Training Celestial Navigation with Vision Technologies

Contents

1 Framework. AT Virtual Project

1.1 What it is

AT-VIRTUAL (INTERREG VB Atlantic Area funded by ERDF funds) aims to improve the operability and performance of Maritime Safety Training Centres (MSTCs) in the Atlantic territory by enabling businesses to develop emerging technology- based solutions to MSTCs needs in the field of simulation-based training systems for maritime security operations. This will improve Atlantic Area capacity, preparedness, resilience and incident response to maritime incidents and emergencies in Atlantic waters, while fostering innovation and sustainable growth in businesses.

1.2 Objectives

AT-VIRTUAL overall objective is to accelerate the digitization of MSTCs in the Atlantic Area, through the introduction of new emerging Industry 4.0 (I4.0) related technologies (Internet of Things, Big Data/Data Analytics, and Vision Technologies) in simulation-based training systems, contributing to more effectively and efficiently tackle of maritime security and safety in the Atlantic Area.

To achieve this, MSTCs will become testing, piloting and demonstration sites of technology solutions to common needs identified in the Atlantic Area. The process of digitization will be carried out through a collaborative hybridization process, facilitating the cooperation between 3 MSTCs and startups who will act as digital enablers, supported by a research organization and I4.0 experts.

It will be developed by using a new advanced platform, which will be ready to be transferred after the project to favour the digitalization processes in new organizations and areas in an outside the Atlantic Area.

AT-VIRTUAL will impact in the current situation by enabling MSTCs the adoption of solutions exploiting the full potentials of latest technologies; the development of new professional fields; and a well-trained and up-to-date work force enabling the sector to become safer and more efficient and sustainable. Also, it will contribute to the consolidation of businesses and startups by promoting the deployment of an I4.0 market with untapped potential so far, contributing to accelerate intelligent growth and innovation in the Atlantic Area.

2 Escola Superior Náutica Infante D. Henrique - Portuguese Maritime College

ENIDH is a public polytechnic higher education institution. ENIDH activities center on the fields of education, professional training, research and service to the national and international communities.

ENIDH was founded in 1924, and since 1972, has been located in Paço de Arcos.

ENIDH is the only public higher education institution dedicated to training education and training in various maritime-related fields, including nautical sciences, marine engineering and maritime transport and logistics.

The college offers undergraduate and postgraduate programs in areas such as Nautical sciences, Marine Engineering and Maritime Transport and logistics. The curriculum combines theoretical knowledge with practical training to prepare students for careers in the maritime industry.

ENIDH has a strong focus on hands-on training, including simulator-based exercises, ship visits, and internships with maritime companies. The college maintains partnerships with industry stakeholders to ensure that its programs align with industry needs and standards.

Students at ENIDH have access to modern facilities, including simulators, laboratories, and workshops, which provide them with practical experience in operating and maintaining maritime equipment. The college also collaborates with other institutions and organizations worldwide, fostering international exchanges and research collaboration.

Overall, ENIDH is a renowned institution in Portugal, dedicated to educating and training professionals for the maritime sector, and it plays a significant role in shaping the future of the country's maritime industry.

Fig.1 - ENIDH

Fig.2 – Main Building and Gym

Fig.3 – ENIDH location

3 MSTC Diagnosis Tool

AT-VIRTUAL brings a free self-diagnosis online tool to Maritime Safety Training Centres to determine their digitalization maturity level. With this tool, they will be able to analyse the current and potential degree of digitalization of the set of processes in different areas.

The use of the Information and Communication Technologies in the society have caused a change in all sectors, including in the MSTCs, with repercussion in the training needs and in the way of teaching.

Likewise, the use of ICTs can also and should be used by the Center for all its processes: teaching, administrative and internal and external communication.

Related to this is the concept of **Industry 4.0**, referred to the fourth industrial revolution that consists of the introduction of digital technologies in the industry. These allow devices and systems to collaborate with each other and with others, allowing to modify products, processes and business models.

However, the use of technology, devices and tools must be used in a coherent way according to their objectives and in a coordinated manner. It is not about using technology to use it, but to look for its real utility.

