NavSim
TECHNOLOGY

Marine Ground-Based Augmentation System (GBAS) CASE STUDY

LNG Terminal in Poland

version 1.2, latest update: 27 January 2020

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1. Executive summary

The Świnoujście-Szczecin Waterway, Poland, is one of the most demanding navigating areas in Europe and in 2015, after the LNG Terminal in Świnoujście was completed, navigating the area became even more challenging. To address safety concerns associated with navigating Q-Flex carriers at the Pomeranian Bay and the LNG Terminal, Polish Maritime Authorities and Szczecin-Pilot, a local pilot group, decided to modernize and expand available navigational infrastructure. After testing a wide range of available systems they decided to employ NavSim solutions, namely: NavSim Ground-Based Augmentation System with RTK corrections and integrity monitoring and OneBoxPro+ Portable Pilot Units.

The GBAS-RTK system is a shore-based infrastructure for determining and broadcasting differential Real-Time Kinematic corrections. Once deployed, GBAS considerably increases local positioning capabilities by enabling compatible devices (e.g. OneBoxPro+ PPU) to determine position with sub-centimeter accuracy.

The OneBoxPro+ Portable Pilot Unit, or OneBoxPro+ PPU, is an advanced Portable Pilot Unit, which offers unchallenged performance and provides pilots with the assistance they require for the most demanding piloting operations.

Finally, as part of the modernisation of the local waterway (including approach to the LNG Terminal), an innovative buoy management and control system was also deployed. NavSim's Smart Buoy Management System, or SBMS, turns each Aid to Navigation into a smart object. As a result, local authorities and pilots were provided with the means to remotely monitor and control (e.g. turn on lanterns) navigational lights whenever needed.

The remainder of the document is divided into five sections. The next section provides details of the LNG Terminal, its rationale and characteristics. The third section describes the Świnoujście-Szczecin waterway and its demanding navigational environment. The fourth section presents modernisation activities performed to prepare the navigational area for Q-Flex carriers. Finally, the fifth section provides details of the maneuvering associated with docking Q-Flex carriers at the LNG Terminal. The last section summarizes the document.

2. The LNG Terminal in Poland

The major idea behind the construction of the LNG Terminal in Poland was to diversify the directions of natural gas supply and thus improve the country's energy security. Toward this end, in 2008, the Council of Ministers adopted a resolution in which the construction of the LNG terminal was acknowledged as a strategic investment for the interests of Poland, compliant with the plans for diversification of sources and roads of supply of natural gas and guaranteeing the energy security of the country.

