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SELECTED PAPERS OF THE 6th INTERNATIONAL CONFERENCE ON RESEARCH, TECHNOLOGY AND EDUCATION OF SPACE

H-SPACE 2020

Edited by László Bacsárdi and Kálmán Kovács

MANT
Magyar Asztronautikai Társaság

EIT
EGYESÜLT INNOVÁCIÓS ÉS TUDÁSKÖZPONT

BME VILLAMOSMÉRNÖKI ÉS INFORMATIKAI KAR

Selected papers of
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February 26-27, 2020, Budapest, Hungary
at Budapest University of Technology and Economics

Organized by
Federated Innovation and Knowledge Centre of
Budapest University of Technology and Economics
and
Hungarian Astronautical Society

Editors
László Bacsárdi and Kálmán Kovács

MANT 2020

Selected papers of the 6th International Conference on Research, Technology and Education of Space (H-SPACE2020)
February 26-27, 2020, Budapest, Hungary
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Budapest University of Technology and Economics
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WELCOME from the Organizing Committee

In 2020 the International Conference on Research, Technology and Education of Space was held for the 6th time. It was hosted by the Space Forum of the Budapest University of Technology and Economics (BME) in cooperation with the Hungarian Astronautical Society (MANT).

BME Space Forum is operated by the Federated Innovation and Knowledge Centre (BME EIT), which was created at the Faculty of Electrical Engineering and Informatics (VIK) of BME in 2009 to stimulate the research and development activity and to assist the exploitation of research achievements at the Faculty. The mission of BME Space Forum is to harmonize and coordinate space activities in BME by a common vision and strategy, recognize the joint human and technical resources and outstanding achievements, make internal and external knowledge transfer more efficient, and utilize opportunities lying in synergies granted by joint capabilities and unified representation. The common aim of BME Space Forum is to become the bridge between academic research and space industry and participate in the research, the development, the innovation and the application processes of space activity. Currently, 16 Departments from 5 Faculties participate voluntarily in the activities of BME Space Forum.

The Hungarian Astronautical Society (MANT) is a civil organization in Hungary that gathers space researchers, users of space technology, and everyone interested in the interdisciplinary and state-of-the-art uses and research of space. MANT, the oldest space association in Hungary, was established in 1956 in Budapest. It is the only Hungarian member of the International Astronautical Federation (IAF) joining the Federation in 1959. MANT aims to raise public awareness about space activity and space applications. The society also provides an opportunity for space enthusiasts of various fields of sciences to meet, exchange ideas and work together. MANT organizes conferences, youth forums, and summer space camps, issues periodicals, releases media material, and holds lectures about space research and related scientific fields.

The H-SPACE conference series started in 2015, in the year when Hungary became the member of ESA and the grands received as new member increased the opportunities for space activity in Hungary. The Conference also met the needs for a joint presentation of space activities pursued at BME. The selection of the event's date, i.e., February, pays tribute to the successful deployment of the first Hungarian satellite, Masat-1, to orbit. Masat-1 was developed and designed by BME professors and students; it was launched on February 13, 2012.

The H-SPACE 2020 conference agenda addressed scientific, technological, and educational issues of space research and space activities. The conference is open for both national and international professionals and provides an opportunity to showcase Hungarian scientific, technological, educational, and outreach activities related to space. Due to the generous support of our partners, the conference had no registration fee. The conference was supported by the Ministry of Foreign Affairs and

Trade, and one of our coffee breaks was sponsored by ESA Business Incubation Centre Hungary.

We started the conference with a particular roundtable discussion in Hungarian with the topic "Changing trends in space flights: development of the private sector".

We had six presentations given by invited speakers:

- Outcome of World Radiocommunication Conference 2019 (WRC-19) from space perspective
  Mehtap Dufour, ITU Radiocommunication Bureau, Switzerland
- Developing European capabilities: the push for next-generation optical telecommunication technologies
  Christopher A. Vasko, European Space Agency, Netherlands
- Future of CubeSats
  Chantal Cappelletti, University of Nottingham, United Kingdom
- Hungarian perspectives in Earth Observation
  Dániel Kristóf, Lechner Non-Profit Ltd.
- Space Academy: A Journey from Hospital to Mars
  Rachael Dixon, Edinburgh Children's Hospital Charity, United Kingdom
- SMOG-P and ATL-1 PocketQube Class Satellites at BME
  Levente Dudás and András Gschwindt, BME Department of Broadband Infocommunications and Electromagnetic Theory, Hungary

The conference had five main sections: Science and Technology I-III and Education and Outreach I and II. Science and Technology III and Education and Outreach II were poster sessions with 23 excellent presentations. Three poster presentations were selected for best presentation award:

- The work of Cosmos Society on introducing the importance of space to the general public *by Ákos Gyenge*
- Demonstrational Remote Sensing Payload Development for High Altitude Platforms *by Zsófia Bodó and Bence Dávid Góczán*
- Precise Orbit Determination and Prediction using GNSS and SLR observations *by Bence Turák and Szabolcs Rózsa*

We had two associated evening events. On Wednesday, an exciting competition named AstroQuizNight was organized by András Ordasi (MANT). On Thursday, the HTE Telecommunications Club discussed the Outcome of the WRC-19 from a Hungarian perspective, organized by the Scientific Association for Infocommunications, Hungary (HTE).

The Organizing Committee has internationally recognized members, namely Prof. József Ádám, Dr. Tibor Bálint, Ferenc Horvai, Prof. János Lichtenberger, Dr. Lóránt Földváry, Prof. László Pap, Prof. Gábor Stépán, Dr. Szabolcs Rózsa. We are grateful for their contributions to the success of the conference.

Although we were not aware of this fact in February, our conference was one of the last international conferences in the space domain, organized as a physical event due to the COVID-19 pandemic. We had more than 200 registered participants, but we started to receive cancellations a few days before the conference. We had to adapt the program and offer the possibility for a virtual presentation for two of our invited speakers.

In February 2020 we published a book of abstracts for the conference. We had six keynote lectures and 45 technical presentations (22 oral and 23 poster presentations). 17 authors of all the presenters submitted a full paper. These papers are included in this conference proceedings.

We appreciated all the positive and constructive feed-back from the participants from all aspects. We look forward to organizing the upcoming event of our conference series in 2022.

Dr. László Bacsárdi
co-chair
Vice President of MANT

Dr. Kálmán Kovács
co-chair
Director of BME EIT

Final Conference Program

In this program, the affiliation of the presenter author is listed.

February 26, Wednesday

Location: Building I, ground floor, IB.027 (and IB.019)
Magyar tudósok krt. 2., Budapest, H-1117

13:00 Greetings (in Hungarian)
László Bacsárdi, Vice President of MANT, co-chair of the Organizing Committee

13:05 Discussion (in Hungarian):
Paradigmaváltás az űrhajózásban: a magánűrhajók; A kereskedelmi űrhajózás fejlődése (Changing trends in space flights: development of the private sector)

Participants:
András Ferenc Horváth, Honorary Member, Hungarian Astronautical Society
Gábor Zsombor, Galileowebcast

Moderator:
Elód Both, President, Hungarian Astronautical Society

Session Chair: László Bacsárdi

14:00 Opening ceremony
Orsolya Ferencz, Ministerial Commissioner, Ministry of Foreign Affairs and Trade
Hassan Charaf, Dean, Faculty of Electrical Engineering and Informatics, BME
Elód Both, President, Hungarian Astronautical Society
Kálmán Kovács, President, BME Space Forum

14:15 Keynote presentation
Outcome of World Radiocommunication Conference 2019 (WRC-19) from space perspective
Mehtap Dufour, ITU Radiocommunication Bureau, Switzerland

14:50 Poster flash talks (Session Science and Technology III and Education and Outreach II)
Poster authors presents their work in 1 minute

15:10 Poster session with coffee break

PARALLEL SESSIONS

Session Chair: Zsófia Bodó

15:40-18:00: Technical presentations – Session Science and Technology I
Room IB.027

Invited presentation:
Hungarian perspectives in Earth Observation
Dániel Kristóf, Lechner Non-Profit Ltd.

Complete 3D Coseismic Deformation Field Reconstruction of 2019 Ridgecrest Earthquakes based on Sentinel-1 TOPS data
Bálint Magyar and Ambrus Kenyeres, Lechner Non-Profit Ltd., Hungary

The GNSS stream gauge
Ágnes Ács and Szabolcs Rózsa, BME Department of Geodesy and Surveying, Hungary

Shielding optimization for the RM-RAD-S Radiation Monitor
Boglárka Erdős, Attila Hirn and Balázs Zábori, Centre for Energy Research, Hungary

Visualization and simulation of ion thrusters possibly usable by small satellites
Árpád Makara, András Reichardt and László Csurgai-Horváth, BME Department of Broadband Infocommunications and Electromagnetic Theory, Hungary

Pneumo planet Mars habitat and Moonbase
Thomas Herzig and Gábor Bihari, pneumocell, Austria

ESA perspective on lunar surface exploration and resource utilization
Mátyás Hazadi, European Space Agency, Netherlands

Antarctic Winterovering in Terrestrial Space Analogues: Cultural Differences in Emotional Expression
Bea Ehmann, Attila István Kiss, Eliza Kollerits, Barbara Matulai, Borbála Tölgyesi and László Balázs
Research Centre for Natural Sciences, Institute of Cognitive Neuroscience and Psychology, Hungary

Area classification and change detection from a time series of remote sensing images by using fusion Markov Random Field model
Tamás Szirányi, SZTAKI, Hungary

Session Chair: Dorottya Milánkovich

15:40-18:00: Technical presentations – Session Education and Outreach I
Room IB.019

Invited presentation:
Space Academy: A Journey from Hospital to Mars
Rachael Dixon, Edinburgh Children's Hospital Charity, United Kingdom

Education and outreach activities in Bükk Starry Sky Park
Richárd Novák, Anna Apró and István Gyarmathy, Eszterházy Károly University, Hungary

Martian Climate Database – an online tool to model the Red Planet
Bernadett Pál, Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungary

Astronomy Clubs for extracurricular Activities in Schools
Oancea Carmen-Adina and Ilesan Daniela Florentina, Colegiul National Octavian Goga Sibiu, Romania

From the Torsion Balance to Space Gravimetry
Annamária Komáromi, Balassi Bálint Secondary School, Budapest, Hungary

We Touched Space Twice in 2019
Florián Vámosi and László Vámosi, Mihaly Tancsics Grammar School of Kaposvár, Hungary

Rocket technology for secondary school students
András Illyés, Budapest University of Technology and Economics, Hungary

Mouse-on-the-Mars and other developments with secondary school students
Balázs Újvári, University of Debrecen Hungary

Official H-SPACE 2020 event

19:30-22:00 AstroQuizNight (in English)
Organized by András Ordasi (MANT)
Location: KEG Sörműház, Orlay u. 1., 1114, Budapest

February 27, 2020, Thursday

Location: Building I, ground floor, IB.027
Magyar tudósok krt. 2., Budapest, H-1117

9:00 Welcome coffee

Session Chair: Andrea Strádi

9:45-11:30: Technical presentations – Session Science and Technology II

Radio Frequency Interference Monitoring at locations in Nógrád County
L. Viktor Tóth, Krisztián Bodzsár, Orsolya Ferencz, András Jánosik and Péter Vári, Eötvös Loránd University, Hungary

Deployment of the Hungarian E-GNSS Network and the results of its first year of operation
Bence Takács, Rita Markovits-Somogyi and Mercedes Reche
Hungarocontrol, Hungary

Pioneer chemical formulation experiments on ISS
Gergő Mezőhegyi, Ferenc Darvas, Ibolya Leveles and Beáta Vértessy, InnoStudio Inc., Hungary

Invited presentation (via web):
Developing European capabilities: the push for next generation optical telecommunication technologies
Christopher A. Vasko, European Space Agency, Netherlands

Invited presentation (via web):
Future of cubesats
Chantal Cappelletti, University of Nottingham, United Kingdom

11:30- 12:00 Poster session with coffee break

Session Chair: Szabolcs Rózsa

12:00-12:05: Opening of Session Education and Outreach II

János Józsa, Rector, Budapest University of Technology and Economics

12:05-13:20: Technical presentations – Session Education and Outreach II

Invited presentation
SMOG-P and ATL-1 PocketQube Class Satellites at BME
Levente Dudás and András Gschwindt, BME Department of Broadband Infocommunications and Electromagnetic Theory, Hungary

The importance of educating students about careers in the space sector: a student perspective
Jacob Smith, Sophia Lee Roberts and Laura Martin, UK Students for the Exploration and Development of Space, United Kingdom

Establishment of the Hungarian Space Engineering Curriculum
László Bacsárdi and László Csurgai-Horváth, BME Department of Networked Systems and Services, Hungary

Investigation of new methods in the education on the field of space communications and space research
Péter Vári and Elek Sántha, Széchenyi István University, Győr, Hungary

Doctoral School in Geospatial Science in Uzbekistan
Lóránt Földváry, Valéria Balázsik, Béla Márkus, Andrea Pődör, Malgorzata Verőné Wojtaszek, Ilhom Abdurahmanov and Mamanbek Reimov, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Uzbekistan

13:20 Closing remarks. Best presentation award ceremony

Official H-SPACE 2020 event

18:00-20:00: HTE Telecommunications Club (in Hungarian)
Outcome of the WRC-19 from Hungarian point of view
Organized by the Scientific Association for *Infocommunications*, Hungary (*HTE*)
Location: Building I, ground floor, I.B.019

Poster presentations (Session Science and Technology III; Session Education and Outreach II)

Adapting Telescopes for Optical Communication
Máté Galambos, Lili Létai, Zsolt Papp, Sándor Imre and László Bacsárdi
BME Department of Networked Systems and Services, Hungary

Affordable statistical testing for quantum random number generators in space applications
Balázs Solymos and László Bacsárdi
BME Department of Networked Systems and Services, Hungary

An overview of the usage of artificial intelligence-based algorithms in satellite operations
Barnabás Futó, Mátyás Papp, Bálint Petró, István Arnócz and Radim Basdi, Space Apps Ltd., Hungary

Asteroid deflection with solar sail and laser-based techniques
Dávid Farkas and László Bacsárdi
BME Department of Networked Systems and Services, Hungary

AstroQuizNight - An event where space doesn't part us but connects us
András Ordasi, Konkoly Observatory, Hungary

Automated and Remote Controlled Satellite tracking station
Elek Sántha and Péter Vári, Széchenyi István University, Győr, Hungary

Current State of the Free-Space Quantum Key Distribution
Laith Al-Soub and László Bacsárdi
BME Department of Networked Systems and Services, Hungary

Deformation monitoring using persistent scatterer interferometry and open-source software
Bence Ambrus and Szabolcs Rózsa
BME Department of Geodesy and Surveying, Hungary

Demonstrational Remote Sensing Payload Development for High Altitude Platforms
Zsófia Bodó and Bence Dávid Góczán, Budapest University of Technology and Economics, Hungary

IRSEL: Innovation on Remote Sensing Education and Learning
Malgorzata Verőné Wojtaszek, Valéria Balázsik, Lóránt Földváry and Béla Márkus
Inst. of Geoinformatics, Óbuda University, Hungary

Local Ionosphere Modelling with GPS in Hungary
Balázs Lupsic and Bence Takács, BME Department of Geodesy and Surveying, Hungary

Planetology Aspects in University Education of Geography and Environment
Csaba Patkos, János Mika and Arnold Gucsik
Eszterhazy Karoly University, Eger, Hungary

Precise Orbit Determination and Prediction using GNSS and SLR observations
Szabolcs Rózsa and Bence Turák
BME Department of Geodesy and Surveying, Hungary

Radiation test facilities at Atomki and their space research applications
András Fenyvesi, József Molnár and István Rajta, Atomki, Hungary

Satellite Images to Support Contribution of Meteorology to the UN Sustainable Development Goals (2016-2030)
János Mika, Eszterhazy Karoly University, Eger, Hungary

Shoot an asteroid – linking laboratory based meteorite mineralogy to European space mission by university support
Ákos Kereszturi, Ildikó Gyollai, Sándor Józsa, Ágnes Skultéti, Bernadett Pál, Dániel Rezes and Máté Szabó, Research Centre for Astronomy and Earth Sciences, Hungary

SiPM based detection of cosmogenic production of radioisotopes in spacecraft substances
Bence Godó, Dávid Baranyai and András Fenyvesi, University of Debrecen, Hungary

Space weathering-related evolution of fine-grained asteroidal and cometary materials: sample return planetry missions
Arnold Gucsik, Eszterhazy Karoly University, Eger, Hungary

Testing the visualization l of the Martian surface with GIS and SIMWE modelling tools
Vilmos Steinmann and Ákos Kereszturi, Konkoly Thege Miklós Astronomical Institute, Research Centre for Astronomy and Earth Sciences, Hungary

The importance of self-education through the method of citizen science -from the basic experiments to the serious emergencies
Péter Pusztai and Judit Turi, Hungarian Astronautical Society, Hungary

The Technology Transfer Program of the European Space Agency from the Perspective of Budapest University of Technology
Bernard Adjei-Frimpong and László Csurgai-Horváth, BME Department of Broadband Infocommunications and Electromagnetic Theory, Hungary

The work of Cosmos Society on introducing the importance of space to the general public
Ákos Gyenge, BME Cosmos Society, Budapest University of Technology and Economics, Hungary

Thermal Thorium Rocket (THOR) – a new concept for a radioactive decay heated thermal rocket engine
Gábor Bihari, University of Debrecen, Hungary

Content

We have published a separate book of abstracts which contains all of the abstracts accepted for the conference. During the conference, we had 6 invited presentations and 45 technical presentations from which 17 authors have submitted a full paper. These papers are included in this proceedings as they were submitted by their authors. We have not edited their text or corrected misspellings.

Ágnes Mária Ács and Szabolcs Rózsa, *"The GNSS stream gauge"*

HSPACE2020-FP-18

Jacob Smith, Sophia Lee Roberts and Laura Martin, *"The importance of educating students about careers in the space sector: a student perspective"*

HSPACE2020-FP-23

Árpád Makara, András Reichardt and László Csurgai-Horváth, *"Visualization and simulation of ion thrusters possibly usable by small satellites"*

HSPACE2020-FP-39

Malgorzata Verőné Wojtaszek, Valéria Balázsik, Lóránt Földváry and Béla Márkus, *"IRSEL: Innovation on Remote Sensing Education and Learning"*

HSPACE2020-FP-40

Lóránt Földváry, Valéria Balázsik, Béla Márkus, Andrea Pődör, Malgorzata Verőné Wojtaszek, Ilhom Abdurahmanov and Mamanbek Reimov, *"Doctoral School in Geospatial Science in Uzbekistan"*

HSPACE2020-FP-41

Csaba Patkós, János Mika and Arnold Gucsik, *"Planetology Aspects in University Education of Geography and Environment"*

HSPACE2020-FP-45

János Mika, *"Satellite Images to Support Contribution of Meteorology to the UN Sustainable Development Goals (2016-2030)"*

HSPACE2020-FP-46

András Illyés, *"Rocket technology for secondary school students"*

HSPACE2020-FP-48

Szabolcs Rózsa and Bence Turák, *"Precise Orbit Determination and Prediction using GNSS and SLR observations"*

HSPACE2020-FP-54

The Technology Transfer Program of the European Space Agency from the Perspective of Budapest University of Technology

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Abstract— **The European Space Agency is managing the development of Europe's space capability and ensures that investment in space continues to deliver benefits to the citizens of Europe. The Agency's projects are designed to study the Earth, its immediate space environment, the solar system and the Universe, as well as to develop satellite-based technologies and services. New technologies, systems and processes are continuously being developed for space programs and many of these have non-space applications.**

ESA's Technology Transfer Program Offices have established initiatives for space technologies to be identified and adapted for non-space use that result in commercially viable products and high potential companies. Within the framework of the "Technology Transfer Demonstrator Competition 2017-2019", the Department of Broadband Infocommunications and Electromagnetic Theory (BME-HVT) at Budapest University of Technology and Economics successfully finished a technology transfer demonstrator project.

The demonstrator project is based on the former and actual research activity of BME-HVT in ESA's Alphasat Ka/Q-band propagation and Q-band telecommunication program. In the Alphasat related research work our department developed a Q-band satellite communications system, and the millimeter wave downconverter unit has been applied and successfully transferred to a terrestrial radio wave propagation measurement system that is suitable to study the terrestrial millimeter wave signal propagation for the future 5G mobile radio systems.

During the execution of the project we performed indoor radio wave propagation sounding measurements in the 38GHz band and we tested different indoor scenarios. The results are compared with the relevant ITU-R recommendations and models.

This paper outlines the ESA Technology Transfer Program, introduces the measurement system that was developed at BME-HVT for this project and some results and conclusions will be also presented. It will be also shown how the results of this project are applied in our current research and education programs at the university.

Keywords—technology transfer; indoor propagation; millimeter wave; 5G

I. INTRODUCTION

The rapid evolution of wireless communication systems has become a development priority because of the quest for the transmission of a large volume of data at high speed and lack available bandwidth due to congestion in the lower frequencies, which has prompted the research community, industry and regulator to consider exploring higher frequencies in the millimeter wave band. The millimeter wave band has a large spectrum available and can be seen as the solution to emerging wireless networks [1].

However, the European space Agency (ESA) has established a technology transfer network which consists of brokers across Europe tasked to identify novel uses for technology that has been developed as part of the ESA space program. The technology transfer demonstrator projects have been developed to support companies to demonstrate and verify the applicability of space technologies on earth where there is potential for strong commercial and societal benefit. The demonstrator projects focus on the technology that relates expertise from space utilization, the processes and the methodologies to narrow the risk in non-space commercialization. This innovation was hatched from existing technologies for purposes unrelated to their original applications [2].

In view of this, the department of Broadband Infocommunications and Electromagnetic Theory at Budapest University of Technology and Economics (BME-HVT) under the framework of an ESA technology transfer demonstrator project developed a Q-band indoor propagation measurement system in the millimetre wave at 38 GHz for studies in the 5G systems. The idea of this technology demonstrator project was to transfer a device with a space heritage [3] into a terrestrial application, which can be applied in indoor propagation measurement for 5G networks [4]. The distances indoor are very important for emerging wireless 5G networks; hence implementation in an indoor environment to show its viability, effectiveness, efficiency and reliability.

In this paper, the description of an experimental campaign under ESA technology transfer program for a terrestrial application used for indoor propagation measurements is presented in I. Section II gives over view of the technology transfer program. Section III gives a description of the measurement the 38 GHz measurement campaign IV describes the measurement, environment or location, results and draws a conclusion on the research.

II. ESA Technolgy Transfer Program

ESA under the leadership of the European space industry has developed high quality space technologies to support missions in the discovery of the universe, understand the environment, navigation, communication, education, health and rescue. Most of this application find their way back to earth in diverse areas like health to transport and from sports to entertainment. Every successful mission carried out by ESA leads to a ground breaking technology, which opens up opportunities for technology transfer to earth and creates new business start-ups.

An investment made by ESA into space has place Europe into the global competitive market due to the delivery of leading technologies that enable new start-ups, creating jobs and inspiring a generation of young people to embrace science. Continuous investment is space research is believed to be the key to keeping Europe at forefront technological innovation.

A. Technology transfer network

ESA has created a technology transfer network (TTN) which consists of brokers, with offices across Europe working to identify novel uses for technology that has been developed as part of their space program. They are also interested in identifying technologies in other sectors that could benefit the exploration and utilization of space. The technology transfer project office (TTPO) runs the technology transfer demonstrator projects to support companies to demonstrate and verify space technologies in a non-space field where there is potential for a strong commercial or societal benefit. The demonstrator project focuses on technology related expertise from space, the processes and the methodologies to narrow the risk in non-space commercialization. There is also a National Technology Transfer Initiative (NTTI) which is responsible for addressing funding and support for local companies. Hence the TTN is a link between the TTPO and the NTTI. In Figure 1 is shown the technology transfer process.

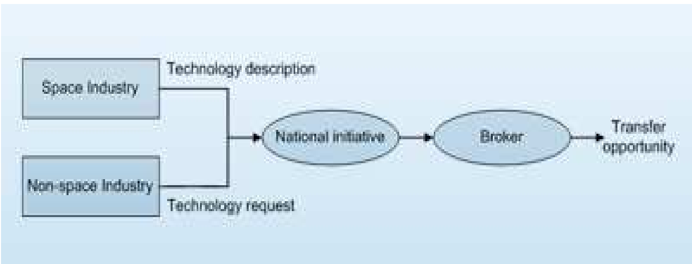

Figure 1.Technology transfer process through a national initiative [2]

The TTPO has also provided space solutions-from space to earth. Many of the innovations have turned out to be key to successful solutions for terrestrial markets. The transfers boost Europe's global competitiveness, forge numerous start-up companies, benefit regional economies and lead to new European jobs and growth.

B. Benefits of technology transfer

Technology transfer promotes a wider application of space technology, systems, and supports industrial growth by identifying new business opportunities in space technologies. These opportunities enhance know-how and competition among providers as they grow and refocus on their space technologies to different and specialized areas.

In the context of European space activities, the technology transfer can:

- Reduces the burden placed on public resources through research and development by adopting emerging technologies, systems and know-how in the space sector for application in the non-space sector.
- Maximize the return on investment in ESA's space research by member states.
- Avoid duplication of research between space and non-space sector.
- Promotes cross disciplinary opportunities for researchers to collaborate with other organizations.
- Provide economic potential and motivation for the donor and receiver of technology to promote society profile and create a potentially large market.

C. Future of ESA technology transfer

ESA has also established a technology forum and data base for members to be able to search for technologies, submit a request for technologies, offer solutions and promote technological service and know-how. ESA also has business incubations that support start-up, brokers network which brings member countries together in technology coordination, intellectual property which help to safeguard the innovation of members and keep Europe at the forefront of technology. Below in Figure 2 is the ESA future technology transfer plan.

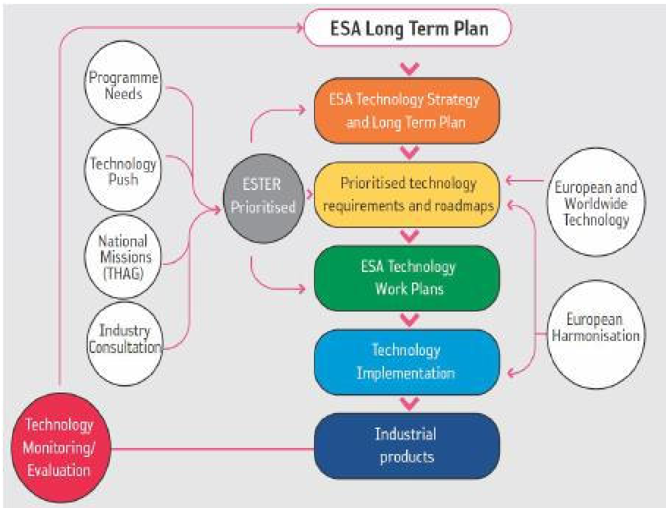

Figure 2 ESA future technology transfer strategy [9]

III. ESA Technology Transfer at BME-HVT

Under the frame of ESA's technology transfer program the Alphasat communication experiment's ground receiver system's elements were applied in a terrestrial, indoor propagation measurement system, designed for the Q-band.
BME-HVT in collaboration with Totaltel [7] developed the Q-band transmitter unit for the experiments. The receiver for the indoor measurement setup originated from the Alphasat ground receiver station of the department.
The schematic measurement setup is depicted in Figure 4, showing the main concept of the system.

A. System description

The transmitter and receiver are made up of two directional horn antenna which is assembled on a motorized tripod rotating platform. The 360° horizontal rotating capability allows scanning the entire horizontal plane and recording of the received signal power parameters for a specific location as shown in Figure 3.

Figure 3. The motorized platform for the receiver system

With a systematic relocation of the receiver, a signal strength map of the room can be provided by the angular dependency of the signal to be measured. In order to measure and process the received signal a Software Defined Radio (SDR) platform is utilized [5]. The SDR-based data collection and the platform-controlling software was developed by other colleagues at the department as it was published in [4].
The SDR acquires the measurement of incoming and downconverter L-band signal. After digitization the whole signal processing will be performed by the controlling computer using the GNU Radio software platform [6].
There is a computer responsible for controlling and managing the SDR. This is an essential issue, because during the measurement human interaction is minimized as much as possible, since the millimeter wave frequency band is sensitive to humans in the measurement area, and this significantly influences the result. The signal reflections and interferences in this band can considerably modify the propagation environment.
As shown in Table 1, PLL-based frequency synthesizers are serving as a local clock source for both the transmitter and receiver. Frequency quadrupling at Tx and Rx develops the Q-band carrier frequency. We applied a signal generator to produce the IF signal, which was an unmodulated sine wave.

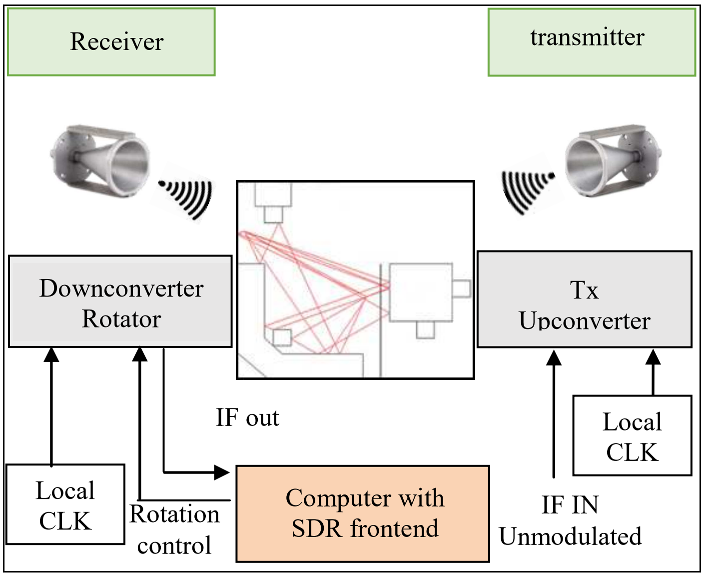

Figure 4. System layout for indoor propagation measurements

Table 1. The technical specifications of the final system

Transmit/receive frequency band	37.79-38.15 GHz
Transmit/receive antenna type	Grante CH 0.05 S 265400
Antenna gain	20-22 dBi
Transmitter	
Output power	0 dBm
IF band	1-2 GHz
Local oscillator frequency	9±0.2 GHz
Receiver	
IF band	1-2 GHz
Local oscillator frequency	9±0.2 GHz

A local clock frequency, generated by the external PLL synthesizer board, operating up to 9.8GHz, has its frequency quadruple in the receiver/ transmitter site, resulting in the Q-band carrier signal. The intermediate frequency (IF) signal is an unmodulated sine wave at between 1-2GHz, therefore the exact transmit frequency is 4•CLK+IF. The fixed transmitter and the rotated receiver configuration allow measuring both Non-Line of Sight (NLOS) and Line of Sight (LOS) scenarios.

The IF signal of the transmitter is a sine wave pilot signal from a signal generator that is upconverted to the Q-band and transmitted to the air. The downconverted received signal was connected to a spectrum analyzer in order to observe the receiving. The signal is reflected from the wall in front of the transmitter, as both antennas are facing the same direction.
The clock source of the system is an RF synthesizer with integrated VCO [6] that generated the central clock in the measurement setup. A spectrum analyzer is applied to visualize the received signal. In this experiment we applied a 1.32GHz IF signal source.

IV. Measurement Of Indoor Environment Scenario

In order to investigate the channel characteristics of the millimeter wave band, for this indoor channel propagation campaign conducted at 38GHz, two site specifics were chosen (i.e. office and corridor) for measurement.

A. Measurement and analysis

The measurement campaign was carried out at BME-HVT in building V1 2nd floor, where we considered furnished office and a corridor environment, with the receiver (Rx) placed in different positions away from the fixed transmitter (Tx) in each case. The dimension of the work office environment in length and breadth is 8.84m and 6.15m with the Tx-Rx place in LOS. The dimension of the corridor in length and breadth is 36.84m and 2.40m, in LOS conditions. The Figure 5 and Figure 6, below depicts the office and corridor measurement environments with the receiver Rx placed in different positions and with a single transmitter Tx position at the right side of the figures. The furniture in the office and a glass door in the middle of the corridor are schematically depicted in the figures. During the measurements, the Line of Sight position of the Tx and Rx was ensured by the exact positioning and rotation of the measurement platforms. For the correct alignment we applied a laser-beam guidance.

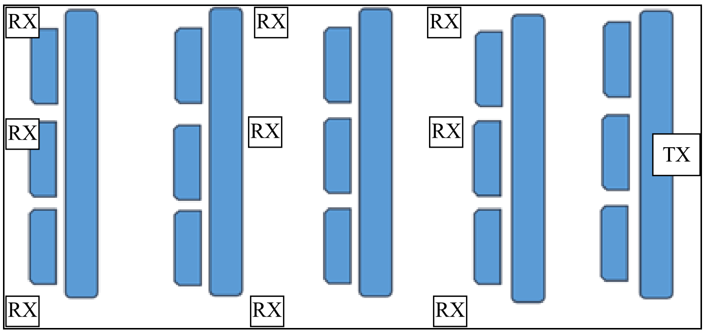

Figure 5. The office measurement environment (8.84x6.15m)

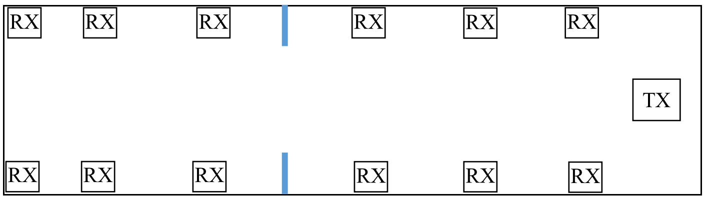

Figure 6. The corridor measurement environment (36.8x2.4m)

In figures we have presented are the typical measurement arrangement of the office room (classroom) with 8.84m×6.15m and the corridor is 36.84m×2.5m where the measurements were performed in LOS conditions at different positions[8]. In this environment are multiple chairs, tables, computers and other materials in the office, and the results displayed are an outcome of the measured path loss.
The path loss was calculated from received the signal power measurement. To get the path loss, we performed a calibration at the closest distance (1 meter) to get a reference level, which is subtracted from the received power measured by our experimental receiver. The reference distance was determined to equal to the shortest path length.
However, the entire dimension of the room is 8.84m×6.15m, due to technical reasons the receiver locations at different positions had a distance between them and the wall of the room. Therefore, the signal map covers 4.5m×6.5m, indicating the area where the receiver is located. In Table 2 the exact receiver's positions are listed. It can be well observed some reflections that are influencing the local propagation conditions. The transmitter location was fixed throughout the measurement while the receiver is moved around. The transmitted unmodulated carrier signal power was -27dBm. In Figure 7 the path loss is depicted after we determine the calibration level from the locally measured received power signals.

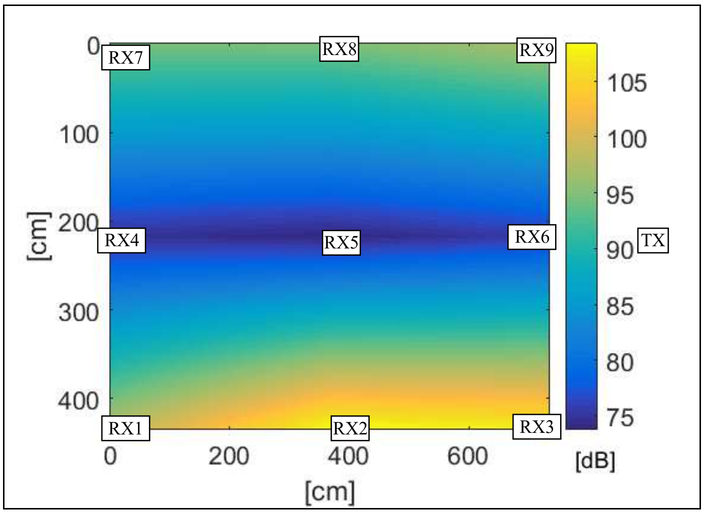

Figure 7. Office environment with measured path loss at LOS

Table 2. Office measurement locations relative to the bottom left room corner

	TX	RX1	RX2	RX3
Location [x,y] [cm]	[784,307]	[50,90]	[300,90]	[550,90]
		RX4	**RX5**	**RX6**
		[50,307]	[300,307	[550,307]
		RX7	**RX8**	**RX9**
		[50,525]	[300,525]	[550,525]

In Figure 8 we show the path loss developed from the corridor environment where the entire dimension is 36.84m×2.4m. However, the actual dimension measured is 32m×1.7m indicates where the receivers are located. Table 3 also indicated the exact receiver's positions are listed.

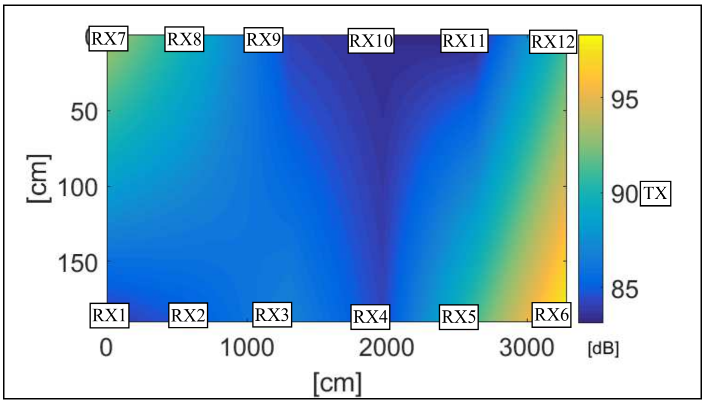

Figure 8. Corridor view with measured path loss at LOS

Table 3. Corridor measurement locations relative to the bottom left room corner

	TX	RX1	RX2	RX3	RX4	RX5	RX6
Loca-tion [x,y] cm	[3584, 120]	[300, 25]	[900, 25]	[1500, 25]	[2100, 25]	[2700, 25]	[6300, 25]
		RX7	**RX8**	**RX9**	**RX10**	**RX11**	**RX12**
		[300, 15]	[900, 15]	[150, 15]	[2100, 15]	[2700, 15]	[6300, 15]

The figures presented from the measurement effectively allow us to visualize the actual point of measurements from the entire area where the activities of the measurement took place. The measurement in the Q-band can be used to start a point of scene generating (map) based on a statistical description of the evolution of an indoor measurement system. It is well observable that the reflections are significantly influencing the local propagation conditions.

