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Applications of GNOM Robot

Joseph Patrick Lombardi
Worcester Polytechnic Institute

Patrick Michael Trant
Worcester Polytechnic Institute

Tucker Caelan Haydon
Worcester Polytechnic Institute

Walter Gage Gallati
Worcester Polytechnic Institute

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Project by:

Walter Gallati   Joseph Lombardi

Tucker Haydon   Patrick Trant

Advised by:

Professor Thomas Balistrieri   Professor Oleg Pavlov

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ABSTRACT

Astrakhan State University (ASU) purchased a submersible robot that is underutilized. The goal of this project was to identify and analyze potential applications for the robot in the Caspian Sea. The team performed research, conducted interviews, and contacted companies around Astrakhan to identify potential roles the robot could fulfill. The team performed SWOT analysis on each application and recommended the best utilization of ASU's robot.

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AUTHORSHIP

The writing process consisted of group research and writing during the early phase of the project. As the project continued team members fell into roles that were best suited to them. Drafts of sections were written and rewritten multiple times by Walter, Joseph, Patrick, and Tucker. Later, for continuity, sections were edited, streamlined, and connected by Tucker. Patrick led editing sessions; Walter developed resources, research, and the bibliography; Joseph contributed to negotiating with sponsors, creating graphics, and paper structure.

INTRODUCTION

Approximately every two years, the number of transistors in a circuit doubles. Often cited as Moore's Law, this pattern is associated with the compression of microcontrollers, an increase in processor speeds, longer lasting batteries, and a drop in price of electronic devices. All of these changes are fueling the development of automated machines and robots that are becoming ever more present in our daily lives.

Robots are opening up new markets and revolutionizing old ones. Their electronic and programmable nature allows them to perform repetitive tasks without tiring; their silicon and steel structures allow them to explore regions beyond human capability. Robots can now drive cars and fly planes. They can enter radiation-contaminated zones and operate in the vacuum of space. The potential of robots seems limitless.

One branch of robotics that has developed enormously in the past two decades is underwater Remotely Operated Vehicles (ROVs). ROVs can swim deeper and stay submerged far longer than any human diver. As a result, ROVs are very attractive to companies whose business ventures are primarily underwater. Oil and gas companies often use ROVs to install, remove, and inspect pipelines laid on the ocean floor. Marine biologists use ROVs to monitor the populations of marine species. Law authorities use robots to probe the undersides of boats for smuggling operations. More applications of ROVs are discovered every year.

Astrakhan State University (ASU) in Russia recently purchased a small ROV named GNOM. The University networked with a local boat-building company, Aurora, and formed a partnership to pursue a profit-driven economic venture. In this partnership, Aurora provides a boat and crew and ASU provides the GNOM ROV and robot operators. The only thing missing: an application for the GNOM robot.

The goal of this project is to identify and analyze potential applications for the GNOM robot in the Caspian region and recommend those applications that are feasible.

BACKGROUND

PROJECT BACKGROUND

Astrakhan State University

Astrakhan State University, located in the Volga river delta, is a multidisciplinary institute that has a broad range of programs and degrees. The University offers bachelors, masters, and doctorate degrees that range from arts and humanities to science and engineering. ASU has more than 15,000 students and an interest in developing their international connections.

GNOM Robot

In 2015, ASU purchased a Super GNOM Pro from Moscow-based robotics firm, Indel-Partner. The Super GNOM Pro seen in Figure 1 is a submersible remotely operated vehicle (ROV) controlled via tether that provides a live video stream from a color camera mounted on the front of the robot. With two forward motors and a third vertical one to adjust depth, the GNOM is light and fast in the water. The ROV is approximately the size of a suitcase (450x300x300 mm) and weighs 12 kg, making it a lightweight, portable system (Gnom ROV, 2013). An additional photo of the GNOM robot is included in Appendix C.

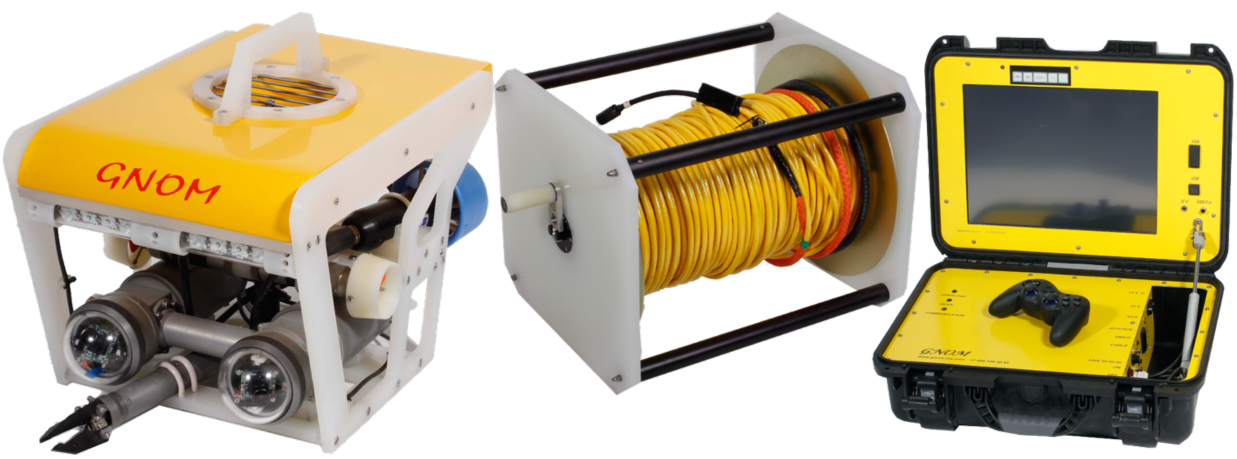

Figure 1: The Super GNOM Pro ROV, tether, and control station (Gnom ROV, 2013).

Aurora Boat

Aurora is an Astrakhan-based boat-building company founded in 2005. The company specializes in developing motorized catamarans, though it also provides services for custom yacht construction, ship repair, and ship refurbishing (Aurora). Aurora is offering to rent out a boat to ASU as a way to market itself and to bring in extra capital.

The boat offered by Aurora is its award-winning AS14 catamaran seen in Figure 2. It is 15 meters long, has two 1700 horsepower engines, a maximum speed of 90 km/h, and a 700 km operating range. The AS14 can carry up to 12 passengers (including the two ship's operators) and can spend up to 10 hours out at sea. Its power, range, and speed, however, come with a hefty cost: nearly $2,500 per day. Additionally, the location of Aurora requires three hours of driving through the Volga delta to reach the shores of the Caspian Sea (Aurora, Aurora's AS14 Catamaran, 2016). An additional photo of the AS14 is included in Appendix C.

Figure 2: The high-speed catamaran AS14 (Aurora, The High-Speed Catamaran AS14)

The Project

Astrakhan State University was looking for value to come out of its investment in the GNOM robot. Director Alexey Rybakov developed a project and coordinated three sub-teams within it. Each group had distinct goals.

The first team was composed of WPI students Joseph Lombardi, Patrick Trant, Tucker Haydon, and Walter Gallati. The end goal of the WPI project team was to identify and analyze uses for the GNOM robot.

The second team was composed of engineering students from ASU. They were Nikita Efremov, Nikolay Svischev, and Dimitry Rodionov. Their goal was to design and fabricate sensors or modules for the GNOM robot.

The third team consisted of economic students from ASU. They were Ludmila Sheketova, Ratmir Bigeev, and Ivan Nikolaev. Their job was to identify clients and market the GNOM system.

The value chain in Figure 3 presents the goals and direction of the project in graphical form. A value chain is composed of boxes that represent activities present in a venture. The size and color of the boxes indicate the duration and the chronological order in which the activities are completed. The green boxes are support activities that span the extent of the project. The red boxes are primary activities that are completed one at a time by the three teams. Project value is created through the combination of the support and primary activities.

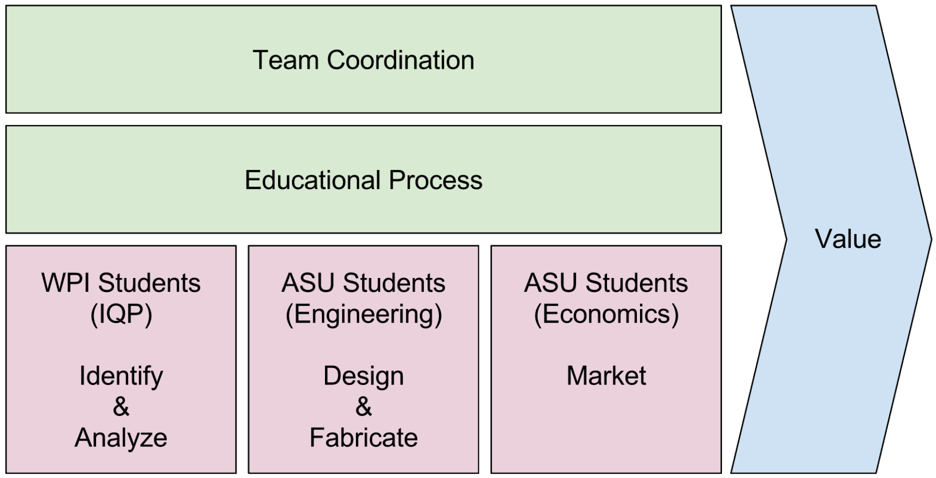

Figure 3: Value chain for GNOM project

ECONOMIC & ENVIRONMENTAL PROBLEMS & OPPORTUNITIES

Oil Pipelines

According to the US Energy Information Administration (EIA), there are approximately 48 billion barrels of oil and 292 trillion cubic feet of natural gas beneath the Caspian Sea (US Energy Information Administration, 2013). Of these riches, the EIA estimates that offshore fields "account for 41% of total Caspian crude oil and lease condensate (19.6 billion barrels) and 36% of natural gas (106Tcf)" (US Energy Information Administration, 2013).

The vast quantity of resources attracts oil and gas companies to the region. According to an EIA study in 2013, oil rigs in the Caspian Sea are extracting approximately 945 thousand barrels of oil per day, with countries such as Azerbaijan producing over 96% of its total nationwide oil through such means (US Energy Information Administration, 2013). Lukoil, the largest oil company in Russia, has announced plans to increase investment into the offshore Filanovsky oil field, increasing Russian oil production in the Caspian Sea by 120,000 barrels per day (US Energy Information Administration, 2013).

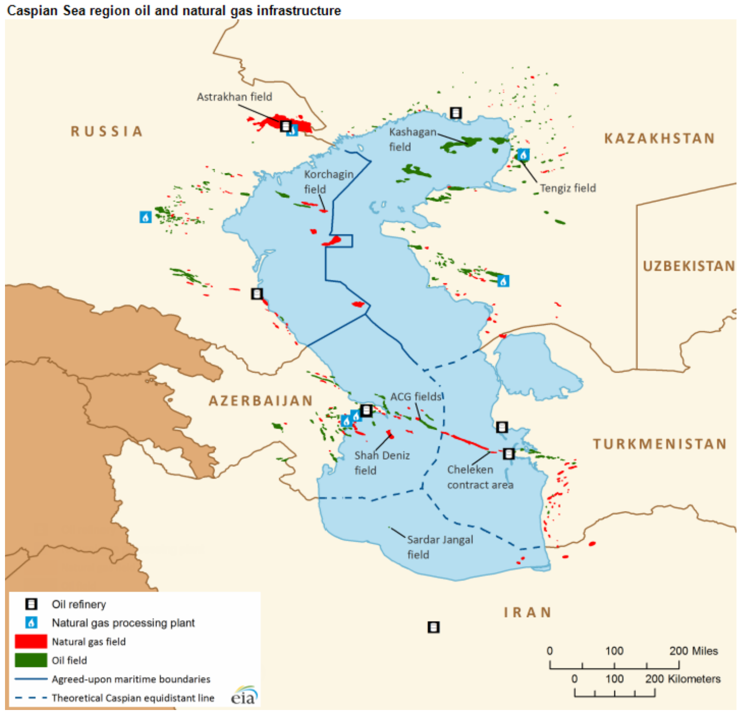

Figure 4: Caspian Sea Oil & Gas Infrastructure (US Energy Information Administration, 2013)

To transport all of this oil to the market, an extensive system of underwater pipelines is required. Many of the oil and gas exports from offshore Caspian fields “tend to rely on old Soviet pipeline networks”, however new pipelines are under construction (US Energy Information Administration, 2013). For example, to accommodate the increased production from the Filanovsky oil field, Lukoil plans to extend the Baku-Tikhortsk pipeline and pipe the fuel directly from the Caspian Sea to the port of Novorossiysk (US Energy Information Administration, 2013).