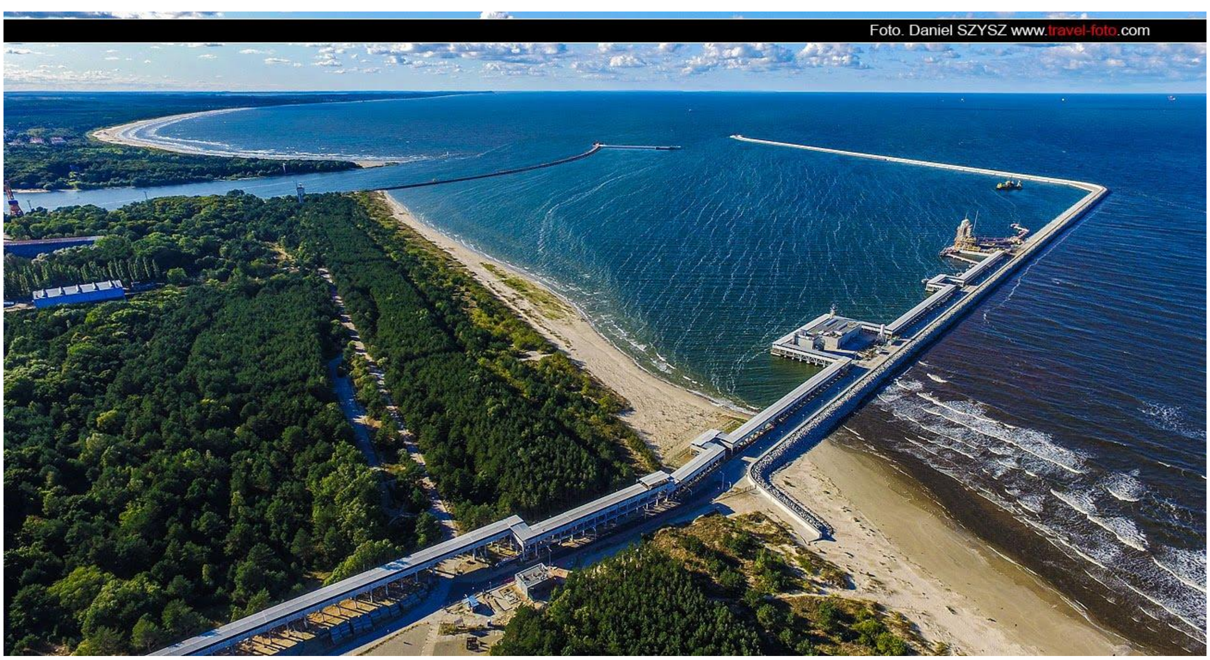
Location

Pursuant to conducted analyses, it was decided to locate the LNG terminal for the off-take of liquefied natural gas in Świnoujście. For the requirements of the project in Świnoujście, pipelines for the off-take of liquefied gas from ships were constructed, as well as LNG tanks and re-gasification facilities. The LNG terminal was built on the right bank of the Świna River.

Dispatch capacity

In the first stage of operation, the LNG terminal enables the re-gasification of 5 billion m^3 of natural gas annually. In the next stages, depending on the increase of demand for gas, it will be possible to increase the dispatch capacity up to 7.5 billion m3.

Figure 1. LNG Terminal Port



NavSim Technology Inc.
1247 Kenmount Road Unit D
Paradise, Newfoundland and Labrador
CANADA A1B 3T5
Tel: (709) 726 - 7779
fax: (709) 726 - 7789
info@navsim.com
www.navsim.com

3. Świnoujście-Szczecin Waterway

The Świnoujście-Szczecin Waterway in Poland is one of the longest and one of the most challenging waterways in Europe. It is 100 nautical miles and relatively shallow. Over 60% of the waterway is the Świna river and the remaining 40% is a dredged corridor of the Pomeranian Bay. The average depth is 14 meters.

Due to its geographical location, the waterway area is characterized by dynamic atmospheric conditions, including heavy rains, fog, strong wind gusts, icing and changing currents.

Figure 2. Frequency of constrained visibility occurance (1969-1999)