B. Conclusion

In this paper we described the technology transfer demonstrator a 5G indoor propagation measurement system, in which we investigated and measured the path loss conditions for the indoor environment in the Q-band. The space components which were successfully transferred are related to Alphasat satellite. Two horn antennas were used for both the transmitter and receiver systems respectively in this indoor signal propagation measurement setup.

Acknowledgment

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Deployment of the Hungarian E-GNSS Network and the results of its first year of operation

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***Abstract*—Global Positioning System (GPS) is widely applied in numerous fields nowadays. Modern people can hardly find a location without a smart device having GPS navigation. In aviation, the significance of global positioning is increasing, even though, in the landing phase, it had been not so widespread formerly especially due to the low integrity of GPS itself. In addition to the American NAVSTAR GPS, further systems are operational at the present time, like the Russian GLONASS, the European Galileo or the Chinese BeiDou. State-of-the art devices can track all these systems; consequently, they measure 40+ satellites or even more at the same time. The number of satellites is expected to increase in the future. For safety critical applications of global positioning, providing sufficient integrity is of utmost importance. This can be achieved by using either Ground Based Augmentations Systems (GBAS) or Satellite Based Augmentation Systems (SBAS). When relying on the consolidated results from several constellations of base and augmentation systems together we speak about the Global Navigation Satellite System (GNSS). E-GNSS stands for European GNSS, which is in the focus of scientific research these days when GALILEO becomes very close to its full operational state, meanwhile the EGNOS (European Geostationary Navigation Overlay Service) Safety of Live service was officially declared available for aviation in 2011.**

Following the strategy of the European Union, satellite based instrument landing approaches have been introduced at a great number of aerodromes all around Europe. Hungarian procedures for seven civilian and three military airports are being designed and published within the framework of the PBN4HU (Implementation of PBN procedures in Hungary) project granted by an INEA (Innovation and Networks Executive Agency) program.

Besides the procedures, the Hungarian E-GNSS monitoring network was also deployed within the framework of this project in 2018. The most important aim of the network is to monitor the performance of the EGNOS augmented positioning and gain the experience necessary for the application of GNSS in navigation. The network consists of 11 stations equipped with the most modern triple frequency, Galileo capable receivers. Raw measurements are recorded with one second sampling interval and post-processed in a full automatic way on a daily basis in accordance with ICAO (International Civil Aviation Organization) standards and requirements. Spectrum analyzers are also installed at the stations to monitor all the three carrier frequencies in order to detect and report interference events.

Keywords*—*GNSS monitoring, aviation, interferences

I. INTRODUCTION

There are a wide range of global, regional and local GNSS networks in use in our days. The International GNSS Service provides, on an openly available basis, the highest-quality GNSS data, products and services in support of the terrestrial reference frame, Earth observation and research; positioning, navigation and timing; and other applications that benefit science and society. The main product of IGS activity is precise GNSS orbits, Earth rotation parameters, global tracking station coordinates and velocities, high-quality ionosphere and troposphere models and many others primarily for scientific purposes. The primary purpose of the EUREF Permanent GNSS Network is to provide access to the European Terrestrial Reference System 89 (ETRS89), which is the standard precise GNSS coordinate system throughout Europe. The EUREF Permanent GNSS Network consists of a network of more than 330 continuously operating GNSS reference stations [1]. In Hungary, the first permanent GPS station was established by the Satellite Geodetic Observatory (SGO) in the middle of the nineties. At the present time, SGO operates the Hungarian Active GNSS Network with 35 Hungarian stations as well as 19 stations from the neighboring countries. The services of the network are applied in many fields, like land surveying, geoinformatics, precise agriculture by thousands of users [2]. In addition to this network operated by the Satellite Geodetic Observatory which is a state organization, there are several further networks with similar services and applications available in Hungary, maintained by private enterprises.

In addition to scientific and geodetic applications of GNSS, its importance in the field of precise navigation is increasing beyond doubt. Due to the poor integrity of the pure GPS systems, augmentation systems have to be applied in safety-critical applications like aviation. While the EGNOS (European Geostationary Navigation Overlay Service) Safety of Live service was officially declared available for aviation in 2011, a wide variety of activities has been carried out to monitor its performance. At the very beginning, EUROCONTROL established the EGNOS Data Collection Network to monitor the actual performance of EGNOS [3]. Within the framework of the project, managed by Pildo Labs, several monitoring stations were operated by universities (just as well as by the Budapest University of Technology and Economics), local air navigation service providers and other organizations.

At the present time, actual EGNOS performances are being monitored and analyzed continuously by the European Satellite Services Provider (ESSP) and (European Space Agency) ESA amongst other entities. Meanwhile, several countries have developed their own local EGNOS monitoring networks. For instance Airbus has developed its own GNSS performance and recording and analysis system, NavBlue, providing near real-time monitoring and alerting. NavBlue is used among others by the Italian Air Navigation Service Provider, ENAV within its project BlueMed [8]. A further initiative is that of the STRIKE3 project, which involves the development and deployment of an international GNSS interference monitoring network in order to develop international standards for threat reporting and GNSS receiver testing [4].

A further solution on the market is The Owl System of Pildo Labs. This system also provides recording and analysis of GNSS performance, near real-time monitoring and alerting and performance/integrity prediction. The Owl is designed to enable states to comply with the International Civil Aviation Organization's Annex 10 standards and recommended practices. The Slovak, the Austrian and the Hungarian Air Navigation Service Provider have opted for the use of this system.

HungaroControl has developed its GNSS monitoring network within the framework of the "PBN Implementation in Hungary project" co-funded by the Innovation and Networks Executive Agency (INEA).

Until 2015, Hungary had featured as a quasi white spot on the maps depicting performance based navigation (PBN) implementation in Europe. The first steps towards implementing GNSS based procedures were laid down in the BEYOND project. Launched in 2015, it consisted of developing capacity building in the field of multimodal applications based on E-GNSS (EGNOS and Galileo) - with a special focus on aviation - to selected Eastern European and Euro-Mediterranean countries with limited EGNSS experience; while supporting competitiveness of EU industry, through development of new market opportunities, networking and liaisons between EU and non-EU players.

Capacity building in the aviation domain was specifically dedicated to the East European (Hungary, Moldavia) and the Balkan (Montenegro, Bosnia HG, Kosovo and Albania) region partners; the knowledge transfer was consolidated through a four stepped methodology (training sessions, guided exercises, technical workshops, flight trials) applied within six key knowledge domains (Performance Based Navigation, Safety, Procedure Design, GNSS Monitoring and Ground Validation, Flight Validation and Future GNSS scenarios).

Building on knowledge and experience gained in BEYOND, HungaroControl applied and won co-funding from INEA to launch the "PBN implementation in Hungary" (PBN4HU) project. Within this activity, PBN approaches are being designed for 7 civil and 3 military airports in Hungary. In order to enable data collection in parallel with the introduction of the new procedures, a GNSS monitoring network has also been deployed within the country. Being aware of the fact that the data received from the GNSS constellations are prone to unintentional and/or intentional jamming and spoofing, HungaroControl decided to procure and install its own monitoring network, in order to gather solid, own data on GNSS performance throughout Hungary. These data also enable the Hungarian Air Navigation Service Provider (ANSP) and Budapest University of Technology and Economics to jointly carry out research in this field. The present paper describes the installation of this system and the results yielded by the first year of operation.

II. System deployment

Before the launch of the PBN4HU project, there had been SBAS-based procedures available just to one Hungarian airport, to the Budapest Liszt Ferenc International Airport (LHBP). Within the project, procedures are being planned to further seven civilian airports (Békéscsaba, Debrecen, Győr-Pér, Nyíregyháza, Pécs-Pogány, Sármellék, Szeged) and three military ones (Kecskemét, Pápa, Szolnok) (**Hiba! A hivatkozási forrás nem található.**).

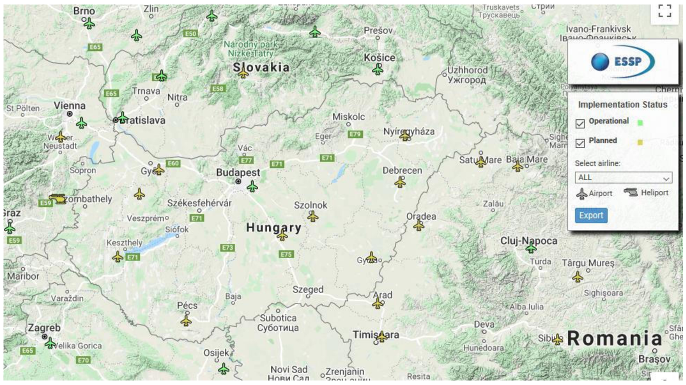

Fig. 1. Airports in Hungary with EGNOS based procedures. Source: https://egnos-user-support.essp-sas.eu/new_egnos_ops/lpv_map/map.php

As part of the implementation process, the country is covered by altogether 11 GNSS monitoring stations. One of them is located on the main building of HungaroControl, which is quite close to LHBP airport, and further seven of them are within the area of the abovementioned civilian airports. The remaining three monitoring points were preferred not to be located within the military premises, rather, also aiming for an even geographical distribution, they were installed at HungaroControl facilities (Bugac, Ságvár, Sajóhídvég) (Fig. 2).

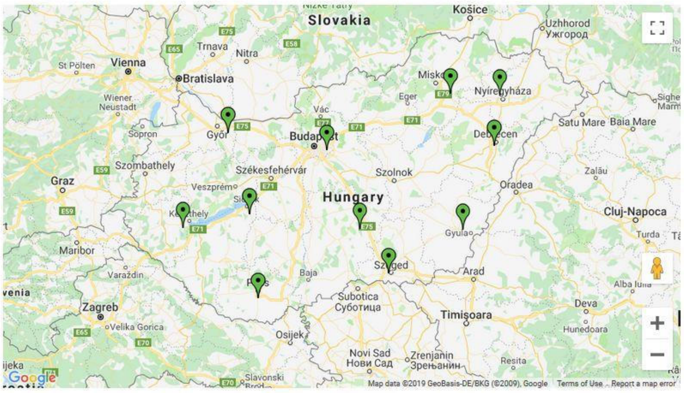

Fig. 2. Location of the monitoring stations in the Hungarian E-GNSS Network

Several conditions had to be kept in mind when choosing the specific location of the monitor stations. First, the GNSS-antenna is to have a clear view of the sky without hindering obstacles and objects, which might cause multipath effects or other signal reception issues. The so-called PildoBox with the GNSS receiver inside should be located in a safe and secure environment, with reliable power and internet connection. Furthermore, the PildoBox should be placed in a way so as not to block the normal operation of the given room, e.g., in the control tower (Fig. 3).

Fig.3. Photos of GNSS antenna (Nyíregyháza) and PildoBox (Szeged)

Monitoring stations are equipped with state-of-the-art GNSS receivers and antennas. The critical hardware elements are GPS, Glonass, BeiDou and Galileo compatible triple frequency Septentrio AsteRx4 receivers and Septentrio PolaNt-x MC antennas. Receivers are configured to track GPS and Galileo satellites since EGNOS corrections are available as of now only to GPS signals. Whereas, undoubtedly, the significance of Galileo measurements is also increasing since the Galileo system is quite close to its fully operational state. In addition, EGNOS is planned to broadcast SBAS messages to Galileo satellites as well to improve the accuracy and robustness of SBAS augmented positioning. PildoBoxes records raw measurements with a 1-second sampling interval in septentrio raw binary files. Hourly files are stored locally and uploaded to our data center. The size of a typical hourly file is 4 to 6 MB. The majority of stations have a wired network connection, while some of them are connected via mobile internet. As based on our experience gained during the recent more than one year of operation, mobile internet communication is reliable and stable enough.

In addition to the GNSS receiver, each PildoBox contains a spectrum analyzer to monitor frequency ranges on all the three carrier frequencies. Interference events are recognized automatically. Once an event has occurred, the spectrum image with the main characteristics is logged, and the operators are automatically alerted.

III. Services provided by the Hungarian E-GNSS Network

A. *EGNOS performance monitoring*

Raw measurements are post-processed daily using the Pegasus software [5]. Data processing and evaluation, which are fully compliant with ICAO standards [6], are carried out by Pildo Labs, and the most important results are made available through the web based "TheOwl" surface. EGNOS performance can be described the exactly defined values of accuracy, integrity, availability and continuity (Table I).

TABLE I. EGNOS Performances Requirements in aviation

	APV-1	**LPV-200**
Horizontal accuracy [m] 95%	16	16
Vertical accuracy [m] 95%	20	6 to 4
Horizontal alarm limit [m]	40	40
Vertical alarm limit [m]	50	35 to 10
Availability	0.99	0.99
Continuity	1 – 8 x 10^{-6} per 15 seconds	1 – 8 x 10^{-6} per 15 seconds

The first results of the post-processing phase are the EGNOS augmented positions, which are directly compared to the known and considered errorless coordinates of the stations to compute true position errors. True position errors are typically between 1.0 and 1.5 meters both horizontally and vertically at 95 % level (Fig. 4). According to ICAO standards, the maximum allowed horizontal and vertical position errors are 16 and 20 m, respectively.

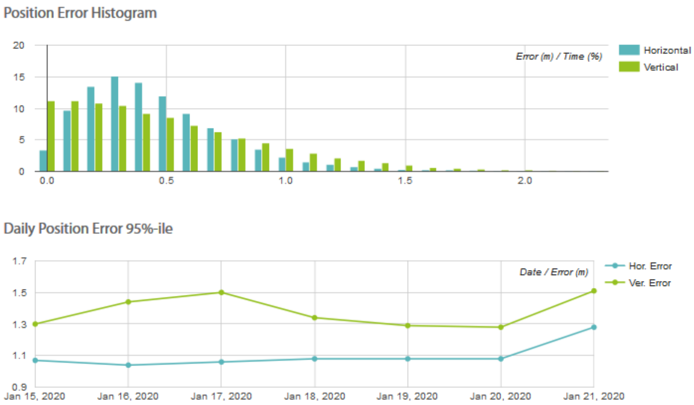

Fig. 4. Accuracy at Budapest station

The protection level and the safety index are metrics used to describe integrity. The Safety Index (SI) is the ratio between the position errors and the protection level for each component (horizontal and vertical). SI should be smaller than 1 in normal condition; typically it is 0.2 or even less (Fig.5.). SI > 1 indicates hazardous misleading information of the system.

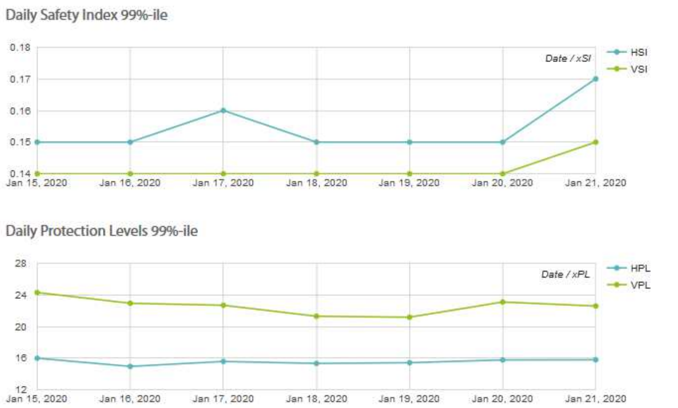

Fig. 5. Integrity at Budapest station

ICAO SARPS establishes APV-1 Horizontal and Vertical Alerts Limits to 40.0m (HAL) and 50.0m (VAL) while LPV-200 Horizontal and Vertical Alert Limits are 40.0m (HAL) and 35.0m (VAL), respectively. EGNOS Availability is defined as the percentage of epochs, i.e. measurements, in which the Protection Levels are below Alert Limits set for a specific operation over the total period, which is typically a 24-hour session. Besides, accuracy requirements should also be met.

Actual accuracy, integrity and availability figures, as well as their requirements, are generally presented using Stanford plots (Fig. 6).

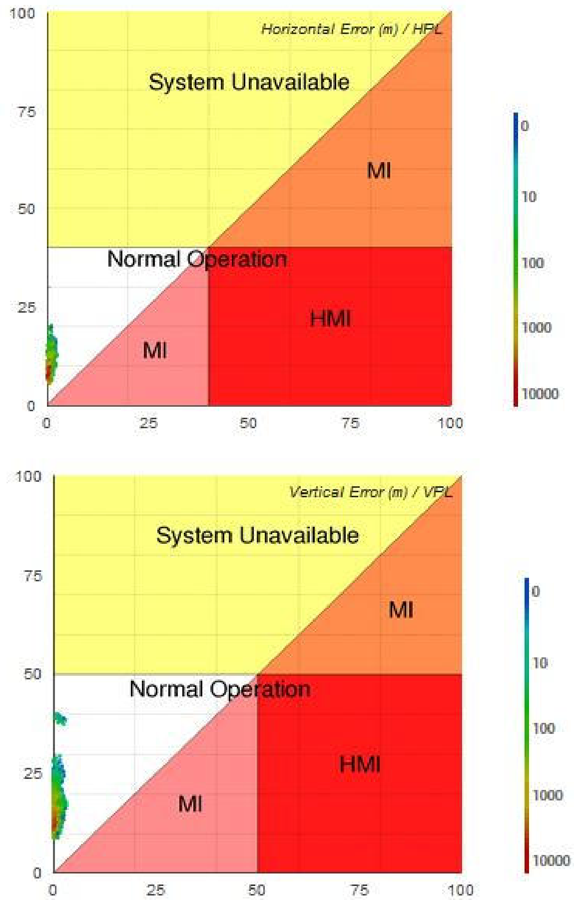

Fig. 6. Stanford plots for Budapest station between 15 and 21 January 2020

Since Hungary is within the area usually well-covered by EGNOS messages, the actual availability is 100 % (Fig. 7). However, we have experienced that some days the availability significantly decreased from 90 to 95 percent at the majority of the stations due to some ionosphere grid issues for short periods in time.

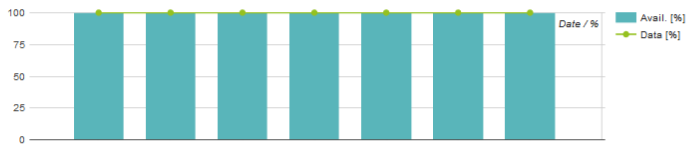

Fig. 7. Availability at Budapest, between 15 and 21 January 2020

The minimum continuity risk performance shall be less than 1.0E-4 per 15 seconds in the core part of European Civil Aviation Conference (ECAC) countries, and less than 5.0E-4 per 15 seconds in most of ECAC countries. Such a minimum performance is not compliant with ICAO requirements for LPV-200 precision approach (8.0E-6 per 15 seconds). These values are, however, considered as sufficient to start using EGNOS in civil aviation [7].

In general, some continuity events have been detected in the network. Granted that only a fraction of analyzed periods have suffered from this issue, the number of such events cannot be considered as serious (Fig. 8.). It is also worth mentioning that the figures are in accordance with the results from other projects as well [9].

Criteria	Maximum allowed value	Actual value	Requirement achieved
ICAO	8.0E-6 per 15s	0.0 per 15s	●
EGNOS SoL SDD	1.0E-4 per 15s	0.0 per 15s	●

Fig. 8. Continuity at Budapest, between 15 and 21 January 2020

B. *Interference Events*

Operators report an increasing number of events related to the loss of GNSS signals due to Radio Frequency Interference (RFI) during operations in some areas of the world. Experts say that the majority of the disturbances are caused by low-cost GPS-jammers used by drivers to block their car navigation systems. Although their usage is entirely illegal, the number of such events is undoubtedly increasing. The drivers intend to block just their own devices; however, these jammers might have an effect on professional equipment even from a considerable distance up to several hundred meters. While it is quite simple to detect such events, there is no easy solution to tackle the problem.

Every monitoring station in the network is equipped with a spectrum analyzer to detect and report interference events on all the three carrier frequencies. As expected, numerous such events were recorded during the first year of operations. All of the stations recorded these kind of events. Taking a closer look, it can be realized that all the anomalies were detected on the L1 frequency. The majority of the stations recorded less than 40 events during the one year. A typical interference event lasts for a few seconds in time and it creates no significant effect on the positioning itself.

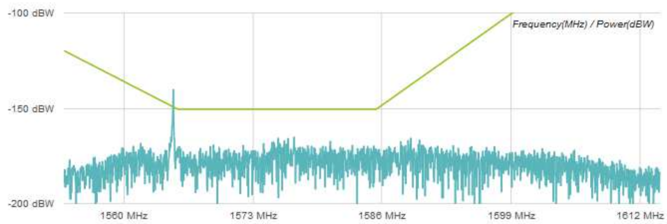

Fig. 9. Spectrum anomaly event at Pécs 2 August 2019

On the other hand, more than half of the events, actually 270 out of 496, were recorded at Pécs (LHPP airport). The characteristic of the spectrum image is almost the same (Fig. 9). The monitor station is located within on the buildings of Pécs-Pogány airport which are pretty close to a major road. It seems that someone or several people taking this road, use a low-cost GPS jammer on a regular basis. In most of the cases, two events a day were recorded, the first one in the morning and the second one in the afternoon.

IV. CONCLUSION

Parallel to the SBAS procedure design tasks performed within the PBN4HU project, an 11-station GNSS network in Hungary was also deployed within the second half of the year 2018. The main purpose of operating this special GNSS infrastructure is to monitor the performance of EGNOS based positioning, just as well as to gain more experience in processing and evaluating raw measurements.

According to the results of the first year operation, the requirements for aviation purposes are thoroughly fulfilled. However, some special situations overt short periods of time have also been detected when integrity, availability and continuity parameters were slightly below the expectations. These facts open the avenue for future investigation.

Since the stations are equipped with state-of-the-art Galileo and L5 frequency compatible GNSS units, maintaining this E-GNSS infrastructure in the future is of utmost importance to check the role and significance of Galileo signals in safety critical applications right from the point when EGNOS starts broadcasting corrections for Galileo satellites as well.

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Affordable statistical testing for quantum random number generators in space applications

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***Abstract*—Many cryptographic and communication use cases today rely on random numbers. Quality of these numbers is usually critical for security, thus requiring the use of quality true random number generators. QRNGs (Quantum Random Number Generators) present a promising solution to satisfy this growing demand. They work according to the postulates of quantum computing and offer random numbers based on physically proven unpredictable behavior. Overseeing the operation of such devices can be challenging given the random nature of the output. To monitor this probabilistic behaviour, statistical tests can be used, which can often be computationally expensive. In resource scarce situations, like on satellites, this can pose a problem. We investigated the possibilities for creating more cost efficient solutions for these cases, when usable a priori information about the system is present (system has been properly analyzed before launch).**

***Index Terms*—random numbers; quantum computing; satellite communications**

I. Introduction

Quality random numbers are an essential resource for many secure communication schemes today [1]. Pseudo random number generators (PRNG) offer an easy solution, because they can be realized simply as software. However, their deterministic nature comes with a big disadvantage. During operation these generators use a hidden internal state to produce hard to predict output data, although, by collecting enough of this output and knowing the internal workings of the underlying algorithm, this state can eventually be predicted. This introduces a potential vulnerability, as an attacker is able to accurately simulate the operation of the generator, thus compromising all past, present and future output strings [2][3]. For environments like space applications this poses an even bigger threat, because any problem emerging after launch is extremely hard to fix. Using true random number generators (TRNG), solves this problem at the cost of requiring the proper construction of physical hardware, with all the challenges that entails. Fortunately, with advancements in technology, these challenges are becoming less and less daunting, therefore these generators are progressively getting cheaper and easier to realize. They typically get their entropy from external physical sources, like radioactive decay, various photoelectric effects, or noises like thermal, avalanche or shot noise. The unpredictability of these phenomena are based on the laws of quantum mechanics, which have already been experimentally proven [4][5][6]. To harness entropy from these physical processes, adequate measurements have to be made, therefore the main challenge associated with these generators is the proper error free construction needed for unbiased operation. Advancements in quantum optics have led to the emergence of several new quantum applications utilizing photons as their information carriers. This allows for more accessible constructions, as modern LEDs and lasers can be used as sources, instead of other more specialized solutions. While most quantum computing and communications use cases are still in the experimental phase, quantum random number generators (QRNG) are already commercially available [7]. Recently several new photon based architectures have become feasible [8], promising faster generation speeds, smaller devices [9] and easier maintainability. With the growing need for unpredictability for secure space communications, these generators can provide viable solutions for quality on board satellite random number generation. Imperfections arise even in the most carefully built systems too, so adequate monitoring has to be realized for random number generators too. Due to the expected random nature, all possible output strings can occur during normal operation, making it impossible to tell with full certainty if a given output is the product of nominal or faulty operations. With the help of well constructed statistical tests, however, some statements with high enough confidence, regarding the state of our system, can still be made.

II. Statistical tests

A. Statistical Testing

The possible outcomes of statistical tests, when applied to a truly random sequence, is known a priori and can be described in probabilistic terms. There are infinitely many ways a given sequence can be non-random, so there are infinitely many possible statistical tests to use, each corresponding to a different error state. Practically the goal is to use an adequate set of these, providing decent coverage, while still affordable. Tests are usually formulated to test a specific null hypothesis (H_0). In the case of random generators this is usually the following: The examined output is truly random. Associated with this is the alternate hypothesis (H_a), that the sequence is not random. During operation a test gathers some evidence trying to decide

TABLE I
POSSIBLE OUTCOMES OF STATISTICAL TESTS

Reality	Conclusion	
	Accept H_0	Accept H_a
Data is random	No error	Type I error
Data is not random	Type II error	No error

between these two competing hypotheses. This is typically done by investigating some probabilistic value with known theoretical distribution calculated from the sequence (calculate a p-value), then checking whether it exceeds some a priori defined critical value or not. If it does, the null hypothesis (H_0) is rejected and the alternative (H_a) is accepted. This is the general principle behind the widely used NIST tests [10] too.

The possible results of tests are shown in Table I. Type I error happens, when a random sequence is decided to be non random. If error states are handled (they should be handled), this might result in minor speed loss, as the output is probably blocked, and some handling operations are made. Due to the expected random nature of the source, some failed test results are expected, so error handling should be done carefully, because blocking all failed outputs would lead to a skewed distribution too. Type II error happens, when a real error state is not detected. It is much more dangerous, as it means a potential unknown vulnerability. Should a potential attacker know of this, while the operator is clueless, the security of the overlaying systems can be compromised. Because of this, Type II error should be minimized. Probability of Type I and Type II error and the length of the examined sequence are connected, knowing two, the third can be calculated. Typically chosen value for Type I probability is 0.01, as recommended by the NIST Statistical Test Suite (STS).

B. Statistical Test Collections

There are already available test collections for generator testing and validation. The two most widely used are the NIST Statistical Test Suite containing 15 tests, and the Dieharder [11] test collection, which is an extension of the 1995 Diehard [12] tests, containing more than a hundred different tests. These are computationally quite expensive, so they can't be used for real time monitoring tasks, especially in resource scarce environments present in the space industry. While not readily applicable, the tests contained within these collections can serve as starting points for identifying, then constructing the reduced test set able to realize real time monitoring.

III. CUSTOM TESTS

Detecting all possible non randomness is theoratically impossible, due to the nature of the output. For practical purposes, however, knowing the probabiliy distribution of potential error cases, an optimization problem can be formulated, where the goal is to cover as much of these cases as possible (weighting the cases according to their probability distribution) using finite computational resources. This a priori information about the generator allows for the construction of custom monitoring tools, tailored to the specifics of the hardware, potentially achieving greater detection efficiency for reduced computational cost.

A. Properties of Quantum Random Numbers Generators

Quantum random number generators sample quantum mechanical phenomena for their entropy. Photon based realizations typically have two main kind of resulting distributions after measurement. The first is the uniform distribution, which is the optimal output distribution even after post processing. Typical example of this are branching path generators [13]. Another common output distribution is the Poisson distribution, as it is characteristic for most photon sources. Typical examples are generators based on photon counting [14] or measuring time of arrival statistics [15]. In this case, however, some post processing is always necessary to transform the raw output, as uniformity is expected.

Most errors arise due to some component malfunction. In resource scarce environments, where possibilities for proper analysis are limited, the main goal is cost efficient detection of the more typical error types as these are the most probable to occur. These depend greatly on specific architecture used, however, change in the ratio of possible output states might be the most common symptom, so we use this as an example for the practices proposed in this paper.

B. Modified Reference Distribution Tests

Statistical tests are usually designed to test for uniformity. Since we want to monitor the actual state of the hardware, especially in limited resource environments, skipping the need to account for the effects of processing, the ability to test before post processing is desirable. When the raw output is non uniform or has some a priori known and expected bias, however, this is problematic as the reference distribution also becomes non uniform. Tests have to be modified accordingly. Generally statistical tests follow 4 main steps during operation:

- Preprocessing, change representation of data.
- Calculate some statistical value.
- Compare this calculated value to its known theoretical reference distribution and calculate a p-value.
- Decision (if p-value is greater than some limit, the test is successful, if not, then it fails).

Testing against modified reference distribution can be achieved mainly in two different ways. Changing the reference distribution for p-value calculation is the most straightforward approach, however, in some cases this can become cumbersome, as the method for calculating p-values has to be modified accordingly. Another method is to change the calculation of the inner statistical value in such a way, that its expected distribution doesn't change for the non uniform case. The following is an example of this approach.

1) Testing for non uniform ratio of ones and zeros: Assume we have a branching path generator, where the two paths have different attenuation, leading to some known bias, that is corrected during post processing. To test the raw data, a modified test has to be designed. Normally, we can test the ratio using the monobit test from the NIST STS. For this case, however, some modifications have to be made to the algorithm. The basis of the original test is the notion, that the sum of probabilistic values following the Bernoulli distribution can be approximated with a normal distribution for large number of samples. This can then be normalized to follow the standard normal distribution, for which easy to use methods for calculating p-values (the erfc() function) already exist. For the modified case, only the starting Bernoulli distributions change (from fixed p = 1/2, to some arbitrary p between 0 and 1), the principles of the calculation method do not. The sum of values following an arbitrary Bernoulli distribution can be approximated with the following normal distribution.

$$S_n \sim \mathcal{N}(np, np(1-p)) \quad (1)$$

Knowing the expected ratio (p is known) the normalization to standard normal distribution can be done.

$$s_{obs} = \frac{(S_n - np)}{\sqrt{np(1-p)}} \quad (2)$$

From this point on calculating the p-vaue and evaluating the result is the same as in the original uniform test's case.

2) Testing for the ratio of multiple possible output states: Another probable non uniform case is, when the raw data follow a Poisson distribution with multilple possible results for each measurement. This can be handled with an appropiately constructed "chi-squred" test, where the test's degree of freedom is determined by the number of possible measurement results.

C. Long Term Testing

Results of individual tests can be used to calculate statistics representing longer periods of runtime. Since p-values resulting from tests have an expected uniform distribution too, tests to check for this property can be defined [16][17], effectively realizing a bigger test aggregating the results of many smaller tests. For space applications, especially smaller satellites with limited resources, this approach may not be useable, due to the computational need of these tests. A simpler method is preferable.

Most tests calculate their p-value and therefore make their eventual decision using some inner statistical value derived from the examined sequence. In some cases this value is (e.g. discrete Fourier transform) closely tied to the sequence as a whole, other times not. For the latter, the monobit test is a good example again. The value used for p-value calculation is only influenced by the sum of ones, and the length of the examined bit string. Saving this sum and the length for later use, extended versions of the original test can be defined. These new variants only need the two saved properties as input. Adding all the previous sums and lengths together, a new, combined sum and length can be calculated for this extended case. Then, similar to the original monobit tests operating on the original bit string, a p-value can be calculated by normalizing the sum with the length, then comparing it to the reference distribution. This essentially realizes a longer version of the original test, defined over all the bits previously examined by the tests that provide the inputs. With this, even a sliding window testing approach is possible, since the statistics saved from individual smaller tests persist as long as we don't explicitly delete them. From the NIST Statistical Test Suite, such extended tests can be made from the following:

- Runs test: saving sequence length, ratio of ones, number of runs.
- Longest run of ones in a block: saving length and number of tested blocks, counts in cells.
- Binary matrix rank test: saving number of blocks, number of full rank and full rank-1 matrices.
- Cumulative sums (cusums) test: saving sequence length, largest excursion, excursion at the end of the sequence.
- Random excursions test: saving sequence length, internal excursion statistics, excursion at the end of the sequence.

IV. Error detection

In a closed system limited by available computational power, choosing the proper monitoring method and suitable set of used tools is essential. The main points to consider when deciding on these are applicability, sensitivity and computational cost. The goal usually is to achieve the highest possible sensitivity for the given environment defined by the capabilities of the hardware. A priori information can help with this by allowing for customized optimizations.

A. Computational Need

Certain statistical tests can be computationally quite demanding, while others are relatively cheap to run. While functions used to compare the calculated inner statistical values to their respective reference distributions (like the complementary Gauss error function) may seem costly to calculate, when a priori information is present, decision making can be greatly simplified. Since using p-values for later testing is computationally expensive, actually calculating them could be skipped when more expensive post processing is not planned. In this case only the fact of failure is important. With fixed threshold for failures and sequence length for each test, the p-value criteria can be redefined for the calculated inner statistics directly, thereby eliminating the need for calculation of the respective error functions. For the preprocessing and inner statistic calculation steps, as these are different for each test, such general simplifications cannot be made unfortunately. The final computational cost of tools is therefore greatly dependent on what can efficiently be done by the host hardware.

B. Detection Approaches

Statistical tests are expected to fail during nominal operations. Detection of errors therefore cannot be done instantly, nor with absolute certainty. When choosing a threshold for a given test, that test is then expected to fail according to this chosen value (e.g a 0.01 threshold expects 1% failure rate). For practical detection approaches unlikely deviations from our expectations can be chosen as error indicators. Given that a

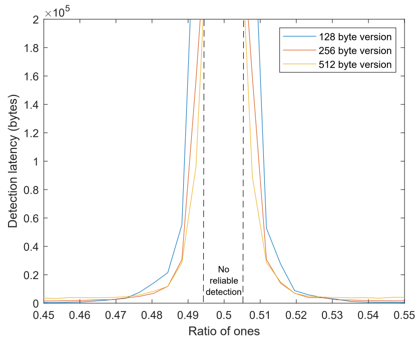

Fig. 1. Error detection latency with different test variants for generator bias ranging from ratios 0.45 to 0.55 (0.5 is the optimal, expected error free ratio).

test is sensitive enough to a particular fault, a notable deviation is expected when that error occurs. Information gathered by tests also has varying significance, inversely proportional to the length of the tested sequence. This inverse relation is also true for sensitivity, meaning that testing longer strings yields more accurate results. This, however, introduces more latency. A compromise between detection speed and accuracy has to be made, while also keeping the rate of false positive results at a manageable level.

C. Simulation

To further investigate tradeoffs between approaches we ran a simulation using the monobit test, simulating various ratios corresponding to more or less severe error cases. The simulation starts with nominal operations, then after a set amount of generated bits, switches to generating faulty output. This is accomplished using an AES cypher based modified software PRNG (suboptimal etalon source compared to TRNGs, but sufficient for our case). To detect errors we used a sliding window (last 100 to 200 results depending on test length) for tracking the failure rate of the most recent test cases. This window can be chosen even bigger resulting in better accuracy (and fewer false positives) at the cost of increased detection latency, or smaller for lower latency, but an increased chance for false positive triggers. For the 0.01 expected failure rate, we used 0.05 as a threshold to trigger an error state. Other detection approaches, like checking for consecutive failures, can also be considered, but the relations between accuracy, latency and probability of false positive results stay the same, as they can be derived from the random nature of the tested data and the characteristics of hypothesis statistical testing. Essentially, the ouput of previous smaller tests is being tested statistically for detection. Three variants of the monobit test were examined, operating on 128, 256 or 512 bytes of data per test.

The detection statistics for each can be seen in Fig. 1. There's a point, after which reliable detection is not possible with these tests, only longer tests or long term statistical tools can signal a fault. For larger deviances, shorter tests perform better, as these reach the critical detection threshold sooner. Due to their higher sensitivity longer versions perform better as deviations get smaller, offering later detections opposed to no detection at all.

Choosing detection thresholds is another critical aspect, due to the possibility of false positives during normal operation. In our simulation a 300 kbyte long nominal section preceded the error states, but for even this relatively small length some false positive detections happened (expected as the threshold is relatively strict), which were filtered out from the results. In real world appications the length of the error free blocks are much larger, implying that more forgiving detection conditions should be used at the cost of latency. A possible solution for this might be the following: Without changing detection conditions, with the introduction of a secondary stronger condition, a two stage detection scheme can be realized. First the output is only blocked, the string is witheld, further operation of the generator (while the output is blocked) is examined according to the second, stricter condition set. If the stream fails the second set too, an error state is declared, if not the block is lifted and the previously examined and saved bit string is sent out, as if the block did not happen at all. This requires an additional internal buffer, but allows for stricter detection criteria and lower detection latency.

V. Conclusion

We examined possible challenges associated with the monitoring of random number generators in resource scarce situations, a condition which is characteristic for many space related applications. Appropiate a priori infromation regarding the properties of the hardware and its possible error states is usually already present in these scenarios, so we explored the possibilities for using this informormation to propose specific, more cost efficient solutions.

Acknowledgment

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Adapting Telescopes for Optical Communication

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***Abstract*—Quantum communication can revolutionize wireless communication and encryption. Our group has started adapting commercially available telescopes for optical communication with quantum communication as a long-term goal. In this paper we compare the values expected from the theory with the parameters of the real system. We find that measured beam spreading is in the same order of magnitude as calculated values. We also measured the link budget at a distance of 167 m under strong turbulence conditions and experienced 50% efficiency in transmitted radiant flux.**

***Keywords*—quantum communication, telescopes, optical communication**

I. Introduction

In our ever-accelerating world, it is more important than ever to share information as quickly as possible. This problem poses many challenges for engineers and researchers. Key factors include security, speed and ease of implementation. At present, one of the most advanced cryptographic solutions is provided by optical communication, specifically by quantum communication.