Subsea pipelines are prone to failure relatively early into their lifespans. An analysis by EFA Technologies in Sacramento concluded that pipelines of “short-to-moderate lengths (for example, 50 miles) are likely to have at least one reportable spill within a 20-year period. Longer lines (as much as 1,000 miles, for example) may suffer a reportable spill within 1 year” (Hovey & Farmer, 1993). Pipelines are often built in harsh environments and subjected to corrosive substances, chemicals, and pressure and temperature extremes. It is a matter of when—not if—a pipeline will fail.

A 30-year study of offshore Gulf of Mexico pipelines concluded that a majority of pipeline failures occur as a result of corrosion—both internal and external—that lead to pinhole pitting (Behler, Silber, & Miller, 2000). Pinhole pitting is a multitude of small holes that slowly leak oil. Unlike ruptures that suddenly change the pressure and volume in a pipeline, pinhole leaks cause minute, undetectable changes in pressure and volume that slowly build up over time, resulting in significant loss of oil product.

To combat corrosion and pinhole pitting, oil and gas companies use ROVs to inspect and repair their pipelines. Companies such as Oceaneering provide diverse fleets of ROVs that can perform a variety of subsea pipeline services. For example, Oceaneering’s Magna Subsea Inspection System uses acoustic waves to inspect 360° around a pipe. This system “is capable of detecting internal and external damage …

including corrosion, isolated pitting, cracking and other potential anomalies" (Oceaneering, 2015). As the offshore oil and gas market grows, the demand for these types of underwater ROVs will too.

Pollution

The Caspian Sea is one of the world's most unique and demanding ecosystems. Aquatic animals must survive variable salinity, anoxic (oxygen-bare) zones, and highly fluctuating water levels (Stolberg, Borysova, Mitrofanov, Barannik, & Eghtesadi, 2006). The ecosystem is becoming even more hostile as significant pollutants are dumped into the sea.

The Volga River is responsible for introducing "90% of the total pollution load that enters the Caspian Sea." It is the longest river in Europe and its water basin is massive—over 1.5 million square kilometers. Pollutants from agriculture, mining, and the petrochemical industry are washed off into its tributaries and carried into the Caspian, causing all sorts of ecological problems. Pollution is linked to a decline in phytoplankton blooms, which in turn "produces hypoxic conditions in some areas causing fish and zoobenthos mortality" (Stolberg, Borysova, Mitrofanov, Barannik, & Eghtesadi, 2006).

Oil and gas extraction from the Caspian Sea is another significant source of pollution. Oil concentrations in the water are as high as 1.6 times larger than the UN's Maximum Allowable Concentration (Stolberg, Borysova, Mitrofanov, Barannik, & Eghtesadi, 2006). Already, the Bay of Saymonov in Turkmenistan has been declared a dead zone, and—despite conservation efforts—continues to leech pollutants into Krasnovodsk Gulf (Stolberg, Borysova, Mitrofanov, Barannik, & Eghtesadi, 2006).

Due to concerns about the rising pollution levels, the five countries bordering the sea have all ratified the Tehran Protocol, a document pledging support to detecting and limiting pollution in the Caspian Sea (Framework Convention for the Protection of the Marine Environment of the Caspian Sea, 2004). Detection and monitoring efforts, however, are stalling. No regular monitoring of the Caspian Sea pollution is currently conducted as a result of funding problems (CaspInfo, 2016).

Nuclear Contaminants

One great concern with the Caspian Sea is that "Caspian waters, bottom sediments, and living organisms contain levels of uranium five to seven times higher than those in other seas" (Diba, 2003). The levels of uranium are concerning for the littoral states whose food (fish) comes from the Caspian Sea. Most of this radiation occurs naturally due to the surrounding area's geological makeup. Over time, elements such as tritium, uranium, thorium, and radium have eroded into the Caspian Sea where they have stayed and built up due to the land-locked nature of the Caspian (Diba, 2003).

Though most of the radiation is naturally occurring, there are other significant sources of radiological contaminants. Tailing ponds filled with nuclear waste are located near the shores of the Caspian Sea and are can leak contaminants into the Caspian. Tailing ponds are "drain-free settling pool[s] for industrial, toxic, chemical and radioactive wastes" (Diba, 2003). One of the most potent tailing pods is the Koshkar-Ata tailing pond, located 8 km from the shore the the Caspian. The real mass of radioactive wastes in this pool is nearly 360 million tons and there is the "potential for penetration of liquid waste…to the Caspian" (Diba, 2003).

Sturgeon & Caviar

The Caspian Sea is home to the Beluga Sturgeon, a critically endangered species of sturgeon that produces one of the world's finest caviar. With its caviar priced at over $2,835/lb and with the ability to produce hundreds of pounds of eggs, a single Beluga Sturgeon is one of the most valuable fish in the world

(Russian Beluga Caviar; Speer, Lauck, Pikitch, Boa, Dropkin, & Spruill, 2000). As a result, the sturgeon has been subject to decades of overfishing. In the "early 20th century, annual sturgeon catches often exceeded 20,000 tons. By the late 1990s, the annual catch had declined to roughly 1,000 tons" (Speer, Lauck, Pikitch, Boa, Dropkin, & Spruill, 2000). Recognizing the ecological problem, Russia "banned commercial sturgeon fishing in the Caspian Sea in 2002" (UPI, 2013).

Despite the ban, the sturgeon still faces a score of problems including poaching and slow population growth. It takes anywhere between six and 25 years for Caspian sturgeon to reach sexual maturity, making it difficult for the population to rebound (Speer, Lauck, Pikitch, Boa, Dropkin, & Spruill, 2000). Population growth is further hindered by the Volgograd dam which blocks "virtually all of the beluga spawning ground" (Speer, Lauck, Pikitch, Boa, Dropkin, & Spruill, 2000). Poachers have continued to hunt the fish and "there is little reason to believe that [this] will cease any time soon" (Speer, Lauck, Pikitch, Boa, Dropkin, & Spruill, 2000). Bribery and violence commonly surround the sturgeon fishing market and the police are poorly equipped to deal with the poachers (Abdullaev, 2000).

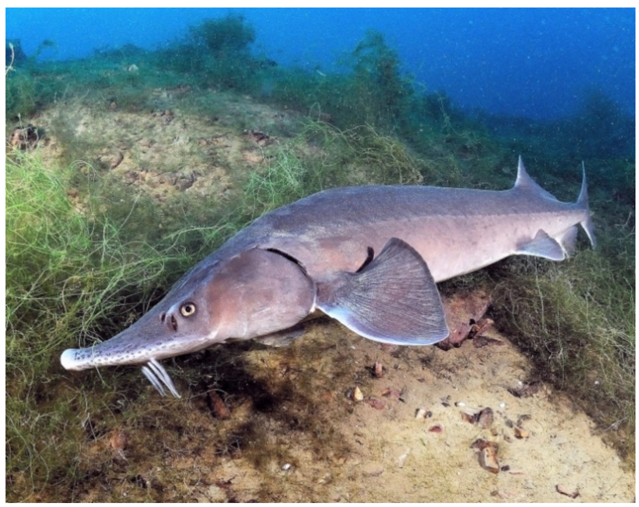

Figure 5: An endangered Beluga Sturgeon in the Caspian Sea (Mann)

Ghost Net Detection and Retrieval

"Ghost nets" are fishing nets that have broken loose and float freely in the sea. They pose a danger to wildlife, as the nets are difficult to spot and can entangle fish, marine mammals, and even birds. The cleanup of such nets are dangerous as well, as they run the chance of ensnaring the very divers attempting to get rid of them. Ghost nets can occur because of a variety of causes; most often, the nets are ensnared by underwater hazards such as rocks and are wrested away or cut loose. Nets are also deliberately abandoned by illegal, unregulated, and unreported (IUU) fishing vessels (Macfadyen, Huntington, & Cappell, 2009).

IUU fishing is prominent in the Caspian Sea, where the price of black caviar and the regional fishing quota drives many anglers to illegally catch and sell the fish. According to the United Nations Environmental Program, "the black market price for one sturgeon buys food for an entire family for one month" (Stolberg, Borysova, Mitrofanov, Barannik, & Eghtesadi, 2006). IUU nets are some of the most difficult to locate, as they often lack identifiers and the owners do not inform authorities of the lost equipment.

There are three main methods for ghost net detection: human divers, ROVs, and boat-mounted side scan sonar. Although not as effective as human divers at detecting ghost nets, ROVs move faster and eliminate the potential for human injury or death due to entanglement (Macfadyen, Huntington, & Cappell, 2009). Side scan sonar is faster still, but has issues identifying nets on hard or deep surfaces and cannot differentiate them from nets in use unless further investigated by a diver or ROV (Brown, Macfadyen, Huntington, Magnus, & Tumilty, 2005).

Boat Inspections

According to the Russian Federation's Maritime Register of Shipping, the hulls of vessels are to be inspected once annually for damages or necessary maintenance. Hull inspections focus on the protective lining near cargo areas and the inspection of ballast locations, though they also look for defects such as "deformations, cracks and excessive wear". If there is any suspicion of damage to the hull, further underwater inspection can be performed by diver, ROV, or a combination of the two (Russian Maritime Register of Shipping, 2016; Damus, et al., 2006).

METHODOLOGY

During the course of this project, the project's goal was reevaluated. As such, the methodology is broken up into two parts that represent and chronicle the respective steps taken for each project goal.

MARKETING THE GNOM FOR SUBSEA PIPELINE INSPECTIONS

Understanding the GNOM Package

Originally, the goal of this project was to develop a marketing plan for the GNOM robot. The GNOM would be marketed to oil and gas companies in the Caspian Sea as system that would inspect subsea pipelines for damage. The Aurora AS14 catamaran was to be used in conjunction with the robot to form an 'inspection package' that could be contracted out.

The first step in the project was gathering information about the various project components. The team organized weekly Skype meetings with the project's sponsor, Alexey Rybakov, and interviewed him. These interviews were unstructured; the team created a list of questions to ask during each interview, but the interviews were conducted as directed conversations as opposed to a question-answer format. Generally, the team inquired about the cost of the GNOM robot, its capabilities, the Aurora catamaran, and the various costs associated with renting the boat. All interview notes are included in Appendix A.

Once a basic idea of the inspection package had been formed, the team reached out to business and marketing experts at WPI to better understand how to formulate a marketing plan. The team interviewed WPI Professors Hall-Phillips and Walter Towner using the same directed- conversation format. During these interviews, concerns about student labor availability and insurance were raised. Afterwards, the team interviewed the project's sponsor again and inquired about student labor. Interview notes are included in Appendix A.

To follow up on insurance concerns, the team reached out to Mark Smithers, a veteran underwater ROV engineer. The interview with Mark Smithers followed the same directed-conversation format. The team collected information about ROV insurance, marketing tactics, and concerns were raised about the technology employed by the GNOM robot. Interview notes are included in Appendix A.