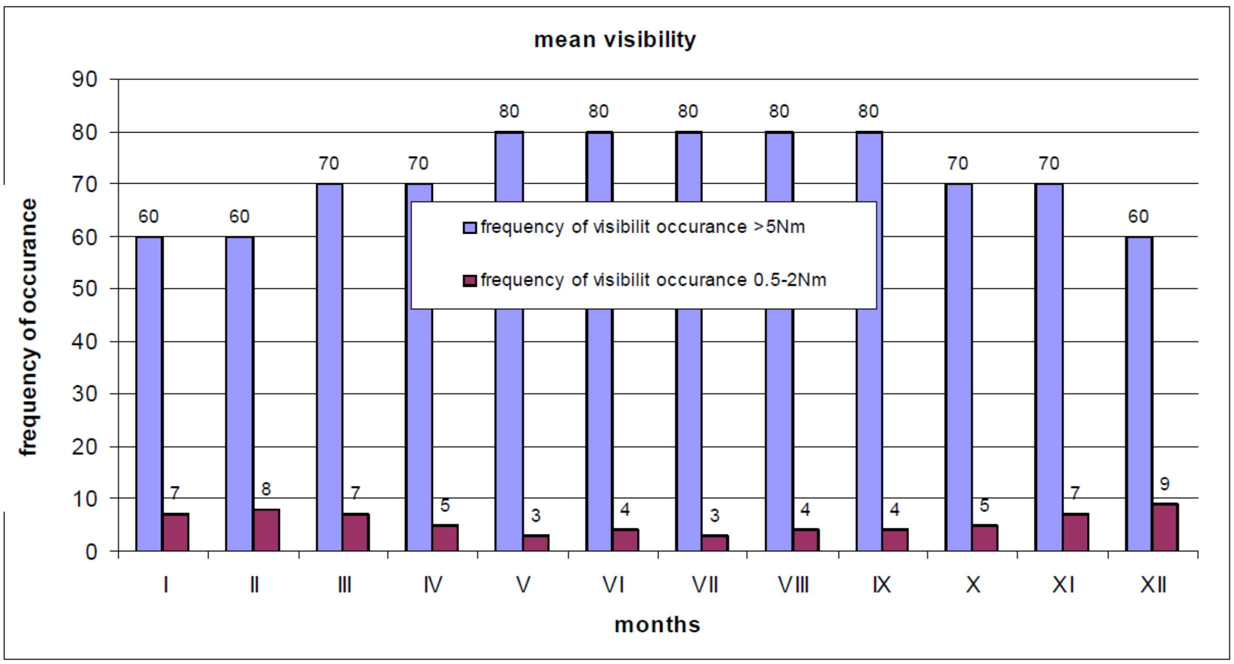
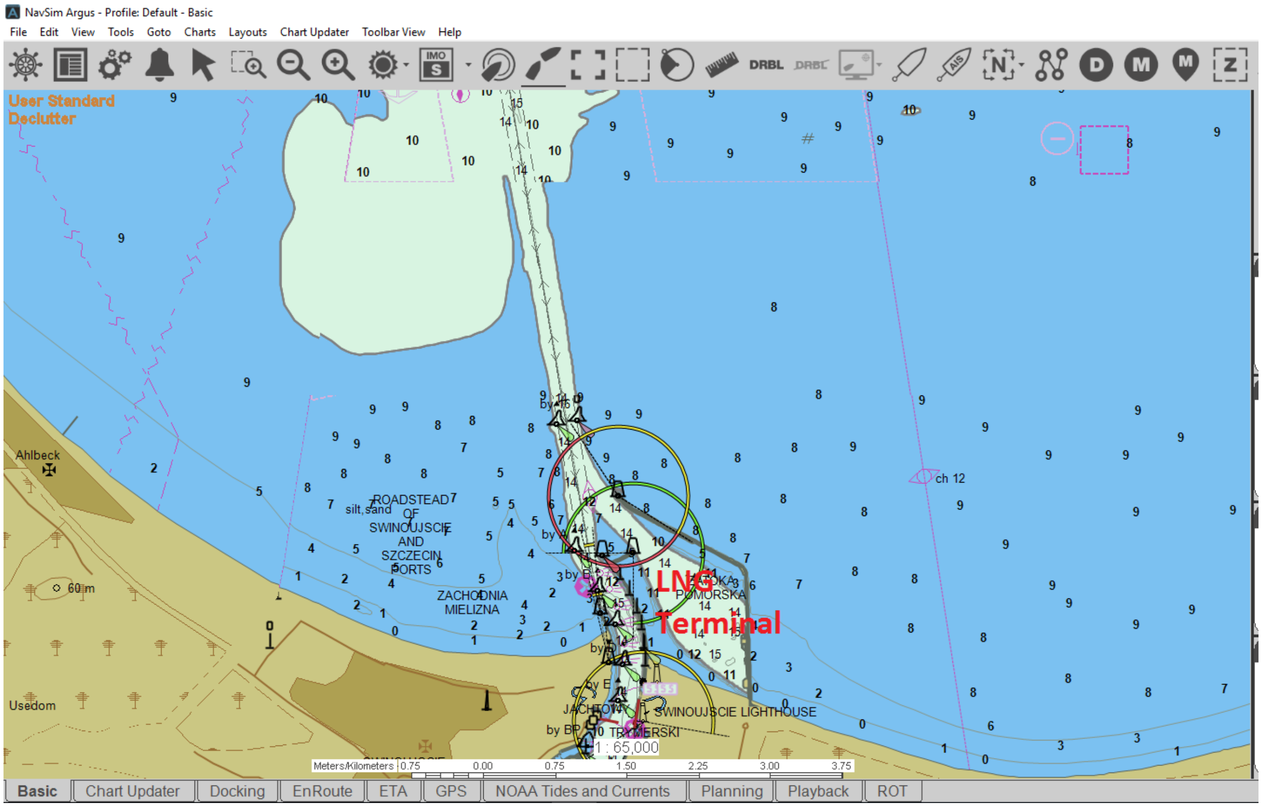


Figure 3. Approaching corridor to the LNG Terminal port



4. Preparing the Navigational Area for Q-Flex Carriers

To prepare the Świnoujście-Szczecin waterway for accommodating large LNG tankers a substantial number of improvements in the waterway infrastructure (both onshore and offshore) were commenced. The waterway had to be adequately prepared to assure safety of navigation of the Q-Flex type LNG tankers (LOA:315m; Beam:50m).

This included:

- Deploying IALA-compliant Ground-Based Augmentation System
- Providing local marine pilot group with high-performance OneBoxPro+ PPU units
- Replacing all existing buoys with newer models (incl. modern LED lantern) and deploying new ones in the vicinity (65 buoys were replaced and 11 new deployed)
- Equipping all buoys with Smart Buoy Management System by NavSim to allow for ease of monitoring and control
- Replacing legacy lanterns in all lighthouses, leading lights and landmarks (128 in total) with modern LED lanterns

As a result of introduced improvements, the Świnoujście-Szczecin Waterway has become one of the safest and most efficient waterways in the world. Currently, it provides pilots with sufficient tools and infrastructure to river-navigate and moor/dock vessels in virtually any weather conditions.

4.1. Ground-Based Augmentation System (GBAS)

Alongside the construction of the LNG Terminal facilities, to assure safety of navigation in the area, improvements in local navigational infrastructure were also introduced. One of the crucial elements of the modernized infrastructure was the Ground-Based Augmentation System by NavSim. The major role of the GBAS is to provide RTK differential corrections for satellites from all available satellite constellations (i.e. GPS, GLONASS, BeiDou, and Galileo) and thus enable local RTK rovers/receivers to determine vessels' position with sub-centimetre accuracy.