Quantum communication can be defined as transmission of information using an ultra-weak light signals. Since in quantum mechanics the measurement irreversibly changes the measured system it also follows that unauthorized persons are unable to listen in and intercept messages without revealing themselves.

Quantum communication can be realized in optical fibers or in free space. The term free space encompasses air as well as the vacuum and space (i.e. communication between two satellites).

Free space communication has several advantages, but its two most important features are a) the ability to bridge much larger distances than the optical fiber solution, and b) a free space system does not require cables to be laid which can lead to cost reduction on a global scale.

Free space quantum communication has already been implemented at a distance of 140 km [1] between two optical ground station, 1700 km [2] between a satellite and two terrestrial receivers and at 7600 km [3] between two ground stations using a store and forward scheme.

II. Challenges

Weak laser beams need to be aimed and focused with great precision. This targeting accuracy can be achieved with telescopes.

In free space, laser light has to cope with dynamically changing atmospheric conditions, unlike in fiber optics, whose parameters are virtually unchanged. [4] [5]

System performance is influenced by several factors, such as wavelength, beam divergence, transmitter-receiver distance, receiver and optical-beam diameter, detector sensitivity.

III. Impacts of Atmosphere on Communication

The atmosphere influences communication in many ways. The most important of which is the channel loss. This loss has multiple sources: molecular and aerosol extinction, targeting and beam widening. In the following sections we will examine these factors.

A. Molecular and aerosol extinction

If the atmosphere is modeled as a static, spatially homogeneous and temporally unchanged medium, losses can occur for two reasons [4][6]. One reason is when a component of the air, which may be gas or aerosol, scatters the light rays, and the other reason is when it absorbs it.

Under the Lambert-Beer law, the transmittance can be calculated as the ratio of the input and the output beam:

$$\tau_{EXT} = \exp(-\gamma \cdot \Delta L) \quad (1)$$

where ΔL is the link distance, and γ is an extinction coefficient. This transmittance is a real number between 0 and 1. In case of singe photons its value indicates the probability that the photon will arrive at the detector's plane.

As mentioned earlier, the airborne absorption and dispersion centers in the atmosphere are molecules of a gas mixture and aerosols (e.g. dust, vapor). Thus, the extinction coefficient can be expressed as the sum of the molecular and aerosol components, and both can be further subdivided into κ absorption and σ scattering coefficients.

$$\gamma = \kappa_{MOL} + \sigma_{MOL} + \kappa_{AER} + \sigma_{AER} \quad (2)$$

Experimental measurements of these coefficients are available in the literature for different wavelengths and under different weather conditions [7].

According to our calculation, assuming a 300-400 meters long channel in clear weather, we can expect less than 5% atmospheric loss.

1) Red laser as an analogue for a near infrared source

Even though our final transmitter will operate at 810 nm, our experiments were performed with a 650 nm red laser. The tables below show the transmittance in case of these wavelengths.

TABLE I.

650 nm	transmittance	
L [m]	clear	hazy
100	0.99	0.94
200	0.97	0.89
300	0.96	0.84
400	0.95	0.79
500	0.93	0.75
1000	0.87	0.56

TABLE II.

810 nm	transmittance	
L [m]	clear	hazy
100	0.99	0.94
200	0.98	0.89
300	0.96	0.84
400	0.95	0.79
500	0.94	0.74
1000	0.89	0.55

Comparing the two tables, it can be clearly seen that the difference in transmittances is negligible. The model thus shows that a 650 nm red laser is a good analogue of the 810 nm light source.

B. Beam wideningeffect of atmospheric turbulence

However due to the finite size of the detector not all photons will be detected at the receiver's plane. To ascertain the losses due to the photons missing the receiver we must calculate the beam widening which depends on the optical turbulence strength.

The optical turbulence strength (denoted as C_n^2) is the degree of turbulence caused by fluctuations of air temperature and therefore the refractive index. In an isotropic approximation, C_n^2 is a scalar quantity whose unit is $m^{-2/3}$, and whose value is weather dependent.

According to the literature [4][8] the value of C_n^2 is roughly 10^{-17} for weak turbulence, 10^{-12} for strong turbulence and we considered $5\cdot10^{-13}$ an average value.

With this, the beam width at the detector's plane can be calculated as [4][8][9]:

$$\rho = \sqrt{\frac{4L^2}{k^2D^2} + \frac{D^2}{4}\left(1-\frac{L}{F}\right)^2 + \frac{4L^2}{(k\cdot\rho_0)^2}} \quad (3),$$

Where L is the channel length, F is the focal length, k is the wavenumber, D is the initial beam diameter (approximately the transmitter diameter) and ρ_0 is the coherence length.

Assuming a constant C_n^2 throughout the atmospheric channel, the coherence length can be expressed as [4][8][9]:

$$\rho_0 = \left[1{,}46k^2C_n^{\,2}\frac{3}{8}L\right]^{-3/5} \quad (4)$$

Choosing F=L we get a minimum diameter for the beam as function of distance. These values are interesting because if the smallest achievable beam diameter in the receiver's plane is larger than the diameter of the main mirror of the receiving telescope, significant losses can be expected.

According to our calculations this situation occurs at 500 m in case of strong turbulence, 650 m in case of medium turbulence and over 1000 m in case of weak turbulence.

However it is worth noting that in practice there are other cumulative factors increasing the effective beam width–namely targeting errors. These depend on the setup and cannot be easily modelled. Therefore we must treat the result of our theoretical calculation as a lower bound.

1) Red laser as an analogue for a near infrared source

Calculating the beam width for 810 nm choosing L and F to both be 1000 m where D is determined by the telescope's main mirror, the final beam widths are 5.16 cm, 18.2 cm and 27 cm in weak, average and strong turbulence respectively. Calculating the same for 650 nm, the beam widths are 4.14 cm, 18.7 cm and 28 cm. From this we conclude that the difference is negligible, and the red laser behaves analogously to the infrared source.

IV. EXPERIMENTS PERFORMED

In our final experiment the two telescopes will be located on each side of the Danube. This means a distance of about 300 to 500 meters, so the link distance will remain under 1 kilometer. Our light source will operate at 810 nm. The light source on the transmitter side and single photon detector on the receiver side will be connected to the eyepiece of the telescope.

A. Experiments

The purpose of the experiments is to make the system as efficient as possible using the tools at our disposal. Both on the transmitter and receiver telescopes are Maksutov-Cassegrain telescopes. The manufacturer of the telescopes has provided two eyepieces, one with a focal length of 26 mm and a higher magnification lens with focal length of 9.7 mm. We performed our test using these eyepieces although the final experiment will use a different, specially designed eyepiece lens.

a) Test 1—Verifying telescope parameters

In our first experiment we examined the linear field of view of the telescope at various distances. We compared the measured values with calculated results based on the nominal parameters of the telescope (as provided by the manufacturer.) We chose the target size to be 10 cm–a value close to the size of the receiver telescope.

This had multiple advantages. First we could test weather we can reliably target a reference object of that size at various distances (i.e. whether the targeting error is low enough and the target is visible at different distances.) Second it allowed us to verify the nominal parameters of the telescope. Third we could compare the mathematical predictions with realistic data. This comparison might later be used in further models such as modeling the signal to noise ratio. (Assuming background noise is a function of the field of view.)

In the figures below we show the measured and calculated values (see Fig. 1 and Fig. 2.) Based on our findings we conclude that the nominal parameters are in good agreement with the measured values.

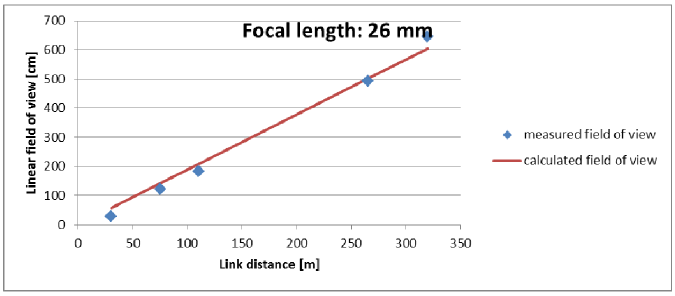

Fig. 1 Linear field of view using an ocular with 26 mm focal length. The figure compares the data estimated from photographs with those calculated from the factory data as a function of distance.

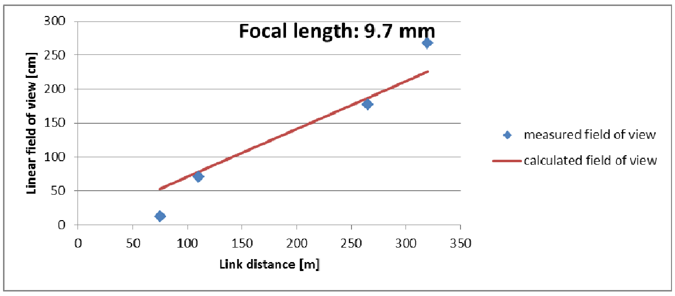

Fig. 2 Linear of field of view using an ocular with 9.7 mm focal length.

b) Test 2—Beam widening field test

We also examined the beam spread and minimum achievable beam diameter in field conditions. We conducted our experiment over water in a bay of the Danube River during clear weather conditions. The link distance was 325 m which is comparable to the width of the Danube River.

We used an unmodified laser source as a control and later used the telescope to focus the beam of the same laser source over the same link distance.

The beam in the control experiment widened to about 30-40 cm. On the other hand using the telescope we were able to focus the beam diameter to about 2.5 cm at the receiver's plane. This value is in the expected range based on our calculations. Results of this calculation are shown in Fig. 3.

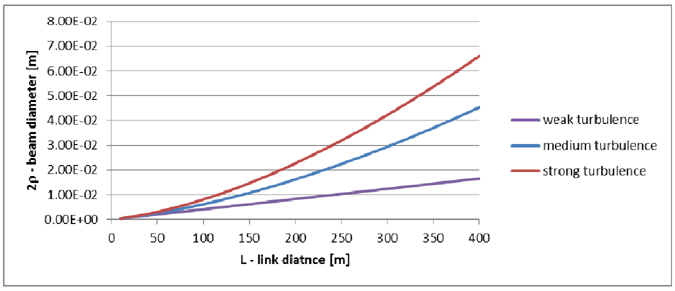

Fig. 3 Beam diameter depending on link distance under different weather conditions.

However our experiment had an unexpected result: the center of the spot at the receiver was dark. Since neither the control experiment nor subsequent experiments with the laser in the laboratory showed the same characteristic dark center we concluded that the source of this effect is not the laser diode.

We examined the telescope and determined that the secondary mirror poses a 30% obstruction. We made this determination by adjusting the focus of the telescope to produce a parallel beam and measured the diameter of the secondary mirror's shadow at close range.

This obstruction does not explain the observed dark center if the beam is perfectly focused but in case the receiver is out of focus it does [10][11][12]. Therefore we concluded that the observed beam width was likely not minimal.

This also highlighted the difficulty of focusing. The transmitter side requires accurate and immediate feedback which is hard to provide. We later solved this problem with a web camera whose transmitted picture made fine adjustments possible on the transmitter side.

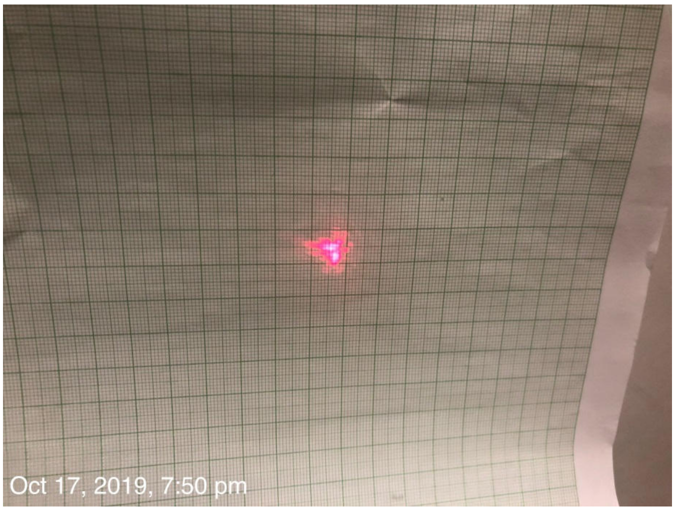

Fig. 4 Snapshot a focused spot. Optical turbulences strongly distort the shape of the spot, which also changes rapidly over time. The picture shows that the beam splits into two, indicating strong turbulence.

c) Test 3—Minimal achievable spot size in turbulent air

We examined the minimum achievable spot size as function of distance in strongly turbulent air. Even though the experiments were carried out in an enclosed corridor, there was a noticeable draft present in that corridor.

Evidence of the strong turbulence was the rapidly changing shape of the minimal spot size. The spot was also observed to break into multiple centers which also suggest the presence of strong turbulence. This effect can be seen on Fig. 4.

Measurements were taken at a link distance of 76 m, 135 m and 180 m. However measurement of the spot size was hindered by its rapidly changing shape and size which caused a large uncertainty in the data as shown in Fig. 5. It is also worth noting that due to the rapid change and irregular shape of the spots still images and photographs likely underestimate the actual spot size. (We took this effect into account when we evaluated the data.)

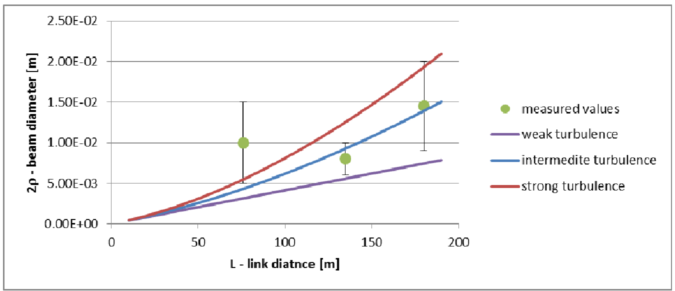

Fig. 5 Measured (scatter plot) and calculated (continuous line) beam diameters for different turbulence strengths. The values we measure are in the same order of magnitude as the calculated values, but their error is too large for direct comparison.

d) Test 4—Transmittance in turbulent air

We measured the link budget in the presence of strong turbulence. This was done by focusing a laser beam through the transmitter telescope at a radiometer to measure the transmitted radiant flux. The link distance was 12 m.

The laser diode was switched on and off to measure the background flux as well as the signal plus background. From this the signal power could be calculated.

Then we attached the radiometer to the ocular of the receiving telescope. We aimed the transmitter telescope at the receiver telescope at a link distance of 167 m. We adjusted the receiver until we measured a peak in the received radiant flux.

Similarly, we measured the background and used it to calculate the radiant flux of the signal.

Based on this we found that the transmittance was 47% percent.

V. CONCLUSIONS

In this paper, we outline experiments conducted with two telescopes, which will be used later in free space quantum communication. One of the telescopes will be fitted with a photon source, which will act as a transmitter and transmit the photons through free space to the receiving telescope, which is attached to a measuring device.

To realize this we compared the calculated values with the measured parameters of the real system.

Based on our calculations we concluded that a 650 nm red laser source is sufficiently similar to the proposed 810 nm single photon source to study the properties of the atmosphere and the link budget.

Our experiment revealed that beam widening is in the expected range. Our measurements suggest that a link budget of around 50% is achievable at a link distance of 167 m even in strong turbulence.

ACKNOWLEDGMENT

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Shoot an asteroid – linking laboratory based meteorite mineralogy to European space mission by university support

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***Abstract*—To support the infrared detector design and observation planning of ESA Hera asteroid mission, infrared analysis of meteorite spectra was realized on different meteorite specimen together with the Eotvos University, supporting the research-education synergy too.**

***Keywords*—asteroids, meteorite, infrared spectra, Hera mission**

I. INTRODUCTION (*HEADING 1*)

Based on recent discoveries of near Earth asteroids with impact threat [1], initiatives for a possible asteroid mitigation action have been started. The Hera mission of ESA aims to analyze the Didymos double Near Earth Asteroid [2] after it will have been hit by the NASA DART mission. To better understand how different minerals of asteroids look like in the infrared region during the analysis by the mission, e.g. to support Hera and its two cubesats, meteorite sample analysis started in collaboration between (CSFK) and the Eotvos University of Sciences (ELTE TTK).

II. METHODS

The meteorite powder was produced by **Fritsch Pulverisette-23 Mini-Ball Mill** zirconium-oxide mortar.

Figure 1. Images related to the pulverizing capability. a: the pulverizer during vibration (the sample is inside the zirconium-oxide sphere at the top left), b: the interior of the mortar with the zirconium-oxide balls, c: balls with weakly pulverized olivine grains (fragments are green and mm sized), d: fine powder produced by long duration (several minutes) pulverizing.

During the work, regular laboratory facilities and mineral analyzing methods were applied, which are similar to those used at the MSc education of geology students at the ELTE. The regular optical analysis was completed with infrared FTIR DRIFT measurements [3, 4], ATR analysis, powder diffraction and some Raman measurements. As meteorites represent interior of asteroids, they give possibility for mineral analysis and composition determination of the source objects - however the possible role of space weathering should be also kept in mind, as this effect could erase several spectral features while observing exposed asteroid surfaces.

During this work it was also aimed to identify those topics, where university courses and students there could be collaborate and linked to laboratory analysis, and finally influence mission design and optimization of operation around the target asteroid.

III. RESULTS

Analyzing meteorites, main minerals were determined, as well as shock related observations were acquired [5]. The project demonstrates how university courses related laboratory methods could be applied in space mission preparation, and support the better understanding of Near Earth Asteroids to prepare future mitigation actions.

First, effects of different observational conditions were surveyed in order to see possible differences between them and understand their role on the planning of asteroid observations.

For analysing **the role of surface texture on spectra** the JAH 055 and NWA 6059 meteorite samples were measured at different sides, showing different surface textures, and the reflectance spectra of smooth and rough surfaces were compared (Figures 2, 3, 4). In most cases (74%) the smooth surface samples have higher reflectance (with 22%) than rough surface samples. In case of rough surface samples the standard deviation of each peak positions is higher (averagely 2.14 cm^{-1}) than in case of smooth surface (averagely 1.96 cm^{-1}) samples, somewhat increasing the uncertainty.

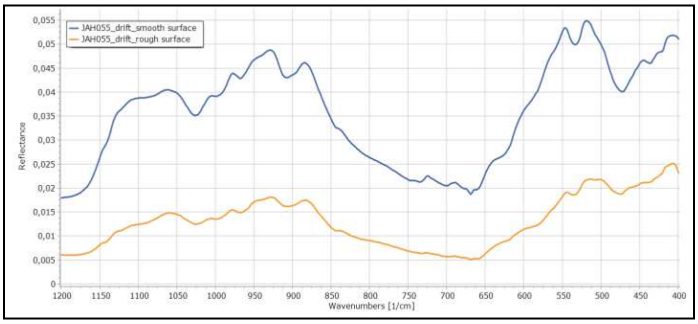

Figure 2. Reflectance spectra of smooth and rough surface JAH 055 meteorite sample.

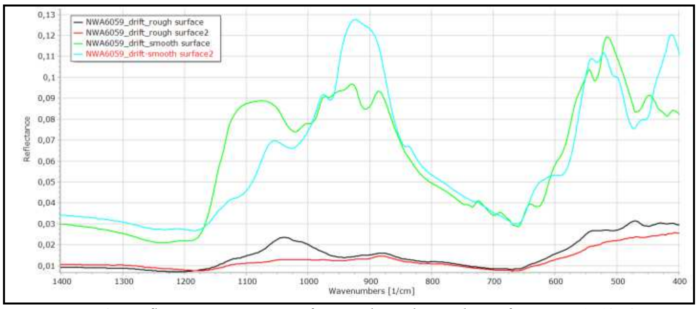

Figure 3. Reflectance spectra of smooth and rough surface NWA 6059 meteorite sample.

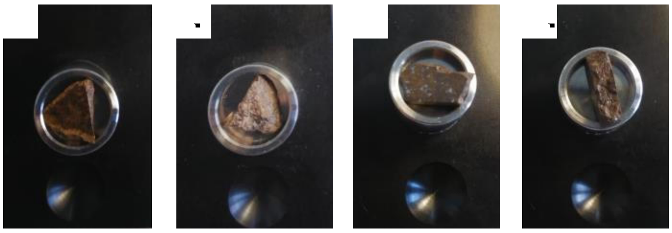

Figure 4. Measured smooth and rough surface samples of meteorites a) smooth and b) rough surface ample of JAH 055 meteorite (spectra observable at Figure 4) c) smooth and d) rough surface sample of NWA 6059 meteorite.

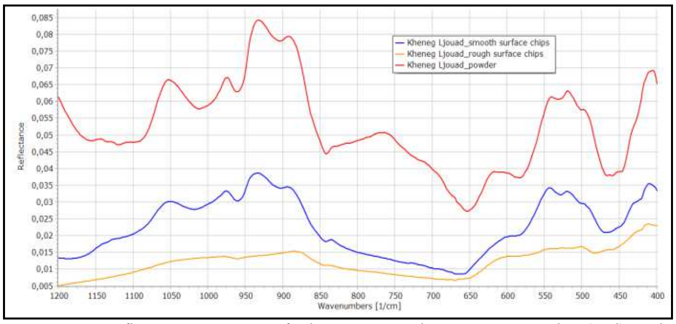

Figure 5. Reflectance spectra of Kheneg Ljouad meteorite powder (red) and chips samples (blue: smooth surface, yellow: rough).

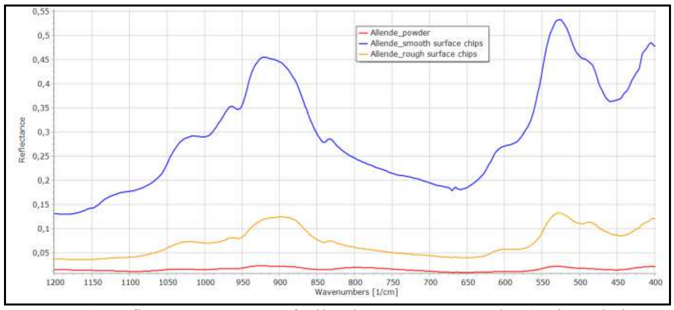

Figure 6. Reflectance spectra of Allende meteorite powder (red) and chips samples (blue: smooth, yellow: rough).

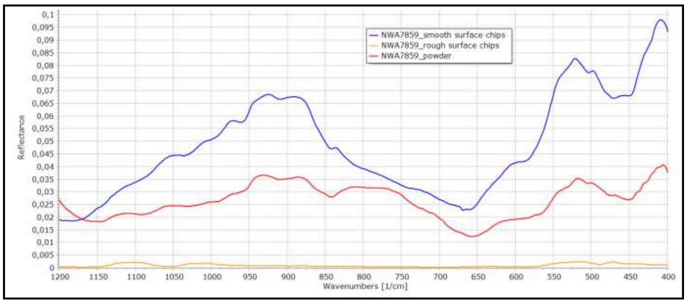

Figure 7. Reflectance spectra of NWA 7859 meteorite powder (red) and chips samples (blue: smooth, red: rough).

The comparison of surface textures of the smooth and rough surface of NWA 6059 was evaluated with two methods using high resolution optial microscopy: analyzing the contour of the surface (wievieng from "the side", and analyzing the pattern of the reflected optical light (viewing from the face of the surface).

Using 40x resolution the surfaces were recorded, where only a small part of the sampe was sharp (in focus) as the surface was undulating (even in the case of the smooth sample). The analysis supports that the surface roughness might have ennect mainly on the intensity of reflectance

Analyzing the spectra of **powder vs. chips (fragments):** Below the same type of meteorites (CC: Allende, OC: NWA 869, Chelyabinsk, Kheneg Ljouad, NWA 7859, ElHammami, NWA 7987), of powdered (<50 µm) and solid chips (1-3 mm) fragments were compared. Three example diagrams are presented below in Figures 5, 6 and 7.

The main results for comparing meteorite powder and chips in reflectance are listed below: In case of four samples (NWA 869, Chelyabinsk, Kheneg Ljouad and NWA 4561) the reflectance intensity of powder is higher than that of chips sample.

While at Allende meteorite sample the reflectance of chips sample is higher than in case of powder sample. In case of three samples (ElHammami, NWA 7859, NWA 7987) the reflectance of powder is between that of chips samples. At NWA 7859 and NWA 7987 samples the smooth surface chips sample have the highest reflectance, this is following by powder sample and the rough surface chips samples have the smallest reflectance. The pattern of meteorite chips and powder spectra do not display significant differences, the main peaks are observable in both spectra but with different spectral contrast.

As a general finding, it can be said that the spectral pattern of the spectra of powders and chips did not show substantial differences, and similar peak positions could be identified. But there are no general trends can be identified, mainly because of the specific effects of geometrical settings for smooth sample surfaces.

Analysing the role of **mixed grainsize:** testing the spectra of mixed chip and power samples, with thin (~100 µm thick) layer of powder situated on the surface of a mm sized meteorite chip can be seen below (Figure 8).

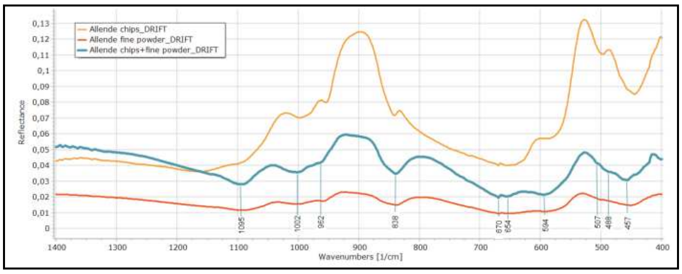

Figure 8. Reflectance spectra of chips, powder and mixed (powder on chips) samples of Allende meteorite.

The spectral pattern of powder, chip and mixed powder and chip sample is similar with the same main peak positions. Based on mixed spectrum the bands and minerals which were identified at the single powder and chip sample (pyroxene, feldspar, olivine, troilite) are also identifiable. The reflectance of mixed sample spectrum is between that of chip and powder sample spectra.

Analyzing **OC-CC poweder mixture:** Mixture of powder of NWA 869 L 3-6 ordinary chondrite meteorite and NWA 11469 CO3 carbonaceous chondrite meteorite wereas analyzed (Figure 22). Using the Spectragryph optical spectroscopy software the addition and average produced spectra of two meteorites were also created (Figure 9, 10). The composite spectra were produced by simple addition or averaging of separate spectra at each data point (wavenumber).

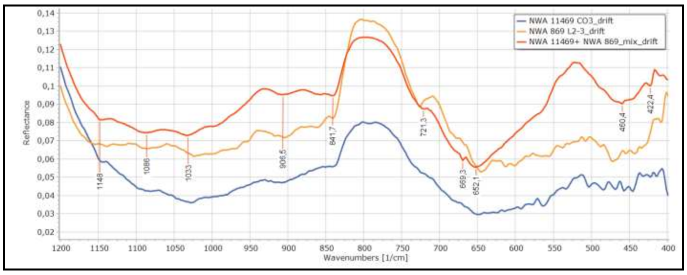

Figure 9. Reflectance spectra of NWA 869 and NWA 11469 meteorite powders and their mixture.

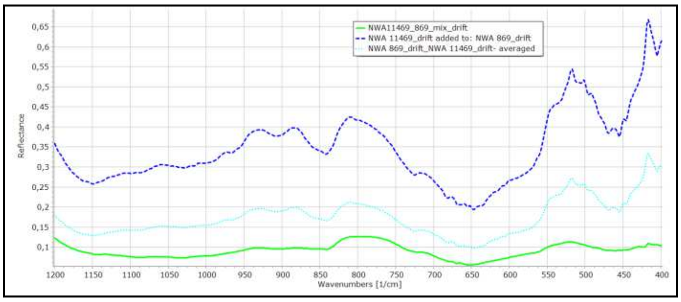

Figure 10. Comparison reflectance spectra of NWA 869 and NWA 11469 meteorite powder mixture (green solid line) with the addition (dark blue dashed line) and average (light blue dotted line) of two single meteorite spectra.

No general rule could be identified regarding the appearance of spectra of separated and mixed meteorite powders. The mixed meteorite sample spectra might also display less or the same number of characteristic bands of the main component minerals, like feldspar, pyroxene, olivine and clay minerals. The observed mixed spectral curves were compared to theoretical one), which were calculated by simple addition or averaging of spectra recorded from pure meteorite type powder.

These mathematically produced spectra usually showed as much bands and spectral features as the separate recorded ones. However in some cases differences could be identified: the artificially created spectra of the NWA 869 and NWA 11469 meteorites are not as flat as the measured mixture spectrum, display higher spectral contrast and intensity with more characteristic bands. This together with the other examples, suggesting in particular cases the noise is probably high enough in the case of mixed spectra to inhibit the identification of all bands that could have been identified using separate spectra.

IV. Discussion and Conlusion

The results presented above provide a range of example case studies, showing which are the more or the less important parameters during the infrared spectral interpretation. Their evaluation helps to focus of infrared detector design and also supports observation planning. Based on this preliminary analysis, temperature has a moderately small effect, however exact mineral identification is more favorable at lower temperature.

Grain size has dominant effect and supports the analysis if targeting fine grain size surface areas on Didymos. The surface roughness might have effect mainly on the intensity of reflectance. No general trends could be identified comparing the mm-cm szed fragments and powders, however the results show difference exists, but probably infuenced by many factors.

Using the experiences of ths project, Table 1 summarizes the connections between the various discuplines of geology course at ELTE and the laboratory analysis at CSFK.

TABLE I. SUMMARY OF INTERCONNECTED TOPICS AN DISCIPLINES FROM THE UNIVERSITY EDUCATION (1. COUMN), THE RELATED RESEARCH ACITIVTY (2. COMUN) AND THE FINAL RESULT TO SUPPORT MISSION DEVELPOMENT (3. COLUMN).

topic / discipline from Earth science education	***scientific laboratory analysis supporting mission optimization***	***mission case scenarios, findings distilled from the education – research synergy***
mineralogy	identification ideal band positions	selection of enough signal/noise ratio observations
petrography		
rock weathering	understanding band changes by weathering	focus on specific spectra regions
sample preparation methods	evaluation of grain size	selection of ideal grain size regions
complex geological history	collection observations under different conditions	selection of insolation conditions

ACKNOWLEDGMENT *(Heading 5)*

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Testing the visualziation of the Martian surface with GIS and SIMWE modelling tools

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***Abstract*—Great amount of data available of the Martian surface and modern computer based visualization software helps not only in the research but also in the outreach of this topic. The exact method of fluvial erosion on Mars is poorly understood, despite various models used for the terrestrial erosion – deposition rate successfully. One of the used model is the SIMWE [1] (Simulated Water Erosion) what estimates the erosion – deposition rate from a single hypothetical rain event. GRASS GIS 7.6 was applied on the testing of High Resolution Stereo Camera (HRSC) based Digital Terrain model (DTM). The results from the test area clearly show the main falls and debris skirts and smaller erosion points, might be poorly or not visible on the CTX or the DTM images. Using the Earth based parameters as a first approach, the transport limited erosion - deposition ranges change between 0.018 and -0.016 kg/m²s, where the positive values show the erosion and the negative values show the deposition.**

Keywords—Mars; erosion; simulation; Martian enviroment

I. INTRODUCTION

The Martian fluvial valleys show many similarities with the terrestrial fluvial systems, especially with the dry and semi-arid valleys: wadis [1], although current conditions are not favorable for bulk phase liquid water on Mars [2], only in microscopic scale or small ephemeral flow gullies, however old fluvial systems are well preserved. The analyzed area of this work is located near the Martian equator to Palos crater and Tinto Vallis (Figure 1). To keep it simple, the analyzed Vallis called Tinto 'B' in the following. The length of the valley is approximately 81 km, the average width is ~1.85 km, depth ~250 m. The highest point of the analyzed area is +689 m, the deepest is -730 m. The flow direction of the valley is from south to north. The analyzed area includes several smaller valleys, what are located west from Tinto-B. The used erosion model, SIMWE estimate the erosion – deposition rate for a given hypothetic raining event. The model successfully used for terrestrial surface end estimates the potential erosion rate. This work aims to estimate the potential surface modification and hidden erosion relations on a Martian surface.

The work is also aims to demonstrate how planetary science could be implemented to the university education of Earth sciences, and how research activity could be done under a PhD course.

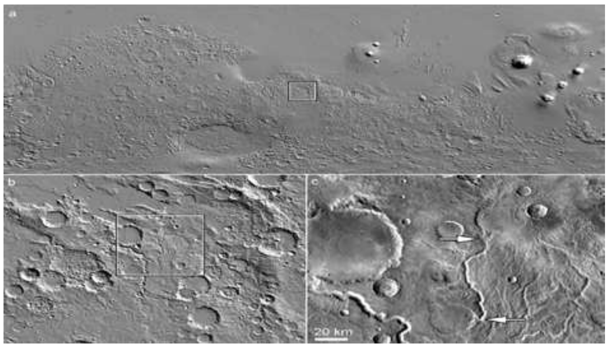

Figure 1: Location of the analyzed area on the planet Mars.

II. METHODS

The source of the modelling is the HRSC DTM h0951_0000_dt4 with 50 m/px (meters/pixel) resolution topographic dataset. The mineral maps, what are made by the TES [6] (Thermal Emission Spectrometer) used here with the spatial resolution 7.5 km/px. These mineral maps were used to calculate the K-factor for the mode, to estimate the erodibility of the surface at the given pixel. The factor used the clay, sand and mud components values as a percentage. In GRASS GIS with the *r.slope.aspect* [3] was calculated the X and Y slope derivate from the source DTM.

The estimated water depth and discharge were calculated with the *r.sim.water* [4] tool with a given single rain event in fixed duration. The rain event lasted 3 minutes and the amount of the perticipation was 15 mm/h. The tool, *r.sim.sediment* [5] was used for the final estimation. The tool uses the previous created datasets, like, elevation map (source DTM) water depth, x and y derivate of slope, detachment coefficient, transport coefficient and shear stress.

The shear stress came from base value as 1 and the detachment coefficient was calculated from the former estimated K-value and the specific weight of water and the average runoff speed. The specific weight of the water was calculated under Martian gravity. The average flow speed was calculated in a 5x5 pixel sized moving average.

III. RESULTS

There are several erosion produced features, what are visible on the DTM and on the CTX in too. The SIMWE model helps to identify the small scale erosion structures and give a hypothetic value to the time limited erosion and deposition rate. The parameters change between a positive and a negative values, where the positive shows the possible erosion in fixed time scale (the time of the rain event) and the negative shows the possible deposition. The maximal value of the estimated erosion is 0.018 kg/m^{2}s.

IV. DISCUSSION

The drainage system of the analyzed area is well discernible on the flow accumulation map. This flow accumulation map shows all the possible drainage routes, what are based on the source DTM, but it is hard to exactly identify (Figure 2). The SIMWE model helps to identify the small-scale erosion processes and find the related surface landforms, what are poorly visible otherwise.

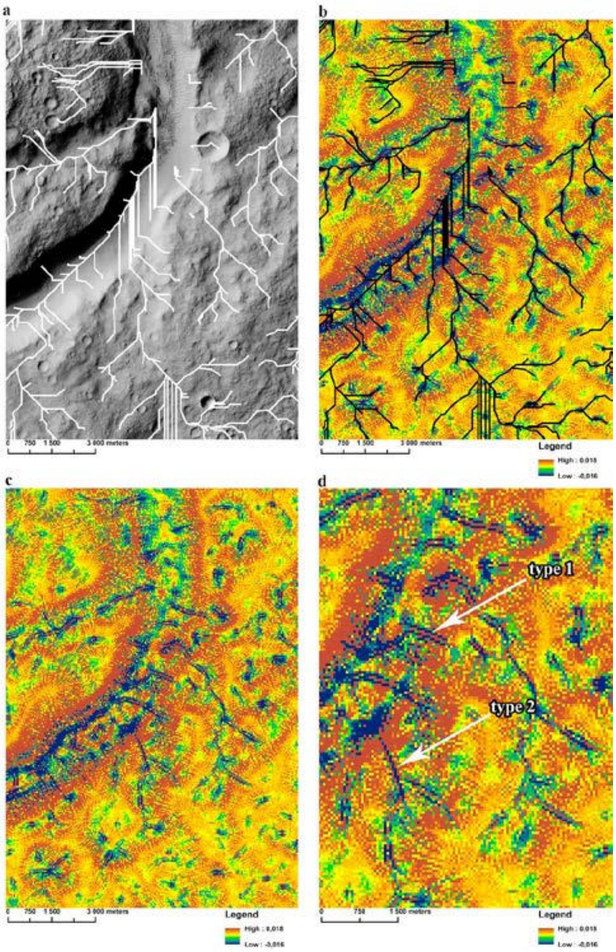

Figure 2: Correlation between the flow accumulation drainage map and the SIMWE erosion model. The positive values (orange) show erosion the blue show the deposition. The black and withe lines on the inset a show the result of the flow accumulation map. The inset d shows the two identified drainage type by the SIMWE model.

The result map of the SIMWE model shows more accurately the erosion dominated areas, than the flow accumulation map but the two maps are correlated moderately well with each other. The used model shows two different types of the small-scaled drainage. The first type of the identified drainage emerges as erosion at the bottom of the drainage routes during the rain event. The second type of the identified drainage shows erosion on the walls and deposition on the bottom of lows during the rain event.

The first type of the drainages are possibly fresh erosion features, which are sand covered on the bottom and can eroded easily. The second type is the opposite of the first one. In this type, the walls of the drainages are more eroded, than their bottom. These differences in the erosion shows two different presumed origin and occurrence in time. The drainage produced features in the first type are younger, than the drainages in the second type. These second type are more slammed or cut into the terrain, than the drainages in the first type.

V. CONCLUSION AND FUTURE PLANS

This work evaluated how much it is possible to adopt the SIMWE erosion model on the Martian surface. This model gives a more accurate information from the drainages and give a hypothetic data from the suspected erosion features, which could not be identified on the DTM, only on the CTX images. The model uses the mixture of the hypothetic and established values.