In this scenario, **the European project AT-VIRTUAL** was born. Its main goal is to improve the operability and performance of Maritime Safety Training Centres (MSTC) in the Atlantic Area (AA) by enabling businesses to develop emerging technology-based

solutions to MSTCs needs in the field of simulation-based training systems for maritime security operations. This will improve AA capacity, preparedness, resilience and response to maritime and emergencies incidents in Atlantic waters, while fostering innovation and sustainable growth in businesses.

On the other hand, and as a prior step before proposing solutions based on emerging technologies, it is necessary to know the level of use of ICTs in the Centers. For this reason, and also as an informative guide, we have made this technological self-check.

This document describes **the Technological Situation of the Training Center** , in all its extension and its most common processes and that it has been completing the Online Self-Check.

Specifically, this model analyzes **four dimensions** in the operation of the Centre, each containing questions on a different set of issues:

1. **Processes:** to analyze how operations are carried out in the Center.
2. **Service Capability:** to know the level of incorporation of technology to existing services.
3. **Infrastructure:** to evaluate the digital capabilities of the Center.
4. **Clients and external agents:** identify the adaptation of the organization to the environment and the market.

3.1 Characteristics of a MST 4.0

In the methodology used is the self-diagnosis will identify the **different characteristics** so that an MSTC is an MSTC 4.0.

CONNECTED: A center that can collect, store and access data in real time of all its elements (machines, processes, people, ...) in a safe, traceable and ubiquitous way. Everything is interconnected and integrated, allowing data to be stored automatically. Hyper connectivity.

SMART: A center capable of working automatically and autonomously, adjusting to the demands of its environment. Able to predict, prevent or correct accurately reducing errors.

FLEXIBLE: A center that reconfigures the processes before changes of the outside in a decentralized way. It can adapt to changes in its service, depending on the needs or demands of clients/customers, etc. thanks to digitalization. Massive personalization.

SOCIAL: A center that has self-employed employees, with the capacity to make

decisions, motivated and adequately trained to use new technologies and perform tasks of greater added value.

EXTENDED: A center that develops the relationship with the supply chain, partners and customers, working with them in a collaborative manner to improve products, services and processes.

Enabling technologies: IoT, Cybersecurity, Cloud Computing, Artificial Vision, Big Data, Data analytics, Simulations, digital twin, Virtual Reality, Augmented Reality, Wearables, System integration, collaborative robotics, etc.

3.2 LEVELS SCORE

There are 4 progressive levels for each of the characteristics:

LEVELS	SCORE
BASIC	from ≥ 1 to ≤ 2
AWARE	from > 2 to ≤ 3,5
COMPETENT	from > 3,5 to ≤ 5,5
ADVANCED	> 5,5

3.3 ENIDH Results

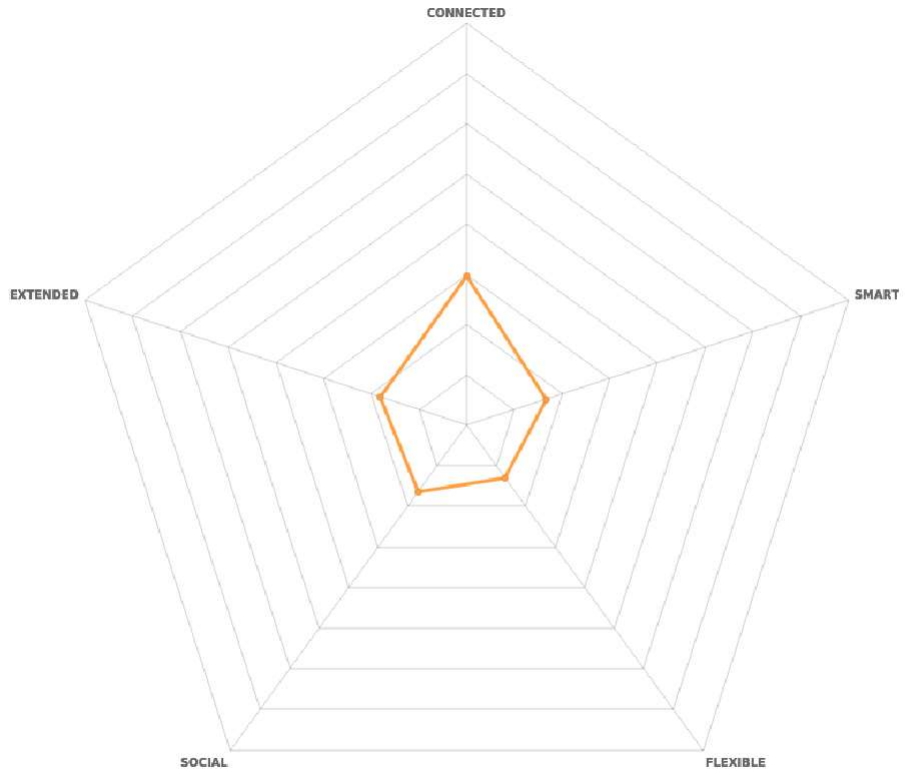
This diagnosis on the technology used in ENIDH has been made exclusively for informative purposes for its assessment and does not contain recommendations or explicit advice.