Client & Competitor Evaluations

The next step in the project was interviewing potential clients and understanding how the GNOM robot could address a problem. After networking with friends and family, the team connected with two ExxonMobil subsea pipeline engineers: Christophe Dhalluin and Mike Cook. The team followed the same directed-conversation format and inquired about pipeline inspections, what the oil and gas industry needs, and competitors. During this interview, it became clear that the oil and gas industry did not need the GNOM inspection package and that the package did not meet the technology or labor standards that ExxonMobil required. The team discovered that oil and gas companies contracted pipeline inspections out to companies such as Oceaneering and Saab Seaeye. Interview notes are included in Appendix A.

To better understand how the GNOM inspection package compared to the services offered by Oceaneering, the team interviewed John Boyle, an asset integrity engineer from Oceaneering. The team asked about current inspection techniques, inspection costs, and liability in the case of pipeline failure. After this interview, it became clear that the GNOM inspection system was outclassed in terms of technology, labor training, labor availability, and risk mitigation. Interview notes are included in Appendix A.

The team presented an analysis of the numerous shortcomings of the GNOM inspection package to the project's sponsor and the goal of the project evolved into an analysis of potential applications for the GNOM system.

Analyzing Applications for GNOM

Identifying Potential Applications

Before any analysis could be performed, the team first had to identify potential applications. The team used U.S. and Russian government websites to initially identify the largest economic and ecological concerns in the Caspian region, then followed up on each concern with journal articles, news articles, research papers, and internet research.

The team interviewed Likhter Anatoli Mikhailovich, an ecology professor at Astrakhan State University, for further background information regarding problems in the Caspian Sea. During the interview, the team inquired about the causes of ecological problems and what the GNOM robot could do to address them.

After basic background information had been collected, the team connected with its Russian partner students and brainstormed further uses for the GNOM robot. In total, fifteen different potential uses for the GNOM robot were suggested (Figure 6). To narrow down this list to only the most feasible applications, potential clients for each application were contacted and interviewed. During each interview, the team asked three questions:

1. What problem could GNOM solve?
2. How could it solve this problem?
3. What sensors/equipment would GNOM need to address this problem?

The interviews were conducted and translated by the team's Russian project partners. The responses are located in Appendix B.

These questions were designed to encourage a potential client to describe exactly how the GNOM would be used for each application. From this information, the team was able to determine the modifications to GNOM and the time/money/labor expertise that each application required. The team used this information to prune the list of potential applications down to five potentially feasible applications.

	Applications	Potential Clients
1	Inspect Pipelines	Lukoil/Gazprom
2	Pollution Monitoring	Каспнирх, Ministry of Civil Defense, Oceanographic Institute
3	Nuclear Monitoring	Ministry of Civil Defense
4	Ecology Monitoring	Каспнирх/ Federal Fish Company "Рыбный край", Ecospas, Fishing Companies
5	Boat Inspection	Fishermen/Tourist Boats/Shipping boats/Police/Shipyards
6	Aquaculture	Fisheries
7	Fishing/Hunting	Tourism Compaines, Astoria
8	Underwater Construction	Construction Company (Bumi Armada) / Gazprom / Environmental Center 'Sigma'
9	Search and Retrieval	Police / Museum / National Guard
10	Fishing net retrieval	Federal Fish Agency
11	Measuring underwater infrastructure	Center of Metrology and Standardization/ Lukoil
12	WWII Artifcat Searching	Ministry of Defense
13	Telecommuncation wire inspections	Telecommunications Companies
14	Education	ASU
15	Private contract object retrieval	Private contractors

Figure 6: Brainstormed applications and clients

Evaluating Potential Applications

For the last step, the team used the SWOT method to analyze each application. SWOT is an acronym for *Strengths*, *Weaknesses, Opportunities*, and *Threats*. SWOT analysis (depicted in Figure 7) is a useful tool for analyzing the feasibility of a concept, displaying related facts, and developing a better understanding of the larger picture surrounding a venture.

Strengths and *Weaknesses* represent the positive and negative internal factors of a project. These are traits of a project that a team has control over. For example, a strength or weakness of a robotic venture might be the sensors the robot employs. A team has complete control over which sensors are added or removed from a robot.

Opportunities and *Threats* represent the positive and negative external factors of a project. These are traits of a project that a team does not have control over. These are often market forces, weather restrictions, regulation, or competitors. For example, an opportunity or threat of a robotic venture might be the regulatory laws that the government imposes. A team has no control over what laws are created and must accept that these may help or hinder the venture at any time.

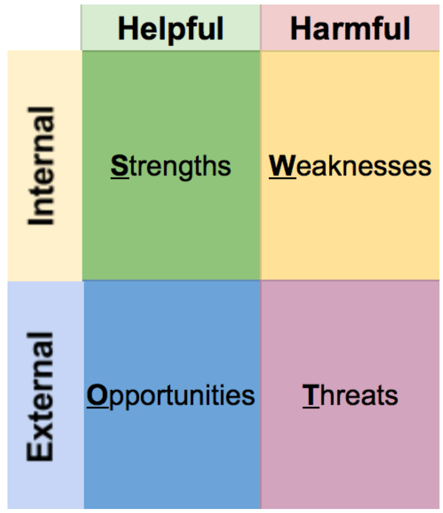

Figure 7: A SWOT analysis matrix

The team performed SWOT analysis on each of the potential applications for the GNOM robot. The SWOT analysis helped the team determine which of the potential applications were reasonable to pursue in terms of feasibility (money, time, & resources) and profitability.

RESULTS: ANALYSIS OF APPLICATIONS

COMMON SWOT THEMES

Many of the SWOT analyses below contain common aspects that help or hinder each potential application. To avoid repetition, the common aspects are described here and referenced in their respective sections.

Common Strengths

Adaptable Robot

The adaptability of the GNOM robot is one of its greatest strengths. The robot can carry up to 2 kg of additional payload and its simple design permits the attachment of a wide variety of sensors and equipment. This allows for easy modifications to detect various contaminants, take temperature/water flow rate data, record different types of videos, etc.

Affordable Labor

Affordable labor is another strength of any GNOM application. Since no special training or certifications are needed, students can pilot the ROV for free as part of their education. Training can be performed in ASU's pool with no risk to the robot. Students can learn how to avoid underwater obstacles and keep the robot stationary while performing measurements from the relative safety of the pool.

Common Weaknesses

Only One Robot

An overarching weakness of the project is that ASU owns only one robot. The weakness is amplified by ASU's lack of insurance for GNOM. Background research into ROV insurance and an interview with ROV industry specialist, Mark Smithers, indicated that it is very difficult to insure these systems due to the volatile nature of their work environment. If the robot became stuck or the tether broken, any project venture would be ruined.

Expensive Boat

A weakness of any Caspian Sea application is the price of Aurora boat. The Aurora boat is expensive, costing nearly $2,500 per day. Discounting the additional costs for research, equipment, and the desire to make a profit, the rental price of Aurora boat is one that few companies or institutions are able to pay for a student-led venture.

Common Threats

Weather and Water Conditions

A threat to all of the outdoor applications for the GNOM robot are the weather and water conditions. Any Caspian application is dependent on the suitable weather conditions for operating GNOM. The region is prone to strong storms, which could interfere with students' already limited time with the robot. Water conditions such as high flow rate and low visibility are also threats to the robot. The robot cannot operate properly and take quality measurements in poor visibility conditions or swift currents.

Labor Availability

Labor availability is a concern for any Caspian Sea application. The benefit of using free student labor comes with the cost of tight schedule constraints. Students are only available to sail out to the Caspian Sea when it does not interfere with their schoolwork.

OIL PIPELINE INSPECTIONS

Originally, the goal of this IQP project was to develop a marketing plan for the GNOM robot tailored towards inspecting oil and gas pipelines. After performing extensive research and interviews, the team concluded that using the GNOM robot to inspect pipelines may not be a viable venture and recommended that other applications be examined. The team presented the following analysis to the project's sponsor and the project's goal evolved into analysis of potential GNOM applications. A summary of the SWOT analysis is depicted below in Figure 8.

Market Saturation and Technology

A pipeline inspection robot is not a new idea. Large inspection companies already exist and have been providing pipeline inspection services to oil and gas companies for years. Oceaneering has been providing pipeline inspections in the Caspian Sea since at least 2009 and is still active in the region (Oceaneering International Inc., 2009; Oceaneering, 2016). Other companies such as SAAB Seaeye are also providing services in the Caspian Sea (Offshore, 2010). If this venture were pursued, it would be difficult to market the GNOM system in such an established and competitive market.

The technology that these other companies use far exceeds the current capabilities of the GNOM robot. For example, Oceaneering's Magna Subsea Inspection System is a cutting edge robot that can scan 360° around a pipeline, detect internal and external corrosion, pinhole pitting and cracks (Oceaneering, 2015). During an interview with John Boyle, an Oceaneering engineer, the team discovered that Oceaneering's robots also have the ability to perform 3D penetration pipe scanning, sub-millimeter scanning, and soon will be able to take HD 3D video. GNOM's single 720p resolution camera pales in comparison to the technology that other pipeline inspection companies have.

The technological barriers to market entry are enormous. The sensors that companies such as Oceaneering use are often proprietary and unavailable to purchase. Even when they are available, they can cost tens of thousands of dollars. In order to compete directly, ASU would have to purchase a suite of sensors, test them, and develop software to visualize or analyze the data. The time and capital required would be exorbitant.

Labor Availability and Expertise

The availability and expertise of the student labor for the GNOM robot is a serious weakness. There are hundreds of kilometers of pipelines under the Caspian Sea. With a top speed of 7 km/h the GNOM robot would only be able to survey ~50 km/day, assuming maximum robot speed, no breaks, perfect weather, no mistakes, no commuting time, and working 8 hours/day. Generally, students do not have this amount of time to dedicate to a project and perform schoolwork at the same time, although the team was assured that students could perform the work over the summer break. Despite this, it would still be difficult for the student venture to compete with other companies. According to John Boyle, Oceaneering will inspect pipelines 24 hours a day, rotating shifts between engineers. This way, no time is lost for commuting, setup, or takedown and the inspection can be performed as quickly as possible.

The expertise of students is also a weakness. Engineers from companies such as Oceaneering undergo extensive training before they are allowed to drive the ROV for the first time. Their training is performed on simulators and is certified by many professional societies such as the International Maritime Contractors Association (ROV Personnel & Training). This is the quality of training that oil and gas companies expect. During an interview with subsea pipeline engineers Christophe Dhalluin and Mike Cook of ExxonMobil, they expressed their concern that students would not be trained well enough to perform accurate and worthwhile visual inspection of the pipelines.

Risk and Liability

Liability in the case of a pipeline burst after inspection is a risk to ASU, the project, and the students. According to John Boyle, if a pipeline bursts after being inspected, an investigation is launched to determine who is at fault. The data collected from the inspection and its analysis are taken into account when determining blame. If the inspection venture is found to be at fault (lacking due process or thoroughness), the project manager (a student, professor, or potentially ASU in this case) is held liable.

Untrained student labor opens up massive risk to both the oil company and to ASU. Students have no credible background in inspections and cannot ensure quality inspections. In the case of a poor inspection, oil and gas companies are at risk of losing capital and students are at risk of being held liable.

Robot Price

The low price point for the GNOM inspection package is its greatest strength. According to Christophe Dhalluin of ExxonMobil, the estimated cost of inspection by companies such as Oceaneering is on the order of hundreds of thousands of dollars per day. In comparison, the GNOM system could be priced much lower in thousands of dollars per day.