In the future, the authors want to change the rain event source to a headspring and simulate only the main fluvial erosion for each identified big drainage structures. This fluvial erosion type and related modeling will run in a bigger time scale to simulate the long-term changes on this valley. The gained results remonstrated that surface erosion modelling software developed for the Earth could help to better understand Martian surface features. This research is a part of the geomorphological analyzation of Tinto B. On that study, the SIMWE model was used as a same with combined the cross profile and hypsometric curve analyzation, as well as impact crater based age estimation, to follow the geological history of the area.

ACKNOWLEDGMENT

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Current State of The Free Space Quantum Communication

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***Abstract*—Quantum cryptography introduces communication security in the physical layer, and therefore differs profoundly from currently employed conventional cryptographic techniques, which operate via algorithms running in the data layers. Despite the fact that several quantum cryptography primitives are currently being investigated, quantum key distribution is the first one to have been experimentally demonstrated and the most technologically mature, as well the only one for which commercial systems are available on the market.**

In our short study, we introduce the different types of QKD approaches (prepare-and-measure; entanglement) which can be used to generate secret keys between communication parties. We detail how the related main protocols work. As main part of our survey, we summarize the important past and actual QKD achievements in different countries in the free-space domain. The list of the countries which are part of our study includes Austria, Australia, Singapore, South Korea and many more.

Keywords*— *quantum communication; quantum key distribution; satellite communication;

I. Introduction

Systems that may constitute the basis for the practical implementation of other primitives. We will therefore take QKD as the starting point for a basic introduction to quantum cryptography [1]. QKD exploits quantum physics to allow two legitimate parties to share a private key that is subsequently used to encrypt a confidential message to be transmitted along a public classical channel. The key is ensured to be private since it is transmitted along a quantum channel in a way that makes any eavesdropping attempt apparent to the legitimate parties. This is accomplished by taking advantage of fundamental laws such as the uncertainty principle (that limits the amount of total information that can be extracted from measurements on pairs of conjugate variables), the no-cloning theorem (that prevents the creation of an identical copy of an unknown arbitrary quantum state), and the existence of entanglement (by which two physically separated particles are intertwined in such a way that interacting with one of them unavoidably affects the state of the other).

Because of these fundamental principles any information leakage from a quantum channel always results in a degradation of the information that is actually transmitted, and this degradation can be quantitatively related to a measurable increase in the quantum bit error rate by employing appropriate techniques. Quantum key distribution is indeed based on the possibility to establish an upper limit on the amount of information leaked from a quantum communication channel: by using suitable mathematical procedures, this amount can then be reduced to a level deemed acceptable for the relevant security purposes. It is important to note that an existing optical link cannot automatically be assumed to be compatible with a QKD protocol, since in general it includes devices such as optical amplifiers, routers, and transceivers, which destroy the information encoded in quantum states.

II. Quantum Key distribution

QKD is a real-time art of generating secure key bit string between remote partners. Its security is not based on the computational complexity, but on the correctness of physical principles [1]. In practical conditions where imperfectly experimental devices are used, it is proven that secure key bit string can still be generated when the tagged key bits are well restricted [2]. For example, phase-randomized weaken coherent sources are used in practical QKD. There are multi-photon pulses emitted from the source. Eve can launch the photon-number-splitting (PNS) to tag the multi-photon events. If the amount of the tagged event can be well bounded, with decoy state technology for example, secure key bits can be generated between remote partners [3].

Recently, the detector side channel attacks have attracted great attention. Eve exploits the drawbacks of the detectors to control the detections. Moreover, the photons registered by the detectors may be not the ones expected by Bob, but well devised by Eve to obtained illegal information. In the fake state attack, Eve intercepts the photons from Alice and reads out the bit values on them. According to her measurement outcomes, she exploits the detection efficiency mismatches and prepares a fake state to be detected by Bob.

The time-shift attack uses the detection efficiency mismatches to eavesdrop on the communication without intercepting on Alice's photons [4]. Furthermore, the problem of information leaking from the detector side channels also exists in the blinding attack and the phase remapping attack. The detector side channel attacks do great harm to the security of QKD because Eve's illegal information gain obtained in the attacks cannot be well bounded [2].

Great improvement must be made on the detectors to avoid the detector side channel attacks. It has been shown that alternative ways of measurements can be used to beat these attacks. In this case, the security of the measurement outcomes relies on the monogamy of entanglement. Accordingly, the experimental realization is more complex and the key generation rate is lower when compared with the prepare-and-measure QKD. An easy way to beat the detector side channel attack from the physics principle is expected.

Quantum theory is exclusive with the local hidden variable (lhv) theory [5]. Loophole-free Bell violation means that the (lhv) theory can be excluded. Or else, if no Bell violation can be obtained in the loophole-free Bell test, the quantum theory is incorrect. Recently, Bell violation is experimentally obtained with all loopholes are closed. These significant results mean the lhvs do not exist. Based on this fact, the detector side channel attack in the prepare-and-measure QKD can be beat with a simple but efficient way. Random Bell test is required to be carried out at Bob's side to check the quantum correlations between Alice and Bob. Though this protocol is devised for the BB84 protocol1, it is applicable to any prepare-and-measure QKD.

III. DISCRETE VARIABLE QKD

A. BB84 protocol

Proposed in 1984 by Bennett and Brassard – that's where the name comes from. The idea is to encode every bit of the secret key into the polarization state of a single photon. Because the polarization state of a single photon cannot be measured without destroying this photon, this information will be 'fragile' and not available to the eavesdropper. Any eavesdropper (called Eve) will have to detect the photon, and then she will either reveal herself or will have to re-send this photon. But then she will inevitably send a photon with a wrong polarization state. This will lead to errors, and again the eavesdropper will reveal herself. The protocol then runs as follows. Alice sends a sequence of pulses (for instance, femtosecond pulses with 80 MHz rep. rate), each of which, ideally, contains a single photon polarized differently. Alice encodes zeroes into H-polarized photons while unities she encodes into V-polarized photons (red arrows in Fig.1 top). But this happens only in half of the cases. The other half of bits, chosen randomly, are encoded using a diagonal polarization basis (blue arrows in Fig.1 top). Then, the 'D' polarization corresponds to zero and the 'A' polarization, to unity. The receiver, Bob, measures the polarization using a standard setup (a PBS or a Glan prism with two single-photon detectors in the output ports, or a calcite crystal also followed by two detectors). This way Bob can distinguish between H and V polarizations if he uses the HV basis (further denoted as '+').

Figure (1)

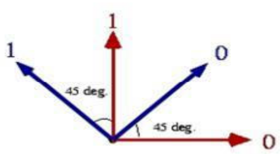

Fig. 1. Using different encoding based. *Top:* Alice sends a sequence of pulses; each one contains a single photon polarized differently. Alice encodes zeroes into H-polarized photons while unities she encodes into V-polarized photons. *Bottom left:* Using two non-orthogonal states. *Bottom right:* selection from different coding.

But in half of the cases Bob randomly changes his basis (the orientation of his prism) to AD (denoted as 'X'). After a certain number of bits has been transmitted (and all photons have been detected and destroyed!), Bob publicly announces which basis he used for each bit. Alice then says in which cases they used the same bases. They throw out the bits where they used different bases, and leave only those where they used the same one. After this procedure (key sifting) the length of the key is reduced twice, but what remains is random and coincides for Alice and Bob. Then, they check if there was eavesdropping. To this end, they take a part of the key for instance, (10%) and compare it. This procedure is also public, but these 10% are then discarded. If the Fig.1 eavesdropping took place, the key would contain errors. Then the whole key is thrown out and the procedure is repeated again.

B. B92 protocol

Proposed by Bennett in 1992, uses two non-orthogonal states, for instance H for 0 and D for 1 (see Fig.1, bottom left).

Alice sends 0 or 1 bits, but 0 she sends in the '+' basis, and 1, in the 'X' basis, and again she randomly chooses the basis. Bob also chooses the basis randomly. If he obtains V polarization in the '+' basis, it could not be H, so he writes down '1'. But if he obtains, in this basis, H, it could be actually D, so he says that the result is inconclusive (see Fig.1, bottom right) and throws this bit out. The same happens if Bob uses the 'X' basis and obtains D: it could be D, but it also could be H; therefore, the result is inconclusive and the bit is discarded. And only if Bob obtains A in the 'X' basis, he writes down '0' because it could not be D. The B92 protocol is easier to realize than BB84 and, as we will see later, it can be applied to continuous variable states. It is scientifically proven however to be less secure than BB84.

C. Selected projects from the past

- Ground stations for aeronautical and space laser communications at German Aerospace Center – Germany 2015. [6]
- Airborne demonstration of a quantum key distribution receiver payload – Institute for Quantum Computing, University of Waterloo – Canada 2016. [7]
- Adaptive real time selection for quantum key distribution in lossy and turbulent free-space channels – Department of Information Engineering, University of Padova – Italy 2015. [8]

IV. CONTINOUS VARIABLE QKD

A. *Overview of CV-QKD*

Continuous-variable (CV) QKD is different from the standard QKD system in the method for detecting weak optical signals. This feature gives an advantage to CV-QKD in terms of practical implementation. In the standard QKD system, weak light is detected by a single photon detector that measures the particle nature of light: the measured observable has a discrete spectrum.

The detector is usually custom built for QKD, requires cooling, and expensive, and it is sensitive to stray light. On the other hand, in the CV-QKD weak light is detected by a homodyne detector that measures wave nature of light: the measured observable has continuous spectrum. A homodyne receiver is commercially available, works at room temperature, is low cost and small and insensitive to stray light because the local oscillator (LO) itself works as a spectral, temporal and spatial mode filter. Since both CV-QKD and coherent optical communication exploit devices which operate on the same principle, we may be able to realize a secure and safe communication infrastructure that can offer diverse functions ranging from unconditionally secure communications to high-speed and high-security data transmission in a unified way, and seamlessly integrate them into coherent optical communication.

B. *Selected projects from the past*

- High-speed continuous-variable quantum key distribution over atmospheric turbulent channels – The University of Arizona 2017. [9]
- "Quantum-limited measurements of optical signals from a geostationary satellite" by Gunthner, K. 2016. [10]
- "Atmospheric continuous-variable quantum communication" by Heim, B. 2014.[11]

V. ENTANGLEMENT BASED QKD

A. *E91*

The "quantum" nature of QKD was pushed further in 1991 when Ekert proposed an implementation usingnon-local correlation between maximally entangled photon-pairs (this scheme is called E91). The quality ofentanglement between a photon-pair can be measured by the degree of violation of a Bell inequality. Anexample of a Bell inequality is the Clauser-Horne-Shimony-Holt (CHSH) inequality. Photon-pairs that aremaximally entangled in the polarization degree of freedom have perfectly correlated polarization states, andviolate the CHSH inequality with the maximum value. The defining feature in E91 is the suggestion to use thedegree of violation of the CHSH inequality as a test of security. This conjecture is related to a concept calledthe monogamy of entanglement: the entanglement between two systems decreases when a third system (forexample, the measurement apparatus of an eavesdropper) interacts with the pair. The drawback of the original E91 protocol was that it lacked a mechanism for error correction and privacyamplification. This was supplied by Fuchs et al.11who showed that the error fraction in an E91 key is relatedto the degree of violation of the CHSH inequality. For entanglement-based QKD it is sufficient to monitor theCHSH violation and then derive the error fraction for use in error correction and privacy amplification. [12]

B. *BBM92*

The BBM92 protocol was, in some sense, aimed as a critic to E91's reliance on entanglement for security. Building upon E91 with a source providing each legitimate party with halves of entangled pairs, BBM92 works more efficiently by having both the legitimate parties each measure in only two differing MUBs instead of the three bases of E91. The two MUBs can be chosen to be the same as that of BB84. By publicly declaring the bases, Alice and Bob select the instances where they chose the same basis to obtain correlated measurement results, from which a secret key can be distilled. A sample is then disclosed publicly to check for errors.

Selected projects from the past

- Chinese QUESS Project (Micius) – China, 2016. [13]
- Free-Space distribution of entanglement and single photons over 144 km – Canary Islands, 2007. [14]

VI. CURRENT TRENDS AND OUTLOOK

Despite its shortcomings, the potential security advantages provided by QKD are such that numerous public initiatives aimed at real field deployments and infrastructural buildups are taking place in several countries. In the last years a number of countries have taken important decision with regards to QKD, often reacting to programs undertaken by strategic competitors. Considerations of national security are explicitly quoted in many governmental programs, alongside the economic opportunity of spurring the development of a completely new industry, which can offset the incumbency advantages of the established providers of information and communication technologies — which are typically from the USA. In the international playground, the most evident trend is the rise of China in the last decade: QKD deployments have been made both in local area networks and in long-haul backbones, and entanglement-based QKD on continental and intercontinental scale by means of a dedicated satellite has been demonstrated. The increasing perception of the threat to communications security constituted by developments in quantum computing has probably also played a role in the Chinese technology push in quantum communications: indeed, in the race towards a fully-fledged quantum computer the USA undoubtedly enjoy a great advantage, not only for its academic research and public funded research but also thanks to the engagement of powerful industry players.

A. Austria

The first real-world application of a QKD link took place in Vienna in 2004, and a working quantum key distribution network was demonstrated in the framework of the SECOQC international conference, prompting the creation of the ETSI Industry Specification Group on QKD. The Austrian Institute of Technology developed an entanglement-based system and in 2012-2015 worked to deploy QKD on real communication networks in the framework of a project funded by the Austrian FFG Program FIT-IT. Vienna's researchers led the experiment that yielded the world record for free-space entanglement-based quantum communications, and are now working with the Chinese academy of science on satellite source of entangled photons: according to a press release issued in coincidence with a visit by the Austrian Minister for Science and Research and the Vice President of the Chinese Academy of Sciences, 'the Vienna Quantum Space Test Link, contractually agreed upon in 2011, is an outstanding example of the successful and long-term cooperation between the Chinese Academy of Sciences and the Austrian Academy of Sciences' [15].

B. Singapore

Quantum cryptography figures prominently in the scientific activities of the Centre for Quantum Technology (CQT), which was established in 2007 by the National Research Foundation (NRF) and the Ministry of National Education, and is hosted by the National University of Singapore (NUS).

CQT has been particularly effective in recruiting researchers from around the world, including Europe. In October 2016 a funding initiative of USD 42.8 million (over 5 years) was announced by the Singapore Deputy Prime Minister and Coordinating Minister for National Security, aimed at establishing a Cyber Security Research and Development Laboratory with the mission to detect and respond to security attacks and to come up with new approaches to IT systems that are 'secure by design'. In particular, staff from Asia's leading communications group Singtel will be working with researchers from the CQT to develop QKD for Singtel's fibre network. In the framework of the SPEQS (Small Photon-Entangling Quantum System) project, a nanosatellite hosting an entanglement source has been launched and tested, and a system of ground stations to track it is being developed on which so called "SpooQysat [16].

C. Japan

In Japan, several industrial and public partners have jointly developed an extensive quantum network in Tokyo, which was inaugurated in October 2010. The network operations include video transmission, eavesdropping detection, and rerouting to secondary secure links; the Japanese teams participating in the project belong to NICT (National Institute of Information and Communications Technology) and private companies such as NEC, Mitsubishi Electric, and NTT. Several European teams participate in the project, notably from Toshiba Research Europe, ID Quantique, the Austrian Institute of Technology, the Austrian Institute of Quantum Optics and Quantum Information, and the University of Vienna. Applications that have by now been implemented include one-time-pad smartphones and the transmission of genetic data. Shields and M. Sasaki at the UQCC 2015 conference. The NICT is working also on space-based QKD, developing an optical transponder for satellites and equipping telescope ground stations [17].

D. South Korea

On 12 December 2016, a so-called special law on Quantum Industry' was proposed at a seminar on Quantum Technologies held at National Assembly. The bill aims at the development of quantum information communication technology and the promotion of their industrialization.

In particular, it states that *'The South Korean Government realized the importance of quantum industries such as quantum information communication and put out a variety of policies such as the designation of quantum industry among one of the 10 promising technologies in the future, the establishment of a K-ICT strategy, and the development of medium and long-term strategies for quantum information communication'.* Several metropolitan quantum networks already exist in South Korea, and the government is funding the development of a ~ 250 km quantum backbone to connect them. The main players are the Korea Institute of Science and Technology Information (KISTI) and SK Telecom, which has a longstanding collaboration with Nokia. To promote interoperability, SK Telecom and Deutsche Telekom launched a group called the 'Quantum Alliance' at the Mobile World Congress 2017 in Barcelona [18].

E. Australia

The Australian government is implementing a Government Quantum Network for intragovernmental communications in Canberra. Leading the technical effort is the 'Centre for Quantum Computation and Communication Technologies' (CQC2T), which is a center of 29 excellence of the Australian Research Council. The CQC2T states that 'the main goal of this program is to demonstrate Quantum Cryptography in the Australian Parliamentary Triangle. In close partnership with Quintessence Labs, University of Queensland and Lockheed Martin Australia, we will implement the Government Quantum Network (GQN). This is an initiative of multiple governmental agencies to provide the highest level of information security for intragovernmental communications in Canberra.' A 'Space-based quantum communications funding' has been announced by the Minister for Higher Education, Training and Research in November 2016, to demonstrate the technology for an Australian quantum ground station to support secure space communication links.

In 2017, the vice president of the Australian QKD firm Quintessence Lab declared that its products are deployed at the 'Australian bank Westpac, and the global data centers of a leading cloud storage provider', adding that 'pilot projects are also underway with a number of defense prime contractors and government agencies [19].

F. United Kingdom

In 2015, the UK government announced a GBP 270 million investment on quantum technologies over 5 years. A quantum communications hub has been set up, comprising universities, industries, and public sector bodies, with the aim to 'deliver quantum encryption systems that will in turn enable secure transactions and transmissions of data across a range of users in real world applications: from government agencies and industrial set-ups to commercial establishments and the wider public.' A detailed work plan has been presented, articulated in four work packages (respectively devoted to short-range consumer QKD, chip-scale QKD, quantum networks, and next-generation quantum communications), including the construction of a quantum backbone connecting Bristol with Cambridge [20].

G. Canada

A survey overview of Canada's quantum ecosystem has been published in March 2017. Later in 2017, a set of recommendations for a national quantum strategy was be. In particular the Ontario regional government has a well-established program aiming at the commercialization of quantum technologies, in collaboration with private investors such as the Lazaridis and Fregin's Quantum Valley Investments fund. The Institute for Quantum Computing at the University of Waterloo is a world leader in applied QKD, and it has a particular expertise in quantum hacking and satellite-based QKD. A government funding for the deployment of a quantum satellite has been announced in April 2017 [21].

VII. Conclusion

This paper was made for the aim of covering the most recent and the state-of-art quantum-key distribution solutions in various institutions over the world. The advances in quantum cryptography in the aforementioned countries can play a remarkable role in aspect of security which is based on physical laws, adding to that the higher distances that can be achieved by the free space quantum communications when compared to fiber-based optical communication.

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Asteroid deflection with solar sail and laser-based techniques

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Abstract— **There are different techniques for asteroid deflection. We can divide these techniques into two groups, the nuclear and the non-nuclear ones. There are several international agreements which ban nuclear weapons from the space, so we started to examine the non-nuclear opportunities. In this work, we propose a new deflection method which is based on combination of the laser deflection and the solar sail. In our system, we will utilize a lot of small solar sails deployed on the surface of the asteroid, and we will increase the deflection power with laser beam. We not only present the system architecture, but we show related calculations which are based on real asteroids' parameters.**

Keywords— asteroid deflection, solar sail, laser technology

I. Introduction

Unbelievable, but hundred tons off asteroids burn in our atmosphere day by day. Most of them are small, only few gram/kilograms, but there are bigger ones which could be hazardous. In 2013, a relatively small asteroid (20m in diameter), which exploded at the height of 30km over Chelyabinsk, could cause a cost of 33-million-dollar damage in buildings in a sparsely populated area of Siberia. One can imagine what happen, if a bigger asteroid explodes or impact into a densely populated area.

This is one of the reason, why different space agencies started to investigate more and more money on asteroid impact avoidance. For example, the European Space Agency works in this topic under the framework of the Space Safety and Security optional program (formerly known as Space Situational Awareness).

Asteroid observation as important as deflection, that's why there are different projects (e.g., Shoemaker project), which goal is to find big, and maybe hazardous asteroids in the solar system. Different projects have been earned good results, by the year of 2018 there were 893 known asteroids, which size bigger than 1 kilometer in diameter. That number is 97% of the expected amount. By the year of 2019, we know 19470 Near Earth Objects (NEO), and NASA's goal is to find 90% of the asteroids, which bigger than 140 meter in diameter by 2020 [1].

Different NEOs need different deflection methods, that's why there are lots of different techniques. We can divide these techniques into two groups, the nuclear and the non-nuclear ones, in the next heading we will tell you more details of them.

Later in this work, you can read how we combined two existing deflection technique to achieve better results, and we answered few questions arise. At the end of this paper, there are computations, which show this method can work at a real asteroid too.

II. Different Techniques for Asteroid Deflection

A. *Nuclear Techniques*

Even though, we don't have any working asteroid deflection method, nuclear based deflection could be deployed faster in an emergency scenario than non-nuclear ones. That's because lot of nations have nuclear weapons, which can be modified easily. But how does this technique work?

Nuclear fusion can produce a lot of energy and we can use this energy in a different way. For example, we can drill a hole, put a nuclear bomb there and blow the asteroid up (like in the Armageddon movie), but the remaining parts of the asteroid could be dangerous (like a grapeshot, multiple smaller asteroids hit the Earth). That's why the scientific world doesn't support this use case of nuclear weapons.

Instead of blowing up the NEO, it's better to explode the bomb on the surface, or near to the surface of the asteroid. In this case, the heat and the energy of the neutrons will vaporize the surface of the asteroid. By Newton's third law, the outflowing particles will interact with the asteroid and pushing it to the opposite direction. The pushing force depends on the size of the bomb, the distance of explosion and the material of the asteroid (in different materials neutrons penetrate differently and vaporize different amount of the surface).

Nuclear based deflection is good against big asteroids and when we don't have enough time to use non-nuclear methods. But it's got its price, nuclear weapons are very dangerous, and a malfunction can easily kill millions on the Earth. And there is another problem: since the cold war has been ended, several international agreements ban nuclear weapons from the space [2].

B. *Non-Nuclear Techniques*

There are many non-nuclear alternatives for asteroid deflection. These techniques are safer, but need more time to change the NEO's orbit, that's why early asteroid detection is very important. The most common techniques:

1. Kinetic-energy impactor

This method based on Newton's third law: if we have a fast and/or heavy object, it has enough kinetic energy to change an asteroid's orbit. The orbit's change depends on the asteroid's material, that's called Beta factor. Softer materials have bigger Beta factor, which means that more material ejected at the impact. Because of Newton's third law, the ejected material increases the pushing power.

One of the several imagined methods, which based on this technique, called multiple kinetic-energy impactor vehicle (MKIV) system, that can be used to disrupt or pulverize asteroids smaller than approximately 150 m in diameter. *"Its baseline architecture is comprised of a carrier vehicle (CV) and several attached kinetic energy impactors (KEIs) that utilize the hypervelocity kinetic energy for intentionally disrupting or pulverizing a target body. The simultaneous imposition of multiple impacts maximizes the fragmentation benefits of large-scale crack propagation over a large fraction of the target asteroid body." [3]*

Kinetic impactors are one of the best non-nuclear deflection methods at small and mid-size meteoroids, this is why NASA launched its own program called DART (Double Asteroid Redirection Test).

2. Laser deflection

This method is based on Newton's third law too, but instead of impact, the laser beam's energy pulverizing the asteroid's surface. *"The standoff distance between the asteroid and the spacecraft is determined by a tradeoff between maximizing the rate of momentum transfer to the asteroid (i.e., maximizing the fraction of the ion beam intercepted by the asteroid) and minimizing the rate of material sputtered from the asteroid surface that is deposited on the spacecraft." [4]*

This deflection technique is a little bit futuristic, because we need hundreds of kilowatts average energy to pulverize the asteroid's surface and that's cost a lots of input power. We don't have such a powerful laser yet. Today the laser called Bivoj has the highest average energy with its 1kW energy [5].

3. Solar sail

In 1864, J. C. Maxwell suggested that light, like an electromagnetic wave, has a momentum that could exert pressure on objects. Maxwell's hypothesis was proved in 1899 by Pyotr Lebedev's experiment. However, this force is not so big, at one astronomical unit (Earth's distance from the sun) it is only 9.08 micro Newton per square meter when the photons perfectly reflected from the object's surface [6].

In 2010 the Japanese Space Agency launched its spacecraft, Ikaros which has proven in practice that it is possible to travel through space with the help of the sun's photons [7].

So, if we attach the solar sail on an asteroid, it can change its orbit. But there are two problem: firstly, the weak solar pressure will be weaker by the square of the distance, which means that, for example at the distance of Jupiter solar pressure will be only 0.3632 micro Newton/m^2. The second problem is how to attach a solar sail on an asteroid, which could spin very fast and how to prevent the sail from falling off the asteroid. Big asteroids could cause problems too, because we need a big sail or enough time to change its orbit.

III. Our Method

Before we started to make create our asteroid deflection technique, we studied the existing ones. Solar sail looks like a good choice, because it's use the Sun's power, so the spacecraft do not have to bring extra fuel. But sail attachment could be a problem, that's why a new idea came to our mind: instead of one-part sail, we can segment the sail into small pieces, which can land on the asteroid. This innovation has a disadvantage: solar sail can't be bigger, than the surface of the asteroid so the pushing force weaker than in the one-part sail design. Weaker pushing force needs more time to change the asteroid's orbit, that's why lasers came into the picture.

Laser beam (like the sunlight) is made of photons, which have momentum. A laser with 1000 Watts of output energy can make 3.3 micro Newton pushing force [8]. With enough laser power we can increase the pushing force, and it can be as strong as the one-part sails. We don't have powerful lasers yet (nowadays Bivoj laser has the biggest average energy, 1kW), so if we want to increase the pushing power, we need more lasers.

Lasers input energy could be provided by solar cells. Lasers efficiency is not 100%, so they need more input power, than output power. Nowadays a common semiconductor laser's efficiency is more than 30%, so it needs 3000 W energy in worst case. If we use similar solar cells like in the International Space Station (2500m^2 solar cells provide 100kW energy), then 75m^2 solar cell can provide enough energy at Earth distance from the Sun. Like solar pressure, solar cells will provide less energy by the square of the distance, so at Jupiter distance we need 1875 m^2 solar cell [9].

We lose lots of energy at light-electricity-light conversion because solar panels, batteries, and wires are not ideal. Solar pumped lasers can solve this problem. Solar pumped lasers make directly laser beam from the sunlight. They concentrate the Sun's energy at a NP junction, and at a threshold value it starts emitting photons. By default, this should be 2500-10000x higher than the standard for the Earth's surface, but with different solutions and additions it can be 25-50x, in some cases even lower.

In the '90s, scientists wanted to deploy solar pumped lasers in the space to radiate energy effectively to the Earth. Because of low energy prices researches stopped for a while. However, in space technology it could be very useful, so there is a chance researches will be continued. There are currently two major problems to overcome: one is that the system is not efficient enough and it's far from 35% sun-to-laser conversion rate they had hoped for. The other problem is that the operation time. The longest operating time was 6 and a half hours and the average laser output was 15.3W. Because of small energy output, we should use a fleet of solar pumped lasers to achieve the adequate thrust [10].

Today's laser technology maybe can change an asteroid's orbit (if we use enough lasers), but another important question is that, how can solar sails land on an asteroid? We cannot simply scatter the sensors in front of the asteroid, because it has weak gravity field, so the sensors would glace off. *"So far, the alternatives considered by various studies for surface attachment and mobility on, in and around an asteroid are:*

- *A penetrator attachment like a harpoon, and moving around by rigid crane*
- *A winch, and being deployed ballistically with a winch*
- *Crawling using a claw device (the claw in turn having many potential designs...)*
- *Attaching a net and moving around along its cables*
- *Two or three penetrator attachments with cables / winches between them to hold any device tightly (and which can change areas covered by moving penetrators)*
- *Using propellant to fly around from spot to spot*
- *Magnetic attachment (iron rich asteroid)*
- *Tunneling in and pushing against opposite walls for wheels, treads or crawling" [11]*

Perhaps, the best application for this solution is how it was applied in the Japanese Hayabusa project. In this case, the asteroid was approached by a landing unit and wait for its weak gravitational field to pull it to its surface. After the landing, sensors moved by little jumps on the asteroid (they won't stuck in holes).

Similarly to the Japanese approach, we can apply jumping sensors. The jump must be high enough, so sensors could jump out from a hole, but if they jump too high, sensors would leave the asteroid's gravity field. With this technique sensors, can spread out and cover asteroid's surface with solar sails.

Sensors will contain radio module, so they can tell their positions, so they could spread out perfectly (based on signal strength and angle of arrival). Their energy consumption could be covered by batteries, which could recharge by solar panels.

IV. Calculations

Our deflection method works in theory, so we made some calculations to prove it. To simplify the calculations, we calculated with circular orbit and spherical asteroid shape.

We used three different existing asteroid's parameters to make it realistic. The smallest asteroid called Bennu, its weight is $7.3*10^{10}$ kg and its diameter is 500 meter. Next asteroid is larger than Bennu, it is called Icarus and its weight is 10^{12} kg and its diameter is 1.4km. The largest asteroid called Ida and its weight is $4.2*10^{16}$ kg and its diameter is 31 km.

The following equation has been used:

$$\Delta s = 3/2A*t^2,$$

where Δs is the deflection's distance, A is the acceleration provided by lasers and solar sails, and t is the time of interaction [12].

In our calculation, we only used one laser with 1 kW output power, solar sail's area was $(d/2)*phi^2$, where d is the diameter of the asteroid. In this scenario, we start the deflection at Jupiter distance and end it at Earth distance. Solar sails are exerting more and more power on the asteroid as they get closer to the Sun, so we calculated this value at the start and end point, and we took the average of them. We made these calculations at the different asteroids with different times, so we got the following spreadsheet:

	5 year	10 year	15 year
Bennu	473.63 km	1894.53 km	4262.7 km
Icarus	271.07 km	1084.28 km	2439.62 km
Ida	3.16 km	12.66 km	28.48 km

1) distance of deflection

As we expected, this deflection method seems ineffective at bigger asteroids, like Ida, but could be used at Bennu size asteroids. We can improve these results by calculate with more and stronger lasers.

V. Conclusion

Although our calculations are simplified, we got encouraging results even with today's laser technology. Hopefully soon or later laser and solar sail technology will evolve and make this deflection method even better.

As we are continuing to work on this project, we start to design the landing sensors and make more accurate calculations and maybe someday we can try this technique in live.

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The GNSS stream gauge

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***Abstract*— For the longest time, humanity records sea levels with traditional tide gauges. However, tide gauges and stream gauges along rivers are susceptible to long term changes in the index level due to surface displacements. In order to minimize this effect, levelling observations are carried out on a regular basis. However, due to their enormous costs, these observations are done with the frequency of some decades at most. Since GNSS technology can provide accurate positions at a low cost, some of the existing tide-gauges were equipped with continuously operating GNSS receiver for monitoring local uplift and subsidence. However, GNSS observations taken at the shores are affected by the satellite signals reflected from the water surface. These effects can be linked with the level of the surface of reflection relative to the antenna position. Our study introduces an approach, with which absolute water levels can be efficiently measured by combining the GNSS positioning technique with GNSS reflectometry observations. While the first one provides the accurate coordinates of the antenna, the latter one can be used to estimate the level of the water surface. Thus the absolute level of water surfaces can be calculated in the reference frame of the GNSS observations. The proposed technique has the advantage, that the calculated water levels are not affected by local vertical surface displacements. The proposed approach is tested with GNSS observations taken by temporary geodetic-quality and low-cost GNSS receivers located on the Liberty Bridge in Budapest, and the observations are processed to estimate absolute water level of the river Danube. The results are compared with total station measurements and records from a tide gauge ~500 m upstream.**

***Keywords*— GPS, multipath, SNR, reflection, tide gauge**

I. INTRODUCTION

Traditional tide gauges are used for centuries to measure sea level, and because of that it is the most established method to record water levels. For most applications, for example navigation and flood predictions, this relative level, i.e., relative to benchmarks on the adjoining land, is adequate. On the other hand, for long-term investigations – such as the monitoring of sea level changes, predicting highest water levels with a recurrence time of 100 years, etc. – the consistency of the water level readings is inevitably important. That means, we have to either transform these relative levels into a global, absolute reference system, or we should change our methods in order to estimate these levels directly in such a system.

It is known that several effects, like glacial isostatic adjustment, coseismic and postseismic deformation and land subsidence make it difficult and expensive (due to regularly repeated benchmark levellings) to measure the water level directly and reliably. Several efforts have been made to estimate this "land-effect" using GNSS measurements at tide gauges, but these are rarely used at stream gauges due to the lack of GPS stations in the vicinity of stream gauges.

GNSS-reflectometry (GNSS-R) is using the reflected signals to estimate the vertical distance between the antenna phase center and the surface of reflection. Usually two approaches are used in GNSS-R. The first concept is called the bistatic radar approach. In this case two antennas are used instead of one. The zenith-positioned antenna is designed to receive the right-hand circular polarized (RHCP) direct signal, while the nadir-pointing antenna is optimized to receive the left-hand circular polarized (LHCP) reflected signal [1]. The height can be estimated by comparing the determined positions of the two antennae, since the derived position of the nadir-looking antenna is located as low below the reflecting water surface as high the antenna is located above it. The principle of this method requires satellites with high elevation angles and of course special antennas to receive the different signals. In contrast to the aforementioned approach the interferometry approach doesn't require special instruments, only a traditional antenna without its ground plane. The so called GNSS interferometric reflectometry (GNSS-IR) is based on the interference of signals with the same polarization (RHCP) and estimates height by analysis of the SNR of the superimposed signals. In the following chapters the principle of GNSS-IR is demonstrated and an approach is introduced to develop a GNSS stream gauge.

II. PRINCIPLE

All current satellite navigation systems are using right-handed circularly polarized (RHCP) signals, i.e. the electric field vector rotates clockwise, when looking into the direction of propagation. Nevertheless, there is a phenomenon, called multipath, whereby some signals from the satellite arrive at the receiver via multiple paths due to reflection and diffraction. In this case the polarization of the signals may change, so the received signals can be right-handed circularly polarized and also left-handed circularly polarized (LHCP). As seen in Figure 1, the reflection coefficients of the transmitted signals are different for the two types of polarization and besides that it depends on both the physical properties of the reflecting surfaces e.g. dry soil, wet soil, snow and water, and the elevation angle of the transmitting satellite [2]. As the elevation angle of the satellite increases, the power of the refelected left-handed circularly polarized signals decreases, and the coefficients of the

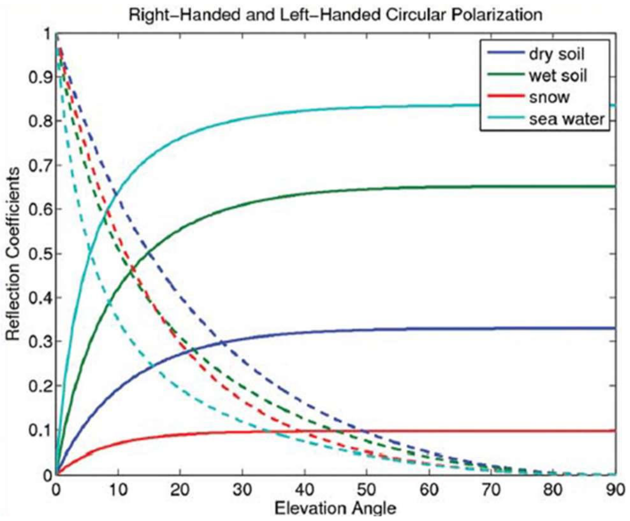

Fig.1 Reflection coefficients for different reflective surfaces at GPS frequencies and RHCP (dashed) and LHCP (solid) signals [2]

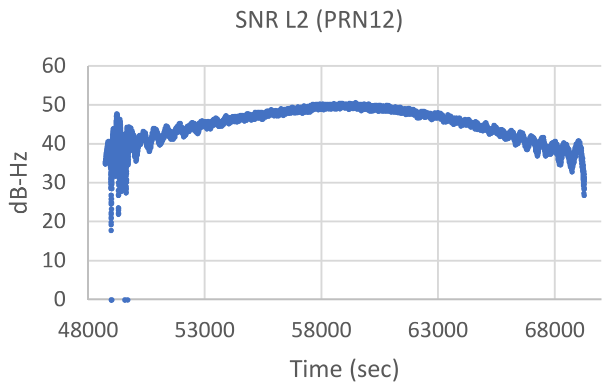

Fig.2 Signal-to-noise ratios observed for a GPS satelite on L2 frequency.

right-handed circularly polarized signals increases. The elevation angle, where the coefficients for the RHCP and LHCP signals are equal is called Brewster angle, and it depends on the characteristics of the reflecting surface. Since the direct and the indirect signals, which elevation angle is smaller than ~30°, have the same polarization (RHCP), the resultant signal is affected by interference. Figure 2 shows how this multipath error affects the SNR (signal-to-noise ratio) data of a particular GPS satellite, which are stored in the RINEX observation file created by the receiver. The direct signal would have a simple polynomial shape depending on the elevation angle of the satellite. The oscillations at the low elevation angles indicate multipath effects caused by reflections.