ENIDH made a self-diagnosis online to determine their digitalization maturity level.

Tecnalia analysed the current and potential degree of digitalization of the set of processes in different areas.

This diagnosis on the technology used in the ENIDH was made and the results obtained were:

Digital Characterization of Escola Superior Nautica Infante D. Henrique (ENIDH)					
Attribute	CONNECTED	SMART	FLEXIBLE	SOCIAL	EXTENDED
Value	2.97	1.66	1.31	1.64	1.82



As the position moves away from the center it is because there is greater use of technologies for that attribute and therefore, higher level of MSTC 4.0. to achieve a better positioning, it is possible to implement impact measures.

CHARACTERISTIC	ACHIEVED LEVEL
CONNECTED 	**AWARE LEVEL** The Center has basic telematic tools and infrastructure for optimization of digitalization and its services. There is information exchange within the Center. The security policy of its assets and infrastructure is not fully developed and implemented. They use ICTs regularly in the pedagogical process and in the administrative process.
SMART 	**BASIC LEVEL** The data of its administrative processes, planning, organization, control and training are informative, with a low level of exploitation.
FLEXIBLE 	**BASIC LEVEL** Its ability to offer training is limited. The contents and the way of teaching are similar for everyone. The Center uses basic resources, without technological support.
SOCIAL 	**BASIC LEVEL** The Center lacks of a digital strategy and transformation based on the use of technologies and innovation. The traditional solutions coexist with telematic tools for internal communication.
EXTENDED 	**BASIC LEVEL** The external communication combines the traditional tools with some related to the website.

4 Challenge: Vision Technologies (VT)

4.1 Title of the challenge

Virtual Celestial Environment for Celestial Navigation

4.2 Context, definition of the problem

The STCW (Standards of Training, Certification and Watchkeeping) Convention requires that training and assessment of seafarers are administered, supervised and monitored in accordance with the provisions of the STCW Code. Knowledge of Celestial Navigation is part of STCW Code including the "Ability to use celestial bodies to determine the ship´s position".
Astronavigation is the only alternative method to electronic means to determine the ship's position in ocean navigation. It is used as a secondary method for confirming the position obtained by electronic navigation equipment and, in lack of these, it will be the primary and the only method to get the ship's position. In this sense, it becomes essential to familiarize the students and simplify the teaching and learning processes of this method.

The training in astronavigation can be summarized in the following items:

- Correctly adjust sextant for adjustable errors;
- Determine corrected reading of the sextant altitude of celestial bodies;
- Accurate sight reduction computation, using a preferred method;
- Calculate the time of meridian altitude of the sun;
- Calculate latitude by Polaris or by meridian altitude of the sun;
- Accurate plotting of position line(s) and position fixing;
- Determine time of visible rising/setting sun by a preferred method;
- Identify and select the most suitable celestial bodies in the twilight period;
- Determine compass error by azimuth or by amplitude, using a preferred method;
- Training in celestial navigation may include the use of electronic nautical almanac and celestial navigation calculation software.

