Rivista bimestrale - anno XXII - Numero 3/2019 - Sped. in abb. postale 70% - Filiale di Roma

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GEO MEDIA

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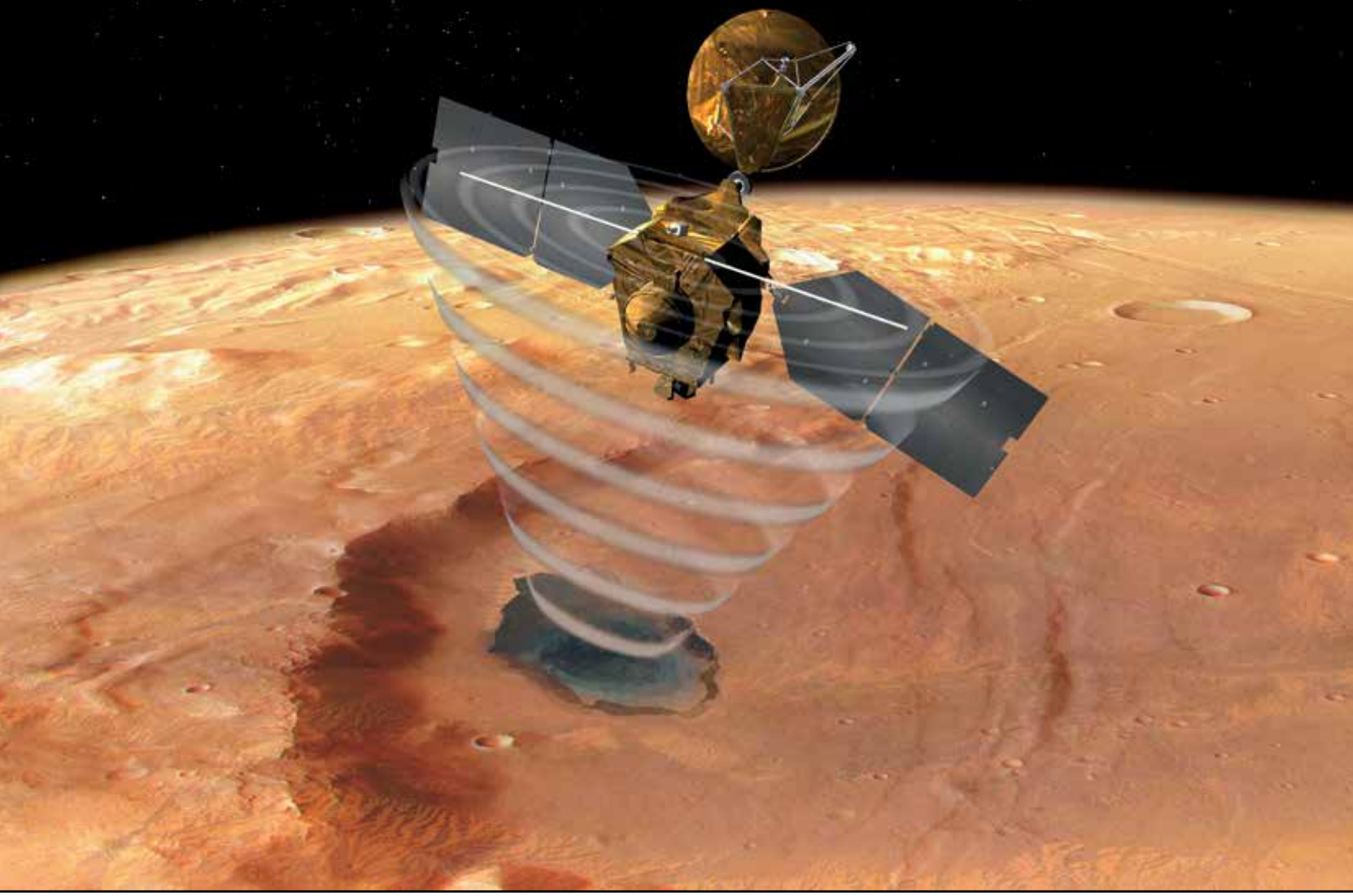
Solar System
from Mapping to Prospecting



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Terrestrial and extra-terrestrial geomatics

Spatial data for the management of structures and buildings are of vital importance for decisions relating to our future. In the next edition of INTERGEO 2019 in Stuttgart, the quality of urban life and the development of rural areas in the long term will be key topics, since they are embedded in the political and social debate of the moment.
A special focus of INTERGEO this year will be the spread of digital technology in mobility and construction, in Smart Cities, Survey, Laser Scanning, Building Information Modeling (BIM), Unmanned Aerial Vehicles (UAVs) and Virtual, Augmented or Mixed Reality. All topics where spatial data are essential.