To demonstrate the relation between SNR data and the distance of the reflecting surface or the reflection coefficient of the surface material it might be expedient to examine the resultant of the direct and indirect signals:

$$A = k_M \cdot a \cdot \cos(\varphi + \Delta\varphi_M), \qquad (1)$$

where a is the amplitude and φ is the phase of the direct signal, k_M and $\Delta\varphi_M$ are the changes in amplitude and phase due to multipath effect [3]. It can be seen, that:

$$k_M = \sqrt{1 + k^2 + 2 \cdot k \cdot cos\Delta\varphi} \qquad (2)$$

$$tan\Delta\varphi_M = \frac{k \cdot sin\Delta\varphi}{1 + k \cdot cos\Delta\varphi}, \qquad (3)$$

where k is the reflection coefficient (value 0-1) and $\Delta\varphi$ is the phase delay of the reflected signal. As seen in Figure 3 $\Delta\varphi$ can be written as:

$$\Delta\varphi = \frac{\Delta s}{\lambda} \cdot 2 \cdot \pi = \frac{4 \cdot \pi \cdot d}{\lambda} \cdot sin\varepsilon, \qquad (4)$$

where Δs is the delay in meter, λ is the wavelength of the signal and d is the vertical distance between the reflecting surface and the phase center, ε is the elevation angle of the satellite. Finally, in case of k=1:

$$k_M = 2 \cdot cos\frac{\Delta\varphi}{2} = 2 \cdot \cos\left(\frac{2 \cdot \pi \cdot d}{\lambda} \cdot sin\varepsilon\right) \qquad (5)$$

Thus, the amplitude of the resultant signal is a periodic function of the elevation angle and its frequency depends on the antenna height (d). Figure 4a shows how the antenna height affects k_M. As seen in the figure, higher antenna phase center causes higher frequency in the resultant signal. On the other hand, changes in the reflection coefficient affects the amplitude of the resultant signal, higher k values cause higher amplitudes (Figure 4b).

These examples prove, that analyzing the SNR data for satellites located in low elevation angles (0° to ca. 30°), can provide information on either the elevation difference between the phase center of the antenna and the reflecting surface or the reflection coefficient, that has a strong relationship to the dielectric constant of the reflecting material. This can be utilized in numerous applications, e.g. estimating snow accumulation and snow depth, vegetation water content, soil moisture and water level.

III. METHODOLOGY OF ABSOLUTE WATER LEVEL ESTIMATION

It is trivial that the analyzation of long-term sea level data requires a common reference system and the correction of local surface displacements in the tide-gauge readings. In order to do this, many tide-gauges are equipped with collocated GNSS receivers to monitor their long-term stability. Reliable tide-gauge data is inevitably important to get insights in the current sea level rise and model the effects of climate change.

Due to the increasing temperature, even freshwater lakes and streams should be monitored with higher accuracy and with a

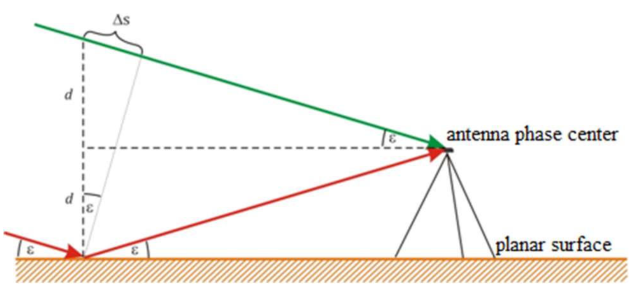

Fig.3 The geometry of multipath for a single, horizontal reflecting surface

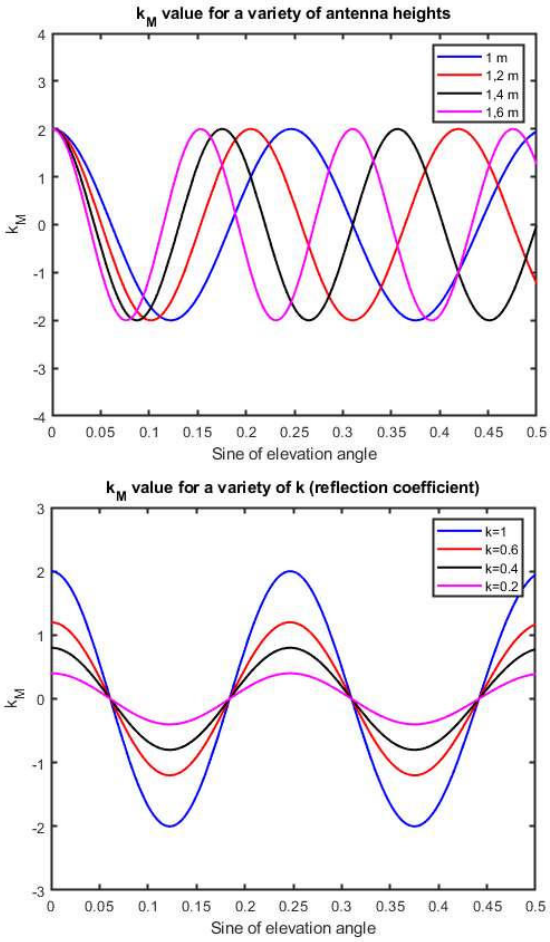

Fig.4 The effect of the antenna heights above the reflective surface (above) and the reflection coefficient (below) on the amplitude of the signal as a function of the sine of the satellite elevation angle.

Fig.5 The Fresnel-zones of the GPS satellite G28 for the DOY 037 (2020).

better spatial resolution. Flood prediction requires a long-term, consistent stream gauge data set, too.

In this chapter, we would like to evaluate the feasibility of the estimation of absolute water level of the River Danube in Budapest using GNSS observations taken at the Liberty Bridge in 2019. Two types of receivers were used for the studies. A geodetic-quality Trimble NetR5 receiver with a Trimble GPS Microcentered L1/L2 antenna and a low-cost u-Blox EVK-M8T receiver with a simple patch antenna in the interest of testing a cost-efficient installation, too. Both of them were set up on the south side of the bridge, next to the barrier, so the reflecting zones of the GPS measurements were located on the water surface. The location and the size of these reflecting zones depend on the height of the antenna above the reflecting surface, the elevation angle and the azimuth of the satellite signal. As the elevation angle increases, the ellipse shaped reflection zones (called the Fresnel-zones) become smaller and are located closer to the GPS antenna (Figure 5).

Absolute water level estimation consists of two steps. Firstly, the antenna position is estimated using single or dual frequency phase observations using the relative positioning technique. The EUREF permanent GNSS station BUTE was used as a reference station, that was established and is operated by the Department of Geodesy and Surveying of the Budapest University of Technology and Economics, since it is located ca. 500 m from the study area.

In the second step the observed SNR values are analyzed. Since SNR values are stored in dB-Hz in the RINEX files, they must be translated to a linear scale (V/V dimension) to represent the oscillation in the amplitudes induced by the interference of the direct and indirect signals. Afterwards a second order polynomial trend was removed from the transformed SNR values as a function of the sine of the elevation angle. The remaining signal shows the oscillation in the amplitudes due to the interference and can be written as:

$$\delta = A\cos\left(\frac{4\pi d}{a} sin\varepsilon + \phi\right) \qquad (6)$$

Thus the frequency of these oscillation is a function of the elevation difference (d) between the antenna phase center and the reflective surface. To estimate this elevation difference the spectrum of the linearized SNR of the signal is analyzed using a Lomb-Scargle periodogram with an oversampling interval that resulted in a precision of 1 cm in antenna height estimation. Lomb-Scargle periodogram is widely used in GNSS interferometric reflectometry, because it can handle unevenly sampled data as well. Figure 6 shows the results of L1 and L2 SNR data of the Trimble receiver. Examining the diagrams, it can be seen, that the periodograms of L1 data have a clearer result, i.e. there is one outstanding peak, not several similar ones. This is mostly due to the fact that L2 signals are transmitted with a weaker power and are probably affected by the reflections of the steel structure of the bridge more severely. Since the u-Blox receiver measures the L1 frequency only, the periodogram of this signal could only be produced, which is very similar to the previous ones.

IV. FEASIBILITY STUDY OF THE GNSS STREAM GAUGE

The main objective of the study was to observe a flood wave and compare it to stream gauge records and total station measurements during the spring of 2019. Unfortunately, due to the dry weather no high floods could be monitored, so the measurements were repeated on several separate days with the maximum water level change of approximately 50 centimeters.

In the first step adequate satellites were chosen so their sensing zones, i.e. Fresnel-zones are located on the water surface. On the planned measurement days, two GPS satellites, G17 and G25 were either rising or setting with the adequate azimuths (120°-180°). Reaching the elevation angle of 30° took approximately one hour and the raw SNR data was recorded with a frequency of 1 Hz to have enough observations to estimate the periodograms. After the GNSS measurements the relative height difference was measured between the antenna and the water level using a Spectra Precision FOCUS total station, which was installed into the position of the GNSS antenna using a forced centering plate. By knowing the vertical difference between the antenna's phase center and the transit axis of the total station the measured height could be easily converted into relative antenna height. Besides that, stream gauge water levels were also collected from a station located approximately 500 m upstream.

As the first step of the calculation, antenna positions were estimated using the relative positioning technique. The computed positions of the geodetic-quality antenna and their standard deviations can be seen in Table I. After estimating the relative antenna height by the Lomb-Scargle periodogram, the absolute water level can be calculated by subtracting this height from the vertical position of the antenna (where the coordinates were translated into a local system). Besides that, total-station measurements were also corrected to the antenna phase center and the water levels were estimated like above.

The differences were computed between the values estimated by GNSS-IR, the total-station measurements and the tide gauge records for both, L1 and L2 frequency. Looking at these residuals one can see, that the SNR data of the L2 frequency gives less convincing results compared to the L1 data (Table II.). This could be the consequence of the differences of the periodograms seen earlier. In case of L1 frequency, the residuals of the GNSS-IR and total-station measurements are acceptable, but the residuals compared to the stream gauge records are greater. By analyzing the differences between the stream gauge records and the total station measurements (Table III.), it can be seen, that the values show a bias of 12 cm (their median is 11.9 cm), thus we decided to remove this bias from the data. As the stream gauge is ~ 500 m away from the Liberty Bridge, change in the water level at this magnitude can be explained with the slope of the river. The modified residuals can be seen in Table IV. and their visualization on Figure 7. The GNSS-IR water levels showed the bias and the standard deviation of -4.4 cm and ±5.3 cm with respect to the levels measured by total stations, respectively. While the residuals between GNSS-IR estimations and stream gauge readings

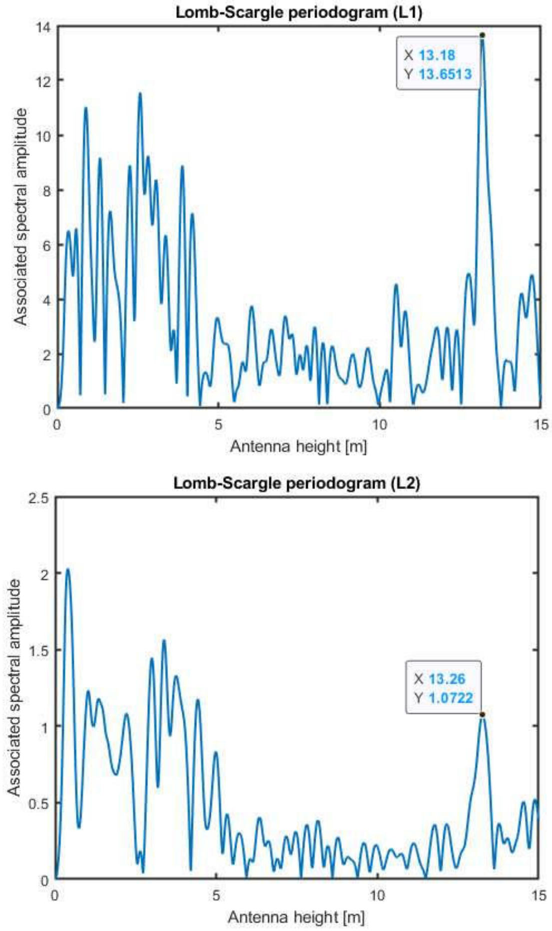

Fig.6 The spectrum of L1 and L2 frequency observations affected by the interference of signals reflected from the River Danube.

Table I Estimated (Trimble GPS Microcentered L1/L2) antenna positions and standard deviations (n - north, e – east, u – vertical, Hz – horizontal)

DOY	Latitude (N)	Longitude (E)	Ell. Height	Std Dev n (m)	Std Dev e (m)	Std Dev u (m)	Std Dev Hz (m)
092	47°29'08,40005"	19°03'18,02523"	158,424	0,001	0,001	0,002	0,001
116	47°29'08,23952"	19°03'17,71479"	158,326	0,003	0,001	0,003	0,003
118	47°29'08,37090"	19°03'17,96447"	158,308	0,001	0,001	0,002	0,002
119	47°29'08,39202"	19°03'18,01408"	158,332	0,002	0,001	0,003	0,002
120	47°29'08,37056"	19°03'17,97229"	158,310	0,002	0,001	0,003	0,002
121	47°29'08,38653"	19°03'18,00193"	158,261	0,001	0,001	0,003	0,002

Table II Differences between the estimated and measured heights (L1 and L2 frequency)

DOY	Δ Total station – GNSS-IR L1 [cm]	Δ Stream gauge – GNSS-IR L1 [cm]	Δ Total station – GNSS-IR L2 [cm]	Δ Stream gauge – GNSS-IR L2 [cm]
092	3.3	14.5	-24.2	-12.0
116	-9.6	5.8	-2.6	13.8
118	-3.3	8.6	-30.3	-17.4
119	-1.7	10.2	-28.7	-15.8
120	-3.9	7.4	-12.9	-0.6
121	-11.2	7.3	-30.2	-10.7

Table III Differences between the total station measurements and stream gauge records (L1 frequency, local height system)

DOY	Total station [m]	Difference	Stream gauge [m]
092	97.338	0.112	97.45
116	97.426	0.154	97.58
118	97.871	0.119	97.99
119	97.861	0.119	97.98
120	97.757	0.113	97.87
121	97.475	0.185	97.66

showed smaller bias and standard deviation. The higher uncertainty of the total station observations could be explained by the complications of direct water level observations using laser distance measurement, which is strongly affected by the amplitudes of surface waves.

V. Conclusions

This case-study demonstrates, that GNSS interferometric reflectometry can be used for water level observations along streams. The estimated heights have an error of a few cm, which is comparable to the traditional stream gauge measurements. Our main goal was to prove, the feasibility of water level observations using the GNSS interferometric reflectometry technique. In addition, as it was shown that low-cost instruments provide comparable results to geodetic receivers, with the deployment of several receivers along the streams one could provide absolute water level observations and link the existing stream gauges to a common height system.

Existing GPS networks, that monitor plate motions and maintain geodetic reference networks within countries, could be utilized for reflectometry studies, when they are located outside urban settings. Besides that, it also suggests that the future development of the GNSS infrastructure should take into account reflectometry applications, meaning that the future GPS sites could be chosen so that the SNR data should be adequate for soil moisture, snow depth or even water level estimations.

In the future we thrive to deploy prototype receivers to stream gauges to evaluate the long-term stability of the observations. These permanent stations may be installed on river banks for large rivers such as the River Danube. On the other hand, estimation of soil moisture could be put to the proof, where the estimated data could be compared to existing data of the Hungarian Meteorological Service.

Table IV Differences between the estimated and measured heights (L1 – corrected)

DOY	Δ Total station – GNSS-IR [cm]	Δ Stream gauge – GNSS-IR [cm]
092	3.3	2.5
116	-9.6	-6.2
118	-3.3	-3.4
119	-1.7	-1.8
120	-3.9	-4.6
121	-11.2	-4.7
mean	-4.4	-1.3
σ	±5.3	±3.0

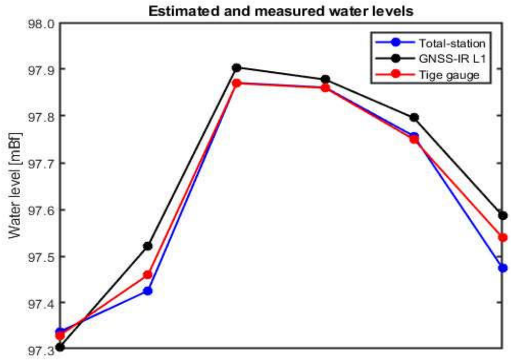

Fig.7 Estimated water levels by GNSS interfeometric reflectometry and tide gauge and total station measurements as comapare (L1 - corrected)

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The importance of educating students about careers in the space sector: a student perspective

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***Abstract*—The UK space sector is rapidly expanding, seeing a 6.4% compound annual increase in employees since 1999/2000 and an average of 39 new companies entering the industry every year since 2012 [1]. Such growth rates are likely to increase as the UK works toward its goal to capture 10% of the global space market by 2030 [1]. To accommodate for this increase in employee demand and avoid the inevitable skills shortage which generally arises in specialist roles, an increased number of capable students will need to join the workforce year on year [2]. The UK Space Agency has recognised the important role of outreach throughout a student's academic career, in the pipeline of developing a skilled workforce [3]. While outreach activities, especially those aimed at younger students, should cultivate a general interest in space and the activities of the sector, in this paper we will highlight the necessity of expanding the scope of activities covered. Many of the existing outreach programmes tend to focus on technical subjects such as engineering, for example less than 20% of projects which ran as part of the Principia education campaign addressed non-STEM subjects [4]. This is unrepresentative of the sector, with approximately 50% of roles in the European Space Agency (ESA) being non-technical [5]. Furthermore, at the ages where students start to think about career options, they must be made aware of the careers and pathways available. This will guide the choices they make with respect to further and higher education, and encourage them to develop certain required skills early, potentially reducing the skills shortage as they enter the sector. We will therefore explore the importance of careers- focused outreach and consider methods for this, including initiatives such as the SpaceCareers.uk educational online resources and events. The discussions in this paper will focus on the UK, but are relevant to all nations looking to grow their space sector.**

***Keywords*— careers; space sector; education; students; outreach**

I. Introduction

The UK has a growing share in the global space market, which the UK Space Agency aims to increase to 10% by 2030. Industry and academia work to provide cutting edge space technology and science, develop novel ways to apply space derived data, and manufacture space hardware; with 40% of all small satellites currently in orbit having been built in the UK [6]. In addition, the UK has become an attractive place to build space businesses, with the number of space related start-ups increasing more than three-fold between 2014 and 2018 [1]. As the sector grows, it requires more graduates to join the workforce, with an anticipated 30,000 new jobs in the next 10 years [1]. Thus, students must be educated about the job opportunities available within the space sector, in order to sufficiently supply the pipeline.

This paper aims to highlight the importance of educating students of all ages on space-related jobs by discussing (1) the awareness of space-related jobs in both technical and non-technical fields; (2) views on the attainability of space-related jobs; and (3) the current demand for careers resources. It will then go on to consider how these can be addressed through existing educational resources, and in some cases proposed modifications.

In this paper, technical jobs have been defined as those which require sector specific knowledge (typically STEM related roles), e.g. planetary scientist, data scientist, and engineer; non-technical jobs are those which focus on business knowledge and communication skills, e.g. those in finance, administration, and management.

II. Approach to Data Collection

A. Purpose-built surveys

Data has been collected by UKSEDS (the UK's national student space society) specifically for the purpose of this paper, through surveys distributed to schools and universities across the UK, as well as directly to individuals through official social media channels. A diverse range of students, studying a spectrum of disciplines were encouraged to take part, regardless of their interest in pursuing a career in the space sector.

These surveys were tailored for students across three age categories: (1) 8-13 year olds (n = 179), (2) 14-18 year olds (n = 102), and (3) those over 18 years old (n = 164). These boundaries were chosen to correspond with ages where students are typically thinking and making decisions about the next stage of their education. The surveys asked about knowledge and aspirations of jobs in the space sector; what, if any, space related activities respondents have taken part in and the extent to which they were taught about space jobs; and what advice they would like to receive related to space careers. Some questions remained constant across all three surveys to allow for comparison between the different age groups, however, many were omitted or rephrased for the sake of relevance. In some cases, open-ended questions were used to find the extent of respondents' knowledge and opinions regarding the sector, so responses had to be generalised and categorised.

B. *Aggregated UKSEDS event surveys*

UKSEDS collects survey data at all of its events including the annual National Student Space Conference (NSSC), the largest student space event in the UK, and their trademark Careers Launch events, which focus on jobs and routes into the space sector. These surveys typically represent students with a prior interest in space, from school students (age 14+) to PhD students, studying a range of technical and non-technical disciplines. It is worth noting that data from all UKSEDS surveys are self-reported, and cannot be independently verified.

III. Why Do We Need to Educate Students About Careers in the Sector?

A. *Increase awareness*

In order to adequately satisfy the growing demand for employees within the space sector, students need to be made aware of potential careers paths which they can work towards. This could encourage them to consider a career which they hadn't previously known about, or could help to foster their interest in particular subjects, making them more likely to invest time in developing skills needed within the sector.

Students' awareness of jobs within the sector has been compared across the surveyed age groups by averaging the instances in which a job is named across the respondents, when they were they were asked to list 5+ jobs (Fig. 1).

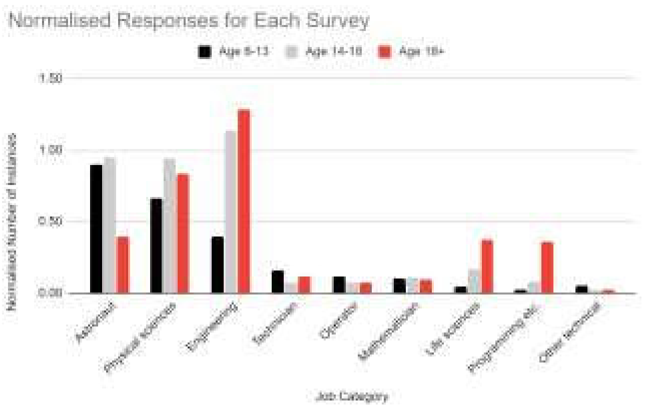

Fig. 1. Normalised responses when students 8-13 (n=179), 14-18 (n=102), & 18+ (n=164) were asked to list 5+ space related jobs.

It was observed that students are more aware of the relevance of engineering to the space sector, than any other profession; with respondents aged 14+ typically naming more than one type of engineering role. This is likely to be because these roles are typically depicted in movies and in classic outreach activities such as building rockets. However, this awareness was not frequently seen to translate to knowledge of engineering as a job; an observation also reported by Engineering UK [7].

In a sector heavily reliant on complex software and programming, it is clear more needs to be done to show the applicability of roles such as programmers, computer scientists, and software engineers. 'Data scientist' was named by 6% of respondents aged 18+, by 1% aged 14-18, and not at all by those aged 8-13, indicating a wide lack of awareness of this role. Data science is fundamental in areas such as Earth Observation, a part of the sector whose income has grown in the UK at a rate of 25% per year since 2014/15 [1]. Artificial intelligence, machine learning, and quantum computing have the potential to revolutionise missions, both on the ground and in space, due to their high processing capabilities. However, this can only happen if enough qualified graduates are aware that their skills are highly sought after in the space sector. Many students studying computer science, who took the survey, believe that they are studying the 'wrong subject' to work in the space sector, and so would not look to go into such jobs after graduation Therefore, it is important that students with these technical qualifications and interests are educated about the opportunities for them to apply their skills them to the space sector.

The UK has also been involved with several life science research projects, including astrobiology experiments on board the Rosalind Franklin rover and human space physiology experiments on board the International Space Station such as the Molecular Muscle Experiment [8]. It is apparent from Fig. I that students only start to become aware of life science's relevance to space at later stages in their academic careers. Younger students who lack this awareness may be driven away from considering careers in the sector, for example, one student claimed that she had been discouraged because "[she] preferred biology more than physics/maths." With technological advances and an increasing upstream workforce comes opportunities for more frequent or more detailed scientific research in space. As well as educating younger students about the relevance of life sciences, it is important to direct university students studying relevant subjects towards these possibilities as they graduate. The survey found that these students were more unsure about how their interests related to the space sector than students studying any other degree, thus demonstrating the need for educating students about available careers within the sector.

It is also necessary to highlight that the job "rocket scientist" was named 19 times across the three surveys; 58% of these by ages 8-13. This shows a lack of space careers education, as companies do not typically hire 'rocket scientists', instead they hire a combination of engineers specialising in structures, propulsion, and systems etc. Similarly, 15 respondents gave "astrologist" as a job (two-thirds of these being age 14-18). 10 respondents were unable to name any jobs within the sector, including students studying degrees in psychology, computer science, and law, showing a complete lack of awareness of the opportunities available to them.

Although it is important to address the skills shortage within technical fields, students must be educated on non-technical jobs in order to encourage those with non-technical skills, who are interested in space, but unaware of these opportunities available to them within the sector, to follow their interests and passions.

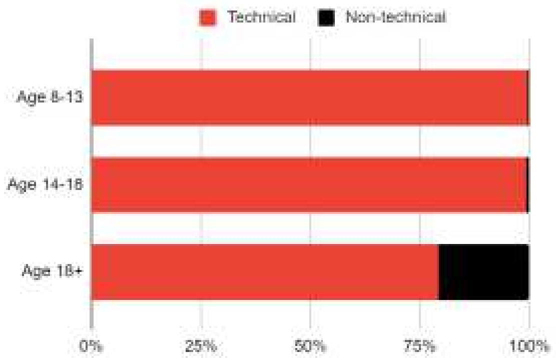

Fig. 2. The percentage of technical and non-technical roles named by students aged 8+ when asked to name 5+ jobs in the space sector (from top to bottom n=179, n=102, n=164).

When asked to list jobs within the space sector, non-technical jobs made up just 21% of all jobs given. 44% of respondents over the age of 18 were unable to name any non-technical roles, 14% of whom were studying for a non-technical degree. This was even more significant with younger students, with 98% and 99% of 14-18 year olds and 8-13 year olds, respectively, being unable to do so. This demonstrates a significant lack of awareness of potential career paths, considering the approximate 50% of non-technical roles within the sector, in turn, potentially affecting the numbers of capable graduates pursuing such careers [5]. It appears that students only become aware of these roles at a late stage in their academic career, when it is likely to be more difficult to change pathways. Many more students never learn about the opportunities available, as they falsely believe that they have studied the 'wrong subject' to enter the space sector. One student aged 17 claimed that "despite finding space interesting [they were] not really into the science behind it as much", which was a recurring view among respondents, demonstrating the belief that space sector jobs are for those studying technical subjects only.

Between 2014 and 2017, business development and policy-making activities within the UK space sector saw income growth rates of 133% and 136% respectively, the second and third largest growth of all areas [1]. If this growth is to continue, individuals with the combination of both knowledge of the space sector and non-technical skills will be in even more demand. Thus, it is important to teach students that a space company runs like any other; requiring business, administration, and marketing professionals to operate, as well as the scientists and engineers who design the products. This will encourage students who had not previously considered working in the sector to apply for roles, allowing them to combine their interests and working life, and potentially build a stronger workforce.

B. Demonstrate attainability

As well as being aware of jobs in the space sector, students need to be shown that they are attainable. 18 of the students aged 8-14 surveyed, specified "NASA" when naming jobs; and 69% of university students surveyed at the National Student Space Conference, who have an assumed prior interest in space, could name fewer than 5 UK space companies off the top of their head, showing that many students are unaware of the range of opportunities available in the UK. If they are unable to identify local companies while at university, they will be unable to apply to roles or form the belief that application processes for such jobs are highly competitive. Thus, a career within the sector may seem difficult or even unattainable.

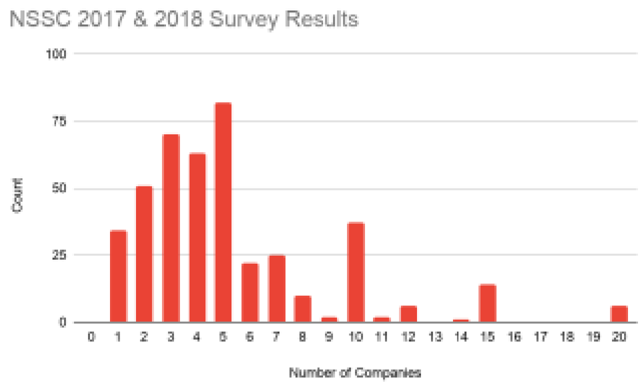

Fig. 3. Results from survey question: How many UK space companies can you name off the top of your head? (n=437).

Students also tend to perceive technical jobs within the space sector as inherently challenging. When asked, 54% of 8-14 year olds and 75% of 14-18 year olds did not think they could pursue a job within the space sector; 31% of all 14-18 year olds surveyed saying 'it's too hard' or that they are 'not good enough' at one or more STEM subjects. 77% of the students with this view had not taken part in any space related activity, indicating that exposure can help to dispel such perceptions. This is further highlighted by Bennett et al., who found there is a stronger belief that one must be 'clever' to do a job in space science or technology, than in maths and science [9].

While it is true that the space industry workforce is highly-skilled, with 3 in 4 employees holding at least a primary degree, there are increasing opportunities for those who do not want to or get the grades to go to university, including various foundation year courses, distance learning courses, and apprenticeships within the space sector [1]. A 2012 analysis of technicians in the UK space industry by Lewis, highlighted a skills shortage at the technician level and in the age of the technician workforce [10]. Of 11 firms that employ manufacturing technicians, 9 expressed difficulty in hiring good talent, one describing it as their 'biggest barrier' to expansion. For this reason, more and more firms are starting to train apprentices. There are now over 1400 apprentices in the sector, but very few students were aware of these opportunities, which to many, might seem more attainable than other space jobs [11].

Because they feel under-qualified, candidates are often deterred from applying for technical jobs in the first instance. They tend to be unaware that some hiring managers prioritise analytical and communication skills above specific knowledge, as they know that new recruits can gain the necessary technical skills on the job. A global study of the Information Security workforce found that 33% of cybersecurity professionals came into their role from a non-technical background (n = 19,641); in a similar way, graduates can be trained to perform roles within the space sector [12]. Students must therefore be made aware of these opportunities for development within companies, in order to encourage those who are capable to apply for roles within the sector.

C. There is demand

Of students aged 14 and over, 78% of those who are interested in space claimed that they have considered a job in the space sector; 84% expressed an interest in space careers resources, 23% of whom had not previously considered a career in space. Students asked for advice on potential job opportunities (37%), and applications (47%); however, only 16% believed they knew enough about jobs in the space sector to want advice on open opportunities, such as training courses and internships. Further demand can be seen by the 330,000 career-advice article views on the SpaceCareers.uk website since December 2015.

IV. How Can We Educate Students About Careers in Space?

Students can be educated about jobs in the space sector by including careers topics in both existing and new outreach and educational activities. The surveys showed a strong correlation between knowledge of jobs and those taught about in activities, indicating their impact, and the effect that modifying them could have.

Unlimited Theatre found that the percentage of students interested in becoming a scientist increased from 76% to 94% after taking part in their Astro Science Challenge, demonstrating the positive effect of outreach activities on students' career aspirations [4]. However, further reports - including ASPIRES, published by King's College London in 2013 - found that there is a lack of careers focused activities within primary schools, and suggested that they would benefit from those which promoted STEM related aspirations [13]. It is important to target this age group in particular, as students appear to develop firm views about the jobs they want to pursue at an early age. One study found that 85% of 11 year olds already knew what path they wanted to follow, very few of these involving STEM; and 80% of students in another study knew they didn't want a science based job before the age of 11 [9] [13]. Thus, outreach activities should aim to showcase the breadth of space jobs to students as young as primary school age, in order to raise awareness of them before students begin to make career choices.

Chambers, in Starting early – the importance of career-related learning in primary school, highlighted that hearing from professionals can be particularly effective in showing students how their studies relate to the real world [14]. This not only introduces students to careers they may not have heard of, but can lead to their increased interest in a subject, and even attainment [15]. However, of 13,000 students aged 7-11 within the study, less than 1% knew about a job from someone visiting their school. It is safe to assume that of all professionals who visit schools, the percentage of those from the space sector is low, as the space sector is significantly smaller than others. Nevertheless, the One Million Interactions programme is addressing this issue, aiming to attract more into STEM and the space industry [16].

This lack of education around careers and pathways in outreach, educational, and training activities appears to continue throughout a student's academic career. Only 19% of students aged 14-18 and 50% of students aged 18+ who have taken part in space related activities said they had learnt about the possible routes into jobs. Thus, information about potential pathways should be incorporated into these activities; one of the simplest ways being to provide follow up resources for those students who are interested. Such resources, including online interviews with professionals working in the space sector, can be found on the SpaceCareers.uk website. These provide freely available insights into specific jobs and journeys, which can be particularly useful for students who do not get access to external speakers. Careers and pathways education is especially important for students aged 14-18, as they will be in the process of making subject choices which could potentially limit future opportunities.

In addition to the SpaceCareers.uk website, UKSEDS holds Careers Launch events to showcase opportunities and career paths within the sector, through careers talks, a pathways/skills focused panel discussion, and speed mentoring (informal networking) with space professionals. 92% of attendees in 2019 agreed that the event increased their knowledge of space careers (n=72), demonstrating the effectiveness of such events. This exposure to professionals gives students the chance to explore the careers available within the sector in more depth, than online resources, as they can ask questions tailored towards the gaps in their own understanding, as well as receive more honest and detailed responses. It is recommended that this setting be used in wider events.

There is also the potential for outreach activities to focus on more non-technical jobs, showing their relevance to the space sector. This may further encourage those students who have an interest in space, but do not think they can do a 'space job', to apply their knowledge to the sector. Activities such as the Space Science and Engineering Foundation's Space Design Competitions are good as they directly expose students to a range of different jobs in the space industry, including non-technical, business aspects of the space sector. Classic space outreach activities such as building rockets or satellites could quite easily be expanded in a similar way. Students could each have a different role within their team, for example project manager, and leads in business, engineering, science, and marketing, really bringing the project to life.

Finally, public attractions, such as museums and science centres, can play a significant part in raising students' awareness of different sectors [17]. 70% of survey respondents aged 8-13, who had taken part in some form of extracurricular space activity, claimed to have visited at least one space themed attraction. However, 33% of those students who reported visiting an attraction could only name astronaut as a space job, suggesting public attractions could do more to incorporate information about the range of available careers within the sector.

CONCLUSION

This paper has demonstrated the importance of educating students about careers within the space sector, supported by a collection of primary and secondary data, and has gone on to suggest methods to achieve this. It has shown that students lack awareness of both technical and non-technical job opportunities within the space sector, leading to the misconception that such careers are unattainable. This can be overcome by educating students through outreach activities, such as talks from professionals, interactive workshops, and online resources. By improving the methods of educating students about careers in the space sector, an increased number of capable applicants will be encouraged to consider technical roles, enabling the UK to reach the goals set out by the UK Space Agency; and those with non-technical skills, and an interest in the sector, may be shown how they can pursue a space-related career.

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Visualization and simulation of ion thrusters possibly usable by small satellites

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***Abstract*—After launching a small satellite and placing it into its final orbit, it can have unwanted and uncontrolled rotation. Therefore a small satellite needs to perform some maneuvers to stabilize or slightly change its position on its orbit. Due to its small size it needs only a small drive system and torque to stabilize. Furthermore, the available energy for attitude control is also limited. Ion thrusters use ionized neutral gases accelerated by electric field to drive the spacecraft or change its attitude. As ionized gas flies out of the thruster it makes an opposite directed force. If we use different outlets for ions to fly out from thruster it can act like a three dimensional steering system.**

A process of finite element based solution is used to calculate quasi-electrostatic field of the internal the thruster. It is also used to perform simulations on the outlets. Using the field calculated we can show possible allowed and forbidden paths of ions spreading inside and outside of the outlets.

We present a visualization technique to show the internal world of a possible three directional steering system. Visualization of our results is import to understand operation of device and find possible improvements. Also it can be used to illustrate internal operations of the thruster for educational purposes.

***Index Terms*—simulation, visualization, ion thruster, small satellite, steering**

I. Introduction

The launch system of a spacecraft is a complex structure and it consists of typically several rocket stages that often use different propulsion systems. A typical and commonly applied structure can be observed in the Ariane rocket family [1].

Usually high-power booster(s) with solid propellant can be found in the first stage, extended with a cryogenic core stage with liquid propellant. The boosters are operating in the first launch phase for a couple of minutes and after the separation are returning to the ground for later reuse. The main stage operates up to its separation when the spacecraft's performance value an appropriate height and speed reached. At this point the upper stage is ignited to place the payload(s), e.g. satellite(s) to their final orbit. Ariane 5 is designed to carry satellites to Geostationary Transfer Orbit (GTO), sun synchronous and polar circular orbits, elliptical or International Space Station (ISS) orbit, but there is a version for Earth escape missions as well. The above-mentioned rocket engines are providing very high thrust in the MN-kN range: the boosters 7000kN, the core stage more than 100kN and the upper stage 67kN. A typical GTO mission has approximately 30min duration.

When we talk about an individual satellite that already reached its planned height and speed by the launch system, a subsystem of the satellite, the propulsion system is supporting the spacecraft's further orbital maneuvers and changes its position by firing thrusters. Depending on the mission's type, the task of the propulsion subsystem may perform apogee injection e.g. to reach a final geostationary orbit. For that one a few hundred of N thrust level is required. In order to perform minor orbit control, like modifying the inclination, maintenance of the orbit low power thrusters with few times 10N is required.

The orientation of a satellite should be also controlled in order to maintenance of the spin rate, perform axes stabilization or rotate the satellite to a specific direction. This kind of maneuvers requires a few N of thrust.

The propulsion subsystem of satellites have many different operating principles. Chemical propulsion systems with monopropellants or bipropellants may provide higher thrusts. However, the resulted chemical products may influence the external environment of the spacecraft and it could be intolerable by the mission's goal, especially when there are sensitive measurement devices among the payloads.

Cold gas systems with neutral gases are operating in the lower power ranges. The primary choice is nitrogen as its relatively high molecular size prevents the fuel leakage. An alternative propellant is argon, when nitrogen cannot be applied for specific reasons.

The electric propulsion systems are using ionizable gases as the propellant. Electrical power supplied by an external energy source is used to accelerate the propellant to extreme velocities and thereby achieve very high specific impulses. However, the power as well as the thrust is limited by the available electrical energy delivered by batteries, solar generators or radioisotope thermoelectric generators (RTGs). The electric propulsion systems have very low thrust, comparing to the previous methods. Thrusters for electric propulsion require propellants which can be easily evaporated and ionized and which have a high molecular weight. Therefore the development of thrusters for electric propulsion concentrated on the use of inert gas xenon, which can be stored in high-pressure gas tanks. Xenon has a high molecular weight and can be

† corresponding author

quite easily ionized. The idea of electric propulsion is not new - NASA Glenn Research Center has been a leader in ion propulsion technology development since the late 1950s, with its first test in space - the Space Electric Rocket Test 1 – flying on July 20, 1964 [3]. In [4] and [5] the principles of operation and the several types of thrusters that are either operational or in advanced development are discussed. Ion thrusters (based on a NASA design) are now being used to keep over 100 geosynchronous Earth orbit communication satellites in their desired locations and there are other missions with electric propulsion system as well.