In the training process, students have difficulty in visualizing the celestial sphere, identifying the Sun, Stars, Planets and Moon, used in Astronavigation, and their localization using the Horizontal and Equatorial coordinate systems, the position triangle and apparent movement over the horizon.

The proposed solution will make possible to develop, with greater ease understanding, the acquisition of knowledge for the use of the Astronavigation by the students and by ship's deck officers at sea.

4.3 Challenge definition. Description of need

The development of a solution of vision technologies (immersive 3D environment) that can show the celestial bodies above the horizon with the essential detailed information to train the celestial navigation. This solution will allow to observe the 57 stars and their constellations, the 4 planets, the Sun, the Moon and to show Aries, on the celestial sphere, with the observer located on the deck of a ship.

Other objective of the solution, is allow the user to identify and to understand the apparent movement of celestial bodies.

The main objective of the solution is to support students and deck officers to identify and view the main topic of Astronavigation. Depending on the geographic coordinates and time, it will be possible to identify the visible horizon and all the stars that are above the horizon. When selecting the star, the observer should graphically visualize the Horizontal and Equatorial coordinates.

The celestial sphere is an imaginary sphere of infinite radius with the Earth at its centre (Figure above). The north and south celestial poles of this sphere, PN and PS respectively, are located by extension of the Earth's mean pole of rotation. The celestial equator is the projection of the plane of the Earth's equator to the celestial sphere. A celestial meridian is a great circle passing through the celestial poles and the zenith of any location on the Earth.

The point on the celestial sphere vertically overhead of an observer is the zenith, and the point on the opposite side of the sphere vertically below him or her is the nadir.

The Navigational Triangle is a triangle formed by arcs of great circles of a sphere is called a spherical triangle. A spherical triangle on the celestial sphere is called a celestial triangle.

The spherical triangle of particular significance to navigators is called the navigational triangle, formed by arcs of a celestial meridian, an hour circle, and a vertical circle. Its vertices are the elevated pole, the zenith, and a point on the celestial sphere.

The observer should also be able to visualize the position triangle and the values of all coordinates.

Will be desirable, to see the apparent movement in real time or fast motion mode, to identify Sunrise, Sunset and meridian passage.

The solution will be very useful in training, but also in use on ships.

4.4 Requirements

The type of solution to be proposed must be within the scope of vision technology and must fulfil the following technical requirements, with the main build a virtual sky to Celestial Navigation:

- Possibility of introducing the geographic coordinates of any location for the visualization and time required.
- Automatic update of the coordinates of the Nautical Almanac for each year;
- Possibility to select each type of celestial coordinates, in order to view only partial information, as described on the expected outcomes.

4.5 Expected Outcomes

The expected outputs of the solution proposed to be developed are the following:

- Attractive and interactive application with different colours displayed to better show the info;
- Identify all coordinates systems;
- Show the Astronavigation triangle;
- Show the prime meridian (Greenwich meridian) in celestial sphere;
- Apparent motion of the sun, moon and stars in real time speed or faster mode, for see the apparent motion of 24 hours in 1 minute.
- The ecliptic with the position of the 4 reference points;
- Show the Zodiac;
- Solar and Lunar Eclipse in the position they happen.

4.6 Video

https://www.youtube.com/watch?time_continue=20&v=n-DXK_Jx328&embeds_referring_euri=https%3A%2F%2Fwww.at-virtual.eu%2F&source_ve_path=Mjg2NjY&feature=emb_logo

5 Selection of the start-up

5.1 Online open call

Online open call for digital providers to propose their VT solutions to resolve the defined MSTC challenge.

5.2 Validation

All the proposals submitted were checked for eligibility, in accordance with the established criteria, required documentation and the conditions to be considered for the application.
Three proposals were received and were eligible to be selected for the next step of the process.