Figure 8: SWOT analysis of Pipeline Inspection

Alternative Applications

Besides the pipeline inspection application, the team also examined other uses for the GNOM robot. These other applications are analyzed using SWOT in the following sections. A summary of each SWOT analysis is depicted at the bottom of each application's section.

Pollution & Nuclear Detection & Monitoring

A potential application of the GNOM robot in the Caspian region is in the detection and monitoring of pollutants and nuclear contaminants. Background research has indicated that pollution is a significant problem in the Caspian Sea, affecting water quality and wildlife health. Research has also indicated that nuclear isotope levels in the Caspian Sea are found to be five to seven times higher than expected, a concern for biologists and health officials.

In addition to the common SWOT themes mentioned above, the following factors were considered for this application.

Weaknesses

Before the GNOM can be used for the detection and monitoring application, it would need to be outfitted with a suite of sensors. In order to merit the cost of this venture (see expensive boat), the robot would have to collect data valued in the thousands of dollars. Multiple types of sensors would have to be utilized to collect data of this value. ROV sensors are expensive, costing hundreds to thousands of dollars each, and need to be installed, calibrated, and tested before use. According to a quote from Teledyne-BlueView, the base cost for an ROV ultrasonic sensor is $25,000. The need for additional sensors is a time and money sink before the robot can even be used for the first time.

Opportunities

The biggest opportunity of this application is the fact that few other companies or institutions do this kind of research. Background research indicated that regular monitoring of the Caspian's pollutants has stalled in the last few years, leaving a gap that GNOM could fill. Companies and institutions such as the Oceanographic Institute and Caspnirh are interested in this kind of information, but do not have the funding to pursue it fully.

Threats

The biggest threat to this venture is the potential lack of funding. Background research indicated that lack of funding has caused other companies and institutions to stop collecting data, and there is no guarantee that the GNOM venture will be any different. One of the main goals of the project's sponsor is to find an application that is profitable. If no funding from the government or grants from the UN can be secured, no sensors can be purchased and no boat can be rented and the venture would not be feasible.

See Common Threats: Weather/Water Conditions

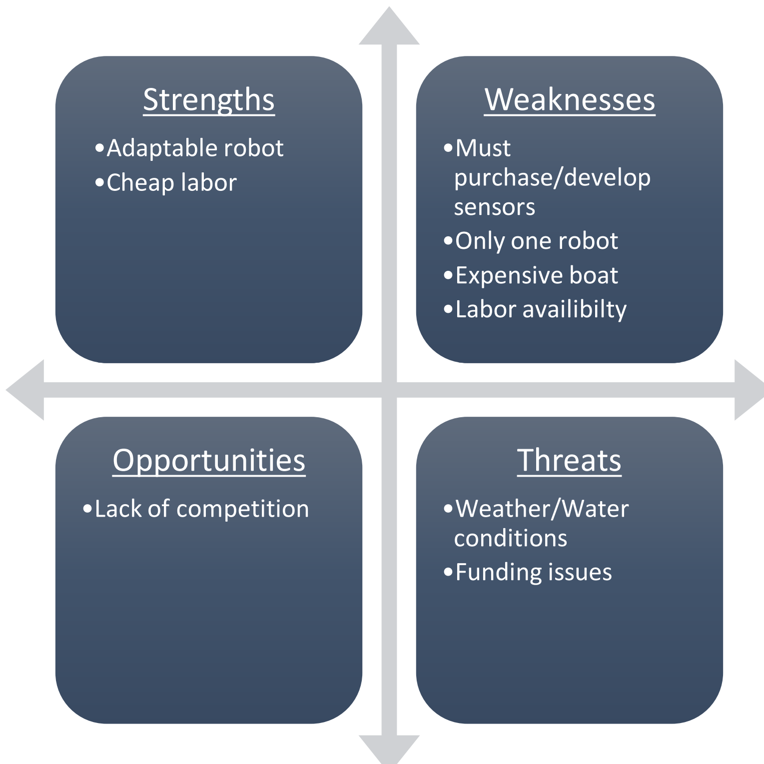

Figure 9: SWOT analysis of nuclear and pollution detection

Ecology Monitoring

One potential use of the GNOM robot—and one use that is realized by other ROV systems—is ecology monitoring. ASU would use the GNOM robot to monitor the growth and development of fish like the Beluga Sturgeon in the Caspian Sea. Videos and data would be collected regarding the fish's population, their spawning grounds, water temperature, and flow rate. Institutions such as the federal fish agency, Caspnirh, and the Oceanographic Institute would be interested in this data.

In addition to the common SWOT themes mentioned above, the following factors were considered for this application.

Weaknesses

Before the GNOM can be used for this application, it would need to be outfitted with a suite of sensors. In order to merit the cost of this venture (see expensive boat), the robot would have to collect data valued in the thousands of dollars. Multiple types of sensors would have to be utilized to collect data of this value. ROV sensors are expensive, costing hundreds to thousands of dollars each. And before they could even be utilized, the sensors must be installed, calibrated, and tested. According to a quote from Teledyne-BlueView, the base cost for an ROV ultrasonic sensor is $25,000. The need for additional sensors is a time and money sink before the robot can even be used for the first time.

Opportunities

An opportunity of his application is that few other companies and institutions are collecting this type of data. Background research indicated that the Oceanographic Institute collected similar data only once a year during an annual tour of the Caspian Sea. The Oceanographic Institute was very interested in this data but only has enough funding to finance one big trip per year with its massive boat and equipment. The GNOM robot has an opportunity to fill the research gap.

Threats

The biggest threat to this venture is the lack of funding. The venture would be rather expensive considering the cost of the Aurora boat, sensor purchases, additional equipment, and research costs. The marketing team could reach out to the federal fish agency, Caspnirh, and the Oceanographic Institute for grants, but it is unlikely that these institutions would be willing to pay over $3,000 per day for this research.

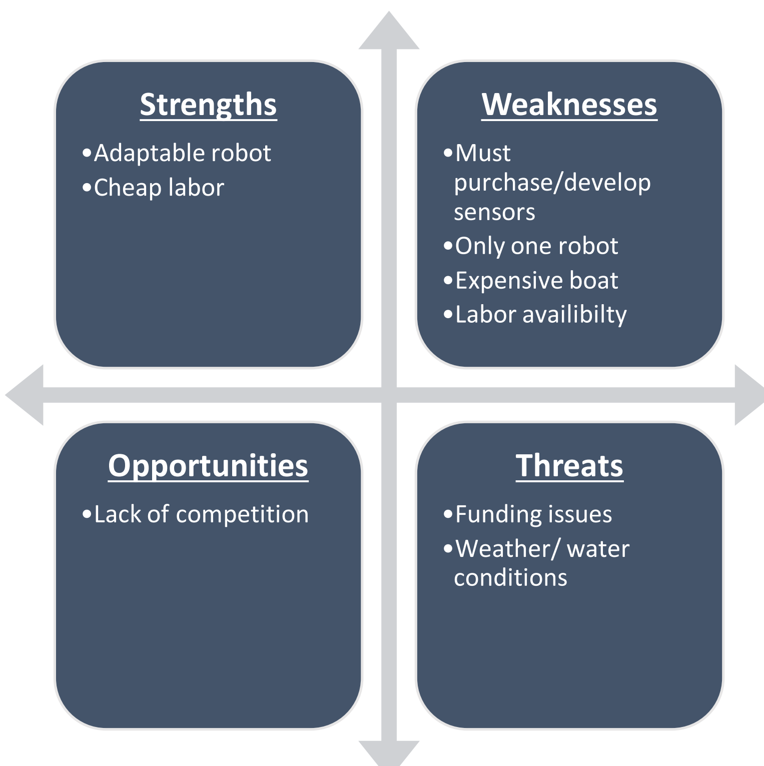

Figure 10: SWOT analysis of ecology monitoring

Shipyard Inspections

Another possible use for the GNOM robot is using it to inspect various underwater structures and pieces of equipment at shipyards. The GNOM robot would inspect the hulls of ships and underwater ship launch rails for damages. Shipyards such as Lotos shipyard would contract ASU to take videos of ships' hulls and launch rails.

In addition to the common SWOT themes mentioned above, the following factors were considered for this application.

Strengths

One of the strongest aspects of this venture is the fact that the robot can be operated from a dock or even on the inspected boat itself. Since the boats and rails in shipyards are within the tether distance of the GNOM, there is no need to rent an expensive boat like the Aurora boat. The absence of any boat costs allows this GNOM application to price itself competitively, making it more attractive to clients.

The GNOM system is the minimum viable product; it is usable without any additional features. This is an extremely strong feature for a first-time venture. No additional costs for a boat or for extra sensors are needed. The robot can be taken to a shipyard and put to work in its current state.

Weaknesses

The availability of students is a problem for boat inspections, though not as consequential as for the other applications. While students will most likely still have to work primarily on the weekends and holidays, they have the option of working during the week when coursework is light. While still a weakness, it is not as problematic as with other applications where students must travel 3-4 hours by boat to reach the Caspian Sea.

Opportunities

One of the biggest opportunities is the lack of competition. Currently, no other company in the region is using robots to inspect ship hulls or launch rails. In addition, the team interviewed four shipyard companies in the region, and all four expressed interest in the system, as it would solve their inspection problems in a presumably cheap and easy manner.

A second opportunity is the reoccurring demand for boat inspections. Russian boats in the Caspian Sea are required to be inspected annually, creating a reoccurring demand schedule. If this application were to be pursued, ASU could expect multiple contracts from shipyards throughout the year and in years to continue. This expected demand schedule is particularly attractive to a start-up venture because it guarantees income for future years.

Threats

A large threat the team found from the interviews was the fluctuating demand for ship inspections. Of the four companies interviewed, three of them currently had no ship docked. While ships are required to be inspected annually, this does not mean that ships will constantly arrive at shipyards. There will be times of high and low demand.

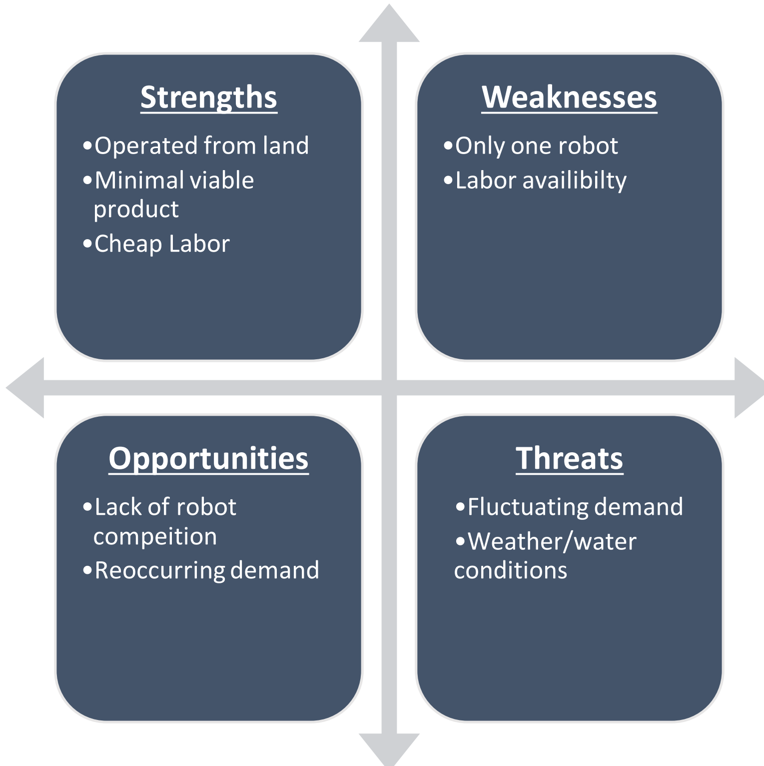

Figure 11: SWOT analysis of Shipyard inspections

Ghost Net Detection

A different use for the GNOM robot is in the detection of ghost fishing nets. As mentioned in the background research, ghost fishing nets occur when nets are accidentally or deliberately abandoned, sometimes as a result of illegal and unregulated fishing. Given the large amount of sturgeon poaching in the Caspian Sea and its tributaries, there is the potential for a serious ghost net problem in the region.