But what about the future possible life outside the Earth?
Fabrizio Bernardini in the Focus of this issue "Exploring the Solar System: from mapping to prospecting" draws a picture of the situation of the cartography of the planets hoping for future simpler and faster missions. The results of these missions will allow creating resource maps that will guide the selection of landing sites. A next step that is not too far as many would like to think.

Examples of specific in-depth studies are not lacking, such as the geological mapping that requires the combination of many different characteristics of the rock sequences studied. This including lithology, stratigraphy and structural deformation to reconstruct the variation of environments and climates over time. The standards of planetary cartography have been associated with principles defined in the 1970s during the Apollo missions, while recently the need for new cartographic guidelines emerged in the light of progress in understanding the geological processes that shape planetary surfaces.

And this is what the Report from Marco Pantaloni, Roberto Graciotti, Lucia Marinangeli and Matteo Massironi "Revising the geological mapping of Mars", tells us from the networks of scientific institutes and many Universities involved in a pilot project to apply the rules of the cartographic standards used in the Italian Geological Cartography Project for the realization of geological and geomorphological maps in a planetary environment.

GNSS Radio Occultation for weather prediction is the theme of the report from Guillermo Bosch that will tell us about a well-proven technique that goes back to the mid-1960s when the satellite Mariner IV transmitted data while it was approaching Mars.

Marco Lisi from Santo Domingo, Dominican Republic, will report on how Galileo and Copernicus are not only flagship technology programs of the European Union, but they can be considered the ambassadors of European cooperation in other continents.

The Low Altitude Airspace and the new business dimension is the report from Chiara Mozzetti and Alberto De Vitis of Aiviewgroup, highlighting the great emerging opportunity for many companies.

Enjoy your reading,

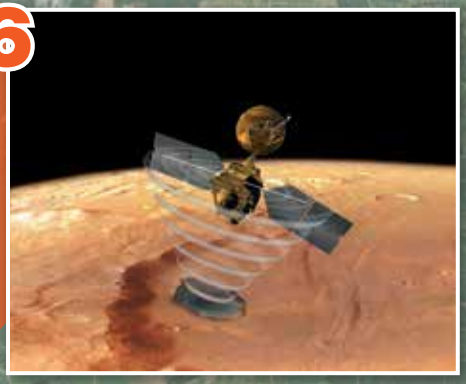
Renzo Carlucci

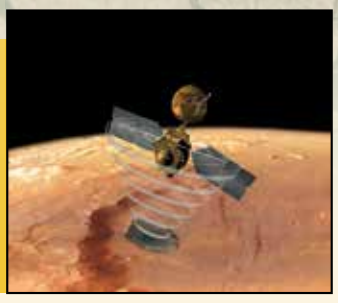
In this issue...

FOCUS

REPORT

COLUMNS





On the cover a pictorial view of Mars Reconnaissance Orbiter using the SHARAD Radar Image Courtesy NASA/Jet Propulsion Laboratory-Caltech.

GEOmedia
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GEOmedia, published bi-monthly, is the Italian magazine for geomatics. Since more than 20 years publishing to open a worldwide window to the Italian market and vice versa. Themes are on latest news, developments and applications in the complex field of earth surface sciences.
GEOmedia faces with all activities relating to the acquisition, processing, querying, analysis, presentation, dissemination, management and use of geo-data and geo-information. The magazine covers subjects such as surveying, environment, mapping, GNSS systems, GIS, Earth Observation, Geospatial Data, BIM, UAV and 3D technologies.