The marine GBAS developed by NavSim complies with IALA R-121 regulations for performance and monitoring of DGNSS services, which established strict accuracy, availability and continuity performance standards. The marine GBAS includes four major elements, namely: (1) Primary RTK Reference Station, (2) Secondary RTK Reference Station, (3) RTK Integrity Monitoring Rover, and (4) Integrity Monitoring Software.

The fundamental role of the Primary RTK Reference Station is to broadcasts (via VHF and Internet) differential corrections. The Secondary RTK Reference station is a back-up solution for the primary station and is activated when performance of the Primary RTK Reference Station is suboptimal. The RTK Integrity Monitoring Rover is a GNSS-RTK enabled receiver responsible for determining RTK position utilizing differential corrections obtained from the primary or the secondary station. Finally, the RTK Integrity Monitoring Software constantly monitors performance of the marine GBAS system by comparing real-time position measurements from the RTK Integrity Monitoring Rover against the rover's reference position (which was very accurately determined by the means of the post-processing techniques). Whenever the monitoring software determines that the system performance is suboptimal, it automatically executes established procedures (e.g. it switches off the primary station and switches on the secondary station).

The marine GBAS by NavSim was designed to comply with strict standards. Since its deployment in 2015, the system performed as expected which has been reflected in the performance ratios (i.e. accuracy, availability and continuity).

NavSim always strives to provide its customers with top-notch solutions which operates in accordance with established international safety and performance standards. Towards this end, we are actively participating in all relevant on-going IALA committees' sessions, which are devoted to further improvements and standardisation of the marine GNSS and RTK regulations.

Figure 4. Marine GBAS Performance Report

POLISH MARITIME OFFICE

Marine GNSS-RTK Reference Station Report

From: 2016-09-01

To: 2017-01-11

OK

System: UM Szczecin	Service Provider: NavSim Polska	Correction: Fixed RTK
Date from/to: 2016-09-01 - 2017-01-11	Frequency: 1Hz	No. of Observations: 10 149 525

Reference position: (datum 2000 and hieght)	X = 14.260149522358	Y = 53.897044252819	H = 48.445

Observed errors:

RMS x	5 mm	CEP(50%)	7 mm	SEP(50%)	14 mm
RMS y	7 mm	CEP(95%)	15 mm	SEP(90%)	23 mm
RMS h	15 mm	CEP(99%)	19 mm	SEP(99%)	31 mm
2RMS x	10 mm	DRMS(65%)	9 mm	MRSE	18 mm
2RMS y	15 mm	2DRMS(95%)	18 mm	2MRSE	35 mm
2RMS h	31 mm	3DRMS(99%)	27 mm		

Performance characteristics:
[*IALA R-121 : Availability*]

Progi [mm]	MTBF (3D)	MTTR (3D)	A (3D)	MTBF (2D)	MTTR (2D)	A (2D)	MTBF (h)	MTTR (h)	A (h)
HAL=20 VAL=30	3678 s	3 s	99.91 %	212859 s	10 s	100 %	3729 s	3 s	99.92 %
HAL=50 VAL=80	547354 s	20 s	100 %	574722 s	21 s	100 %	1044979 s	5 s	100 %
HAL=100 VAL=150	574723 s	20 s	100 %	574723 s	20 s	100 %	1149477 s	5 s	100 %
HAL=150 VAL=200	574723 s	20 s	100 %	547355 s	19 s	100 %	1149477 s	5 s	100 %
HAL=200 VAL=300	547355 s	19 s	100 %	522476 s	18 s	100 %	1436847 s	5 s	100 %

Performance characteristics:
[*IALA R-121 : Continuity*]

Progi [mm]	Interwał	Okres	Cel	Ciągłość	Prawdopodobieństwo awarii
HAL=20 VAL=30	1968 s	133 d	99,97 %	99.08 %	0.92 %
HAL=50 VAL=80	1968 s	133 d	99,97 %	99.66 %	0.34 %
HAL=100 VAL=150	1968 s	133 d	99,97 %	99.66 %	0.34 %
HAL=150 VAL=200	1968 s	133 d	99,97 %	99.64 %	0.36 %
HAL=200 VAL=300	1968 s	133 d	99,97 %	99.62 %	0.38 %

4.2. OneBoxPro+ Portable Pilot Unit

Szczecin-Pilot Group, that is the group of marine pilots which is responsible for docking Q-Flex carriers at the LNG Terminal, after conducting a series of trials with many PPUs from different manufacturers, has chosen the OneBoxPor+ PPU by NavSim as their primary tool for marine piloting purposes.