In addition to the common SWOT themes mentioned above, the following factors were considered for this application.

Strengths

There are currently two methods to finding ghost nets; ROVs and human divers (Brown, Macfadyen, Huntington, Magnus, & Tumilty, 2005). ROVs, including the GNOM, are faster than human divers and can cover more area in a shorter amount of time. The act of searching for ghost nets is also safer with GNOM, as there is no potential for a human diver to become entangled in an unseen net (Macfadyen, Huntington, & Cappell, 2009).

Opportunities

Due to the threats that ghost nets pose to wildlife, grants are available for marine cleanup and have been awarded to similar ventures across the globe. Ranging in size from organizations such as the United Nations to smaller companies like Santa Monica Seafood, grants for clearing marine debris are available from institutions around the world.

Threats

Ghost net detection has an element of danger involved, as it is distinctly possible that the searcher will not see the net until they have already entangled themselves. Although the GNOM allows this to present no physical harm to the humans operating it, it still allows the GNOM to become entangled itself, possibly to the point where it will not be able to be recovered until the net is retrieved and it can be cut free.

Despite the potential for ghost nets in the Caspian Sea, there is very little evidence that the problem exists in the region. A Caspian Environmental Program (CEP) report stated that all of the Caspian states reported either "low" or "unchanged" levels of maritime waste (Caspian Environmental Programme, 2009), and a UN evaluation of maritime waste and lost fishing equipment in 12 seas (including the Caspian) did not report any waste or lost netting issues with the region (Regional Seas Corporation Office, 2005).

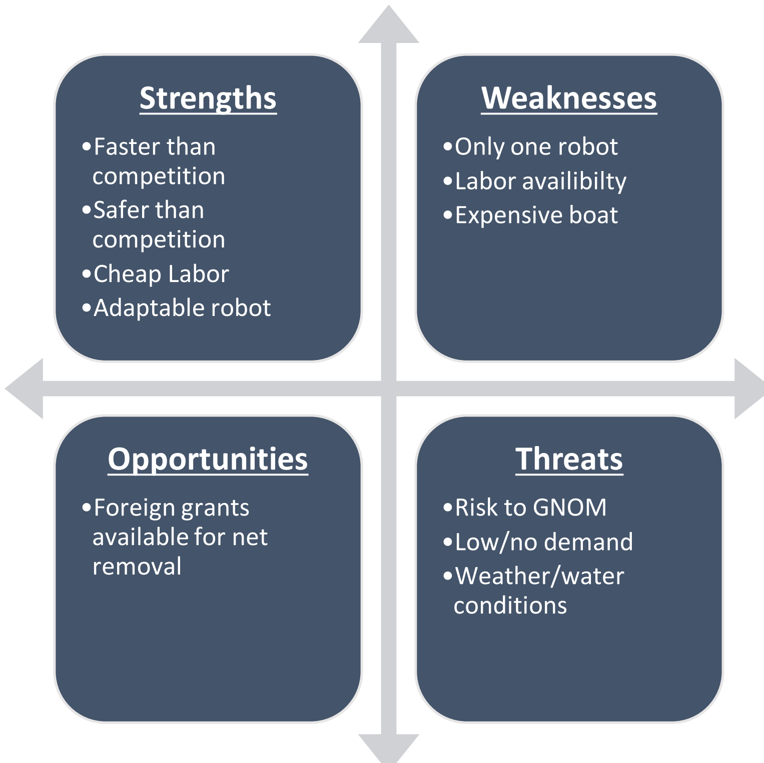

Figure 12: SWOT analysis of Ghost Net detection and removal

Develop an Educational Program

The last potential application of the GNOM robot is one that the team brought from WPI: using the robot as a platform for project-based learning. Third- or fourth-year students at ASU would program the robot to autonomously accomplish some task as a project for a course. For example, use image processing and the robot's camera to automatically find and retrieve an object on the bottom of ASU's pool. During the course of the project, students are encouraged to develop new sensors and techniques in order to meet the criteria of the challenge.

In addition to the common SWOT themes mentioned above, the following factors were considered for this application.

Strengths

ASU's pool and the proximity of the Volga River are strengths of this application. Other applications are beholden to students' schedules, only able to be completed on the weekends or holidays. In comparison, this application is built into the students' course work and is able to be integrated without schedule conflicts or dependencies on the weather.

An attractive feature of this application to ASU is that there are no additional costs. There is no need to rent an expensive boat, negotiate contracts, or purchase special equipment. Many projects can be assigned and completed by just using the GNOM's camera alone.

This application has no risk to the GNOM robot. The uninsured status of the GNOM robot is a concern for all of the other applications since the robot will be working in uncontrolled, risky environments. In comparison, the use of the robot in the ASU pool poses no threat of the robot becoming damaged or lost. Students can easily see where the robot is, preventing it from tying knots in its tether or becoming stuck underwater.

Weaknesses

Ultimately, the major disadvantage of this application is that it generates low profits. It is a low-risk, low-reward application. While there is little chance of damaging the GNOM robot, there is little reward to to the robotics program in terms of monetary gain. If the robot and coursework bring in extra students to ASU, the extra students must pay fees and tuition, generating revenue. Any profits, however, are indirect and are not directly reinvested in the robot and the robotics program. Despite this, the University could still use videos and demonstrations of the robot to market and advertise the University as it does with the welding robot and rapid prototyping labs.

Opportunities

Astrakhan State University is the only university in the region that owns a submersible ROV. ASU could leverage this and market it as an opportunity that is unique to ASU's education. The high initial cost of the GNOM robot (~$40,000), acts as a market barrier, preventing other universities from quickly or easily acquiring a competitive robot. During this time, ASU could further develop its program and brand itself as *the* robotics university in the region.

Figure 13: SWOT analysis of creating an Educational Program

SWOT Comparison

To create a visual and concise comparison of the SWOT analyses, the team created a table depicting how the various SWOT aspects stood out in each application (Figure 14). The colors represent how attractive each application is with respect to a SWOT aspect. Green indicates that a strength/opportunity is particularly strong or that a weakness/threat is particularly weak; yellow indicates that a strength/weakness/opportunity/threat is neutral; red indicates that a strength/opportunity is particularly weak or that a weakness/threat is particularly strong.

The evaluation of each SWOT characteristic is relative to the other applications. Green does not indicate that the strengths are overwhelming and conclusive, rather just that the strengths of that one application are more compelling when compared to the strengths of the other five. The best option would have green across its row. An entirely green row would represent high strength, low weakness, high opportunity, and low threat. The opposite would be an entirely red row representing low strength, high weakness, low opportunity, and high threat.

When laid out in graphic form, it is clear that one application stands out as the best: shipyard inspections.

Figure 14: A visual comparison of the six SWOT analyses

Conclusion & Recommendations

The team recommends that ASU use the GNOM robot for shipyard inspections. When compared to the other applications, shipyard inspections are particularly strong with respect to all four characteristics of the SWOT analysis.

Shipyard inspections require no expensive boat and the GNOM robot as it stands needs no modifications. There is no need for contracts or for sinking time and money into sensor purchases. As a result, the robot can be immediately utilized; there is no need for grants or to request additional funding.

ASU only owns one GNOM robot and it is uninsured. Insurance for underwater ROVs is difficult to acquire due to the volatile nature of the ROV's work environment. In considering any application, one must weigh the risk of the application to GNOM and understand that damage to the robot will likely end the venture and any future prospects. Shipyards are reasonably safe environments for the robot to work in. The underwater environment is known and unchanging. If the robot encounters a problem, it is only a short distance from shore, as opposed to miles from land.

The shipyard inspection application is more accommodating to students' schedules. Shipyards in Aurora are much easier to travel to than to the Caspian Sea. Students can drive to the shipyards in under an hour, whereas it takes half an hour to drive to Aurora boat, three hours to drive the boat to the Caspian, and another hour to drive the boat to a place of interest. Students will be much more willing to work in shipyar (Diba, 2003)ds than on a boat in the Caspian.

The lack of competition and the reoccurring demand of this application make it particularly attractive. At the moment, no other companies are using robots to inspect the hulls of boats and underwater shipyard equipment in Astrakhan. During interviews with four shipyards in Astrakhan, all four of them expressed interest in contracting a robot for inspections, as it would be an innovate solution to their problems. Furthermore, the demand for ship inspections is reoccurring. By law, all Russian ships operating in the Caspian must be inspected once a year. This guarantees demand year after year and ensures that initial investment into this application is not squandered after one year.

In conclusion, the shipyard application is attractive because it has no initial investment costs, is relatively safe for the GNOM robot, works well with the labor schedule, is in demand by clients, and will have reoccurring demand in the future.

Future Work

Finding an application for the GNOM robot is only the first step towards creating a professional and business-worthy system. At this point, the team passes off the robot to the next team in the value-chain: the ASU engineering team. Their job is to design and fabricate any additional systems and parts the robot may need before the robot can be marketed.

As this project draws to a close, the team would like to propose some recommendations about future steps. The team recommends that ASU "start small and build big" with the GNOM robot. The team encourages ASU to begin with small shipyard contracts and get experience using the GNOM robot in a new environment. Currently, ASU's GNOM robot has not been used in the Volga nor the Caspian. The only experience that students have with the robot is in the regulated environment of ASU's pool. Use this as a chance to vet the robot's abilities in the open water.

Use the shipyard contracts to build up capital. This could be used to self-insure the robot or to reinvest in the robot as a way to further develop its sensor suite or equipment. Take videos of the shipyard inspections and create a website displaying the various tasks is has performed. Use this website to advertise the robot and build it up as a credible and reliable system. From there, use the capital from contracts and the robot's credible status to pursue more ambitious contracts.

EDUCATION INITIATIVE

The education initiative compared strongly against many of the other possible applications due to its low risk to GNOM and the marketing opportunities it brought to ASU. The team suggests combining the shipyard inspection application with the education initiative and incorporate the best aspects from each application. As part of university work, students could program automatic functions or develop and install sensors to better assist with inspections.

The combination of the two applications plays on their respective strengths while introducing few risks. ASU brings in the profits from shipyard inspections, educates their students, and can use the program to market the University. While using the GNOM robot in shipyards will be riskier than using it in the pool, shipyards will still be relatively safe. The conditions in shipyards are relatively static; there are not many swift currents or unknown obstacles. With an experienced driver, the risk to GNOM should be minimal.

OTHER APPLICATIONS

The team recognizes that not every possible application of the robot has been analyzed and that this analysis is in no way conclusive. Over the course of the research project, dozens of possible applications for the GNOM robot were considered. The team pruned many of these possible applications down to a list of six before deeply analyzing these six. During the pruning process, the team considered how well the robot could perform, what additional equipment the robot would need, costs and profits, and potential clients before settling on the six applications that the team thought the GNOM could best address. The analysis of other applications is left to future studies.