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The image on the background is a Copernicus Sentinel-2 over palm oil plantations in East Kalimantan - the Indonesian part of the island Borneo. In this image, captured on 15 February 2019, the various stages of the deforestation process are clearly visible on the green patches in the plantations are the well-established palm oil farms, while the light brown patches show the newly harvested land. The surrounding lush rainforest is visible in dark green.
Copernicus Sentinel-2 is a two-satellite mission, used mostly to track changes in the way land is being used, as well as monitoring the health of vegetation.
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ISSN 1128-8132
Reg. Trib. di Roma N° 243/2003 del 14.05.03
Stampa: SPADAMEDIA srl
VIA DEL LAVORO 31, 00043 CIAMPINO (ROMA)
Publisher: mediaGEO società cooperativa

mediaGEO
Science & Technology Communication

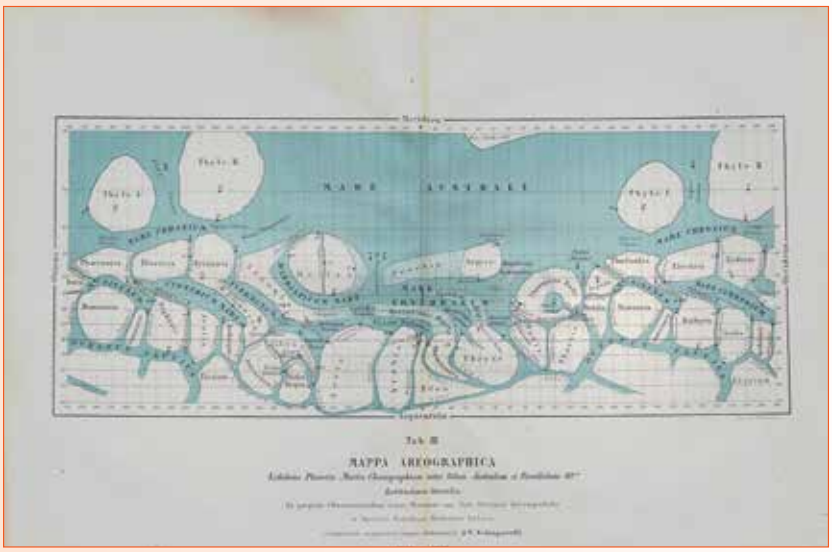
Paid subscriptions
GEOmedia is available bi-monthly on a subscription basis. The annual subscription rate is € 45. It is possible to subscribe at any time via https://geo4all.it/abbonamento. The cost of one issue is € 9 € for the previous issue the cost is € 12 € Prices and conditions may be subject to change.

Magazine founded by: Domenico Santarsiero.

Issue closed on: 20/08/2019.

Exploring the Solar System: from mapping to prospecting

by Fabrizio Bernardini, FBIS



The Italian Giovanni Schiaparelli, astronomer and engineer, in the second half of the 19th century drew the maps that assigned, to features he could barely detect, the names we are still using today. (Map is reversed, with south at the top).
Credits: INAF Osservatorio Astronomico di Brera, Biblioteca, Foto: Mario Carpino. The assistance of Agnese Mandrino is gratefully acknowledged.

Solar System exploration is changing, opening the field to prospectors and then miners after a long phase of mapping. This is a process we have already seen many times on our planet, but for the first time in human history we are witnessing a revolution that hold the keys to a new frontier outside the boundaries of our planet.

There has been a first revolution when humankind started exploring the solar system sending automated emissaries, also known as deep space probes, to the Moon first and then the other main celestial bodies that orbit the Sun. After the first attempts at the very dawn of the space age, attempts which produced grainy images and few precious amounts of data, we had a steady increase in the return of science data, with larger missions until we sent flagship missions to orbit Mars, Jupiter and Saturn, with landers on the Moon, Mars, Titan. And then, other orbiters around Venus, Mercury and even to comets and asteroids: many missions that helped characterize our Solar System from Mercury and way beyond Pluto.