In this paper we provide a finite element based solution to calculate quasi-electrostatic field of the internal the thruster and we perform simulations on the outlets. The applicability of this thruster method for small satellites is also investigated.

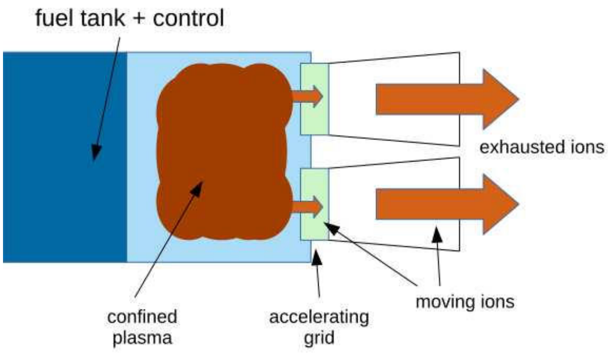

Fig. 1. Schematic of an ion thruster engine

The organization of this paper is as follows. Section II, gives a general overview of principle of operation of ion engine we simulate later. We give a short introduction to interior of an ion engine. Section III describes simulation steps and assumptions. Section IV shows results on the jet formation effect of engine nozzle simulations. Finally, section V concludes the paper.

II. Principle of operation of simulated ion engine

A. *Types of electric propulsion engines*

Electric propulsion (EP) can be categorized by many ways. First types is the ion thrusters when only electric field to accelerate ions (see Figure 1). The other type is that use magnetic field and electric field to accelerate and control ion or plasma jets [5]. This type is more sophisticated and due to its size it is not possible to implement in a Cubesat environment.

Both types use electric field acceleration grid (AG). It is formed as two grids separated from each at a few centimeters and potential difference made between. On one grid ions comes in and on the other grid leaves it with a higher speed.

B. *Electric propulsion system proposed*

We are propose a simple electric propulsion system for small satellites. These EP system is based on the basic principle that we accelerate the gas (ions) that moves outward of the spacecraft will thrust the spacecraft to the opposite direction. The gas must have charges (ionized) to be accelerated by electric field.

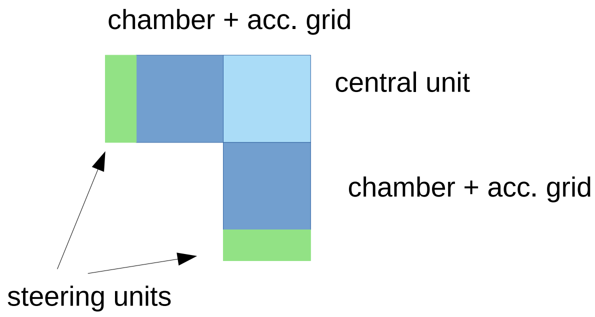

Fig. 2. A possible system usable on small satellites for steering using only fuel tank and control unit (light blue box), two chambers and acceleration grids (blue boxes) and two steering units (green boxes). Great boxes are 1U sized, green boxes are 0.5U sized.

Our model is based on a simple discharge chamber where gas is ionized and an acceleration grid that moves ions outward. Control of ion jets are performed using electrodes attached to nozzle inner surface and driven by potential.

In this paper we analyze control of movement of ion jets inside the nozzle through only electric field.

C. *Possible system for Cubesat steering*

Cubesats have a limited space and mass. Currently there are spinoffs that offers a plan for 2 unit large propolsion systems based on Xenon or Iodine [8].

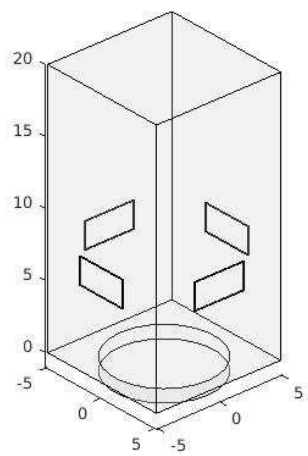

Fig. 3. Outline of the nozzle. Small rectangles on the sides are control electrodes. The tube on the bottom is the upper side (top side) of the acceleration grid. The top of the grid is connected to zero voltage. The potential of the electrodes is used to control ions movements.

If we assume that this system works, an additional steering mechanism can be used for steering. It is based on deflecting ions that fly out from thrusting. The deflector system can bend the beams, and thereby it can help to maneuver the satellite. The system is shown on Figure 3. The rectangular formations are electrodes of the deflector system. It can turn the ion beam and thereby it can turn the satellite too.

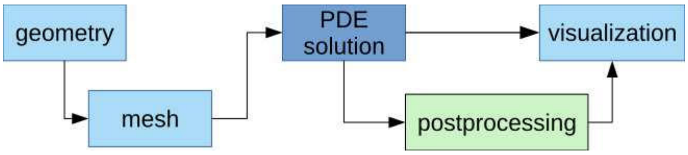

Fig. 4. Chain of simulation

III. Simulation background and Layout

A. Background of simulation

We start our model when ionized plasma paces the accelerating grid and enters nozzle region. Principle of ions motion is determined by Newton's law. Force of action is specified by electric field caused by electrodes (control electrodes) placed on the hull of nozzles. We use the outer grid (negative grid) as a nearly zero potential electrode. The nozzle hull's electrode has a higher potential (about the same magnitude as the inner grid which is on the inner side of the accelerator). The hull's region and the control electrodes are shown on Figure 3.

In the model the accelerator grid is not included. We take its effect into account through the speed of ions that enters the nozzle region. Top of accelerator grid is connected to zero potential while the control electrodes has a higher potential (in the few kV range). Interaction between the ions are not taken into account. Effect of outer magnetic was also not investigated.

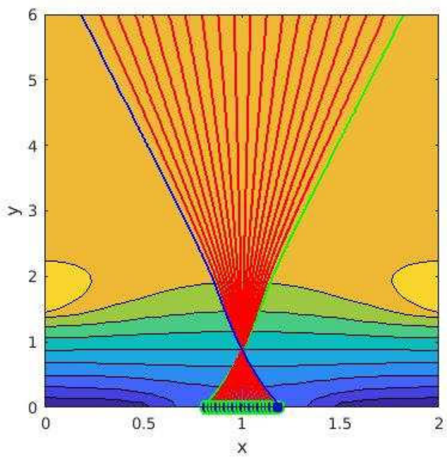

Fig. 5. Path of ions in case of symmetrical driving

B. Steps of simulation process

Steps of simulation process is shown on Figure 4. Our goal was to use as much free software as possible. Therefore only for solution of the finite element model was used commercial software. Geometry and mesh generation was made using gmsh [9], visualization was performed using Paraview [10]. While gmsh and Paraview are free software they have a lot features usable for 3D simulation.

Solution of the partial differential system (PDE) is the main part of simulation chain. It solves Laplace-equation of electrostatic potential caused by electrodes which are used as boundary conditions using finite-element method (FEM). A FEM solver needs a good mesh for solution. Using result of FEM solver we calculate possible ion paths starting on top of grid with a given velocity. As part of the project we implemented an import function for Paraview that enables us to export solutions of FEM (solved using Matlab). Since solution of FEM model is the electrostatic potential we calculated path of moving particles starting at the top of acceleration grid.

IV. Results of simulations

Our simulations were performed on 2-dimensional structures. Because the structures have symmetries it was a good idea to use them. As our expectations are fulfilled by 2D results, it can be extended to 3-dimensional cases.

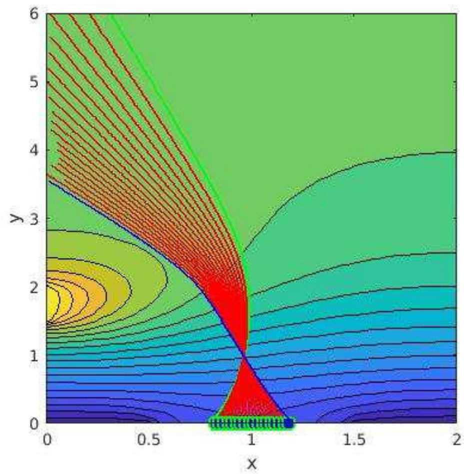

Fig. 6. Path of ions in case of using guided electrodes. Path of ions (red) and equipotential lines of electric field are shown.

Analyzing the possible structures we found that only small region in the middle can be used to start ion beams. We examined the motion of different ions, Xenon and Iodine ions were used. It is found that it has no essential difference between the two possible fuels.

A. Effect of electrodes with free unguided electrodes

First we use a simple non-guided case as reference. Non-guided or symmetrically guided means that the control electrodes have the same potential. The results are shown on Figure 5. Equipotential surface (lines) are shown (smaller potential means more blue). The path lines of ions started from the green region on the bottom. There is an extra acceleration introduced through the control electrodes while the ion jet gets a splayed cone shape as shown on Figure 5.

With no guidance, we have an ion beam directed outward. As we use different potentials on the control electrodes, we can inflect the beam toward the electrode with the higher potential, as shown in Figure 6.

The spread of ion jet is smaller in this case (we used the same starting points of ions as before). The main direction of the beam is bent about 20o compared to the unguided case. Surprisingly the bending has a maximum at the shown angle.

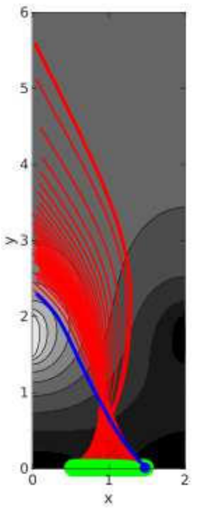

Fig. 7. Effect of connecting unguided electrode to the same potential as top of acceleration grid

And this limit is reached at a relatively low electrode potential of a few hundred Volts in case of average acceleration.

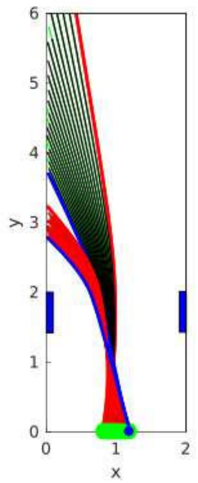

Fig. 8. Trace of ions (red – when other electrodes are connected; black – when not-connected) and equipotential lines of the electric field

B. Effect of connecting unguided electrodes

It is possible to connect unguided electrodes to the same potential of the top of accelerating grid. In this case we get into a different situation. As shown in Figure 7 connection produces a higher gradient in potential as in earlier case. As a consequence a higher electric field is produced that affects ions. The stronger field produces a higher rotation on the beam.

Rotation of ion beams are shown on Figure 8. Ions are started at the green region with an average speed of 10000 m/s. As they fly to the nozzle region the direction of electric field changes drastically and directs them in the direction of driving electrode. Because the ions have a large speed thus they fly over the electrode and pop out from nozzle. The thrusting force of this acceleration grid can make about 5-20 mN force depending on the expended amount of fuel.

If we connect the unguided electrodes to the same potential like that the top of AG, the ions are deflected more than in case when unguided electrodes are not connected to anywhere.

V. Conclusion

We presented first results of a control system that can control ion thruster's ion beam using only electric field. The effect of guiding electrodes can be controlled by the magnitude of electrode potential and connection status of the the other electrodes. It is found that thrusting material doesn't affect the ability of control.

It was presented that the ion beams can be controlled only by the electric field. Out future work is to show that this control mechanism can be used to guide the beam to any direction in a conical shape.

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IRSEL: Innovation on Remote Sensing Education and Learning

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Abstract— **The objective of the IRSEL project is to develop an innovative learning platform, a Learning Management System (LMS) in the field of Remote Sensing Applications for Asian countries, China and Thailand. Beyond establishing the LMS at each Asian university, a Knowledge Pool of high-level e-Learning teaching materials for a wider scientific and engineering community is developed, furthermore workshops, trainings for the teaching staff and a summer school for selected students are organized. The LMS proposed at 4 Asian universities will serve the practical applicability of increasingly higher resolution Remote Sensing data coming from more and more sources for wide range of disciplines (including different tasks of Environmental protection, Agriculture, Forestry and fishery, Physical sciences, Engineering and engineering trades, Transport services, Security services). All intellectual products of the project will be available via internet for the whole Remote Sensing society at large, while the full feature will be hosted at the Thai and Chinese partners and will be involved in their higher education.**

Keywords—Remote Sensing applications, e-learning, LMS

I. INTRODUCTION

The EU space strategy according to [1] says "The Commission's aim is to optimise the benefits that space brings to society and the wider EU economy. Achieving this means boosting demand among public and private users, facilitating access to and use of space data, and stimulating the development and use of innovative downstream applications." The demand is in line with the practice observed in the field of Remote Sensing (RS), which has wide range of potential applications unused [2].

The wider objective of the IRSEL project is to develop an innovative learning platform, a Learning Management System (LMS) for Asian countries, China and Thailand, which already have relevant activity in the field of RS. Though the content of the implemented LMS would not correspond to any level of tertiary level education, it is basically planned to be developed for meeting from BSc to MSc level of RS related disciplines.

More specifically it is planned to improve the related education: 1) by establishing LMS at each of participating Asian universities, 2) by creating a Knowledge Pool of high level e-Learning teaching materials for a wider scientific and engineering community, and 3) by organizing workshops, trainings and a summer school for the teaching and the administration staff.

Specific Project Objectives:

1) To ensure researchers and academic staff in RS and geospatial sciences for studies integrated into world-wide sustainability academia (research) community

2) To strengthen and integrate RS and geospatial science into Multi-Inter-Trans-Cross-Disciplinary sustainability studies and research of Socio-Ecological Systems

3) To enhance the role of Asian institutions in socio-ecological systems studies and researches for the benefit of Asian region

4) To promote internationalization on the relevant knowledge areas

5) To enhance international cooperation between EU and Asian universities and research institutes

The promotion of the professional development of staff and youth workers in the field of remote sensing and related interdisciplinary sciences is planned to be implemented in the form of a Learning Management System, which makes use of recent advancements of ICT methodologies and technologies. Transversal skills, e.g. digital competences, or in general, 21th century skills are developed by the education methodology, i.e. a practical remote teaching / learning in a true multiorganizational collaboration.

The LMS will host 20 newly developed modules on Remote Sensing in the curricula of participating universities, improving the quality of higher education, delivering a background for studying the practical use of the Remote Sensing techniques. This would by time enhance the practical use of Remote Sensing on a wide range of applications serving the labour market and society. The competences and skills in the participating Higher Education Institutions (HEIs) will be developed using these learning modules.

The LMS to be developed at 4 Asian universities will serve the practical applicability of Remote Sensing data for wide range of disciplines (including different tasks of Environmental protection, Agriculture, Forestry and fishery, Physical sciences, Engineering and engineering trades, Transport services, Security services). The aim of the LMS is to foster the uptake of Remote Sensing applications to boost the benefits that Earth Observation (EO) brings to society and the wider economy. Society will benefit from the improved contacts between research and application for sustainable development.

For up-to-date information on the IRSEL project, visit the website at http://irsel.eu/, which can be reached by the QR code on Figure 1 as well. Also, actual tasks and challenges of project implementation can be reached at [3].

Fig. 1. QR code of the irsel.eu webpage

TABLE I. THE CONSORTIUM

Partners		
HEI	***abbr.***	***Country***
Obuda University	OU	Hungary
University of Natural Resources and Life Sciences	BOKU	Austria
Jagiellonian University	JU	Poland
University of Twente	ITC	the Netherlands
Fujian Normal University	FNU	China
Yunnan Normal University	YNNU	China
Asian Institute of Technology	AIT	Thailand
Khon Kaen University	KKU	Thailand
Associated partners		
HEI	***abbr.***	***Country***
Government Office of the Capital City Budapest, Department of Geodesy, Remote Sensing and Land Offices[1]	BFKH-FTFF	Hungary
Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Science	MTA RCAE	Hungary
Yunnan Hanzhe Technology Co. Ltd.	-	China
Southwest Forestry University	SWFU	China
Mahasarakham University	MSU	Thailand
Thammasat University	TU	Thailand

[1] Now it is merged to Lechner Knowledge Centre.

II. THE CONSORTIUM

The project is implemented in an international cooperation of 8 higher education institutions additionally to the 6 associated partners. The list of the involved institutions is summarized in Table I.

III. LEARNING MATERIAL DEVELOPMENT

The learning material development is fundamentally important in order to ensure the adequate basis of Remote Sensing teaching. They provide the e-Learning material content of the Learning Management System stored and disseminated on the Knowledge Centres.

Prior to the learning material development, the Needs Analysis was done. As a result, we've created a Needs Analysis Report. It is a document describing detailed needs and expectations from Asian Remote Sensing Society. The report contains results of needs analysis questionnaires, summarize the recommendations according to local demands, and list the targeted stakeholders and respondents from China and Thailand. The report provides necessary information for module development for the IRSEL project.

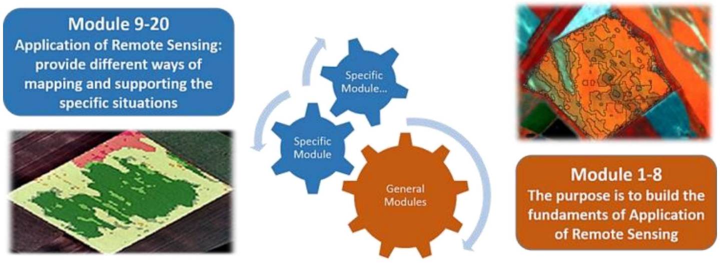

Fig. 2. Structure of the Learning Materials

The learning materials can be divided into two parts: the first 10 modules provide the fundamental knowledge on Remote Sensing at appr. BSc level, while the last 10 modules deals with actual Remote Sensing applications at appr. MSc level (Fig. 2). The actual course specifications are detailed below:

M1 Physical Principles of Remote Sensing: providing students with physical principles of Remote Sensing, the tool to obtain information on the earth from deci-meter level to km level locally and globally, as well as basic RS image processing techniques and skills. The main focus remains on theories and laws on nature of light, its interactions with the atmosphere and earth surface. Additionally, this module focuses on introducing spectrometer, their types, applications and approach to conduct laboratory experiments.

M2 Data Acquisition, Sensors and Platforms (passive sensing): The module provides an overview of different sensors and platforms for the acquisition of passive EO data with emphasis on satellites. EO data, and subsequently the sensors, can be characterized based on the different types of resolutions (spatial, spectral, temporal, radiometric). The main platforms -

such as unmanned aerial vehicles (UAV), airplane, and satellite - are presented. Further, the data acquisition process and the different types of sensors (frame cameras, scanners) will be analysed.

M3 Data Acquisition, Sensors and Platforms (active sensing): This module aims at introducing basic and applications of active remote sensing. It covers the basics of imaging system and polarmetric of radar. The differences in type of sensor and availability of spaceborne and airborne sensor. The characteristics of scattering and reflection of microwave energy in various type of surface. An Introduction to Lidar system concepts. The exercises and case studies allow students to explore a range of practical techniques.

M4 Airborne Photogrammetry Remote Sensing Simulation: Understand and master the definition and classification of aerial photogrammetry and Remote Sensing; understand the mission, history and current status of aerial photogrammetry and Remote Sensing; master and thoroughly understand the basic theoretical basis for aerial photogrammetry. Through the study of this course, students are required to understand the whole process of photogrammetry operations, and they can analyse and interpret the aerial photogrammetry process from theory and practice and provide a theoretical basis for solving practical problems.

M5 Digital Image Processing I.: This module aims at introducing basic and advanced techniques of digital image processing. It covers the fundamental concepts required to understand and apply commonly used and more advanced algorithms for pre-processing of remotely sensed data, image manipulation, characterization, segmentation and feature extraction in direct space.

M6 Digital Image Processing II. / Image Classification and Interpretation: This module aims at introducing basic and advanced techniques of digital image processing. It covers the fundamental concepts required to understand and apply commonly used and more advanced algorithms for classification of remotely sensed data. It focuses on an image classification knowledge, techniques and skills for getting information from imagery and ability to solve complex tasks based on Remote Sensing. Emphasis is placed on gaining a practical understanding of the principles behind each technique and a consideration of their appropriateness in different applications. (For an example see Fig. 3)

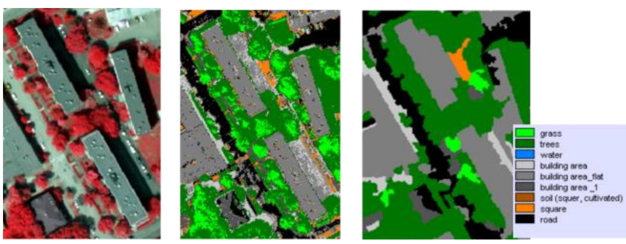

Fig. 3. Pixel and object approach for land cover classification (example)

M7 Available Software Applied in Remote Sensing: This module aims at introducing software tools available for applications in Remote Sensing. RS software landscape will be introduced and their practical methodologies of using this software for real-world problem solving will be explored. Some selected fully-fledged software packages including proprietary and free and open source will be used for image processing, analysis and visualization processes or for information extraction.

M8 Land Change Detection: This module aims at introducing concepts of land change and how basic and advanced techniques of digital change detection can be applied to detect and monitor changes on the land surface. It builds on fundamental concepts related to principles of Remote Sensing and basics of image processing and extends knowledge and skills of students into a temporal dimension. Topics are illustrated with examples and case studies supported by remotely sensed and ancillary data.

M9 Terrain modelling and analysis: introducing concepts of digital elevation models, and how basic and advanced techniques can be applied to analyse and visualize terrain and surface. It builds on fundamental concepts related to principles of photogrammetry, Remote Sensing, and image processing, and extends knowledge and skills of students into a third dimension. (For an example see Fig. 4)

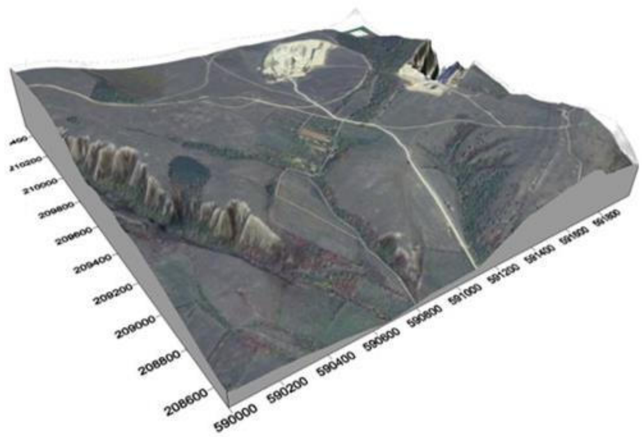

Fig. 4. An orthophoto projected onto a LIDAR-borne terrain model

M10 Remote Sensing and Geographical Information Systems (GIS): aims at the basic of geographic information system (GIS) and data type for integrated with Remote Sensing data. The integration between GIS and Remote Sensing data for data acquisition, analysed, presentation. Technology trends in Remote Sensing and GIS in the future.

M11 Application of Remote Sensing in Agriculture: This module aims at providing the principles, potentials and challenges of Earth observation technologies in the context of crop type mapping, change detection and, more generally, crop condition monitoring. It combines theoretical and practical sessions. The scope of the practical (computer-based laboratory exercises) is to consolidate the theory, to learn & train practical skills and to apply problem-solving methodologies to real-life examples. The main focus lies on the added values of multi-spectral data to retrieve crop bio-physical indicators and the use of multi-temporal data to study the changes and evolution of these indicators over time.

M12 Vegetation mapping and monitoring: providing students with knowledge of satellite Remote Sensing processing techniques and analysis for vegetation mapping and monitoring. Derived products of vegetation index, water stress etc. are generated to track the length of growing season, vegetation health and anomalies.

M13 Application of Remote Sensing (optical satellite data) in Forestry: This module presents different application possibilities of Remote Sensing in forestry. The main focus remains on tree species classification on different levels of detail. Additional contents are biomass / growing stock estimation and change detection applications for forest monitoring. Starting with the presentation of existing and free available data products the module provides some basics about different (active and passive) Remote Sensing data and analysis techniques.

M14 Monitoring the environment by using of RS: This module aims at introducing RS methods of mapping, monitoring and modelling of the resources for management of the environment and solving environmental problems. It will help learners to understand the methods of analysing environmental problems using RS tools for identification and application of possible solutions to support decision making.

M15 Application of Remotes Sensing in Water Management: In this module the theoretical background of the different water budget components is discussed. For each of the components the role of Earth observation is highlighted. To assess the water balance component, you need data. Data can be obtained from the ground and/or from satellite observations and/or already available satellite products. This module explains how to gather and combine data from these two sources, and where applicable, it refers to procedures already included in linked courses.

M16 Oceans/See and Coastal Monitoring: The main objective of the module is to give an overview about Earth observation solutions related to ocean and coastal monitoring. After a generic overview, which covers all application fields, some aspects will be described in detail, including water quality and sea surface monitoring and coastal processes monitoring.

M17 Remote Sensing in Archaeology: This module aims at providing students with knowledge of airborne and terrestrial Remote Sensing in archaeology in order to perform archaeological site detection and identification. It covers the fundamental concepts for data pre-processing and analysis of the multi various airborne and terrestrial Remote Sensing to derive an integrated archaeological mapping and interpretation of detected structure and features. (For an example see Fig. 5)

Fig. 5. Example for using orthophoto of an archeologic application in Székesfehérvár

M18 Application of (optical) Remote Sensing in Urban Environment: providing the principles, potentials and challenges of Earth Observation technologies in the context of land cover mapping, monitoring and change detection within urban environment. The scope of the practical (computer-based laboratory exercises) is to consolidate the theory, to learn and train practical skills and to apply problem-solving methodologies to real-life examples. The main focus lies on the added values of multi-spectral data to retrieve vegetation bio-physical indicators and the use of multi-temporal data to study the changes and evolution of these indicators over time. (For an example see Fig. 6)

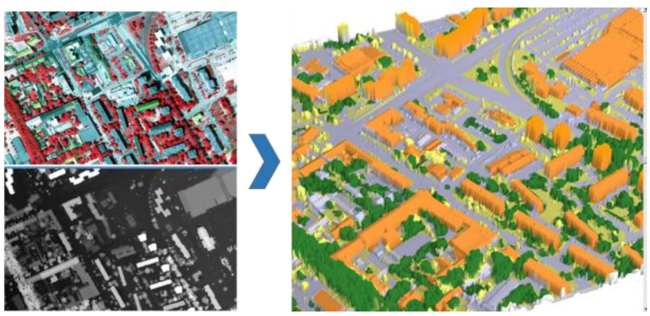

Fig. 6. Example for land cover mapping by OBIA

M19 Disaster Monitoring: This module aims at introducing the benefit of satellite images to monitoring disaster as flood, drought, tsunami, Hurricanes, earthquake, pollution. The data selection for analysed and detected each kind of disaster. The exercises and case studies allow students to explore a range of practical techniques.

M20 Weather and climate monitoring with Remote Sensing: introducing basics of satellite meteorology and climatology, principles of data processing and analyses. The main focus remains on particular spectral channels applications and the interpretation of processed weather and climate information. The module content will give also a broad overview of satellite weather and climate data records and databases as well as data integration towards assessing and monitoring climate change.

IV. Knowledge Centres and knowledge pool

A key outcome of the IRSEL project is the development of 4 Knowledge Centres (KC) hosting Learning Management Systems at each Asian partner Universities. Beyond the hardware and software demands, also some equipment for data acquisition is included in the KCs.

The LMS has been decided to be host on Moodle. Moodle is an open-source learning platform. It is the most widely used LMS software available in many languages. By the end of the project, the core material in the Moodle will be the 20 modules, which will be identical in all the 4 servers, but will be extended by additional knowledge pool. The knowledge pool contains scientific papers published within the frame of the IRSEL project, freely accessible research and teaching materials. It may also contain translation of the modules to local (Chinese or Thai) languages, Remote Sensing software and Remote Sensing data.

Generally, the knowledge pool hosted on the LMS will be involved at different levels of the education of the Asian partners, including distance and blended learning forms as well. For supporting the use of the LMS for self-study, a learning guide is provided. Similarly, for boosting the use of LMS for teaching, a teaching guide is also delivered.

A major part of the equipment purchase within the IRSEL project is meant to establish the hardware and software demand of the knowledge pool. Beyond the hardware, software and data demands, also tools for data acquisition are invested, as no Remote Sensing application can be performed without acquiring data. Without the sake of completeness, the equipment park for data acquisition, which are purchased by the Asian partners contains laser scanner, multispectral UAV, camera, spectroradiometer, plant canopy analyser.

V. Competence development

Within the frame of the project, certain trainings and workshops are organized in order to improve the competences of different target groups of the Thai and Chinese partner HEIs. The main parameters of such events are summarized in Table II.

TABLE II. Events for competence development

event	target group	topics	date and location
Workshop on Remote Sensing experiences	Research and teaching staff	Up-to-date research results in the field of RS and GISc	27-31 August 2018 Vienna, Austria
Workshop on systematic course evaluation system	Teaching staff, university management, administrative staff	Quality management and enhancement, course evaluation plan of project outcomes and expected impacts	4-8 March 2019 Enschede, Netherlands
Workshop on innovative teaching/learning methodologies	Teaching staff	Learning support methodologies, e-Learning tools	26-30 August 2019 Cracow, Poland
Train-the-teachers on learning management technologies	Teaching staff	Up-to-date learning management methods, pedagogic strategies	25-29 November 2019 Kunming, China
Summer School on Remote Sensing	Students from FNU, YNNU, AIT, KKU	Practical and methodological aspects to use advanced Remote Sensing, spatial analysis methodologies and spatial decision support	13-24 July 2020 Pathum Thani, Thailand

VI. Summary

The IRSEL project is aims to develop an innovative learning platform, a Learning Management System for China and Thailand in the field of Remote Sensing applications. More specifically it is planned to improve the related education: 1) by establishing the LMS at each of participating Asian universities, 2) by creating a Knowledge Pool of high level e-Learning teaching materials for a wider scientific and engineering community, and 3) by organizing workshops, trainings and a summer school for the teaching and the administration staff.

The project involves equipping people with the skills, experience and motivation to plan and develop complex educational materials. The project breaks down the traditional educational scheme what contribute to sustainability of results. It promotes (a) multi-method approaches: learning materials (modules), tutorials, webinars, meetings, etc., (b) critical, analytical and integrative thinking, (c) problem solving and research capability, (d) creative and innovative, (e) global and locally relevant information.

It focuses on the use of partnerships to build networks (knowledge platforms) and relationships, also improves communication between different sectors of discipline. The outcomes foreseen go in line with needs of educational and research institutions as well. In addition to the tangible results there are many areas of exploitation, such as cooperation in academic sector to offer new e-Learning approaches, also cooperation with geospatial industry to offer new innovative business products, furthermore the benefit of the society due to the improved contacts between research and application for sustainable development.

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LEGAL NOTICE

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Doctoral School in Geospatial Science in Uzbekistan

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***Abstract* — With the coordination of the Óbuda University, Hungary, an Erasmus+ Capacity Building in Higher Education, Key Action 2 project is conducted named Doctoral Studies in GeoInformation Sciences (abbreviated as DSinGIS). The wider aim of the project is to support Uzbekistan in sustainable development by the application of GeoInformation Sciences (GISc). The objectives envisaged with the project is to establish a missing puzzle from the Uzbek educational system after the MSc level has been completed and before the DSc is targeted. The project established an accredited Doctoral School in the field of GISc, developed its programme, defined the requirements, advanced supporting teaching and learning materials in English and/or Uzbek languages, all developed in accordance to international standards and in accordance to the Uzbek education system.**

As a support for the new Doctoral programme, a set of activities is conducted to improve the educational and research capacity of the Uzbek society. Among these activities, an international network of the 5 leading Uzbek universities is established. Also, their education capacity is developed by creating a Knowledge Centre at each Uzbek partner universities containing an e-learning platform with a jointly developed knowledge pool. The knowledge pool is also supporting research activities of future PhD students. Furthermore, a Joint Research Centre, a research lab is developed to improve the research capacity of PhD programmes. Finally, annual GI conferences are initiated and organized to provide a platform for presenting research results.

The aim of the paper is to share information about the DSinGIS project in general and to summarize its results and experiences gained.

Keywords: GeoInformation Science, PhD programme, e-learning

I. INTRODUCTION

GeoInformation Science (GISc) is a relatively young science, however, has its roots thousands of years. It integrates three traditional geosciences (firstly, geodesy as the science of precise spatial data acquisition; secondly, geography as the science of studying human and physical aspects; finally, cartography as the science of making maps). The integration of these sciences is based on the rapidly evolving computer science. The methods of GISc are widely applied in other sciences, essential in decision making for sustainable development. GISc provides the theoretical foundation of handling geo-related (ie. spatially referenced) digital spatial data acquired primarily by satellite-borne methods. As a result, GISc delivers an essential tool for interpreting, visualizing and analysing measurements of Earth Observation satellite missions, such as Remote Sensing. It makes use of the methods of geospatial analysis and modelling, information systems design, geocomputation and geovisualization.

With the coordination of the Óbuda University, an Erasmus+ Capacity Building in Higher Education, Key Action 2 project is conducted named Doctoral Studies in GeoInformation Sciences (abbreviated as DSinGIS). The wider aim of the project is to support Uzbekistan in sustainable development by GISc. The objectives envisaged with the project is to establish a missing puzzle from the Uzbek educational system after the MSc level has been completed and before the DSc is targeted. The project established an accredited Doctoral School in the field of GISc, developed its programme, defined the requirements, advanced supporting teaching and learning materials in English or Uzbek languages, all developed in accordance to international standards and in accordance to the Uzbek education system.

As a support for the new Doctoral programme, a network of activities is conducted to improve the educational and research capacity of the Uzbek society. Among these activities, an international network of the 5 leading Uzbek universities is established. Also, their education capacity is developed by creating a Knowledge Centre at each Uzbek universities containing an e-learning platform with a jointly developed knowledge pool. The knowledge pool is also supporting research activity of future PhD students. Furthermore, a Joint Research Centre, 5 research labs are developed to improve the research capacity of PhD programmes. Finally, annual GI conferences are organized to provide a platform for presenting research results.

There are several challenges in UZ, where GISc may efficiently support solutions, for such issues as climate change, land degradation, heavy use of agrochemicals, diversion of huge amounts of irrigation water from the two main rivers of the region, water scarcity, the chronic lack of water treatment, e.g. Aral Sea, or the growing threat to air quality.

The DSinGIS project shows synergies with other EU-funded project like "Furthering the Quality of Doctoral Education at Higher Education Institutions in Uzbekistan" [1], “Environmental Protection in Central Asia - Disaster Risk Management with Spatial Methods” [2] and “Sustainable development in rural areas of Uzbekistan” [3] projects.

For up-to-date information on the DSinGIS project, visit the website at http://www.dsingis.eu/home/, which can be reached by the QR code on Figure 1 as well. Also, actual tasks and challenges of project implementation can be reached at [4].

Fig. 1. QR code of the dsingis.eu webpage

II. THE CONSORTIUM

The project is implemented in an international cooperation of 9 higher education institutes (HEI) additionally to the 3 ministerial institutions contributing as associated partners. The majority of the consortium is Uzbek HEIs consisting of all relevant universities in the field of Geoinformatics. The list of the involved institutions is summarized in Table I.

TABLE I. THE CONSORTIUM

Partners		
HEI	***abbr.***	***Country***
Obuda University	OU	Hungary
Paris Lodron University of Salzburg	PLUS	Austria
Royal Institute of Technology	KTH	Sweden
Leibniz Institute of Agricultural Development in Transition Economies	IAMO	Germany
Tashkent Institute of Irrigation and Agricultural Mechanization Engineers	TIIAME	Uzbekistan
National University of Uzbekistan named after Mirzo Ulug’bek	NUU	Uzbekistan
Karakalpak State University named after Berdakh	KSU	Uzbekistan
Samarkand State Architectural and Civil Engineering Institute	SamSACEI	Uzbekistan
Tashkent Institute of Architecture and Civil Engineering	TIAC	Uzbekistan
Associated partners		
HEI	***abbr.***	***Country***
State Committee of Republic of Uzbekistan on Land Resource	GKZGDK	Uzbekistan
Ministry of Higher and Secondary Specialized Education	MHSSE	Uzbekistan
Supreme Attestation Commission under the Cabinet of Ministers	SAC	Uzbekistan

III. ESTABLISHMENT OF THE DOCTORAL SCHOOL

The DSinGIS project focuses on the development of a PhD level educational system. The demand on establishing a Doctoral School in the field of Geoinformation Science is in line with the aims of the Ministry of Higher and Secondary Specialized Education of Uzbekistan (MHSSE). The project specified a PhD programme and methods to deliver its courses.

As a major achievement of the project is that the establishment of the Doctoral School has already been registered in 2019 by the Supreme Attestation Commission under the Cabinet of Ministers (SAC) as a state-recognized PhD programme.

The PhD programme consists of 18 courses divided into 6 compulsory courses and 12 advanced courses in 3 specializations. Among the 18 courses, 8 are prepared in English and 10 in Uzbek language. The rationale behind the share of languages is a consequence of the project partners are expected to contribute equally to the course development, each HEIs developing 2 courses. The structure of the programme and the content of the courses are as follows.

I. Compulsory courses prepared in English

1) Spatial representations and Spatial Data Infrastructures (SDI). The course provides a comprehensive overview on the state-of-the art of SDI, the underlying principles, as well as technological and non-technological components of SDIs.

2) Spatial statistics. The course aims at advancing knowledge on spatial data analysis and spatial statistics. It focuses on methods that are relevant in fields related to sustainable resource use and development of rural areas, such as land use change, climate change, soil degradation, and spatial analysis of well-being.

3) Global Navigation Satellite Systems (GNSS). This course provides the students with an in-depth knowledge about global navigation satellite systems, in particular positioning methods and algorithms as used in the fields of geoinformation science. The course focuses on high accuracy positioning methods, long term static observation methods for deformation monitoring and reference networks, and on atmospheric effects on GNSS signals.