5.2.1 Assessment

The 3 proposals that passed the eligibility check were assessed, in accordance with the following evaluation criteria and scores based on a 100 points scale:

- **Coherency** of the proposal for the implementation of the project. (0-10 / Treshold:5)
- **Experience / background of the company** related to the challenge / topic addressed. (0-20 / Treshold:10)
- **Evaluation of the technology**, equipment required and innovation of the proposed solution according to the state of art. (0-20 / Treshold:10)
- **Risk evaluation** that could be introduced in the project. (0-10 / Treshold:5)
- Availability and assessment of **company resources** in relation to the plan proposed. (0-20 / Treshold:10)
- Feasibility of the **budget** regarding the services proposed for the definition and implementation of the solution (according to the timeframe). (0-10 / Treshold:5)
- Other added value to be assessed. (0-10).

5.2.2 Results

The coordinating team of the project from ENIDH and Tecnalia, made individual assessments trying to guarantee objectivity in the process. The average score obtained from joining the individual assessments were:

Startup	Score
A	86
B	86
C	84

The three companies were pre-selected and will take part in the Selection Event of call which is a public competition organized per each call where the contesters will pitch and meet the MSTC as well as a technological seminar about the features and potentials of the technology Vision Technologies.

Detailed information about the companies and the assessment is included in the back-office part of the AT-Virtual official webpage.

5.2.3 Selection event

The Selection Event included:

- A business competition for the participants with a5 minutes **Fast-Track Pitch presentation** of the essence of the company. And,

• A 30 minutes **B2B meeting** where every applicant had the opportunity to defend privately their proposal responding directly to the questions formulated by the MSTC for a better understanding of the solution.

MSTCs judgment were expressed in a scale of 0 to 10, in both categories, accordingly to the following criteria:

Fast-Track Pitch Presentations:

- Substance: clarity and eloquence of the information presented.
- Delivery: Ability to grab and hold the attention.
- Creativity about the contents showed in the presentation.
- Timing: pitches will last 3 minutes as maximum.

B2B Meetings:

- The company responds clear and effectively to all the questions asked by the MSTC.
- Added value information provided

5.3 Selected company

The final score that determined the selection of the company was calculated by means of the following formula established:

Final Score = 30 % (Assessment score) + 20 % (Pitch Score*10) + 50 % (Interview Score*10)

Startup	Score
A	17
B	15
C	16

Inklusion won VT call of AT-Virtual to develop a Training Celestial Navigation application with Vision Technologies to give solution to the VT challenge of ENIDH, Portuguese maritime college.

6 Hybridization and development of the prototype

TIMETABLE	PROGRESS
JULY 2022	• First visit of Inklusion to ENIDH • Inklusion gets familiar WITH celestial navigation •
SEPTEMBER 2022	• Hybridization: Joint work on the possibilities of the solution developed by ENIDH and Inklusion. • Second visit of Inklusion to ENIDH. Hybridization. Design of the final solution. Presentation of possibilities and capabilities of potential VT solution •
November 2022	• Development and testing of the first version of the application • Upgrades detected
December 2022	• Development, minor upgrades and testing of the tailored VT application • Testing phase
January 2022	• Delivery of the applications •