From planets to places

All these missions are associated by a common science goal, that to explore to improve our science knowledge (many models were based only on the Earth) and to better understand the evolution and the possible futures of our Solar System. These missions, however, also achieved an important practical result, transforming far worlds from astronomical targets into places. Wherever and whenever humans have explored, they first traced the boundary of the land, then the contours of the topography, while at the same time giving names to features: this is called mapping. Mapping is essential to continue the exploration, but also as an aid to describe the characteristics of a new territory. The names on the maps will be foreign ones initially, but soon they will have a very practical sense when resource exploitation or the establishment of settlements will take place.
In the Solar System, we have done the same: we have pictured distance planetary bodies, we have established a reference system, and then we have mapped the surfaces and the topography giving names to outstanding features and regions. What we have been doing since the very first deep space probes started exploring, has been transforming planets in places.

From science to resources

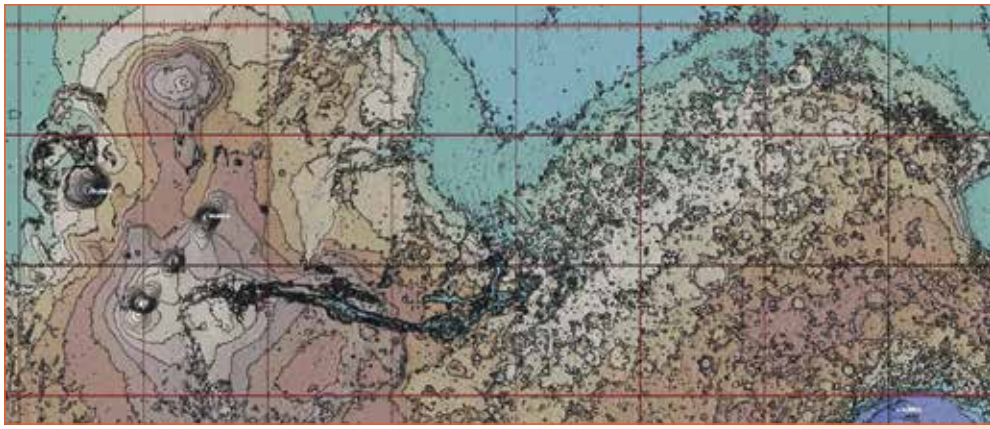
The tools available to the researcher are more complex than just simple images. Even images are studied at pixel level, considering the characteristics of the light received by the detectors, to extract, or infer, additional data from them. More than just visible imagery, we have seen the importance of other instruments, like spectrometers, able

to discern the chemical composition from a distance, and sounding radars that provided incredible results, as on Mars, with the detection of underground features not otherwise discernible from the orbit, and even from a rover. Variation detected in the radio waves for communications, helped understand the inner structure of distance bodies with important clues about subterranean oceans and other features. The collection of all this data has enabled a better understanding of surface conditions and characteristics, and particularly its composition.

The amount of data collected on specific planetary bodies, like the Moon and Mars, has reached such a volume that is transforming our use of the same data. While science data collected so far can keep planetary scientist busy for many years to come, the realization that we can now draw map of minerals and other resources with unprecedented precision, has opened an entire new avenue of applications. In fact, after more than 50 years of Solar System exploration, we are now approaching a second revolution: the shift from mapping to prospecting, that is looking for, and quantifying, the available local resources. And the resources looked for are those specific ones that will be able to support a permanent human presence on other worlds.

In order to facilitate the next steps in human exploration of the Solar System, we need to start building new deep space probes that will have a focus on local resources characterization. Technically speaking, these will not be much different from science-oriented missions, but practically speaking they will be cheaper and quicker to build and their operations will be initially constrained to reduce the uncertainties in specific areas of a planet. In this respect, it will be not necessary to design a spacecraft to explore for many years a whole planet, but limit its performances to the achievements of resource-driven goals, at least for the main part of its mission.