OneBoxPro+ is the next-generation NavSim PPU and was built to support high-precision navigation, docking and mooring activities. Embedded GNSS-centric technology uses all available GNSS signals equally (GPS, GLONASS, BeiDou, Galileo) without any constellation preference to deliver fast and stable solutions. Implementing multipath mitigation algorithms minimizes dilutions of precision, whilst fast initialisation makes the PPU operational within 3 minutes from powering on. All this leads to incredibly robust and dependable measurement processing, resulting in enhanced field productivity.

Featuring two independent high-gain yet portable antennas, OneBoxPro+ offers independent heading (HDT) in the smallest form factor and at the lowest power consumption available today on the market. The state-of-the-art RG5-ROT generator delivers rate of turn data with unprecedented accuracy (0.07°/min) and responsiveness (<1 sec), while the GNSS Real-Time Kinematic (RTK) differential corrections allow docking vessels with unprecedented positioning (sub-centimeter) and speed over ground accuracy (0.007m/s).

Each OneBoxPro+ unit supports up to 5 simultaneous Toughbook/Toughpad connections, meaning that every pilot on-board will have the same navigational data on their personal machine. It comes in the smallest and lightest form factor available on the market. Thanks to its IP67-rated sealed enclosure, the OneBoxPro+ is suitable for operations in any part of the world, including the gas-proof environment. The built-in battery ensures uninterrupted operation for 20+ hours.

OneBoxPro+ features the latest version of the award-winning Argus 3.0 software. NavSim's ARGUS 3.0 PPU system offers a considerably higher level of feature content and functionality than any other PPU provider in the industry. The ARGUS software has enhanced capabilities in the areas of AtoN and MET-HYDRO message handling, 'Cloud' based delivery of software and chart updates, navigational objects and assignment vessel information. Our software was designed with input from marine pilots so that it would specifically address some of the functionalities that were lacking in other PPU software systems. Some of the ARGUS features include highly-precise docking aids to assist pilots responsible for berthing, the ability to program many types of information such as alarms and zones, and the ability to display, record and playback both AIS positioning information and DGPS information. This software allows the user unprecedented configuration flexibility, allowing each individual pilot to create separate tabs and layouts depending on what information they want displayed at any given time. The system also gets auto updates for charting software so pilots always have up to date information.

NavSim's Portable Pilot Unit is unique on the market not only due to its unchallenged performance but also due to technical support and additional services offered by NavSim. First of all, we develop and manufacture both our hardware and software in-house. This gives us the unique ability to diagnose and resolve any issues that occur immediately and effectively. Many of our competitors develop hardware or software only, not both. This means they are only able to provide support for one part of the PPU system. In some cases, our competitors do not provide support at all for their systems. NavSim feels that this is an essential part of providing a PPU system. Every PPU we sell is covered by NavSim's Maintenance, Service-Support and Warranty (MSSW) service, including all spare parts and 24/7 technical assistance. Therefore, we can quickly and easily troubleshoot any issue that arises. Furthermore, we are also able to adapt our product to the unique needs of any pilot group. We are responsive, flexible and open to your suggestions.

4.3. Smart Buoy Management System

In order to increase efficiency in the management and monitoring process of the local marine infrastructure at the Świnoujście-Szczecin Waterway and the LNG Terminal, Polish Maritime Authorities decided to adopt the Smart Buoy Manager System by NavSim.

The Smart Buoy Management System, or SBMS, is a low power consumption bidirectional multi-channel system/portal enabling the establishment of complete AES-encrypted two-way communications and data reception with remote and/or autonomous sensor arrays. NavSim developed the SBMS to be a communication conduit that allows it to interface with and seamlessly integrate different payloads on a remote/ isolated unit such as a maritime buoy or surveillance tower. The SBMS allows an operator to effectively and seamlessly manage virtually any station equipped with a SBMS. Each station with a SBMS can integrate optical payloads (visual and IR), Electronic Countermeasures (ECM), Electronic Support Measures (ESM), provide met-hydro and weather data and can receive and transmit AIS data (including vessel's data). The SBMS can be located anywhere, as the system flexibility allows for bidirectional communications including Satellite Transceiver, AIS AtoNs, UHF Data Transceiver and GSM. It has an operating temperature of -40 to 85℃, allowing it to operate in any environment.

Once an SBMS is installed in or on a platform, each monitored platform becomes a 'smart station' capable of receiving instructions and sending back reports. Each station working under SBMS control is equipped with a SBMS controller for gathering, processing and storing data, and a communication module to exchange information with the main operating center. The operator can choose which payloads they want to integrate with the SBMS.