7 Virtual Celestial Environment for Celestial Navigation

7.1 – Application

Fig.4 – Selection the localization

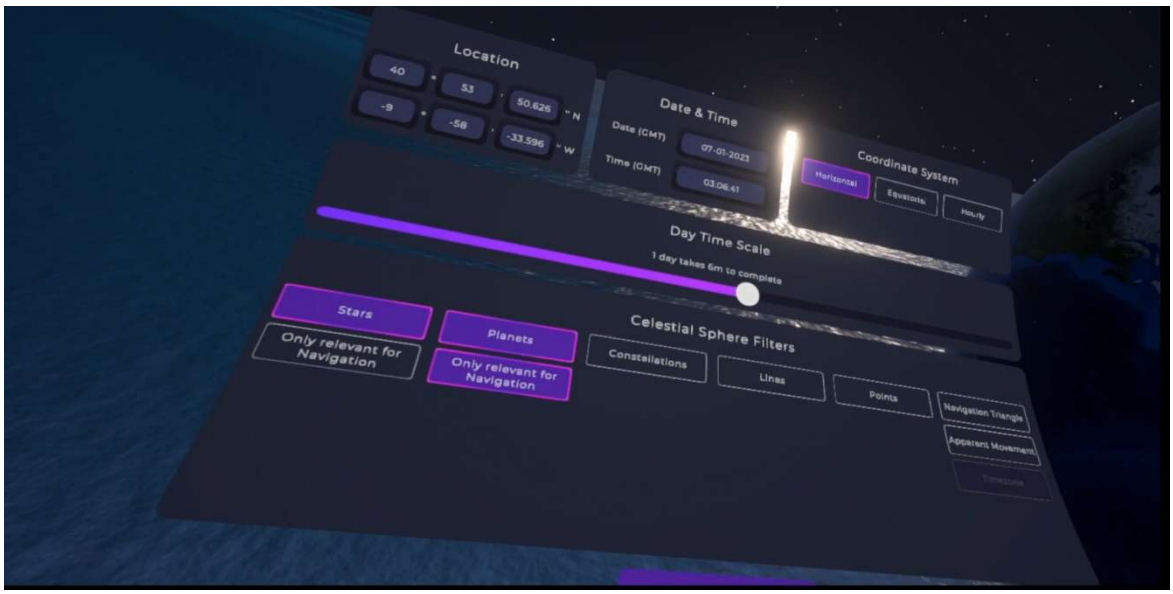


Fig.5 – Main menu

Fig.6 – Celestial Sphere Filters

Fig.7 – Astronomical coordinates

Fig.8 – Constellations

