760 tons HFO and the other for a continuous 24h release spill from the drifting ship. In both cases the same wind was used as in the previous simulation - but here we also considered surface currents field constructed automatically from one point (at the initial ship’s position) by the oil spill application PISCES 2. The big difference in the spilled (oily covered sea surface area) area is evident. During this extended period the benefit to the students of their initial involvement was clear. They understood more rapidly than usual the process involved and the gravidity of various data. At the end the most common point of understanding was that allowing the ship to drift rapidly increased the potential threat. An interesting ancillary benefit of this particular case was that no one was

---

\(^1\) “Leeway is the velocity vector of the SAR object relative to the downwind direction at the search object as it moves relative to the surface current as measured between 0.3 and 1.0 m depth caused by the winds (adjusted to a reference height of 10 m) and waves.” (Fitzgerald et al., 1994; Allen and Plourde, 1999)
killed, there was no environmental damage worth mentioning, the fire was put out, the ship was not a total loss, and yet the very anti-climactic nature of the story illustrated to the students the importance of safety measures in general.

This unquantifiable yet definite added benefit of course requires the flexibility of the professors, who must immediately identify the vast educational potential of the crisis and invite the students into the story. The strange combination of a mundane yet fascinating notion – that we had to turn to the movement of the life boat to determine surface currents – became in this case a fulcrum point at which the students became scientific thinkers.

Figure 11: Comparison of the ship’s drift based on the real AIS trajectory with the simulated one

Figure 12: Oil spill simulation – with the winds and the field of surface currents (Δt=24h)
5. CONCLUSION

Shipping is perhaps the most international of all the world's great industries - and potentially one of the most hazardous. It has long been recognized that the best way of improving safety at sea is by developing international regulations that are followed by all shipping nations. The Und Adrazytik case will certainly contribute to the overall safety in the Adriatic Sea. The drama which happened early in the morning was not significant only for the seamen and passengers on board the ship who spent more than an hour in the dark and cold sea and for the ship-owner who lost his ship and cargo but mainly for the responsible authorities. This case should be the last warning to set up a preparedness and response system and mainly to improve coordination and regional cooperation. We as a researching and education institution will further support authorities during the crisis situation. This and other similar cases are also great added value for education purposes. Students involved in such a living crisis are usually more motivated for further work. And obviously they gain valuable experience regarding ‘real life’.

Limitation
An extensive study was done to find out wind conditions and surface currents as well as the ship’s drifting during the first 24 hours. However this work could not include much consideration of the tidal currents, which we were not able to derive from any source and it is likely that these may affect a presumed oil spill’s drifting. This part is still under research. The presumed oil release of the entirety of the bunker fuel is also unlikely to occur in reality but the foot print from a continuous release would be similar even for a release of a smaller amount of heavy fuel oil.

Acknowledgement
Some very important information was obtained from the Italian Coast Guard office and Slovenian Maritime Administration. We would like to express special thanks to Cdr. Dario Cau, Cdr. Vittorio Pagotto, Cpt. Primo Bajec and Cpt. Matjaz Felician. Additional thanks we would like to express to Ms. Barbara Burgarelli (JRC) for the fine analysis of the Modis satellite image.

6. REFERENCES

ADRICOSM, Adriatic Sea Integrated Costal Areas and River Basin Management System Pilot Project, [http://www.bo.ingv.it/adricosm/](http://www.bo.ingv.it/adricosm/)
Investigation of Leeway and drift for ovatek life rafts, Project final report, Oceans, 2006, Kod Rovinja se zapalio turski teretni brod krmeni deo potpuno izgorio, [http://www.index.hr/vijest/clanak](http://www.index.hr/vijest/clanak)

477
Journal
Environ. Sci. & Tech., 18, pp.834-840
Tonani, M., Guarnieri, A., De Dominicis, M., Coppini, G., Pinardi, N.; Oil spill risk in the Adriatic Sea: an
example of operational support capability in aid to the management of emergency, http://www.ingv.it/
WINDGURU, Special wind and weather forecasts, http://www.windguru.com/int/