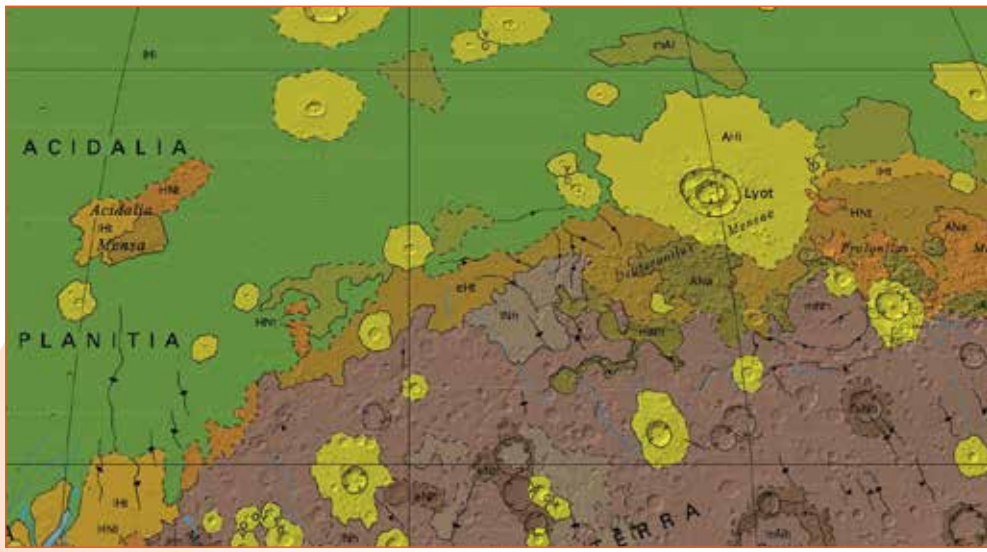
Prospecting missions can be designed for specific kind of resources, like a better characterization of water ice deposits on Mars (or finding better proof of the elusive water ice traces on the Moon), while others can target the composition of surface materials. Smaller, specific, missions mean also an increase in operational flexibility, also for what regards simplifications in the communications and propulsion needs, and will be characterized by a high level of autonomy, to reduce ground operations costs substantially.



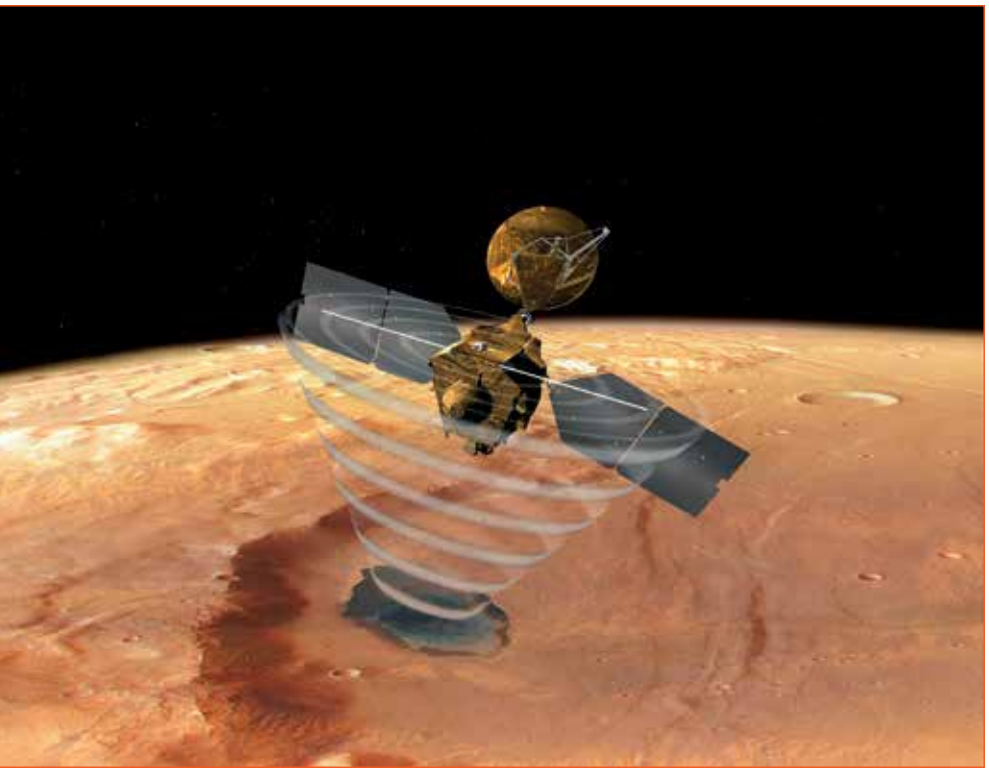
The Mars Orbiting Laser Altimeter provided enough data points to create full topographic maps of Mars of unprecedented accuracy (on a global scale) in the whole Solar System, the Earth included. MOLA data are the basis for innumerable analysis and also to enable science investigations with other instruments.
Credits: Color-Coded Contour Map of Mars, 2003, US Geological Survey Astrogeology Team