The operator can manage and monitor all payload objects on all connected platforms in a simple and intuitive manner using NavSim's dedicated SBMS Monitor software, smartphone app and/or web interface. SBMS Monitor uses official (SOLAS / commercial ECDIS) ENCs (S-57/S-63) as base charts, therefore all monitored objects correspond with their ENC peers. Confidentiality and integrity of transmitted data is assured at every level by the Advanced Encryption Standard for group data encryption and there are also advanced user and group permissions.

All operators, including marine pilots, who have been authorized to use the system can remotely turn on buoy lanterns as need.

5. Docking Q-Flex carriers at the LNG Terminal

The docking Q-Flex carrier at the LNG Terminal in Poland is a relatively complex tax task (not sure if this is the word you meant?). Total time required for completing all maneuvers is approximately 5 hours. Navigational maneuvers can be divided into four distinguished phases:

- **Phase #1:** Deploying PPU and navigating the approaching corridor
- **Phase #2:** Final-decision point to port maneuvers
- **Phase #3:** Port maneuvering and circulation
- **Phase #4:** Mooring

Each of the above phases presents its own unique set of challenges and requires pilots to show a different set of piloting skills. After the final-decision point is reached, the pilot has no other option but to continue operation until the LNG tanker is safely moored at the final dock, even in the most extreme weather conditions. In order to successfully and safely accomplish all tasks, the OneBoxPro+ PPU is utilised to support pilots at each of the five manoeuvring phases.

5.1. Phase #1: Deploying PPU and navigating the approaching corridor

According to the existing procedures, every LNG tanker is embarked by two experienced pilots at N1 buoy that is 20 nautical miles from the port entrance. Before embarking, the pilots pre-configure the OneBoxPro+ at the pilot station (e.g. fill-in basic vessel's information, plan for the most optimal route and determine weather conditions and forecast). After embarking on the vessel, pilots only need around 3 minutes to deploy and further configure the OneBoxPro+ PPU. This includes determining offset of the position and vector antennas.

Both pilots are connected to the same OneBoxPro+ units simultaneously. This assures that they both have access to the same navigational information at all times.

Besides adequately deploying and setting up the PPU gear, the major role of the pilots during this first phase is to navigate the Q-Flex carrier along in the middle of the 150-meter-wide approaching corridor to the LNG Terminal port.

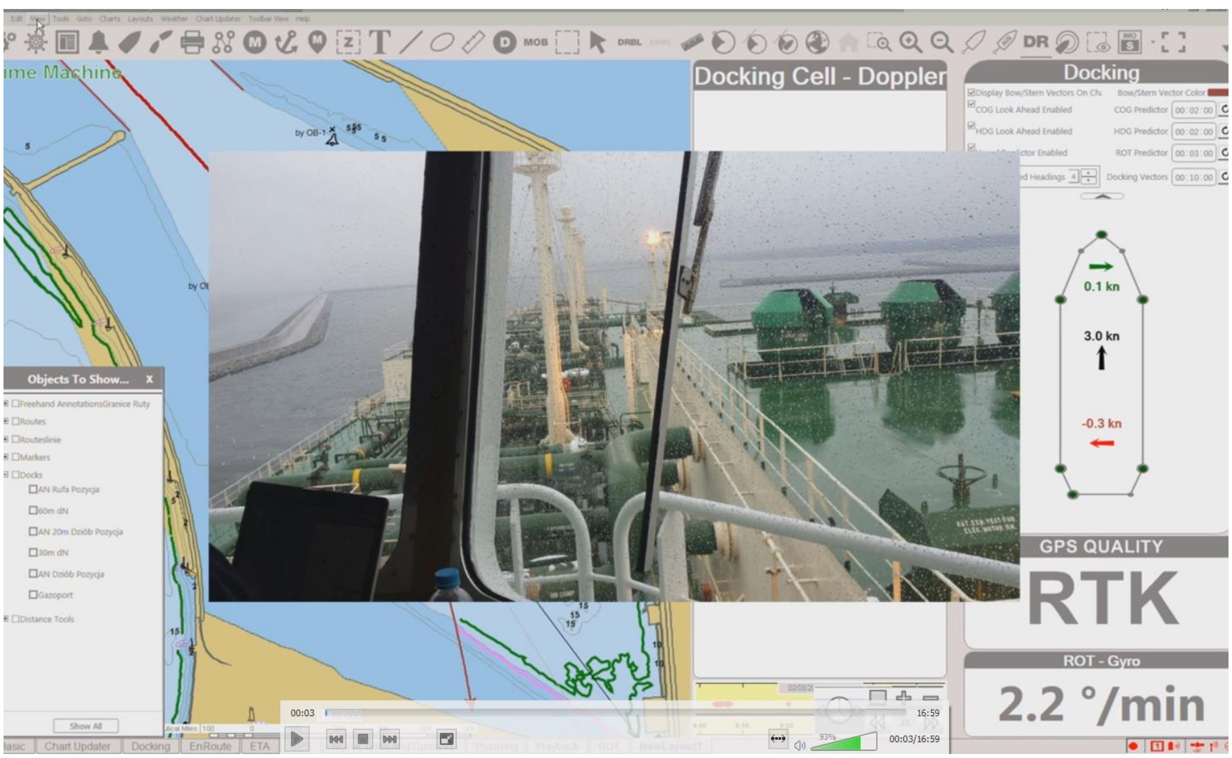
The OneBoxPro+ utilizes the benefits of the RTK positioning from the very beginning of Phase #1.