BIBLIOGRAPHY

Abdullaev, N. (2000, October 11). *Dagestanis Fish for Sturgeon, Caviar, Bribes.* Retrieved September 01, 2016, from The Moscow Times: http://old.themoscowtimes.com/sitemap/free/2000/10/article/dagestanis-fish-for-sturgeon-caviar-bribes/258221.html/

Aurora. (n.d.). Retrieved September 01, 2016, from Aurora: http://www.aurora-boat.ru/en/index.html

Aurora. (2016, September 21). Aurora's AS14 Catamaran. (T. Haydon, W. Gallati, P. Trant, & J. Lombardi, Interviewers)

Aurora. (n.d.). *The High-Speed Catamaran AS14*. Retrieved September 01, 2016, from http://www.aurora-boat.ru/en/boatbuilding/resuscitation-rescue-catamaran-aurora-as14.html

Behler, M., Silber, P., & Miller, S. (2000, March 27). *Study tracks internal-corrosion trends in aging gulf pipelines.* Retrieved from Oil & Gas Journal: http://www.ogj.com/articles/print/volume-98/issue-13/in-this-issue/pipeline/study-tracks-internal-corrosion-trends-in-aging-gulf-pipelines.html

Boyle, J. (2016, April 28). Oceaneering ROV Systems. (T. Haydon, P. Trant, W. Gallati, & J. Lombardi, Interviewers)

Brown, J., Macfadyen, G., Huntington, T., Magnus, J., & Tumilty, J. (2005). *GHOST FISHING BY LOST FISHING GEAR* . Institute for European Environmental Policy / Poseidon Aquatic Resource Management LTD.

Caspian Environmental Programme. (2009). *Marine Litter in the Caspian Region: Review and Framework Strategy.*

CaspInfo. (2016). *Environment*. Retrieved September 01, 2016, from CaspInfo: http://www.caspinfo.net/content/content.asp?menu=0120000_000000

Damus, R., Desset, S., Morash, J., Polidoro, V., Hover, F., Vaganay, J., et al. (2006). A NEW PARADIGM FOR SHIP HULL INSPECTION USING A HOLONOMIC HOVER-CAPABLE AUV. *INFORMATICS IN CONTROL, AUTOMATION AND ROBOTICS I* , 195-200.

Dhalluin, C., & Cook, M. (2016, April 14). Subsea Pipeline Inspections. (T. Haydon, P. Trant, W. Gallati, & J. Lombardi, Interviewers)

Diba, B. A. (2003, June 11). *Nuclear Pollution in the Caspian Sea: Introduction of several studies*. Retrieved September 04, 2016, from Payvand: http://www.payvand.com/news/03/jun/1061.html

Framework Convention for the Protection of the Marine Environment of the Caspian Sea. (2004, November 4). Tehran, Islamic Republic of Iran.

Gnom ROV. (2013). *Super GNOM 2*. Retrieved from http://www.gnomrov.com/products/super-gnom-pro/

Hall-Philips, A. (2016, April 26). Marketing the GNOM Robot #2. (T. Haydon, P. Trant, J. Lombardi, & W. Gallati, Interviewers)

Hall-Phillips, A. (2016, April 12). Marketing the GNOM Robot #1. (T. Haydon, P. Trant, J. Lombari, & W. Gallati, Interviewers)

Hovey, D. J., & Farmer, E. J. (1993, July 12). *PIPELINE ACCIDENT, FAILURE PROBABILITY DETERMINED FROM HISTORICAL DATA.* Retrieved from Oil & Gas Journal: http://www.ogj.com/articles/print/volume-91/issue-28/in-this-issue/pipeline/pipeline-accident-failure-probability-determined-from-historical-data.html

Macfadyen, G., Huntington, T., & Cappell, R. (2009). *Abandoned, Lost, Or Otherwise Discarded Fishing Gear.* Rome: United Nations Environment Programme.

Mann, G. R. (n.d.). *Beluga Sturgeon.* Retrieved September 01, 2016, from Ocean Treasures Memorial Library: http://otlibrary.com/beluga-sturgeon/

Mikhailovich, L. A. (2016, September 14). Caspian Ecosystem. (T. Haydon, P. Trant, W. Gallati, J. Lombardi, Interviewers, & A. Rybakov, Translator)

Oceaneering International Inc. (2009, September 3). *Oceaneering Announces Corrosion and Inspection Management Services Contract Award.* Retrieved from Oceaneering: http://www.oceaneering.com/2142/oceaneering-announces-corrosion-and-inspection-management-services-contract-award/

Oceaneering. (2015). *Magna Subsea Inspection System.* Retrieved from Oceaneering: http://www.oceaneering.com/oceandocuments/brochures/inspection/AI%20-%20Magna%20Subsea%20Inspection%20System.pdf

Oceaneering. (2016, May 26). *SOCAR-DALGIDJ LLC and Oceaneering to Jointly Exhibit at the Azerbaijan and Caspian Oil & Gas Exhibition.* Retrieved September 01, 2016, from Oceaneering: http://www.oceaneering.com/21504/socar-dalgidj-llc-oceaneering-jointly-exhibit-azerbaijan-caspian-oil-gas-exhibition/

Offshore. (2010, November 01). *Saab Seaeye upgrades ROV for Caspian duty.* Retrieved September 01, 2016, from Offshore: http://www.offshore-mag.com/articles/2010/11/saab-seaeye-upgrades.html

Regional Seas Corporation Office. (2005). *UNEP Regional Seas Programme, Marine Litter and Abandoned Fishing Gear.* Nairobi: United Nations Environmental Programme.

ROV Personnel & Training. (n.d.). Retrieved September 19, 2016, from Oceaneering: http://www.oceaneering.com/rovs/rov-personnel-and-training/

Russian Beluga Caviar. (n.d.). Retrieved September 01, 2016, from Caviar Express: http://www.caviarexpress.com/russian-beluga-caviar-half-kilo

Russian Maritime Register of Shipping. (2016, January 1). Guidelines on Technical Supervision of Ships in Service. Saint Petersburg, Russian Federation.

Rybakov, A. (2016, April 01). Creating a Marketing Plan for GNOM Robot. (T. Haydon, P. Trant, W. Gallati, & J. Lombardi, Interviewers)

Smithers, M. (2016, April 21). Marketing Underwater Robots. (T. Haydon, P. Trant, J. Lombardi, & W. Gallati, Interviewers)

Speer, L., Lauck, L., Pikitch, E., Boa, S., Dropkin, L., & Spruill, V. (2000, December). *Roe to Ruin: The Decline of Sturgeon in the Caspian Sea and the Road to Recovery.* Retrieved September 01, 2016, from Caviar Emptor: http://www.caviaremptor.org/roe_to_ruin.PDF

Stolberg, F., Borysova, O., Mitrofanov, I., Barannik, V., & Eghtesadi, P. (2006). *Caspian Sea, GIWA Regional Assessment 23.* University of Kalmar, Kalmar, Sweden: United Nations Environment Programme.

Towner, W. (2016, April 13). Pricing Plan for GNOM Robot. (T. Haydon, P. Trant, J. Lombardi, & W. Gallati, Interviewers)

UPI. (2013, December 27). *Extinction risk prompts ban on fishing for caviar-producing sturgeon.* Retrieved September 01, 2016, from UPI: http://www.upi.com/Extinction-risk-prompts-ban-on-fishing-for-caviar-producing-sturgeon/41011388179609/

US Energy Information Administration. (2013, August 26). *Caspian Sea - International - Analysis.* Retrieved from US Energy Information Administration: http://www.eia.gov/beta/international/regions-topics.cfm?RegionTopicID=CSR

US Energy Information Administration. (2013, September 11). *Oil and natural gas production is growing in Caspian Sea region.* Retrieved from US Energy Information Administration: http://www.eia.gov/todayinenergy/detail.cfm?id=12911

Appendix A: Interview Notes

Interview with Alexey Rybakov : 1 April 2016

- Aurora owns boat
    - http://www.aurora-boat.ru/en/index.html
- Hydraulics are ASU project
    - Used for launching and retrieving robot
- GNOM is ASU owned
    - Two missions: Control robot, test robot in Caspian sea
    - Find commercial use - OUR GOAL
- ASU Aims
    - Control/Understand robot
    - Modernize robot
- GazProm and LukOil own pipelines
- Help with program - Students
- FIND COMMERCIAL USE (Marketing Plan)
    - Cost to rent boat
    - Cost to rent robot
    - Fuel cost
    - Taxes
    - Find similar companies for comparison
    - Risks - Not part of our project
- Aurora wants to know their estimated profit
    - Rents out boat to ASU, ASU rents out system to businesses

Interview with Professor Hall-Phillips : 12 April 2016

- Marketing professor at WPI
- Who are the clients?
    - Pipeline people
- Rented equipment versus buying?
    - Will they be interested in renting only?
    - Or will they want to buy the system?
- What is so special about the Aurora boat?
    - Another third party that has a boat
    - Nothing special about the boat
    - Make a bundle package
    - AURORA needs to be special… bad that they are ordinary
    - --Needs to look like the greatest thing on the market--
- How can we convince other people to rent the service
- **Did ASU only build a crane to put on the Aurora boat??**
    - Is it only built for Aurora boats?
- What are the mods on the robot?
    - We can make the robot "Sexy"
    - Sell the mods make it look better
    - Get the end user to be cool
- Techie V.S. practical stuff on pipelines
    - Satisfy both types of people
- **What makes this system SPECIAL?**

    - Crane
    - Mods
    - Partnership
    - What makes this awesome
- ASU
    - What are the deeper needs
    - Where did this idea come from?
    - What problem are they solving...
        - ASU acquired robot?
        - Brainstormed -> Pipeline?
- Aurora
    - Make money?
- Marketing is all about storytelling
    - Persuasive
    - Know the problem
        - Have you thought about this…?
    - This takes care of a small issue that____ does not
- Get info about oil and gas industry in Russia
    - Regulations
    - Incentives…?
        - Patch up _____ amount of leaks
        - Environmental "rebates"
- Why are they checking
- When are they checking… time of day?
- Tides are different
- Lower sea creature activity
    - Use different systems to use
- Keep thinking holistically!
    - Impact things well
- What is this service going to cost
    - Cost: money, time, energy and people
    - X Rubles. manpower, resources, transportation
    - Supply chain
        - Parts come from
        - Wires come from
        - How much it costs to power the system
        - Cost to repair
        - Aurora and ASU
            - To make the robot or make a boat
        - What is the rental contract?
            - Use of the boat, robot or crane
            - For how long in time
            - What will be provided?
            - "Tech support"?
        - ~~Contractor's model??~~
- Has to get to the Client
- Who is paying the four people?
    - Paid by respective companies
    - But who pays for it?
        - Client?
        - 8 hour work day? Overtime etc

        - General pay
        - Aurora may be paid different than ASU
        - What are the costs of the boat/crane?
        - Wages??
- Pricing model?
- Find out what the other Universities have paid
- Crane
    - New piece developed
- Does Aurora have insurance on their boats already?
    - Will this be in our price or no?
- Answer for the rental
    - Do more than 1 tier
    - Not just length of rental cycle
    - Add 1 more person
    - Do this for tier 1…. Added things in tier 2 cost X more but has more services
    - What are the limitations and what can they offer?
    - Companies will want X and may need or want Y
- Hammer out
    - Is ASU getting a boat from Aurora?
    - Or are the 2 boats switching?
        - What are the difference between the 2 boats
        - Age/packages or whatever
    - Rental waiting period?
- Fuel
    - Can do ______ amount of money the average fuel cost over a few months
    - Or Client must fill up the boat upon return
- On average what is the energy usage of the robot?
    - What is that cost of energy?
- Rent a room in the hotel…
    - Room price built in on average
        - Water
        - Electricity
        - Etc
    - Rent a car?
- There are costs such as taxes on rentals and whatnot
- Rent-a-center?
    - Contact them?
    - Is there a break out of the pricing model?
    - Ball park figures
- How do you go about gaining credit?
    - Discount for the first run?
    - Build hype around the System
    - ASU will have its name on it
    - Needs to function like a business
    - Website
    - Marketing materials
        - Single page handout
        - Video of the robot working
            - Students talking about the robot and system
            - Love testing footage
            - Build the hype woot woot

- See a prototype
- Weekly or monthly emails
  - Telling more info each time
- Good about being new
  - First ones to do this
  - Have the technolgy
  - Have the experience
  - Need an interactive space
  - Soical media? VK- End users?
  - Where do the clients get their info
    - Go there to advertise
  - Minute and a half long video
  - Need a cool name and logo
  - Word of mouth
  - Have an expo showcasing the robot?
  - Expo have a feedback to a large screen
    - Free food
    - Demonstration of the robot
    - Get people interested
    - Project the image feed to show what is happening
    - Learn everything about the sea
    - Cool to watch how it works
      - Do a demo and record it
- What is the contingency plan?
  - Do people need to go into the water?
  - How to stop risks
  - Can the robot see anything of secrets?