Mars as a case in point

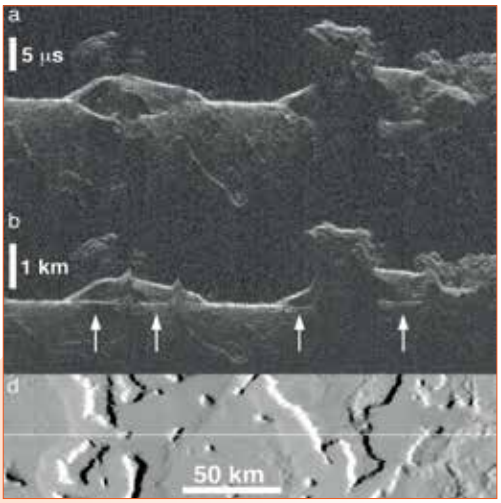
Going to another world and li-



The recently released new geological map of Mars integrates many layers of information from Viking to the most recent missions. It can be considered the basis cartographical product for a future Mars resources map based on existing and prospecting missions data.
Credits: Geological Map of Mars, 2014, Tanaka et al., US Geological Survey Astrogeology Team



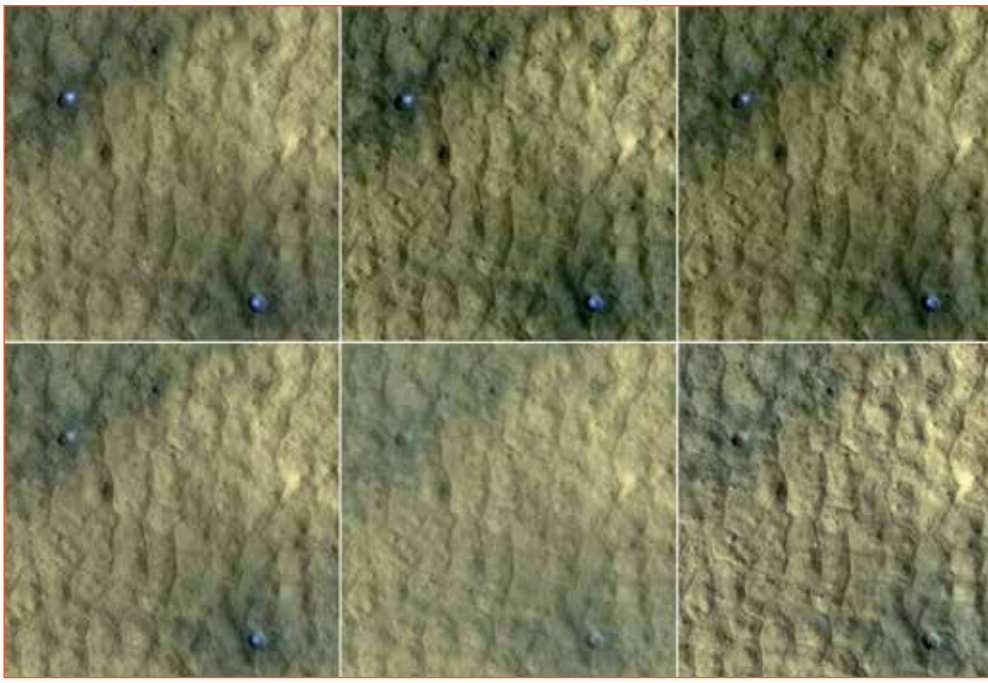
NASA/JPL flagship orbiting mission around Mars, is providing since 2006 and incredible quantity of data thanks to its powerful instrument and its very high performances communications system. It is also a key element for landed asset, as it is their main relay platform to Earth. University of Arizona HiRISE camera, the Italian SHARAD sounding radar, and all other instruments, have transformed the way we see and understand Mars and its resources.
Credits: NASA/JPL-Caltech