5.2. Phase #2: Final-decision point

Due to the characteristics of the waterway, the Phase #2 begins after the final-decision point is reached. The final-decision point is located at BY-5 and BY-6 buoys, approximately 10 Nm miles from the LNG Terminal port entrance. After reaching the final-decision point, pilots have to continue navigating the vessel even under deteriorating weather conditions (e.g. fog, unfavourable changes in wind and current speed/direction) and with virtually no room for errors. In other words, at this stage there is no way back – manoeuvres have to be continued, even if there is virtually no visibility, until the vessel is moored at the LNG Terminal dock.

Thanks to the functionality and performance offered by the OneBoxPro+ PPU, the Phase #2 can be safely completed even in the event of extreme changes in the hydro-met conditions.

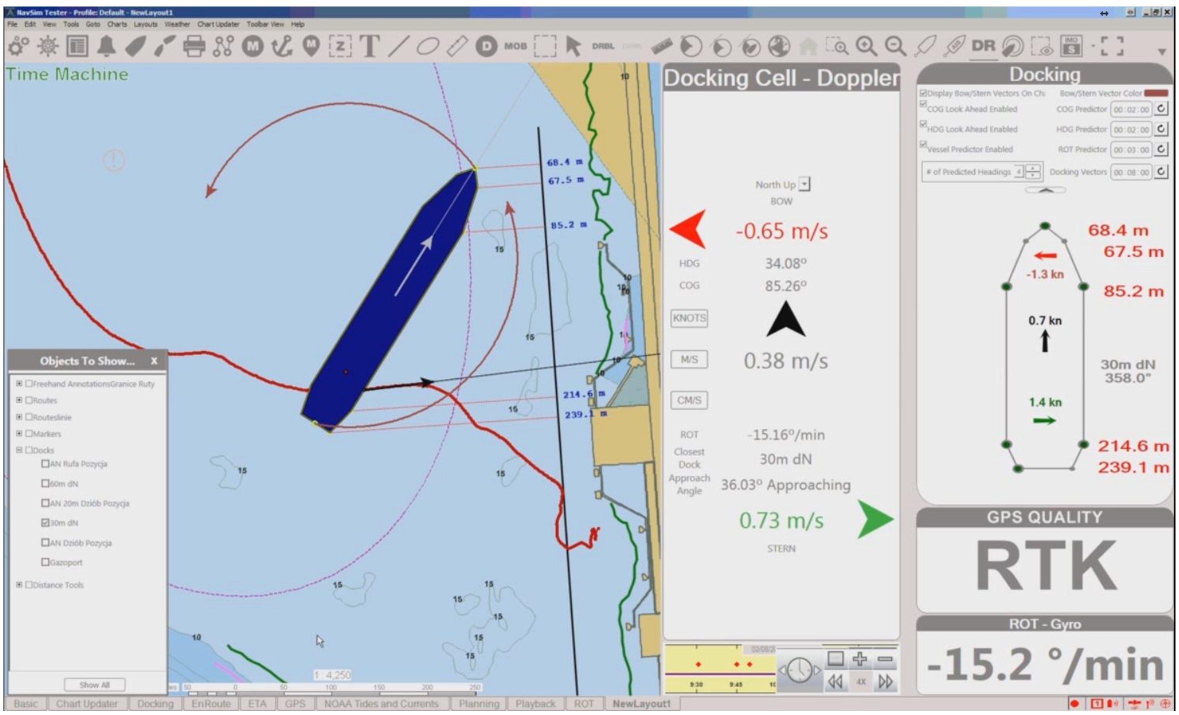
Figure 5. Phase #2: LNG Terminal port entrance - bridge view from m/v Al-Nuaman, 11 December 2015



5.3. Phase #3: Port maneuvering and circulation

The Phase #3 begins around 5 cables from the port entrance with a tight left turn. After passing the port entrance, the vessel has to be stopped at the centre of the vessel's turning area and turned by 180 degrees. During this phase, pilots closely monitor wind speed and direction, Rate of Turn (ROT) and prediction vectors to carry on the manoeuvre as planned. Every instruction issued to the tug boat operators is closely monitored at the PPU screen and usually visible only 4 seconds after it has been issued. This provides pilots with sufficient means to complete turning operations safely and efficiently.