4) Visually interfacing with spatial information. This course aims at introducing the complex field of visually interfacing with spatial information. Techniques and tools as well as concepts and standards to find, filter and visualize spatial data are presented. Technical skills and human-computer interaction competencies are built up.

5) Research methodology and scientific communication. This course introduces to students general research methods as well as practical research process, with focus on critical and creative thinking, addressing also scientific writing and

communication in different forms and different media. Furthermore, social impact of scientific research, commercialization of research results through innovation is concerned.

6) Advanced remote sensing and digital image processing: This course aims at advancing remote sensing and digital image processing knowledge, techniques and skills for getting information from imagery and ability to solve complex tasks based on remote sensing. Emphasis is placed on gaining a practical understanding of the principles behind each technique and a consideration of their appropriateness in different applications.

II. Courses for specializations (there are 3 specializations, each consists of 4 courses, mostly in Uzbek language; when it is in English, it is noted).

II/1. Geodesy:

7) Geodetic Reference Systems. This course aims to deepen the theoretical knowledge and practical skills for the development and management of research projects.

8) Advanced theory of errors. This course consists of studying the theoretical foundations of multivariate statistical analysis in relation to the processing and analysis of geodetic measurements.

9) Satellite gravimetry (in English). The course aims at advancing on physical geodesy knowledge from observational aspects, focusing on obtaining positioning and physical information from satellite-borne observations.

10) 3D laser scanning and mapping by UAV. This course focuses on application of 3D laser scanners and unmanned aerial vehicles in analysing data and creating digital maps or update existing maps.

II/2. Geoinformatics:

11) Geo-databases and distributed architectures. This course is on developing techniques and skills for designing and building a geospatial database, as well as managing such distributed geodatabases, and working with multi-user spatial data base.

12) Advanced thematic mapping. The course supports candidates in cartography, thematic mapping, cartosemiotics, contemporary issues of spatial data representation, use of automation and tools in geovizualisation.

13) Advanced spatial analyses. This course aims to provide knowledge and skills necessary to investigate the spatial patterns, advanced analytical and practical skills to identify and apply the correct analytical tools for problem solving, and to appropriately interpret the analysis results.

14) Integration of remote sensing and GIS. The main aim of this course is exploring the synergies of integrated remote sensing systems and GIS.

II/3. GIS applications:

15) Spatial decision support in land management. The course is aimed to get an idea of the current regulatory and legal acts that regulate the subject of green law, and the application of this knowledge in practical activities, with emphasis on the current legislation of Uzbekistan.

16) Land use economics. This course is aimed at promoting the knowledge of doctoral students in the field of land use and its economics.

17) Spatial simulation of environment. This course is a critical introduction to spatial simulation of ecosystems, embedding of the PhD student in modern research practices, introducing a young scientist into up-to-date context and language of the simulation domain, including proper software background.

18) Sustainable resource management (in English). This course introduces key concepts related to natural resource management for food security and sustainable development. The course summarizes major trends in changes in resource management globally, across scales, and by geographic zone and country, considering also impacts of global climate change on water and land use, and their implications for sustainable resource management.

IV. Knowledge Pool

Beyond the courses of the PhD programme, a knowledge pool is built providing a theoretical background for the PhD students in the field of GISc and related disciplines. The knowledge pool consists of a glossary of geospatial terms, proceedings of annual scientific conferences organized within the frame of this project, relevant digital libraries and scientific journals, 8 modules developed within the Tempus GE-UZ project [5], 18 modules developed within the Erasmus+ DSinGIS project, online library/database such as Scopus, EBSCO, Sciencedirect and Proquest, products of PhD students in GISc (e.g. DSinGIS Grantholders' technical reports, papers/articles, presentations and posters), MSc, PhD thesis related to GISc, GIS related scientific journals and articles, and also GISCA&GI-Forum conferences Proceedings. The structure of the Knowledge Pool is presented on Fig. 2.

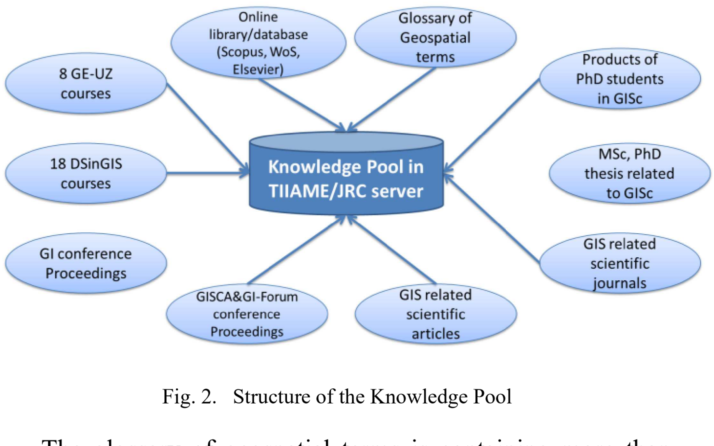

Fig. 2. Structure of the Knowledge Pool

The glossary of geospatial terms is containing more than 1000 terms in Uzbek, helping interdisciplinary communications.

GISc conferences are organized annually (by the date of the present paper, 2 of the planned 3 have already been completed successfully), the submitted papers are published in a conference proceedings and selected papers in local journals.

According to the DSinGIS work plan in total 15 selected doctoral candidates will receive grant to study in one of EU partner institutions (60 days/person) in 3 cohorts. The candidates have been carefully selected by the Admission and Examination Committee. The doctoral candidates will be actively involved in project evaluation, dissemination and exploitation (see section VI. later). They should prepare travel reports focused on their research activities during their study visits in EU partner universities.

V. KNOWLEDGE CENTRES AND JOINT RESEARCH CENTRE

Advanced IT network is installed at each UZ partner institutions, which handles a Moodle Learning Management System. The centres are equipped by GIS and Remote Sensing specific devices. The centres have an IT platform for acquiring and sharing knowledge, videoconference system will be installed for frequent communication between doctoral schools, and it helps collaborative, blended learning. Each centre is equipped with a server, a video conferencing system set, and 3 workstations with advanced GIS & Remote Sensing software. An interactive projector set supports professional presentations of doctoral students.

A sustainable Joint Research Centre (JRC) is implemented for the benefit of doctoral candidates in geoinformatics, not exclusively DSinGIS partners, but covering the interdisciplinary applications in the country. The JRC is established and hosted at TIIAME, which will be completed by May 2020. JRC will be equipped with advanced hardware and geospatial software. The technical / scientific staff will be offered by TIIAME for free. JRC will result directly improved quality of doctoral researches and increased collaboration within partners and wider GI community. The long run benefits of JRC: (1) UZ institutions are able to increase cooperation with EU research institutes, (2) Industry in geospatial sector able to offer innovative business products, (3) Society benefit from innovations, e.g. smart city concept to enhance quality, performance and interactivity of services, to reduce costs and resource consumption and to improve contact between citizens and government.

VI. COMPETENCE DEVELOPMENT

There is a lack of experiences in the new educational methodologies and international tendencies in the Uzbek GI community. The aim of the project is to improve the knowledge, skills and competences of related Uzbek staff regarding management, administration, supervision and mentoring in doctoral studies. The competence development activity focuses on three target groups: 1) management/administration staff, 2) teaching staff and supervisors and 3) doctoral candidates.

There are trainings and workshops are organized in order to improve the competences of the different target groups of the Uzbek HEIs. Also, annual international GISc conferences are organized, which is a huge opportunity for the Uzbek Geoinformatic society to participate and present up-to-date researches in the field of GISc and related sciences. The main parameters of such events are summarized in Table II.

TABLE II. EVENTS FOR COMPETENCE DEVELOPMENT

event	target group	topics	date and location
Training for management and administration	administrative staff, senior managers	management, administration, quality management, quality enhancement, internationalization issues	22-26 May 2018 Hungary
Workshop on learning support methodologies	Teaching staff, scientific advisors	learning support methodologies, eLearning tools and competencies in mentoring	15-18 October 2018 Uzbekistan
1st GI Conference	Teaching staff, research community, PhD students and PhD candidates	presenting and discussing research findings, interests of young and senior, Uzbek and international GI scientists	19-20 October 2018 Uzbekistan
Workshop on interdisciplinary doctoral courses	Teaching staff, scientific advisors	experiences on interdisciplinary GISc issues of doctoral courses	June-July 2019 Austria
Training on supervision and research methodologies	Teaching staff, scientific advisors	supervision and research methodologies in GISc	15-18 October 2019 Uzbekistan
2nd GI Conference	Teaching staff, research community, PhD students and PhD candidates	presenting and discussing research findings, interests of young and senior, Uzbek and international GI scientists	22-23 October 2019 Uzbekistan
Geoinformatics Summer School	PhD students	practical and methodological skills for advanced use of spatial analysis methodologies and techniques of GISc in solving environmental management, socio-economic issues and spatial decision support	23-27 May 2020 Uzbekistan
3rd GI Conference [6]	Teaching staff, research community, PhD students and PhD candidates	presenting and discussing research findings, interests of young and senior, Uzbek and international GI scientists	1-3 June 2020 Uzbekistan

Also, a relevant contribution to competence development is that the project provides scholarship for the young PhD student generation for a 2-month visiting research at an EU partner university to get international experiences. The list of the awarded researchers and their parameters of visit is listed in Table III.

TABLE III. SCHOLARSHIP AWARDEES

name	HEI	host	date
Yakhshimurad Khudaybergenov	KSU	IAMO	October - November 2018
Mamanbek Reimov	TIIAME	OU	January – March 2019
Zokhid Mamatkulov	TIIAME	OU	January – March 2019
Otabek Avezbaev	TIAC	PLUS	March – May 2019
Kuwatbay Bekanov	KSU	IAMO	April – May 2019
Sitora Sodikova	SamSACEI	PLUS	May – June 2019
Ilhom Abdurahmanov	TIIAME	OU	February – March 2020
Medetbay Uteuliev	KSU	OU	February – March 2020
Azizjon Ruziev	NUU	OU	April – May 2020
Abdujalil Muminov	NUU	IAMO	April – May 2020
Vohidjon Niyazov	SamSACEI	OU	April – May 2020
Sherzod Uzokov	SamSACEI	PLUS	June- August 2020
Akbarjon Khamraliev	TIIAME	OU	June- August 2020
Barno Khalilova	TIIAME	PLUS	June- August 2020
Ilkhomjon Abdullaev	NUU	OU	June-July 2020

The candidates are selected carefully by an Admission and Examination Committee. In addition to UZ supervisors EU teachers are assigned to mentoring learning, supporting researches.

VII. SUMMARY

With the coordination of the OU, an Erasmus+ Capacity Building in Higher Education, Key Action 2 project named Doctoral Studies in GeoInformation Sciences is conducted. The wider aim of the project is to support Uzbekistan in sustainable development by GISc. The objectives envisaged with the project is to establish a missing puzzle from the Uzbek educational system after the MSc level has been completed and before the DSc is targeted. The project established an accredited Doctoral School in the field of GISc, developed its programme, defined the requirements, advanced supporting teaching and learning materials in English or Uzbek languages, all developed in accordance to international standards and in accordance to the Uzbek education system.

As a support for the new Doctoral programme, a network of activities is conducted to improve the educational and research capacity of the Uzbek society. Among these activities, an international network of the 5 leading Uzbek universities is established. Also, their education capacity is developed by creating a Knowledge Centre at each Uzbek universities containing an e-learning platform with a jointly developed knowledge pool. The knowledge pool is also developed supporting research activity of future PhD students. Furthermore, a Joint Research Centre, a research lab is developed to improve the research capacity of PhD programmes. Finally, annual GI conferences are organized to provide a platform for presenting research results.

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LEGAL NOTICE

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Planetology Aspects in University Education of Geography and Environment

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Abstract— **The paper comprehends those aspects of planetology which are in the process of introduction into geographical and environmental curricula of the University given in the heading. The Planetology-related subjects can be classified into five groups: (A) Basic sciences taught for the Earth with respect to our wider environment, the Universe, (B) Science on the Earth with respect to the Solar System, (C) Research methodology focused to the Earth but applicable for wider sense, in the Universe, (D) Earth-Space interactions: depleting resources of the Earth solved by the Space, potential risks for the Earth threatening from the Space, (E) Training prospective teachers to include the planetary scope into the public education. The main body of this limited study consists of the names of the planetology-related subjects and some examples of the teaching material. The study ends with brief information on the performed planetary research and on the International Summer School on Planetary Sciences being organized in August of this year at the Eszterházy Károly University in Eger, Hungary and with summary of planetary analog territories in Hungary.**

Keywords — education; planetology; geography; environment

I. Introduction

This study comprehends those aspects of planetology, which are educated in geographical and environmental curricula of the University given in the heading. More specifically, it covers six curricula: Geography BSc (GB), environmental studies BSc (EB), Geography MSc (GM), Teacher of Geography MA (TG), Teacher of Nature and Environment MA (TE) and Environmental Education Program in the PhD School of Educational Sciences (PhE). Partial similarity (common subjects) is seen between GB and GM vs. TG, as well, as between EB vs. TE. Except the Geography MSc, also accredited in English and provided for the Erasmus students, all subjects are held in Hungarian.

The key mission of the University is training prospective teachers for public education, but there are many disciplinary BSc and MSc curricula not related to teacher training.

The Institute of Geographical and Environmental Sciences consists of three Departments: Dept. of Physical Geography and Geo-informatics, Dept. of Social Geography and Regional Development, Dept. of Environmental Sciences and Landscape Ecology. Number of full professors involved in the education is four and there are seven associate professors, too.

II. Grouping The Subjects And Examples

The planetology related subjects will be classified into five groups:

A. Basic sciences taught for the Earth but with respect to our wider environment, the Solar System and the whole Universe.
B. Science on the Earth but with respect to the Solar System.
C. Research methodology, which is focused to the Earth but applicable for wider sense, in the Universe.
D. Earth-Space interactions: depleting resources of the Earth solved by the Space, potential risks for the Earth threatening from the Space.
E. Training prospective teachers to include the planetary scope into the public education.

A. Basic Sciences

Group A is obviously represented by introductory and advanced courses in Mathematics and in Physics. Kinematics of the planets around the sun, i.e. the track along the ellipse, or laws of Kepler are good and often cited examples. For introduction to Chemistry the need for planetary contents is not obvious, but relation between mass number and chance for spontaneous production of the various materials is a part of the subject. As concerns Biology, conditions of life established for the Earth are valid also for the rest of the Universe.

B. Science on the Earth

Group B is certainly led by the Astronomical Geography, which deals both with Astronomy of the Solar System and history of the Universe in detail. Orientation here in the Earth beneath the bright sky is also a core part of this subject. Further subjects, i.e. History of the Earth and the Life, General Geology and Earth History, or History of Geography and Earth Sciences help the students to see the processes in time as well as in synchronism with the human culture.

Figure 1. *A quarry at the Permian/Triassic boundary in Bükk Mts (the southern part of the Mt Bálvány, photo by AG)*

Figure 2. *Planetary analog sites in Hungary (based on [2], their Figure 3).*

Leaving these historical aspects aside, the subjects of Volcanology and of Energy Resources of Our Planet helps to understand formation of the minerals in connection with the past conditions in the Earth. The stability of solar irradiance together with its short-term fluctuation is mentioned in the course of Applications of Solar Energy. Besides these theoretical possibilities, the on-site practices Earth Values and Geo-Parks as well as Geo-Parks and Geo-Sites of the World are very good opportunities to demonstrate and to further explain all cosmic events, which are saved in these sites and made them famous. Another subject, called Paleoecology can only be understood in small reminiscences in the classroom, if the students could perceive similar events on-site.

C. Research methodology

Group C, teaching planetology related research methods, collects diverse subjects. Mineralogy and Petrology apply methods for elaboration of any known mineral in the same way as it should be done with any stone from the Earth. Environmental analytics teaches careful chemical operations to get information about the composition of the object in question. At the master level, the subject Modeling and Simulation opens wide scope to deal with complex processes of the Universe. Furthermore, the alternatively selectable subject Elaboration of data remotely sensed from satellites introduces the students into the world of multi- and hyperspectral sensors also applied to the Planetary Sciences. Besides the above subjects two further possibilities are the Research Seminar, which can also be chosen from planetology related measurements of e.g. meteorites and which is organized in biannual scientific competitions all over Hungary. Finally, the subject Geography in English always contains authentic cosmic texts besides the more Earth and environment related ones.

According to Bérczi et al. [1] and Hudoba et al. [2] Hungary has some places, which would be applied to the planetary analog studies, as follows (Fig. 2).

1. Martian Shergottites and their terrestrial analogues such as basalts with lherzolite inclusions can be found in Szentbékkálla at the Balaton Uplands.
2. Dunavarsány might be an analog field to study the flood-related deposition on Mars.
3. Permian-Triassic boundary layers in Bükk Mts and at Lake Balaton are suitable for the study of mass extinction and its paleoenvironmental consequences.
4. NASA Lunar Sample Set at Eötvös Loránd University, Budapest [3].

D. Earth-Space interactions

First side of Group D is represented by subjects, which demonstrate, which materials are we run out here in the Earth. The subject Renewable Energy Sources points at the alkali Earth metals needed for devices of various renewable resources. Subject of Waste Management, Reuse and Recycling points at the possibilities of obtaining these materials on the Earth. The rest should be found in the Space. The other side of this coin is set of the risks coming from the space. In the geography MSc, we have three relevant subjects all of them in the Risk and Resource Analyst specialization. They are Lithosphere and Soil, as Risk and Resource, Physical and Chemical Interactions in the Geospheres, Learning from Occurred Catastrophes of the World and Hungary. Majority of these dangers are of Earth origin, but solar eruptions, meteorite incidences or unexplained events can also be mentioned.

E. Training prospective teachers

Let us start the Group E with a similar subject already from the Doctoral School where one of the five programs is Environmental Education. Following a set of risks from cosmic origin, collected by Jha [4], we warn the students of the course Pedagogy of Treating Resources and Environmental Risks about the potential problems. Thought, his source is not a scientific monograph of planetary sciences it provides a list of all potential risks found in the sci-fi sources. Table 1. lists the threats that are related to the Space tackled by [4]. Of course, these potential threats are professionally evaluated according to their likeliness and existence of the event in the history of our planet.

Table 1. Potential risks of extra-terrestrial origin for the Earth (based on [1]),

Extra-terrestrial risks	
Cosmic gamma-ray	*Solar collision*
Asteroid incidence	*"Death" of the Sun*
Solar storms	*Runaway black hole*
Galactic collision	*Space debris*

Another set of the subjects in the Doctoral School deals with Age Specifics of Environmental Education, divided according to typical age of the different school class-groups (7-10 years, 11-14 years, 15-18 years). Students of these subjects obtain information on the possibilities of including space knowledge into the school subjects.

Finally, one should mention the unique possibility to observe minerals collected from the Moon illustrated in Figure 3. Presenting them for prospective teachers, at least on images, improves their attitude towards Planetology.

III. ADDITIONAL INFORMATION

A) Research activities in brief

In a pioneering study, a contribution was written in the field of Astrobiology, which describes a laboratory experiment of a simulation of the cryptobiotic crust under Martian condition ([5]) and an active participation in an on-going research of the Martian simulation fields and their terrestrial analogs ([6]).

The Kaba meteorite as the most primitive, less-metamorphosed carbonaceous chondrite was investigated in a collaboration with the University of Debrecen (Hungary) ([7,8]). Furthermore, forsterite from Kaba was studied by Gucsik et al. ([9]) using microspectroscopical methods in order to understand more about the temperature effects of a parent body in an early Solar System. Sztakovics et al. ([10]) used Fast Identification of Mean Motion Resonances (FAIR) of the Hungaria Asteroids.

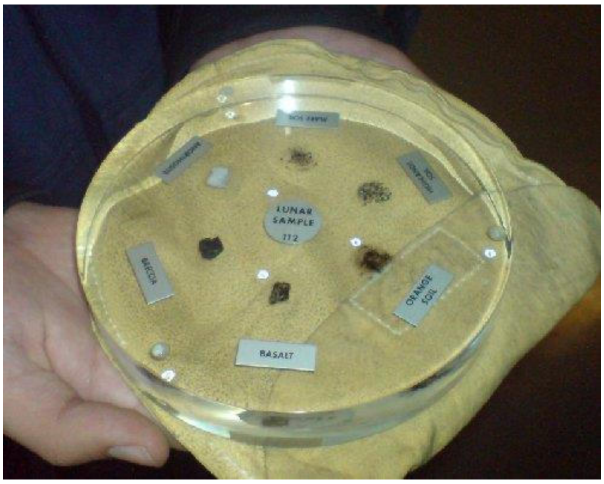

Figure 3. *NASA Lunar Sample Set at Eötvös Loránd University of Budapest, Hungary. (Source:* [1])

A low light pollution area such as Bükk Dark Sky Park was described by Novák et al ([11]). More recently, Gucsik et al (2020) ([12] studied space weathering processes and their mineralogical consequences in the fine-grained astromaterials delivered from asteroid Itokawa by JAXA. Based on the above-mentioned scientific activity at Eszterházy Károly University (Eger, Hungary), a Research Group in the Planetary Sciences and Remote Sensing was established in 2019. Furthermore, AG is a member of the European Space Agency HERA Mission working the Impact Simulation Working Group.

B.) International Summer School 2020

Based on the above-mentioned qualifications as well as circumstances, it is already planned to open a new session in organizing some international summer schools of the Planetary Sciences at Eszterházy Károly University (Eger, Hungary) starting in August of this year.

It is a purpose of this school above to have a week-program including introductions to different fields of the Planetary Sciences such as Planetary Morphology, Meteoritics, Cosmochemistry and Space Technology for the Planetary Missions, as well. It is also planned to have several field trips during the term of the summer school to visit the Permian/Triassic Boundary, Astronomical Observatories, etc.

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Satellite Images to Support Contribution of Meteorology to the UN SDG (2016-2030)

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Abstract—**The United Nations (UN) accepted the 2030 Agenda for Sustainable Development including 17 Sustainable Development Goals [1] and 169 detailed targets. The aim of our study is to present those Targets in which meteorology should play important role and to illustrate how satellite images are applied to support various activities of meteorology. 22 Targets are relevant for meteorology, marked according to the four main branches: air-chemistry, climate information, climate change and weather forecast. The most targets (18 from the 22) request climate information (CI). Climate change (CC) and weather forecast (WF) can be attached to 11-11 targets. A slightly smaller number, 9 targets can be supported by information on air pollution (AP). For possibilities of satellite application the weather forecasts take the lead, mostly considering the observations for nowcasting purposes. Concerning air pollution satellite applications are somewhat limited by the resolution of operational satellites. Heavy tasks of climate change uses satellite information in rather variable ways. Climate information is still mostly based on surface-based information, though the longest satellite information series is available, the higher share can be obtained for them even in this branch of meteorology.**

Keywords — sustainability; climate; weather; air-pollution

I. INTRODUCTION

The General Assembly of the United Nations (UN) accepted the 2030 Agenda for Sustainable Development containing 17 Sustainable Development Goals [1] including 169 more detailed targets. These goals spread over all natural, human and economic aspects of sustainability.

The 17 established Goals are not ordered into any logical structure. In the followings, we recommend a fairly unequivocal logical classification of the 17 Goals. Please, see SDG (2015) for full wording of the Goals.

- Primary needs of humans (2. Food, 3. Health, 6. Water and 7. Energy)
- Equality between humans (1. No poverty, 4 Education, 5. Gender equality and 10. Reduced inequalities)
- Efficient, sustainable production (8. Economic growth, 9. Innovative industry, 12. Responsible consumption and production, 13. Climate action)
- Landscapes in danger (11. Cities, 14. Life in water and 15. Life on land)
- Worldwide cooperation (16. Peace and justice and 17. Partnerships)

The above listed 17 Goals contain 169 Targets. The larger part of the Targets contain quantitative objectives, mostly related to 2030, their number is 126. Another part of the targets point at organisation tools, as preconditions of the objective targets, encountering 43 Targets. The quantitative targets are marked by two numbers, and the latter ones by one number and one letter. Let us cite examples for both types: **"1.1** By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day." vs. **"1.b** Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions."

II. THE GOALS WITH RELEVANCE TO METEOROLOGY

The ways how meteorology can contribute to these targets is presented in the tables of this Section as follows: Air-pollution (AP), climate information (CI), climate change (CC) and weather forecasts (WF). References on these branches of meteorology will be provided after the main sections in the Conclusion. There is only one Goal in target of which we could not find any task for meteorology: *Goal 5. Achieve gender equality and empower all women and girls.*

We go along the Goals according to the above topical classification with one exception for technical reasons: Equity issues will be re-directed to the worldwide cooperation in order to avoid too small tables.

A. Primary needs for Humans (4 Goals, 5 relevant Targets)

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

Goal 3. Ensure healthy lives and promote well-being for all at all ages. Target 3.6: By 2020, halve the number of global deaths and injuries from road traffic accidents. Target 3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.

Table 1: Meteorological contribution to targets of primary human needs

	Air pollution (AP)	Climate information (CI)	Climate change (CC)	Weather forecasts (WF)
Target 2.4		+	+	+
Target 3.6				+
Target 3.9	+			+
Target 6.4		+	+	
Target 7.2		+		+

Goal 6. Ensure availability and sustainable management of water and sanitation for all. Target 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all. Target 7.2: By 2030, increase substantially the share of renewable energy in global energy mix.

Reading along the lines of *Tab. 1,* meteorology can contribute to them as follows. Sustainable food production (Target 2.4) requires use of climate information (not only the means, but also frequency distributions). Long-term weather prediction, not impossible at the lower latitudes, in connection with the El-Nino La-Nina fluctuation is also useful, whereas in agricultural practice, even the weather forecast for several days ahead are useful. Against the accidents (Target 3.6) adequately tailored and distributed weather forecast on road conditions and visibility are especially useful. For decreasing illnesses of chemical origin (Target 3.9), air-chemistry knowledge is obviously useful. Besides that, information on usual and extreme conditions for accumulation of various pollution types is of value. Finally weather prediction of smog events are especially needed for sick people and their doctors. Against water scarcity (Target 6.4) both climate information and climate change regional projections are of unavoidable use. To increase share of renewable energy (Target 7.2) climate information is useful to assess the potentials and weather prediction of e.g. actual wind energy are relevant.

Fig. 1, indicating the skill of operational predictions, points at usefulness of satellite information: By the first years of this century the quality difference between the two Hemispheres disappeared, despite the big difference in the density of ground-based observations.

Figure 1.Evolution of pattern correlation between predicted and real 500 hPa heights. Note the decreasing difference between the two Hemispheres. [2]

B. *Efficient sustainable production (4 Goals, 7 targets)*

Table 2: Meteorological contribution to targets related to efficient production

	Air pollution (AP)	Climate information (CI)	Climate change (CC)	Weather forecasts (WF)
Target 8.9		+		+
Target 9.1		+	+	
Target 12.2		+	+	
Target 12.4	+			+
Target 12.8	+	+		
Target 13.1		+	+	
Target 13.3		+	+	

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. Target 8.9: By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products.

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. Target 9.1: Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.

Goal 12. Ensure sustainable consumption and production patterns. Target 12.2: By 2030, achieve the sustainable management and efficient use of natural resources. Target 12.4: By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment. Target 12.8: By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature.

Goal 13. Take urgent action to combat climate change and its impacts. Target 13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries. Target 13.3: Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.

Among all global observation techniques, the use of satellites is the youngest methodology to monitor climate changes (Fig. 2)

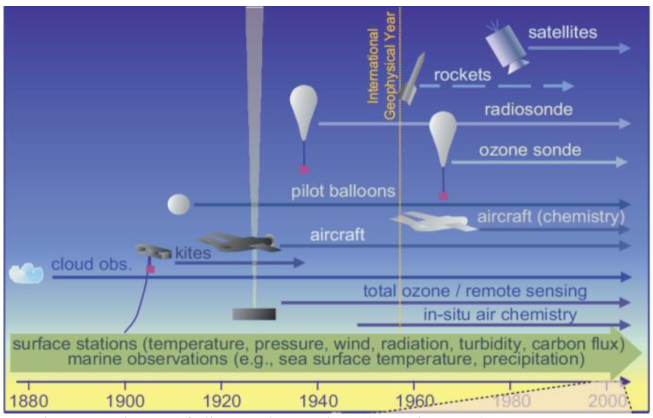

Figure 2. History of climate observations ([3]: Fig. 1.12)

C. Landscapes in danger (3 Goals, 5 Targets)

Table 3: Meteorological contribution to targets of landscapes in danger

	Air pollution (AP)	**Climate information (CI)**	**Climate change (CC)**	**Weather forecasts (WF)**
Target 11.5	+	+		+
Target 11.6	+	+		+
Target 14.3	+		+	
Target 14.5	+	+	+	
Target 15.3		+	+	

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable. Target 11.5: By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations. Target 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development. Target 14.3: Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels. Target 14.5: By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information.

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Target 15.3: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world (see Tab. 3).

Fig. 3 illustrates a natural event, the cloud of the eruption by the Eyjafjallajökull volcano in Island, two days after the eruption. The orange form pointed by white arrows indicate the volcanic cloud above Germany and Poland. The ejaculated tropospheric particles blocked the air traffic for two weeks.

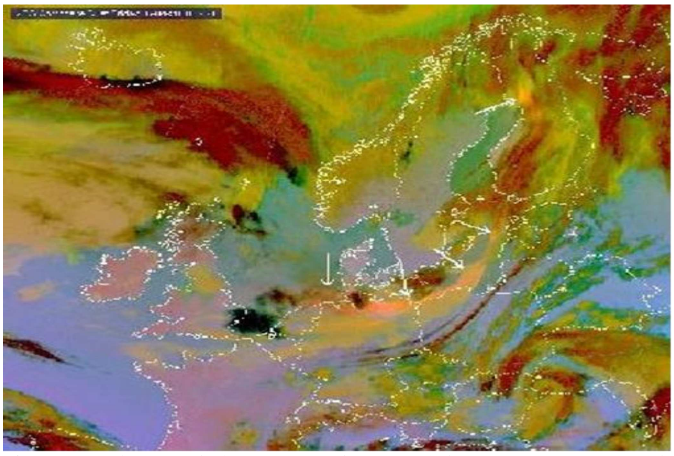

Figure 3. *Volcanic ash (orange, see the arrows) by METEOSAT-9 particle composite on April 16, 2010, 06:40 UTC-(*[4]*: Fig. 2)*

D. Equity of humans, global cooperation (5 Goals, 5 targets)

Table 4: Meteorological contribution to targets related to equality between humans and to worldwide cooperation

	Air pollution (AP)	**Climate information (CI)**	**Climate change (CC)**	**Weather forecasts (WF)**
Target 1.5		+		+
Target 4.7	+	+		
Target 10.7		+	+	+
Target 16.10	+	+		+
Target 17.7		+	+	

Goal 1. End poverty in all its forms everywhere. Target 1.5: By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters.

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Target 4.7: By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development.

Goal 10. Reduce inequality within and among countries. Target 10.7: Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies.

Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels. Target 16.10: Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements.

Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development. Target 17.7: Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed.

Not explaining all cells of *Tab. 4,* let us emphasize only the cells on target 4.7, i.e. education for sustainability. Everything, potentially provided by meteorology, can significantly contribute to the key questions of sustainability, i.e. limited resources, pollution and environmental risks. These interactions should be distributed in all forms of education.

In this set of Goals relevance of meteorology is not so obvious. Climate change projections play important role to attract the decision-makers' attention to the problem. The ozone depletion is another example. Public access to climate and weather information is would also be of key importance.

Let us finish this presentation of targets by pointing at the values of the international cooperation in meteorology, in particular with those obtained by meteorological satellites. The most frequent and realistic climate variables, observed by remote sensing, are listed in *Tab. 5,* organised according to the components of the climate system.

Table 5. Climate related components of the climate system available by satellite observations ([5] *updated by* [3]*: Figs. 1.3 & 4.25)*

Atmosphere	*Surface*	Air temperature, precipitation, air pressure, water vapour, surface radiation budget, wind speed and direction.
	Upper air	Cloud properties, wind speed & direction, Earth radiation budget, upper air temperature, water vapour
	Composition	Carbon dioxide, methane & other GHGs, ozone, aerosol properties
Ocean	*Surface*	Sea-surface temperature, sea-level, sea-ice, ocean colour, sea state, sea-surface salinity, CO_2 partial pressure
	Sub-surface	Temperature, salinity, current, nutrients, carbon, ocean tracers, phytoplankton
Terrestrial		*Glaciers & ice caps, land cover, fire disturbance,* photo-synthetically active radiation, LAI, albedo, biomass, lake levels, snow cover, soil moisture, water use, ground water, river discharge, permafrost and seasonally frozen ground

III. Using Satellite data in Climate Scuence

This chapter presents how satellite observations are used to detect and to explain the changes of climate. The three ways are (A) observation of climate forcing factors, (B) observation of the changes, and (C) validation of climate models by testing their past and future simulations. These possibilities are illustrated by key figures of [3].

Climate applications of the satellites mostly rely on fair spatial resolution (few kilometres) of the images rather than their good time resolution (15 minutes).

A. Observation of climate forcing factors

Spatial distribution of the greenhouse gases, that extremely likely cause the recent warming, is rather even over the Globe. Therefore, observation of these gases is rarely in the focus of satellite development projects. Despite this fact, *Fig. 4* contributes to estimation of CO_2 emission due to the land-use changes. This Figure also demonstrates that results by the various satellite based methodologies differ from each other by tens of percent. At the same time, the uncertainties among the surface-based estimations are of similar magnitude.

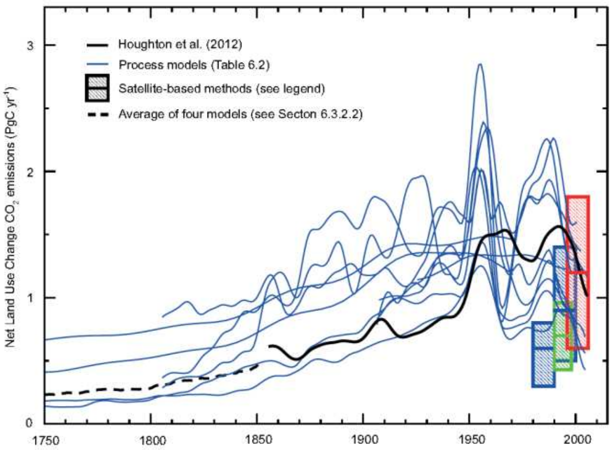

Figure 4. *Land use change CO_2 emissions ($PgCyr^{-1}$) according to two empirical, one model-based and one satellite estimates. The satellite-based methods are available for the tropics (*[3]: *Fig. 6.10)*

B. Observation of the climate changes

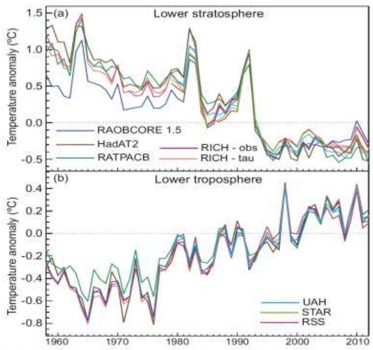

Figure 5. *Global annual mean temperature anomalies in the lower stratosphere (top) and lower troposphere (bottom), relative to 1981-2010, from different data sets. Note that the y-axis resolution differs between the two panels. The curves contain five surface-based and three satellite-based methods, listed in the upper and the lower panels, respectively. (*[3]:*Fig. 2.24)*

Let us first look at air temperatures near the surface and at higher altitudes. The use of satellites is possible by micro-waves which are not absorbed by cloudiness, so not only bright subsamples can be climatologically analysed. *Fig. 5* indicates that the lower troposphere had been continuously warming from the 1960-s to the end of the 20th century. Since then, warming has slowed down significantly. The lower stratosphere exhibits opposite tendencies with unequivocal cooling and stopping of it before the turn of the century. This cooling tendency can be explained be the stronger lapse rate that leads to colder stratosphere, as the surface warms. Most likely, the cooling is also supported by increasing absorption by the more and more greenhouse gases, but diminishing of the cooling takes place, despite the further increase of CO_2.

Stratospheric water vapour content is also investigated by satellite observations. In Fig. 6 they are compared with the USA NCAR radio-sounding observations. Clear coincidence between the two observations is seen, especially in their inter-annual fluctuations. Their longer tendencies diverge a little, but it may be a consequence of short period of observations.

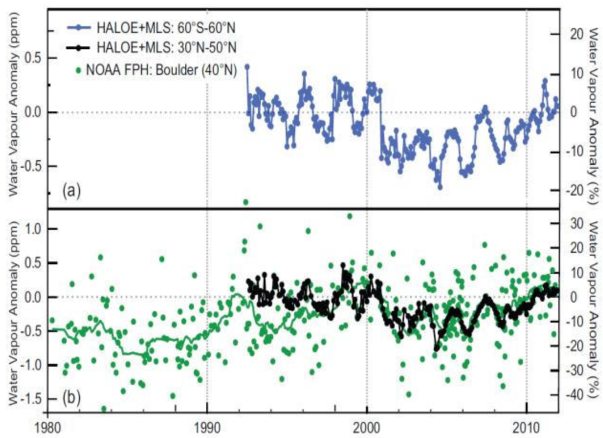

Figure 6. *Stratospheric water vapour by satellite and in situ observations, compared to 2000-2011. (a) Monthly mean at 83 hPa for 60°S-60°N. (b) Monthly balloon-born water vapour from Boulder, at 40°N (green) in 16-18 km, and monthly means as in (a), over 30°-50°N (black) (*[3]: *Fig. 2.5).*

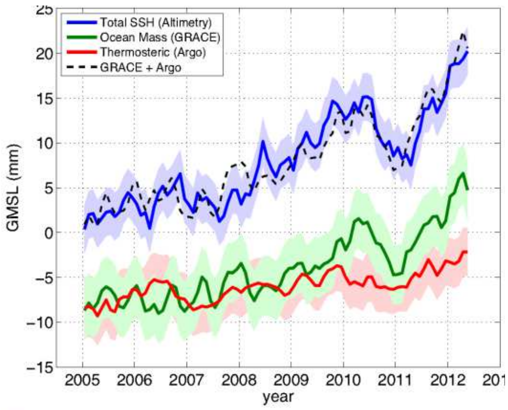

Figure 7. *Global mean sea level from altimetry, (upper solid line), ocean mass changes (middle solid line, by the GRACE Project) and thermosteric sea level changes (lower solid line, by the Argo Project). The dashed line shows sum of ocean mass and thermosteric contributions. (*[3]: *Fig. 13.6)*

Turning to the oceans, Sea-level is seen in *Fig. 7* in four different approaches. They are satellite-born and sea-shore direct sea-level indications, as well, as water volume changes connected with melting of ice and also with thermal expansion. The previous variables are characterised by unequivocally increasing tendency. The latter components of sea level rise are of nearly equal importance.