- Can we get a video of the robot from ASU?
  - That would be beneficial

Interview with Professor Towner : 13 April 2016

- Marketing professor at WPI
- Boston Engineering--Lookup
- Mark Smithers- Chief technical
- 30 minutes of his time ask him about technology commercialization business
- Skype
  - Need to have an executive summary
    - Objective
    - What is our road block?
    - Here is what we think we know
      - Have assets that rent together
      - We don't understand what the proper pricing model would be
      - 2-3 Paragraphs- Give to him beforehand
      - And then the question
        - How to build a pricing model for________
      - What are 1-3 ways to find out what we need to accomplish

- Built a robotic Tuna
- How to price out a model:

- Need to study up on Boston Engineering
- Surplus Lines market- Usually costs more
- Self-insure- Build a pool of cash (Invest?)
- Pretty easy with Insurance with a big company
- Rent the Robot to the entity that has a property and casualty plan
    - They could give… With billions of $$$ what is 40K/
  - Insurance could be a huge task
    - Don't really have to worry if it's no good?

- Could get people from Hanover to talk to us- Connection to WPI and them
- Get a meaningful conversation with an Insurance part
  - Who to send us to? No clue
- Good to a company that has a broad knowledge with insurance plans
- **If need the information then can try to get Hanover
- Diane Strong? - MQP's at Hanover
- There are alums at Hanover
- Go to the Alumni office to get some phone numbers and emails
  - 2 or 3 different Alums
    - Explain what we need to know to them
    - Get pretty reliable information from them

- Financial model: Get most of our answers from Mark
- Best way to use time
  - Make concise statement about what we want to accomplish and what we think that we know currently

- The only thing that actually has value is time
- Km/day
  - Feet/sec
  - This robot can detect_____ expensive but we can do it for this amount_____
  - Bottom up model
  - Top down model
- Solving a problem for a company: Can charge a lot of money
  - Pavlov can help us through that

INTERVIEW WITH CHRISTOPHE DHALLUIN & MIKE COOK : 14 APRIL 2016

- ExxonMobil Subsea Pipeline Engineers
- Various types of robots
  - Inside of casing/jackets
  - External
- ROVs are used for inspection
  - Do away with divers
    - Risk
    - Involvement subsea
    - Currents visibilities
- Highly skilled robot operators

- Well established market
    - Oceaneering, based in US
    - Major support business
    - Specialist service companies
    - Suppliers will contract people with the boat and the vessel platform
        - ROV supplies: Quite a number
            - ROVs- Get a handle full of actual suppliers
            - In house or a supplier
            - Permanently on their service companies
            - Oceaneering services
            - Off shore in Mexico
- Inspections usually done yearly
    - Survey them regularly
    - Pipelines don't leak usually
    - Check to make sure pipelines haven't moved
    - Design for particular aspects:
    - Internal/external corrosion
    - Internal- sticker wall pipes
    - external-coatings , anodes on the pipeline
        - Concrete stabilities
        - Newer pipelines might not corrode
        - Old ones 30-40 year old will corrode outside
    - Fishing
        - Trawling
    - Vessel grabs an anchor and damages it
        - Happens occasionally
    - Depends where the pipelines are
    - ROV spots damage: After steps
        - Is it leaking?
            - Leak detection don't need ROV for
        - Internal PIGing
            - Most are PIGed regularly
            - Clear out wax
            - Every 5 year run an intelligent PIG… ultrasound magnetic flux can detect external and internal corrosion
            - Dominant way of inspection
    - Marine growth, stuck in the silt
    - ROV
        - Visual inspection
        - Concrete coating is okay
        - Damage? Dropped something nearby or on the pipe
        - Has it moved?
            - Not on the sea floor anymore
            - Big storm goes through
    - 100M long span, currents go by and cause he pipelines to vibrate
        - External issues or spans
            - Fatigue failure
        - Own Span analysis or contract it out
        - Mattress under the pipelines to support it
        - Take the picture and use sonar

        - Pipelines cross other pipelines
            - If they are touching
    - ROV will inspect
        - Depends on where you are
    - Some annual 2 or 3 years
    - Other areas may move: Large currents, ice areas, storms
    - Russia has ice, check ice
    - Russia: Caspian is very shallow
        - Ice in the winter time
        - Most pipelines have to be buried very deep
        - Problem would be:
            - Wave forces and currents
            - Wind -> Wind
            - A lot of movement on the seafloor
                - Pipelines could become unburied
        - 200ft of water or less to bury the pipeline
    - Recreational use of the sea?
    - Trawling
- Lots of pipelines how to survey:
    - Depends on how is doing it
    - The inspector
    - Who is doing it and where is it
- Inspected on a regular basis
- Depends on corrosion and the factors talked about previously
- ROV speed
    - ~2 knots
- Pricing model:
    - How much will they pay?
        - Vessel changes
- Day rate:
    - Depends on a lot of factors
    - Usually quite expensive
    - Mostly vessel base, incremental for the higher equipment and personal
    - Compiling the information created after the survey
    - Operating costs
    - Mobilization and demobilization
    - Data analysis after the run
    - People + ROV + Operators
- Other companies:
    - Gulf sub sea
    - UMoss?
    - Gulf of Mexico
    - Oceanengineering
    - Adolt subsea
    - Canyon Offshore**
    - Fugrow- Survey company

INTERVIEW WITH MARK SMITHERS: 21 APRIL 2016

- Has a similar application
- There will be a service to the Company
- Larger Corporation
  - Are investigating robots
- Does the University know about ____capability?
- Why do the corporations want to use the ROVs
  - Government regulation
  - Don't want to lose $$, PR and
- $100,000 a day to operate?
- Why do the robots have to be tethered
- What are they gathering from the Robot?
  - Video
  - Automated software to look for potential problems
- Not too good about Marketing
- How do you Price the system?
  - Guiding forces
    - People developing the platform
      - 50-60% margin Gross Profit
        - Not necessarily goal
        - Every term on your cost over x years
      - Sale price- cost to deliver
    - Applying all the other stuff
- Insurance?
  - How a warranty works?
  - 3-5%
  - No one will insure an underwater robot
  - Access why are the insurance companies not investing?
    - Probability of loss is very high
- Variable costs worked into the model
  - His comment…
  - Increase frequency of inspection, resolution of inspection
  - Benefit to market was:
        - Price could be much lower
        - Since smaller and nimble "Lose one, meh here is tiny one of 3 or 4"
        - Much smaller price may be appealing to the industry
- $50,000 is extremely small
- Sonar vision/ Doppler velocity logs/profiler
  - 20 - 40 thousand each… those are the sensors
  - Need to talk to the liaison about how much each sensor is on
  - What is the exact payloads of the robot?
- Two partners how to deal with pricing
  - Let the partners deal with it
  - Need to go learn their business
  - Operational model
    - Maintenance costs/ cost to operate/ pay their people
    - Students are not super reliable to operate on a boat
    - University are not in position to sustain an operational business
      - Work off a different schedule

            - Don't drive the same as companies
            - Has not seen it work yet
    - Inquire about how the universities work in Russia
    - Professor Tawner give us some info into a university
        - Economic drivers behind a university
        - Start off a whole other entity
    - iRobot?
        - How did this start and work?

- $100, 000 a day to operate on average
- Price for the robot; 60% profit margin : revenue - direct expenses
- 3, 6, 9 months investment return
- Service models can be more profitable
    - Locks in customers and gets more revenue in the long run
- Insurance companies will not insure. Very risky.
    - Self-insure
    - 3-5% on warranty
- Price could be much lower & have multiple systems
    - Advantage over more pricy systems
- Robot seems way too cheap
    - Will large companies think this too and be wary?
- "Typically universities are not positioned to support a company."
    - Work at different schedule and pace
    - Summer comes and professors go away
    - Drivers for universities are different from businesses.
    - Ask professor Tawner about the economic drivers behind universities.

Meeting With Professor Hall-Philips : 26 April 2016

- University start a Corp venture?
    - What is in it for them?
- SWOT analysis
    - Industry + idea (boat robot)
    - Concerned with weaknesses and threats

- What can these opportunities be?
    - Tie it into background ideas

- Justify decisions with moving forward with this project

- Feasibility instead of marketing plan

- Here is what we would like to change
- This is what we need for this to work

- 3 scenarios:
- 1] do this make no money

- 2] do this to make money but students aren't employed
- 3] everyone is somewhat happy

- Figure out how long this project has been going on for
- Cost analysis Feasibility analysis as input for our project

- Lemonade stand idea: Feasibility to do this…
- Time of day
- People stopping buy and

- Who is Alexis
- Faculty?
- Staff?

- They want to make a profit…

- Ask the question:
    - Pool of student workers on the boat…?
    - "Work studies"?
    - Volunteer based is not viable

- Why is this a big deal for the director?
    - Director and Aurora relationship

- Russian students:
    - What they were doing before they met us?
    - Before it became an IQP
    - Students = building the robot
    - We = make marketing plan

- Ask the students and the director the same questions

- There usually is a real end goal
    - What does he have in mind?
    - Reach the same goal

- Work this way… as opposed to make this happen

- Look to see if there are other options for boat companies what are we being charged to use said boat?

- Just to see what is out there

- Entrepreneurship venture?
    - Look to see what other economic ventures are happening

- Why would we want this to happen?

- Aurora wants to make a Marina…

- Tawner, renting a service vs purchasing
    - Top down and bottom up
    - Do top down
- What is the history of this project

- SWOT- Just do it

- Marina?
    - Check local news for the area about a revamping of the neighborhood, spruce up the area
    - Local initiative?
    - Social impact initiatives or do they just want to make money

INTERVIEW WITH JOHN BOYLE, ASSET INTEGRITY, OCEANEERING: 28 APRIL 2016

- Categorized into two types of inspections
    - Internal with PIG
    - External with robotic trawler
        - Strap or magnetic wheel, slides along
    - Clamps onto
        - Raster inspection device
- Oceaneering offers its services globally
    - Gulf of MExico
    - North Sea
    - Trinidad
    - Egypt
    - Nigeria
    - Asia
- Magna Subsea Inspection System
    - http://www.oceaneering.com/oceandocuments/brochures/inspection/AI%20-%20Magna%20Subsea%20Inspection%20System.pdf
    - Clamps onto pipe with magnet
    - Slides down the robot
    - Scans the circumference of the pipe
    - Acoustic mapping
        - Guided wave"
        - Transmitter on one side, a receiver on the other"
        - Can scan the whole pipe
        - Use a magnetic field to produce the sound waves
    - Advantage: Don't have to dredge underneath the pipe
    - Tethered and operated remotely
    - Can inspect 1000 ft/ day
    - This inspects everything
        - Complete volumetric wall thickness
        - Can be set up to inspect the environment

                - Used for a lot of non-piggable pipelines
                - A lot of pipe cannot be pigged for various reasons
                    - Diameters, traps, awkward angles, etc
                    - Pigging a pipe stops production
                        - Costs money
                    - Dirt build up inside a pipe and the PIG gets stuck
                        - Very bad
                        - Millions of dollars a day
                        - Affects production
    - This system may require prior cleaning of the pipe
    - If a pipe is buried, the pipe must be excavated before inspection
- Neptune ROV
    - http://www.oceaneering.com/oceandocuments/brochures/inspection/INS%20-%20Neptune%20System.pdf
    - Comes in after the Magna when a problem is identified
    - Much higher resolution
    - Must raster the whole pipe
        - Go back and forth, x and y
    - A few hours for a 1-meter section
    - Cleaning is the most time-consuming factor
- In order to deploy these tools, requires service vessel
    - Two extra ROVS
    - 200-300,000 dollars per day
    - All the people + boat + 2 ROVs
    - Must rent the boat
- Risk Based Inspection is the first inspection
    - Engineers analyze what the service is, what the product is, what chemicals are inside the pipe
    - Look for the highest risk pipe and then inspect that
    - Sulfide gas, scour
    - Based on previous inspections
    - Most likely place where a problem might occur
    - Deploy the visual inspection, then continue from there
    - Not possible to inspect everything
- Initial inspection is visual inspection
    - Drive down a pipe and create a video
    - Take measurements
    - Say they see a gouge, look at it from two angles and take a measurement
- The report depends on each client
    - Generally client wants the raw data
    - Depending on contract, some clients have their own engineering departments that will analyze the data
    - Some clients want the service to do the analysis
- Who is the crew?