The discovery of debris covered glacier is entirely due to radar sounding techniques. Water ice is invisible at SHARAD frequencies and assuming its presence the radargram in (a) has been corrected for the dielectric constant. The correction produced a flattened bottom of the glacier coherent with the rest of the plain. There are hundreds of similar features in the same area with an average thickness of 450 meters of 90% pure ice.
Credits: NASA/JPL

ving there off local resources has always been a theme very dear to science fiction and to space exploration visionaries. The concept is sound, but in practice too many unknowns prevented transforming these visions into reality. Until now. Despite the recent talks and actions toward establishing a more permanent human presence in lunar orbit, and maybe even on the surface, the reality is that lunar resources are still a big unknown. Water ice is a major factor for human exploration, and as of today there is not a single paper that clearly identifies a Moon ice deposit with some hope of being accessible for extraction. Mars on the other hand, is a completely different story. Mars is the best-known planet of the Solar System (after the Earth) in the sense that its topography is better known that Earth's (because of the lack of oceans). We have landed in different zones of the planet and many missions are orbiting it. A small fleet of more missions is expected to reach Mars in the next two years, turning its orbital environment the busiest (after Earth's of course) in the Solar System.
What it is not well perceived by the general public, is that Mars is extremely rich in the most important resource for space exploration, which is of course water ice. And we are not talking about the polar caps, we are talking of vastly abundant reservoirs of water ice, in multiple zones of the planet, and in particular at those latitudes that are of particular interest for human exploration.
Italian-built sounding radars, and in particular SHARAD on Mars Reconnaissance Orbiter, have unlocked the knowledge of these water ice deposits.
Of primary importance is the discovery, in 2008, of large debris covered glaciers concentrated in mid-latitude zones like Deuteronilus Mensae and Hellas Basin. These glaciers, composed of 90% pure water ice, have been mapped to reach a current estimate (which is growing) of 400000 cubic kilometres of ice, available over the surface. Other glaciers, in less practical areas have also been found, while it is known the presence of multiple layers of water ice in the polar caps.
Radar data studies also provided strong evidence to support that the soil of northern plains, like Arcadia and Utopia, is mixed with water ice. In Arcadia, there are evidences of ground ice down to about 40

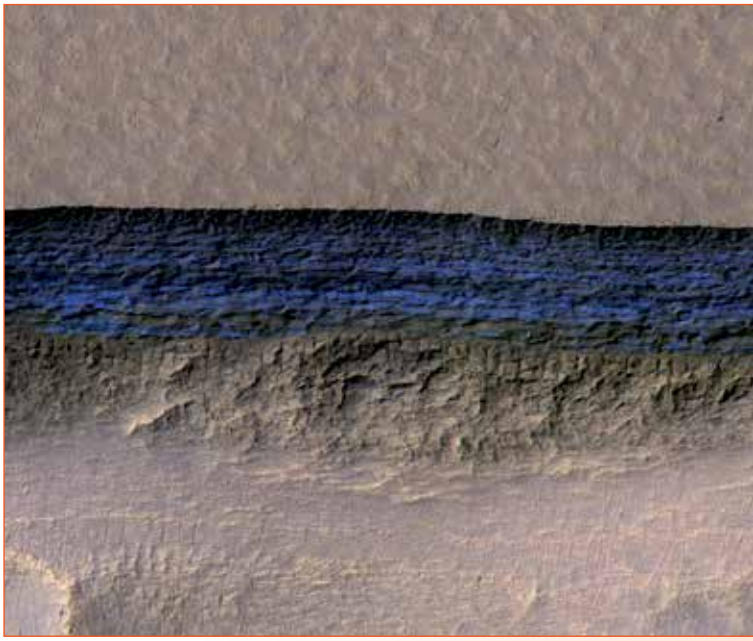
meters, in an area about 1 million square kilometres in size. In Utopia, soil characteristics provided clues for another 14000 cubic kilometres of ice underground. And if in these cases radar data are not enough convincing, there are also images from the powerful HiRISE camera on MRO, that has pictured both ice exposed after meteoroids impacts and effects of melting ice on cliffs and slopes. Of the many high-resolution pictures provided by MRO, one of the most spectacular one is that of a scarp in which underground ice layers are clearly exposed and the presence of ice can be seen just one meter below ground.
NASA's SWIM study, carried out by the Planetary Science Institute, is integrating neutron data, thermal data and radar data to complete a mapping of water ice resources in shallow (< 5 meters) and deep (> 5 meters, down to 100) zones. While the interpretation of resulting "data sets is to a degree subjective and does not lend itself to precise calculation of probabilities" but the "identification and mapping of ice is warranted and highly desirable for planning future landing sites that rely on the presence of ice for resources".
This study, like the ongoing ones for the characterization of Mars resources (thanks also to the rovers that crawled over its surface determined that many useful minerals are available, complementing the data of spectrometers flown on various orbiting missions) have a clear accent on the implications that the results will have for the human exploration of the Red Planet.