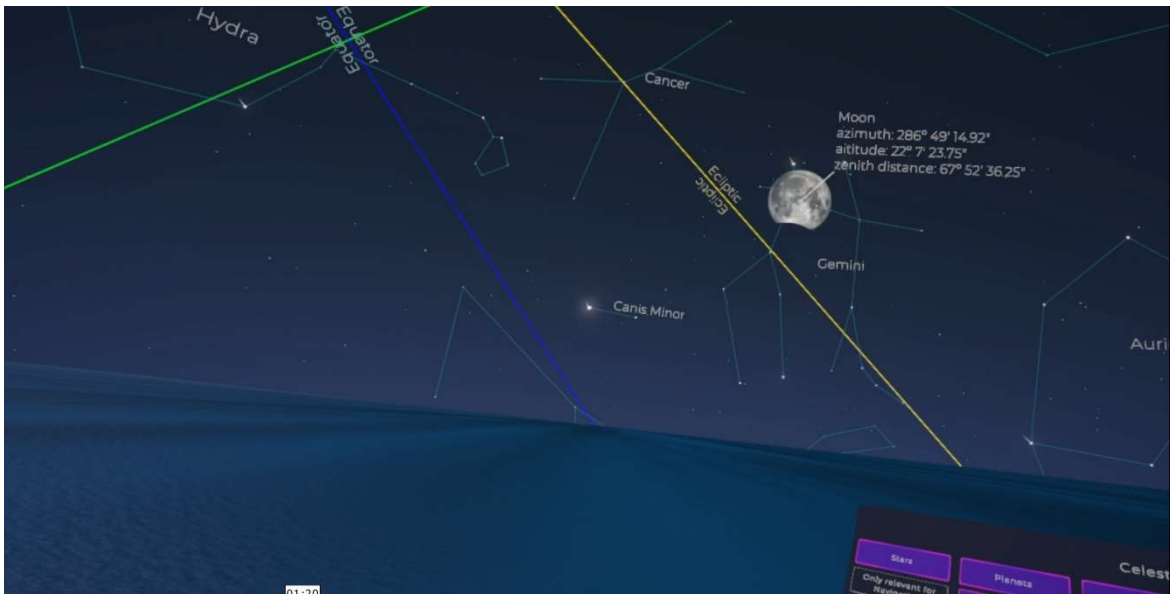


Fig.9 – Equator, Horizon and Moon coordinates

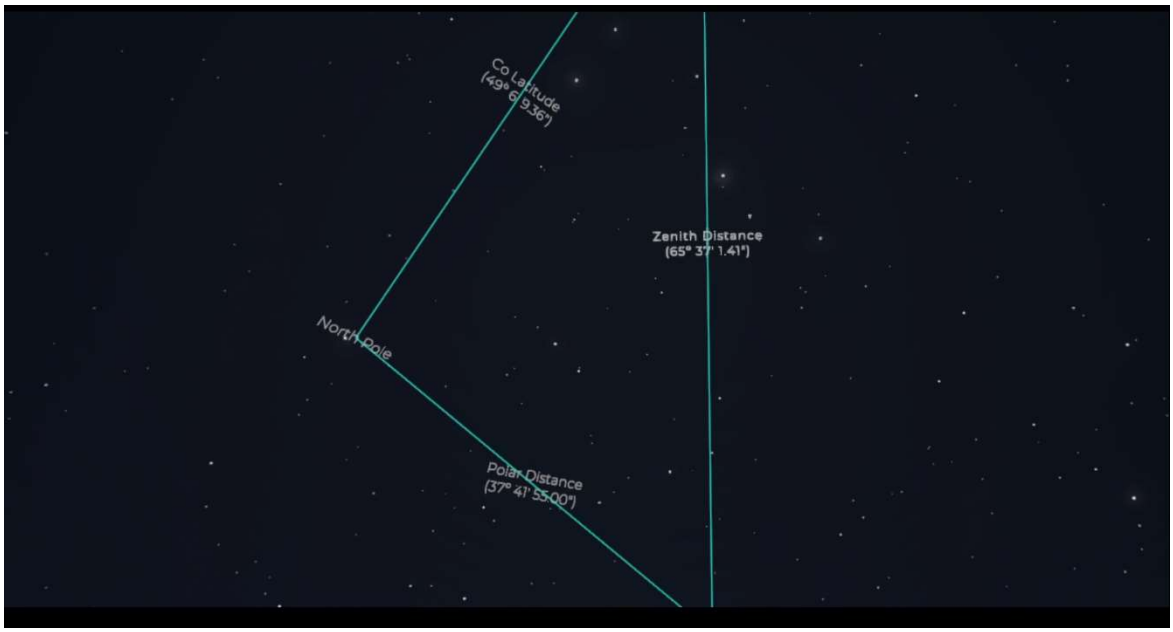


Fig.10 – Position triangle

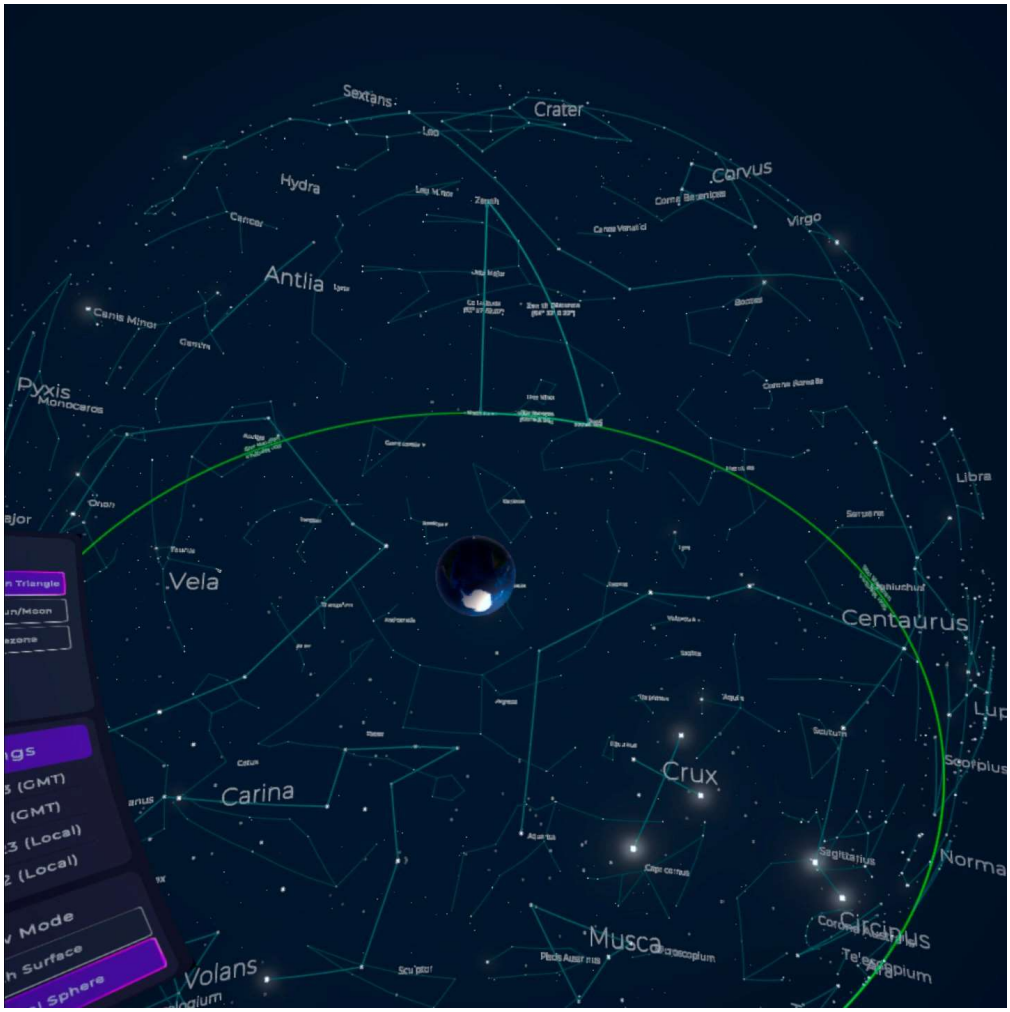


Fig.11 – Celestial Sphere