- Dependent on the equipment
    - Some you only need one person to operate
    - Because of expense, operate 24 hours
    - Need night shift
- Most common crew is a crew of 5
    - Managers + technicians + night crew
- Usually two people driving the robot
    - There's the guy who is actually driving the ROV
    - A secondary person who is using the manipulators
    - 5 function + 7 function arm
        - Requires high detail + training
    - <u>Highly</u> trained.

- Oceaneering has a lot of experience
    - Has developed a lot of innovative technologies
    - Magna-scan is a world-first
- Who is responsible/liable for missing something
    - Investigation to see who is responsible
    - Not had experience in subsea, but had experience in oil refinery
        - More of a "lessons learned" rather than prosecution
    - Manager is liable and responsible for the quality of the inspection

INTERVIEW WITH PROFESSOR ANATOLI MIKHAILOVICH IN RUSSIAN. TRANSLATED LIVE BY ALEXEY RYBAKOV: 14 SEPTEMBER 2016

- Caspian Sea internal sea. No connection with other oceans.
- Many countries around caspian
    - Very big problem to collaborate between countries about fishing, drilling, boundaries, etc
- Countries used to be part of Soviet Union. No problem then.
    - Ecological situation good because collaboration and communication
- 2 types of activities: <u>Fishing</u> and <u>Oil & Gas</u>
- Azerbaijan has many plants for oil extraction
- Many oil producing companies today. In past, very few. Was better back when few oil companies and when fishing was main business.
- Types of fish: Sprat, Mullet, Sturgeon
- Sturgeon fishing was prohibited
- Before modern year, there was a large population of sturgeon.
    - Very important product -> Black caviar
    - The sturgeon produce the caviar every <u>16 years</u>
- Caviar contains over 60 amino acids and other useful qualities
- After soviet collapse and discovery of new oil in the Caspian, uncontrolled fishing and oil extracting. Poaching.
- Oil companies build many artificial constructions like oil platforms and islands
- Many large oil companies like shell & BP came to Caspian and performed business
    - Created artificial islands

    - Many buildings on islands to support the oil venture
- All of these reasons influence the hydrodynamic profile of the caspian sea floor
    - This influences temperatures conditions, often with negative results
- Understand the ecological chain
- Sturgeon eat sprat eat plankton
- Breaking the food chain in one place hurts other parts of the food chain
- In 2002, critical situation with Sturgeon population
    - 3 types of sprat:
        - Usual
        - Big-eyed
        - Anchoves
    - Anchoves decreased. 250,000 tons of anchoves were killed by ecological situation. Hurt the already vulnerable sturgeon
    - Scientists think that this was caused by oil pipe rupture
    - Other reasons may be the use of special fishing equipment
        - Ex: special light fishing or pump
- Want to catch only the old fish
- Earlier, fishing was done only in the winter.
- Now, fishing is often down during the summer. This hurts the population because many small fish are caught
- Really interesting to observe the fish population of anchoves/sprat. Very interesting to ecological institutes
- Inspect the bottom profile of the Caspian Sea and see how it changes
- Observe changes in temperature. See how it influences plankton, sprat, anchoves, sturgeon
- Detect, observe, deduce hof profile affects there
- 40 billion cubic meters of gas under Caspian Sea
- Oil extraction. Difficult infrastructure. Electrical cables, pumps, pipelines
- The artificial buildings influence the environment. Need to control ecological system parameters.
    - Temperature, flow velocities, contaminants (oil & gas), use systems like GNOM that can automatically do this work
    - Need to perform observation from air with quadcopter
- If temperature of water changes by 1 degree celsius, we can detect from space
    - Use thermometer on robot to detect temperature
- All of this data goes to special monitoring center. Every oil & gas company has this center
- Look into Caspnirh as an institute that may fund this kind of research
- They have a special boat that makes an annual expedition
    - Calculating fish population
    - Underwater monitoring of bottom of sea (temperature, flow speed, etc)
- Population of anchove/sprat increased a bit in the last 2 years
- A special contract between neighbor countries about coast usage, fishing zones, oil, etc.
- Disagreement on the separation of Caspian Sea
- Earlier, all countries had a 12-mile zone. Production in this zone is a special right. After big source of oil was discovered, every country wants more of the Caspian Sea.
- Main reason for uncontrolled usage of the Caspian

- Agreement important step for ecological regulation
- Special collaboration zone. Can probably use GNOM in this zone.
- Different ecological regulations in different regions of Caspian.
- Every company that does business in this zone must control ecological situation in this area
- Ex: In 1900s, we know that Turkish companies took more than 400 tons of black caviar. Turkey bought from Azerbaijan. Azerbaijan uncontrolled fishing activity.
- Price of black caviar fell as a result. Bad for Russia.
- Interesting to understand the population of sturgeon. What percentage of old 'fishable' fish
- Now cannot catch Sturgeon in Caspian sea. Only in rivers. Significant poaching exists.
- Idea of marking fish with robot
- 12-15% of sturgeon return to artificial sturgeon farm
- We need not only robotic system. Need monitoring system. Special center & department where data can be sent and processed.

INTERVIEW WITH AURORA BOAT COMPANY: 21 SEPTEMBER 2016

- Huge boat
  - 15 meters long
  - 4.5 meters wide
  - Can carry 10 people
- Two engines
  - 1700 horsepower each
- The boat can travel 90 km/h
- Boat can travel in weather up to level 3
  - Caspian rarely experience a level 3 storm so the boat can always operate
- Boat used by EMERCOM for emergencies
- Glonass navigation system
- A crane can be used to lower the GNOM robot into the sea from the boat
  - Crane already made and owned by Aurora
- Boat can spend 10 hours out at sea
  - 40 miles from coast of Caspian Sea
- It takes 4 hours to get to oil platforms from Aurora
  - 3 hours to the Caspian Sea
  - 1 additional hour to the platforms
- Boat can carry 3500 liters of diesel fuel
- 700 km range on full tank
- Costs 160,000 rubles for boat + operators per day -> ~$2,500 per day
- Aurora owns a special license to operate the the waters of all of the countries surrounding the Caspian

APPENDIX B: COMPANY CONTACT NOTES

Interview Questions in Astrakhan:

Russian:

1) представиться Имя Фамилия;
2) я студент АГУ;
3) мой преподаватель дал мне задание найти потенциальных
клиентов для проекта подводная робототехническая система ГНОМ;
4) вас интересуют такие услуги как подводная видео-съемка или анализ дна
с помощью акустической установки;
5) кому интересно были бы такие услуги?

English:

1) Introduce your name
2) I am a student of Astrakhan State University
3) My professor has given me project to find client for underwater robotic system GNOM
4) Ask the client if the robot is interesting for you, for example underwater recording or analyzing bottom with help of ultrasonic sensor
5) After that, ask if another company would be interested in this service

Companies:

Oceanographic Institute

1. What problem could GNOM solve?
    a. Detecting temperature in Caspian Sea and in Volga
2. How could it solve this problem?
    . Attach a thermometer to robot to measure temperature in the water and create a map
3. What sensors does GNOM need?
    a. Temperature sensor

Красные барикады (Ship building company)

1. What problem could GNOM solve?
    a. Detection of damage to the hull of a ship
2. How could it solve this problem?
    a. By taking a video of the hull of a ship/Ultrasonic detection
3. What sensors does GNOM need?
    a. Camera
    b. Ultrasonic Sensor

Первомайского СРЗ (Ship buildingcompany)

1. What problem could GNOM solve?
    a. Inspecting the hulls of ships

2. How could it solve this problem?
   . By taking a video of the hull of a ship
3. What sensors/equipment does GNOM need?
   . Camera

** Company had no business at the moment

United Ship Building Company

Caspian Energy - Talked to chief welder
They do not have a rail to inspect
Name of shipyards - Galactica, 3ий интернационал
These two companies do ship repairs

1. What problem could GNOM solve?
2. How could it solve this problem?
3. What sensors/equipment does GNOM need?

Lotos Shipbuilding

1. What problem could GNOM solve?
   a. Move ships to water by rails
   b. Rails go down through the water
   c. Use robot to inspect the rails underwater
2. How could it solve this problem?
   . GNOM will use camera to look at the rails
3. What sensors does GNOM need?
   . Only camera

Problem operating GNOM in Volga River. Difficult to move robot side to side because of lack of motor. No need for extra sensors. Not a lot of time. Easy to operate. Not very risky. Must train students in pool. Put rail in pool and teach students how to inspect the pipe as train.

Company News

Lotos Shipbuilding News

1. Special Education Building. Trains people from companies. Perhaps create something to train people for underwater ROVs
2. Moscow state technical institute
   a. Professors & teachers want to get experience with using underwater system
3. Astrakhan State University
4. Make a course for using mobile robotics
5. Educational Plan
   a. If want make course, make educational program
   b. How to work/use this robotic system
   c. Ex: Design of mobile underwater robotic system

International Companies in Astrakhan

Shipbuilding, Tourism, French company that produces equipment for oil and gas (шлюмберже)

Underwater Construction Company

Builds oil platforms

Забод Сталуна

Caspnirh

Laboratory of Water Problems and Toxicology:

1. What problem could GNOM solve?
    a. Microlandscape study
2. How can GNOM solve this problem?
    a. Scans the bottom of the Caspian Sea
3. What sensors does GNOM need?
    a. Camera
    b. Ultrasonic Sensor

4. Record Video(For an advertisement?)
5. Understand fish population
6. Need Pilot and robot
7. No boat

Attachments:

Camera
Acoustic sensor

Emercom

1. What problem could GNOM solve?
    a. Inspecting the undersides of boats
2. How can GNOM solve this problem?
    a. By looking/scanning the undersides of boats
3. What sensors does GNOM need?
    a. a. Camera
    b. b.Ultrasonic Sensor

Astrakhan State Technical University

1. ASTU
2. They have students who study Agronomy

3. Institute of Oil and Gas
4. Perhaps rent robot to this university for students to us
5. Underwater video or laboratory work for students

Astoria

1. What problem could GNOM solve?
    a. Promotional Video
2. How could it solve this problem?
    a. Take a video of the underwater environment
3. What sensors/equipment does GNOM need?
    a. Camera

APPENDIX C: ADDITIONAL PHOTOS

Figure 15: Walter holding GNOM robot for scale

Figure 16: Aurora AS14 Catamaran. People on left for scale.