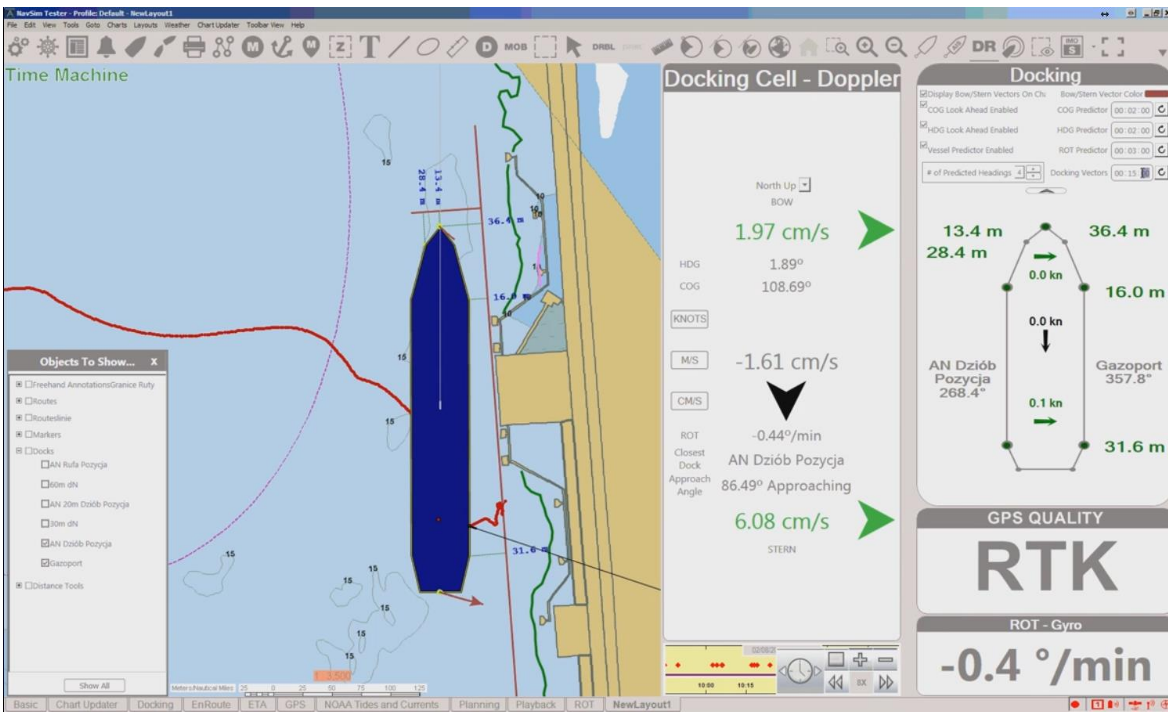
Figure 6. Phase #3: Turning maneuver



5.4. Phase #4: Mooring

Once the circulation is completed the final mooring phase begins and the pilots switch the PPU software view to the Docking Mode. The Docking Mode assists the pilots in determining the vessel's precise moving parameters (e.g. ROT, HDT, Approach Angle) and distance to docking lines. During this phase the OneBoxPro+ also delivers very precise speed measurement (the maximum approaching speed cannot exceed 11cm/s). As it is very hard to observe such slow speed movements by physical observation, the OneBoxPro+ PPU is an indispensable tool for successful completion of this final manoeuvring.

Figure 7. Phase 4. Mooring the Q-Flex carrier at the dock



Manoeuvres from Phase #2 to Phase #4 are available for a preview at:
https://www.youtube.com/watch?v=GoTFM1LI7rM

NavSim Technology Inc.
1247 Kenmount Road Unit D
Paradise, Newfoundland and Labrador
CANADA A1B 3T5
Tel: (709) 726 - 7779
fax: (709) 726 - 7789
info@navsim.com
www.navsim.com

6. Summary

Manoeuvring in confined areas of the Świnoujście-Szczecin and LNG Terminal demands great nautical skill. Vessels have to be safely guided through the narrow waterway, often in heavy traffic, deteriorating weather conditions and strong currents. The work of the Szczecin pilots is to ensure a ship's safe entrance and a safe exit from the LNG Terminal.

After modernisation and deployment of additional infrastructure, including the marine GBAS and OneBoxPro+ PPU, the Świnoujście-Szczecin waterway and LNG Terminal port offers navigational standards comparable with those of the ILS CAT IIIc aviation airports.