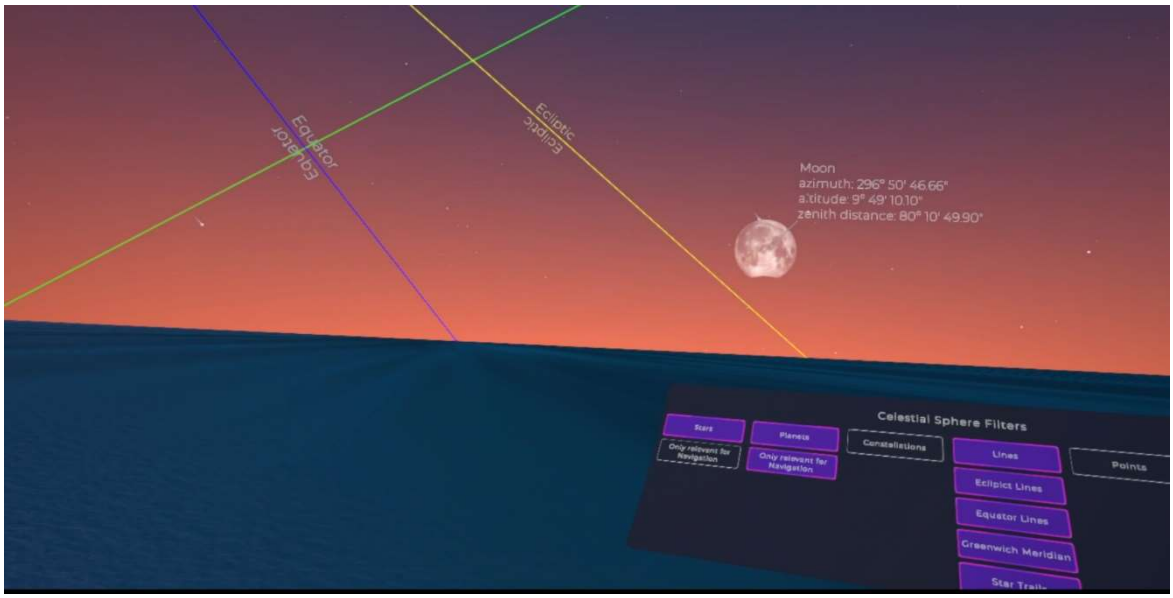


Fig.12 – Twilight

Fig.13 – Sun coordinates

7.2 – Capitalization event

Fig.14 – Demonstration

Fig.15 – Demonstration

Fig.16 – Demonstration

7.3 – Training with the application

Fig.17 – Training students

Fig.18 – Training students