Tendencies of the sea-ice show rather unique patterns in *Fig. 8*. The two graphs of the Figure can be characterised by completely opposite tendencies. Shrinking of sea ice over the period, maybe with slow-down in the recent decade, can well be explained by the overall warming of the climate system. But, increase of sea ice in the southern hemisphere, near the Antarctic is no way coherent with the overall warming! This problem, and the actual missing of correct explanation, has also been admired by the IPCC WG-I Report ([3]).

According to our view, derived from the figures and statements by [3], this contradiction can be explained by the experienced stronger heat uptake by the deep oceans, which is the likely reason of stagnation of the air temperature. Since 2014 the warming continues by stronger pace than before the ca. 2002-2013 period of temporary stagnation (e.g. [6]).

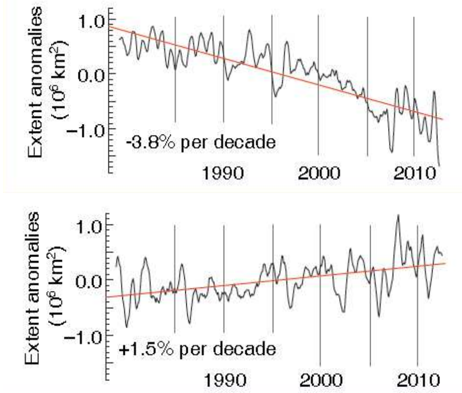

Figure 8. *Decadal trends (km^2) of annual sea-ice anomalies, after removal of the seasonal cycle in the Arctic (upper) and Antarctic (lower) oceans. The average sea ice covers the period 1979 through 2012 (*[3]: *FAQ 4.1 Fig. 1).*

C. *Validation of the climate models*

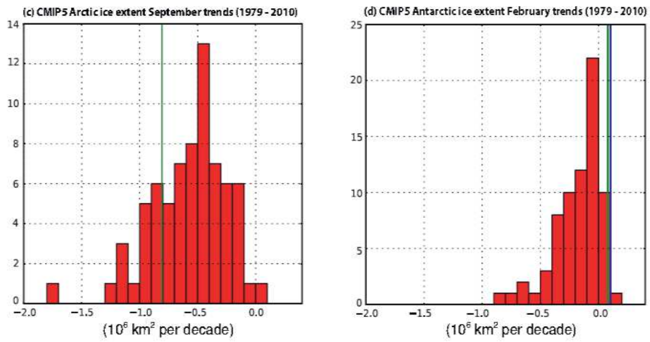

Figure 9, *CMIP5 sea ice extent trends over 1979–2010 for (c) the Arctic in September and (d) the Antarctic in February. 66 realizations of 26 models are compared to observation-based trends (*[3]: *Fig. 9.24)*

Climate system is one of the most complex and non-linear systems. The important space scales spread from sub-millimetres of cloud processes to the length of the Equator. None of the present climate models can correctly tackle all scales. Hence, testing of climate models is very important.

As a negative example, i.e. limited success of simulation, *Fig. 9* indicates to what extent the models were capable to mimic the tendencies of sea-ice cover in the two Hemispheres during the 1979-2010 period. One must admire that not too much! Majority of the models underestimated melting in the Northern Hemisphere, but strongly overestimated the retardation of sea-ice around the Antarctic. (CMIP5 is the abbreviation for the Coupled Model Intercomparison Project Phase 5 to obtain a wide set of new model simulations for [3].)

Conclusion

Meteorology can contribute to 22 targets of the UN SDG (2016-2030). Having classified the meteorological activities into four groups, examples of satellite applications are presented, with special emphasis on climate change,

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Rocket technology for secondary school students

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A sounding rocket (or research rocket) is an instrument-carrying rocket designed to take measurements and perform scientific experiments during its sub-orbital flight.[1] A good example is the rocket series repeatedly used by NASA, called Black Brant. We at the BME Cosmos Society[2,3] ('BME Kozmosz Kör' in Hungarian) build a sounding rocket which can be used in the Hungarian CanSat Competition[4]. Our rocket is a solid-propellant rocket (fuel and oxidizer both are in a solid state), just like the one used in the European CanSat Competition of ESA[5].

Keywords: sounding rocket, solid-propellant rocket, rocket technology, education, university project, CanSat, Hungarian CanSat Competition

I. Introduction

Various space organizations, agencies organize CanSat competitions with slightly different educational purposes. The CanSat Competition of the European Space Agency (ESA) [5] aims to give secondary school students and teachers a space-experience.

We, in the space-related student organization of Budapest University of Technology and Economics (BME), called Cosmos Society [2,3] are willing to organize this year's Hungarian CanSat Competition with the help of the Hungarian Astronautical Society (MANT) and the Hungarian Ministry for Foreign Affairs and Trade (KKM) with the same goals as ESA's CanSat Competition. Our aim is to prepare the students for ESA's competition and also to select the Hungarian team for the European CanSat Competition from year to year.

This paper contains our plans for the Hungarian CanSat Competition with some technical achievements in rocketry.

II. About our team

Our original idea to organize the Hungarian CanSat Competition came after the great achievement (special prize at ESA's competition in 2018) of Team HunSat (I was a member here). CanSat Final Paper of Team Hunsat can be seen on ESA's website [6]. We have been talking about a potentional Hungarian CanSat Competition, but things started to get more serious when I started to study at BME.

Here I found the team of the BME Cosmos Society, which conducts different kind of space projects, and we are currently working with members of the Society to create the Hungarian CanSat Competition. The SMOG-1 Team [7] helps us from the beginning, later MANT and KKM also started to believe in our concept.

III. Technical description - Rocket

The rocket will be able to bring two CanSats to at least 1 km of height in 30 seconds and then return with its parachute (120 cm diameter) after releasing the CanSats. Two CanSats weigh about 700 g, the mass of the rocket is around 1.5 kg, thus a relative strong motor is needed, at least a 38mm motor from the H class (according to the model rocket motor classification system used in the USA).

The rocket is made from a carbon-fiber material, it has a small mass compared to its strength. There is a metal aft part of course.

The motor is reusable, the rocket operator team just needs to change the propellant stick inside of the motor and fasten it with the aft closure ring, then fasten it inside the engine with an engine retainer cap. It's easy to do it fast and efficiently on site.

The nose cone has an ogive-shaped design, although it's not too efficient, but very easy to produce.

Later we plan to use more and more custom-designed components and want to learn more about rocketry, but now – with safety in mind – we started to do our experiments with a rocket, which is well-known in model rocketry and in other CanSat competitions as well.

IV. Technical description – Rocket motors

Before working with the rocket motors, we did some simulations with a software called RockSim. We also started to use Ansys in order to run fluid mechanical simulations, but at this moment, RockSim gives us better results.

We are testing a motor from Cesaroni: H225-14A and later we plan to use J270-13A model if everything works fine. With these our rocket can reach approx. 650 m and 1500 m of height respectively.

The H225-14A is a relatively cheap motor and it's easy to start with. It weighs about 293 g fully loaded and it contains 123.6 g of propellant inside. A 2-grain casing (called 'motor hardware' in rocketry) for this motor is needed as well, because H225-14A is just the so-called reload. It burns out during the launch.

The H225-14A motor burns out in about 1.2 seconds while generating 226 N of thrust in average. This gives us approx. 273 Ns impulse in total. The thrust graph of the H225-14A motor can be seen on Fig. 1.

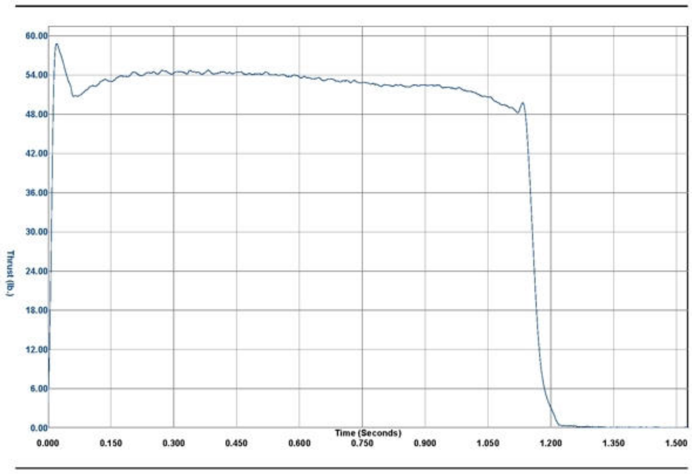

Fig. 1. Thrust graph of H225-14A motor

A couple of simulations have been run in RockSim, one of the results is depicted on Fig. 2. as a 2D flight profile. This simulation ran until the apogee point, which is now at the height of 2148 ft, which is about 655 m, this height was reached in 12.21 seconds.

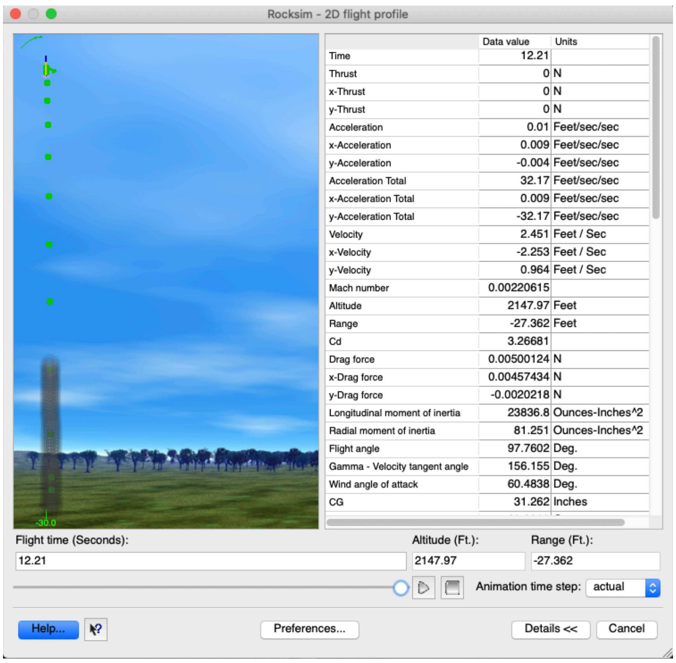

Fig. 2. RockSim simulation

Further testing is needed in order to make sure everything is going to be alright during the CanSat Competition. We also plane to take a step forward with the aforementioned J-class motor. We are currently building a new launchpad as well.

V. TECHNICAL DESCRIPTION – CANSAT

The CanSat main mission is to design and build a CanSat to be launched and deployed from a rocket at an altitude of about 1000 meters. The CanSat is to descend no faster than 11m/s.

The key devices on the board of the CanSat should be:

- Data collection
  - Power supply
  - Microcontroller
  - Communication transceiver
  - Temperature & humidity sensor
  - Pressure sensor
  - (GPS)
  - (Acceleration & gyroscope sensor)
- Parachute
- Chassis

The GPS and the acceleration & gyroscope sensor aren't necessary, but highly recommended.

Besides these, the participants also need to design and implement a scientific or technological experiment: this is called the secondary mission.

A. Data collection: PCB and electronics

The main PCB gives place to the sensors, so it needs to be from a durable material, for instance it can be a professional printed board. The participants can save space by integrating every sensor and communication system on one unit. The PCB board of Team HunSat is depicted on Fig. 3.

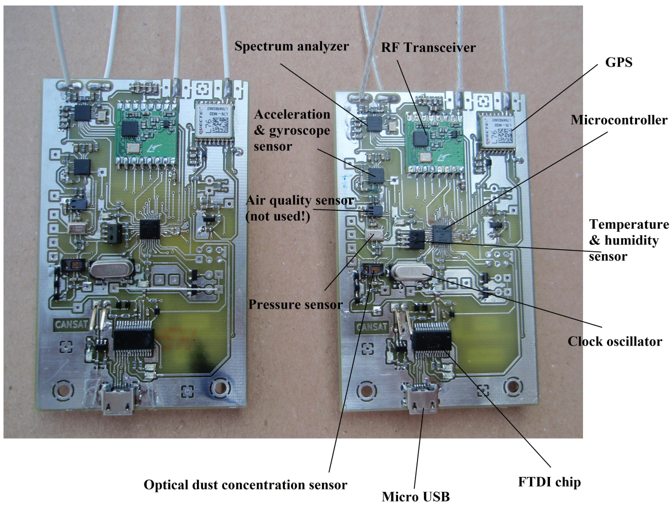

Fig. 3. Main PCB board of the HunSat CanSat

B. Parachute

It can be difficult for a CanSat team to make their own parachute instead of buying one. With Team HunSat we decided to do so and we worked with a polyamide-silk material of the NZ Aerosports parachute manufacturing company. This means our CanSat was very strong and durable. We also designed the shape of the parachute after many tests.

C. Chassis

The main task of the chassis is to absorb the impact of the collision. It is always a challenge to find a place for every component and also protect them. Another challenging task is to find a way how all the sensors on our board can get enough air inside a closed chassis. This is why it can be a good idea for the teams to design an own chassis from scratch. The chassis can be 3D-printed with FDM or SLS technology.

D. Ground Station

The ground station of HunSat was based on a Raspberry Pi 3 single board computer running Linux operation system. A PCB containing the same RFM26W radio module (hardware radio) as the CanSat was connected to the Raspberry.

VI. TECHNICAL DESCRIPTION – CANSAT KIT

The CanSat kit is a starter pack for the newcomers in the Hungarian CanSat Competition. The CanSat kit is depicted on Fig. 4. It's based on a Raspberry Pi, it's really easy to use. Two of these are needed: one is going to be the CanSat, the other one can be the used as a Ground Station.

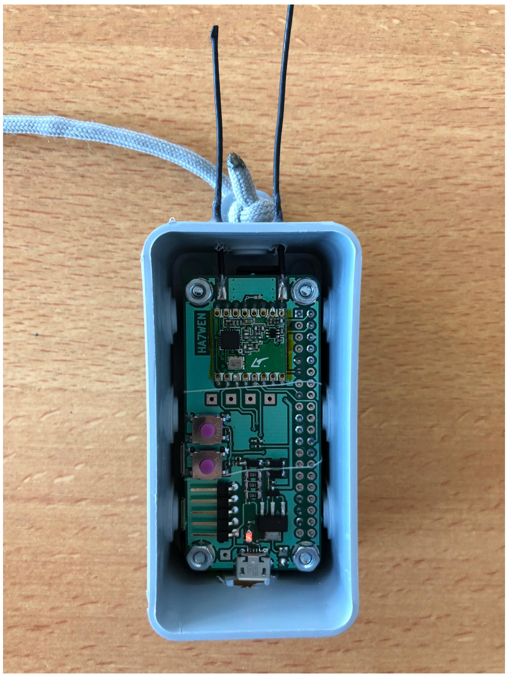

Fig. 4. CanSat kit of the Hungarian CanSat Competition

VII. EDUCATION & SCHEDULE

We have educational goals related to the competition: on the one hand we would like to gain knowledge about rockets, rocket launcher and organizing a nation-wide competition, on the other hand we would like to bring the rocket technology closer to secondary school students. In the USA many great space-relate STEM programs exist, just like the ThinSat program. This [8] article describes how they use space for STEM education.

During the Competition the students can experience teamwork, meet new people with similar interests, and of course will have many opportunities to gain knowledge about technology.

We hope that in the future this Competition will be the official National CanSat Competition of Hungary in the European CanSat Competition.

The schedule of the Hungarian CanSat Competition along with other useful information will be available on its website[4]. Please don't hesitate to contact us with any questions.

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Precise Orbit Determination and Prediction for GNSS satellites

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***Abstract*—The availability of precise orbit solutions with the accuracy of a few centimeters/decimeters is necessary for numerous satellite applications, such as gravity field studies, precise positioning and near-realtime remote sensing applications. Although the International GNSS Service (IGS) provides ultra-rapid orbit solutions for both GPS and GLONASS navigation satellite systems, similar orbit solutions are currently not freely available to the users for the European Galileo satellites. This paper introduces the precise orbit determination and prediction algorithm used for the determination of the Middle Earth Orbits of GNSS satellites at the Department of Geodesy and Surveying of the Budapest University of Technology and Economics. The developed system produces regularly updated ultra-rapid satellite orbits four times a day based on 24 hours of global multi-GNSS observations of a subset of the IGS network. Furthermore, the products include an orbit prediction for an additional 24 hours. To validate GPS satellite orbits, the ultra-rapid satellite orbit solutions are compared to the rapid one and later to the final orbit products of the IGS, too. The derived precise orbit products enable us to include the newly available Galileo observations in the operational near-realtime GNSS processing system used for the estimation of atmospheric water vapor content in Hungary. These data sets are being used for improving the meteorological forecast of precipitation over the country.**

Keywords—precise orbit determination; GNSS; ultra-rapid orbit; orbit prediction

I. Introduction

With the development of Earth sciences and space research the demand has increased for the near real time precise satellite orbit determination. Many applications, such as gravity studies[1], Precise Point Positioning (PPP) [2] and GNSS-meteorology[3] require GNSS satellite positions with the accuracy of less than one meter. . For the majority of these applications, the post-processed rapid or final orbit products are not suitable due to their latency. To ensure cm level accuracy and real-time availability, firstly an orbit must be fit to the GNSS observation using the post processing technique, but it must be accompanied by an orbit prediction step for the next 24 hours to support real-time applications.

The types and characteristics of the orbit products determined by the International GNSS Service (IGS) can be found in Table I.

TABLE I. IGS ORBIT TYPES

Type	Accuracy(orbit, clock)	Latency
Broadcast	~100cm ~5.5ns	real time
Ultra-Rapid (predicted)	~5cm ~1.5ns	real time
Ultra-Rapid (observed)	~3cm ~50ps	3-9 hour
Rapid	~2.5cm ~25ps	17-41 hour
Final	~2.5cm ~20ps	12-18 days

One can observe in the data that there is no difference in the orbit position accuracy between the rapid and final solution, mainly the clock products improve significantly in the final products of IGS with respect to the rapid ones. Due to this fact and the need for realtime orbit products, the rapid orbit solutions were used as ‘a priori’ orbits in the orbit determination algorithm and later for comparisons in the validation phase.

The IGS provides near-realtime (ultra-rapid) orbits for GPS and GLONASS satellite systems [4], but for the Galileo satellite system similar products are not available. The Center for Orbit Determination in Europe (CODE) at the University of Bern provides rapid orbit solutions for GPS, GLONASS and Galileo systems, but ultra-rapid products are available for GPS and GLONASS only. Although the GeoForschungZentrum (GFZ) in Potsdam provided ultra-rapid Galileo orbits in the past years, this service was shifted recently to a spin-off of GFZ and is available as a subscription service at the GeoBM GmbH [5]. Thus we are not aware of any freely available ultra-rapid Galileo orbit products, that could be used for GNSS meteorology applications.

The purpose of this study is to develop an automated GNSS observation processing system to determine GNSS MEO (Middle Earth Orbits) and predict an orbit solution for an additional 24 hours for high-precision real-time and near-realtime positioning applications.

The paper is organized as follows. Chapter II introduces the observation network and the methodology of orbit determination and prediction. The developed processing system is tested using GPS, GLONASS and Galileo observations and the results are validated using rapid orbit solutions provided by CODE with the latency of approximately 2 days. Finally our results are presented in Chapter III.

II. Methodology

A. GNSS observations

Although Global Navigation Satellite Systems are continuously developed and new systems have been made available in the recent years, the full permanent network of the International GNSS Service could not have been upgraded to observe all the available signals up to now. Therefore, our first task was to check the availability of multi-GNSS signals (at least GPS, GLONASS and Galileo) in the IGS network.

The selection of the stations was done to fulfill the following requirements:

- the stations should provide a homogeneous geographical coverage;
- stations must provide hourly data sets reliably: since ultra-rapid orbit solutions should be updated 4 times a day and recent hourly data sets must be processed;
- availability of multi-GNSS observations (at least GPS, GLONASS, Galileo);

Although the IGS network consists of more than 400 continuously operating reference stations (CORS), only a subset of them log hourly multi-GNSS observations. After removing the stations too close to each other, finally 65 IGS stations were selected for our studies out of the original 91 stations (Fig 1).

The Bernese GNSS Software V5.2 [5] was used for our studies. Since this software is capable to process dual frequency GNSS observations, firstly the Galileo signals had to be selected. The E1 and E5a signals were used for this study to form dual frequency observations.

The orbit determination relies on accurate station coordinates in a common reference frame. Since only 40 out of the selected 65 stations were available in the most recent ITRF2014 solution, for the rest of the stations, the coordinates had to be determined using a 24-hour observation and precise orbit solutions provided be the IGS. Thus all the station coordinates were estimated with cm accuracy, that is suitable for GNSS orbit prediction. It must be noted that in the current study these station coordinates were heavily constrained. On a long-term, the coordinate estimations will be carried out on a daily basis with weekly combination. The weekly station coordinate solutions will enable us to consider station displacements in the ITRF2014 reference frame and maintain the consistency of the estimated orbit solutions at the same time.

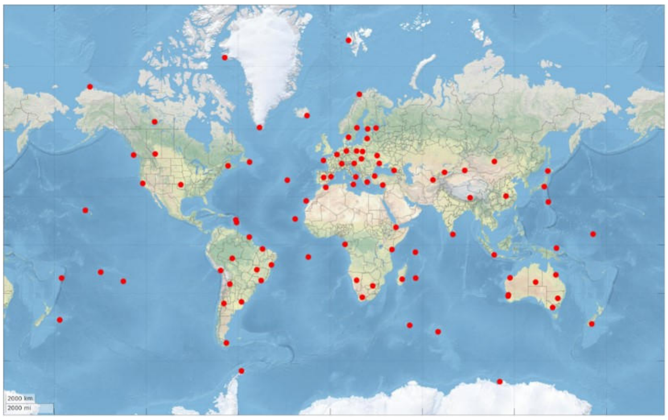

Fig. 1. The multi-GNSS network used for this study

In order to estimate precise orbits for the studied satellite constellations, a good ‘a priori’ orbit is necessary. Although each GNSS broadcast the satellite ephemerides in real time, these orbits are approximately 1m accurate. However, CODE provides rapid orbit solutions with the latency of 17-41 hours based on the processing of daily GNSS observation sets for GPS, GLONASS as well as Galileo. Thus we decided to use CODE’s rapid orbit solution as ‘a priori’ orbit for our studies. Due to the latency of this solution, the automatic data processing algorithm fetches the rapid orbit solution 2 days earlier with respect to the processed session and extrapolates the ‘a priori’ orbit for 48 hours to cover the observed period of the orbit determination process.

The orbit determination starts with a 6-hour batch processing of GNSS data. The receiver clocks are synchronized using code observations and the phase observations are screened for outliers. The orbital parameter estimation is done using the screened phase observations after the phase ambiguities are resolved for each baseline. The normal equations of the parameter estimation of each 6-hour-session are stored for the estimation of long-arcs in the second step.

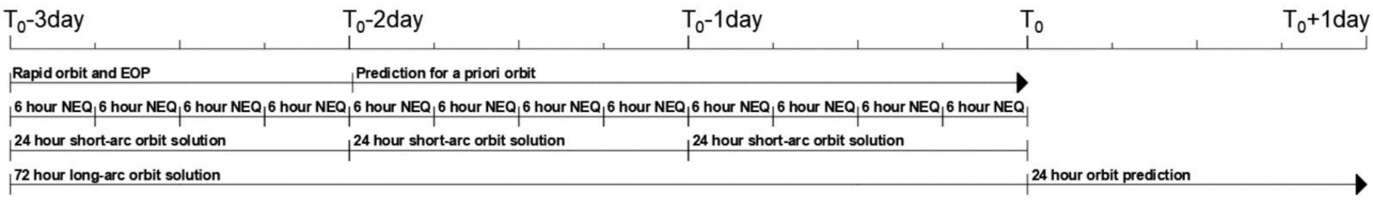

Fig. 2. Orbit determination and prediction timeline

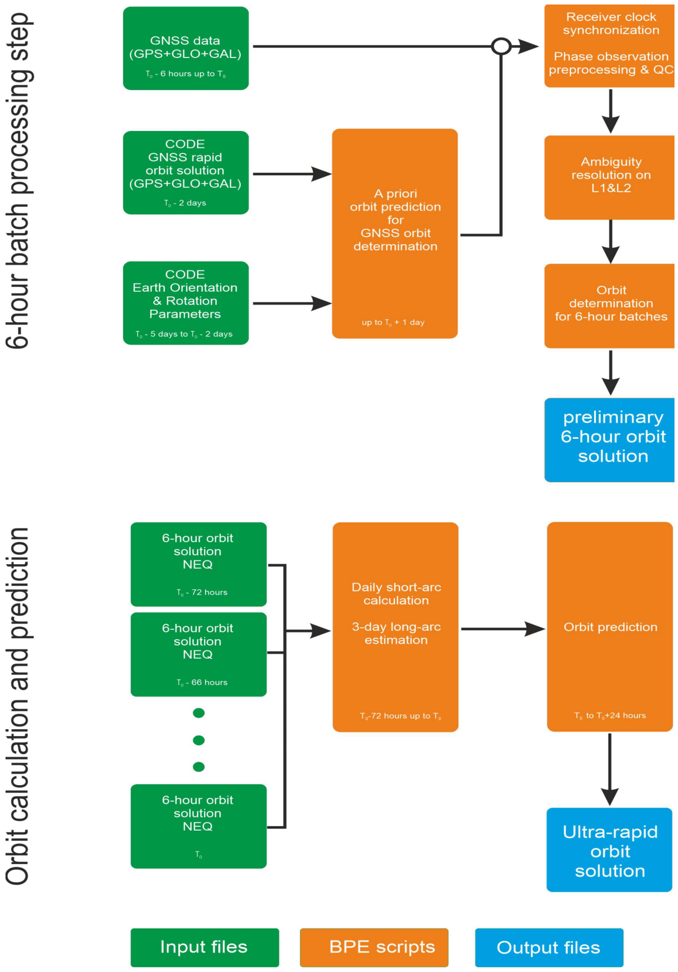

Fig. 3. Methodology – Bernese V5.2 processing algorithm using Bernese

Since GNSS satellites have the orbit period of approximately 12 hours, the normal equations are combined to estimate daily short-arcs. Afterwards these short-arcs are combined in a next estimation step to estimate the orbit parameters of long-arcs based on the daily solutions of 3 consecutive days. The estimated long-arc is used as the up-to-date orbit solution, since it contains all the available data from the past 72 hours.

In the orbit prediction step the long-arcs are extended to the next 24 hours to form the ultra-rapid orbit solution. Thus each orbit solution is derived using 3 days of GNSS observations and contains a predicted part for the next day to enable realtime and near-real time GNSS observation processing.

III. Results

The determined ultra-rapid orbit solutions has been validated with post-processed GNSS rapid orbit solutions provided by the IGS. As GPS, GLONASS and Galileo satellite orbits were estimated in our study, the residuals of the satellite positions for each constellation have been calculated for every 15 minutes for DOY 054.

Fig. 4, Fig. 5. and Fig. 6. show the differences of one satellite for all the three satellite systems with respect to the

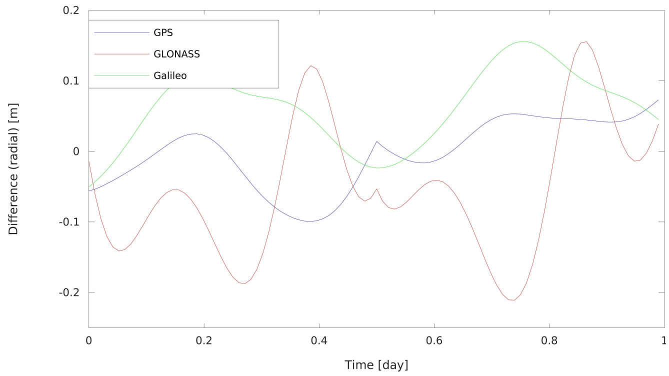

Fig. 4. Radial orbit differences between our ultra-rapid and IGS rapid orbit solutions for GPS, Glonass and Galileo SV01.

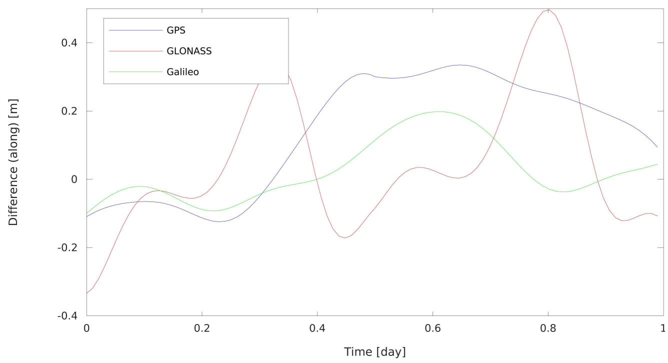

Fig. 5. Along orbit differences between our ultra-rapid and IGS rapid orbit solutions for GPS, Glonass and Galileo SV01.

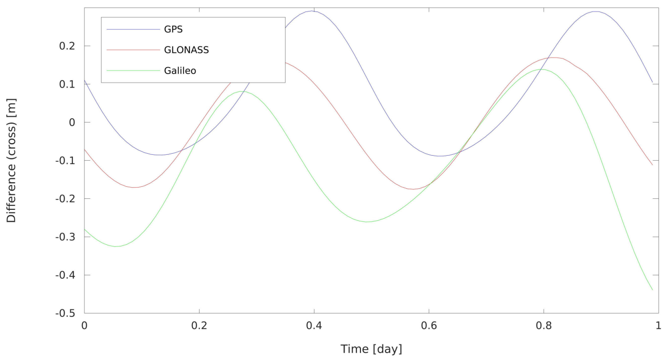

Fig. 6. Cross orbit differences between our ultra-rapid and IGS rapid orbit solutions for GPS, Glonass and Galileo SV01.

orbital coordinate system (radial, along-track and cross-track components).

Comparing the performance of the orbit determination for the different systems, one can recognize that the results for the Galileo satellite are more stable in the along-track component (Fig. 4.) than the other satellite systems. This might be explained by the more accurate satellite clocks on board the Galileo satellites. One can also observe the approximately 12 hour period of the satellites in the residuals. It is more prominent for the GPS satellite, but can be observed for the other constellations especially in the cross-track component (Fig. 6.).

In order to better assess the overall performance of the orbit determination, the mean and the root mean square (RMS) of the residuals were calculated for every satellite. These statistical parameters can be seen on the Fig. 7.

The mean of residuals are a few centimetres in the radial direction for each satellite, it reaches sometimes 25 cm in the cross direction and – mainly for the GPS satellites – even 60 cm in the along-track component. One can observe that the performance of GPS satellite orbit determination is significantly worse for the along track component than for the other satellite constellations. The clarification of this phenomena needs further investigations.

The root mean squares of the residuals show that the satellite orbits could be estimated with 10-15cm accuracy with respect to the rapid orbit solution. But even in this case some differences can be observed in the three coordinate components. Although the RMS in the cross-track direction is between 4-8 cm, it reaches 15-20 cm in the along-track component.

Comparing the derived Galileo orbit elements one can

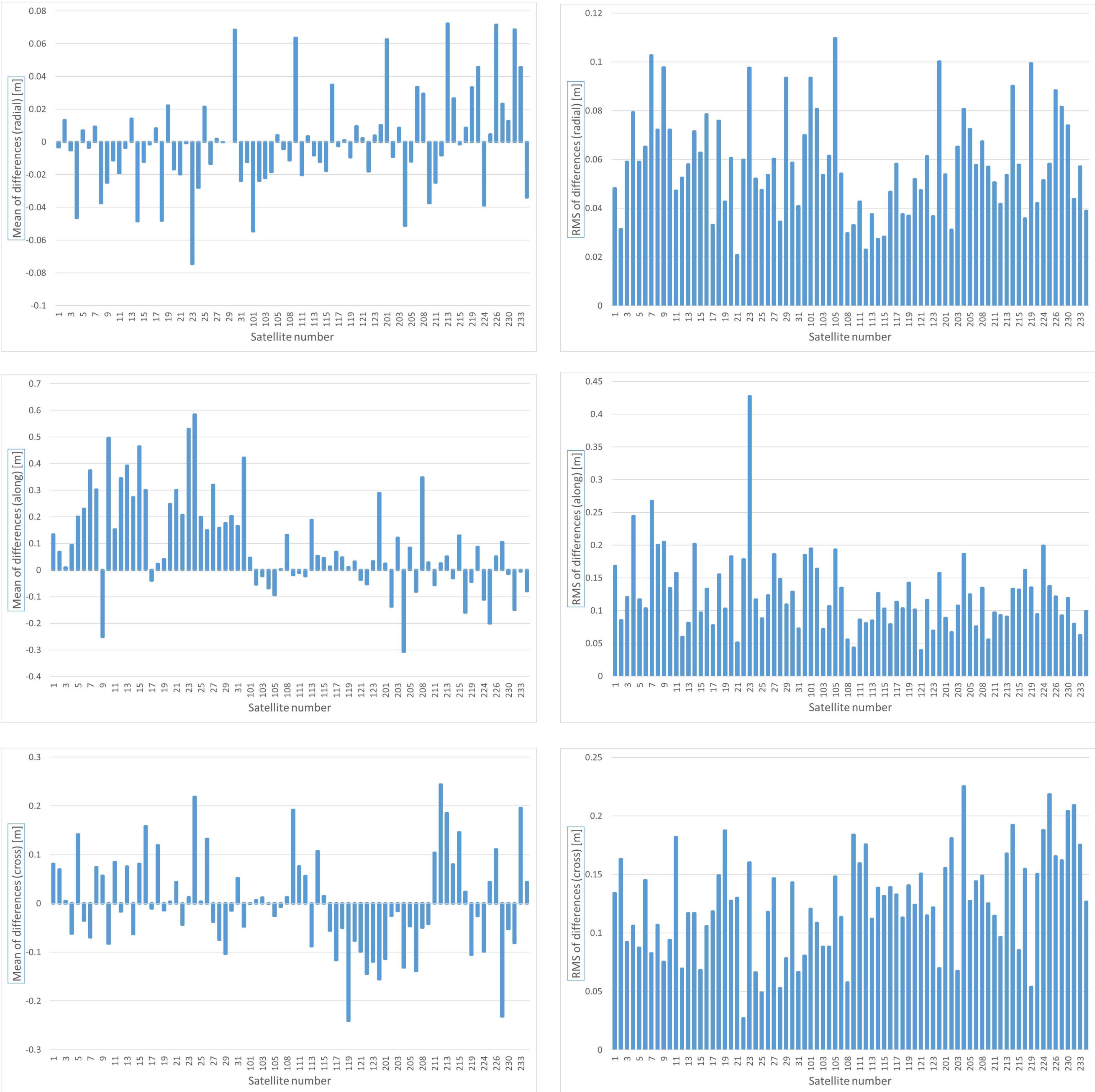

Fig. 7. Mean and root mean square (RMS) of differences for each satellites. Satellite number 1-99 are GPS, 101-199 are GLONASS and 201-299 are Galileo

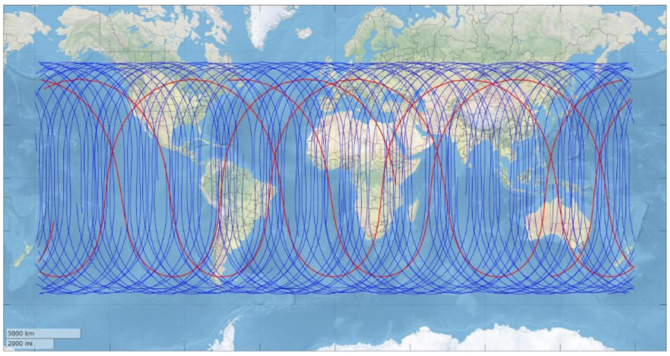

Fig. 8. Galileo satellites groundtrack (24 hours). Red satellite orbits are the two which are on eccentric orbits.

observe that there are 2 satellites located in an elliptical orbit (Fig. 8.). It is well known that during the third launch of Galileo satellites, Galileo 5 & 6 satellites were not placed in their expected orbit due to the failure of the Soyuz Fregat upper stage. The satellites were injected into a lower elliptical orbit instead of the higher circular orbit with only one of the solar panels deployed on the spacecraft.

After a series of orbit corrections, the satellites became available for the originally planned navigational purposes. The corrected orbits have approximately 1.600km lower altitude compared to the nominal orbit., while their orbit eccentricity is approximately 0.166 instead of 0.

Our results showed that despite the different orbits, the derived elements have comparable reliabilities to the satellites in the nominal orbits. The semi-major axis could be estimated with the accuracy of 1.7 and 1.9 centimetres using daily observations and similar accuracies have been observed for the other Galileo satellites (Fig. 8) .[9]

IV. CONCLUSION

According to results, we can state the daily orbit elements can be estimated with the accuracy of a few centimetres/decimeters depending on the satellite constellation. Nevertheless, the comparison with rapid orbit solutions shows that the residuals vary during the day in the magnitude of a few decimetres. A 12-hour period can be clearly identified in the residuals.

Based on the RMS and the bias of the residuals it can be stated that the resulting orbits are less accurate than the IGS specifications. This can be mainly explained by the limited number of multi GNSS stations in the IGS network. Nevertheless, the derived orbits are suitable for several real-time and near-realtime applications, like GNSS meteorology. Thus, the developed orbit determination technique provides a good foundation for the inclusion of Galileo observations in the estimation of zenith wet delays and atmospheric water vapour in Hungary.

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