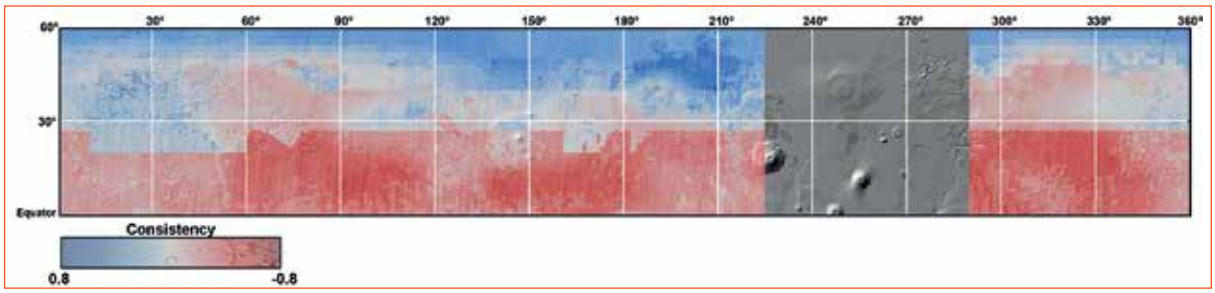
The occurrence of new meteoroid impact craters on Mars, monitored continuously by MRO CTX and HiRISE cameras, provided clues about ground ice just below the surface in many regions. In this sequence it is seen that exposed ice is seen dissipate slowly via sublimation processes, confirming its nature.
Credits: NASA/JPL-Caltech/University of Arizona

Conclusions

What about the other "places" we have identified in the Solar System? An extensive mapping of asteroids is in the agenda also of private entrepreneurs while NASA is now focusing its objectives on the Moon, despite its evident shortcomings in term of easily available resources. The search for life has found new hope in the Jovian moon Europa (even if the Mars discoveries may shed new light in this same arena), while also Titan is on the list of the most interesting places of the Solar System (thanks again also to Italian instruments and science).
Do we still need pure science



In both Mars hemispheres, steep scarps gave evidence of layers of underground water ice in the proximity of the surface. It is estimated that one third of Mars surface contains shallow deposits of water ice in the ground.
Credits: NASA/JPL-Caltech/University of Arizona



Current status of SWIM study (https://swim.psi.edu) points at the abundance of water resources in the northern hemisphere of Mars by combining results from multiple sensors. Mars can provide many resources to support human exploration, but in particular it has an unbelievable abundance of the most critical of all resources: water. An abundance of water means the ability to create breathable air, manufacture propellants, grow crops and of course enable many other activities, simplifying and improving the living conditions of the settlers.

missions to explore the Solar System? Yes, but it is also time to think more about simpler, quicker, prospecting missions. Mapping the results of these missions will permit creating the resource maps that will guide the selection of landing sites and that the first settlers will use to find them. That step will be the next revolution: extracting and processing the resources, a next step that is not too far as many would like to think.

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KEYWORDS

Solar System; Mapping; Mars; Sharad

ABSTRACT

Solar System exploration is changing, opening the field to prospectors and then miners. This is a process we have already seen many times on our planet and for the first time in human history we are witnessing the revolution that hold the keys to a new frontier.

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Revising the geological mapping of Mars

by Marco Pantaloni, Roberto Graciotti, Lucia Marinangeli, Matteo Massironi

The geological map is a unique graphical tool that summarises through colours and symbols, the complex evolution of a planet. It requires the combination of many different characteristics of the studied rock sequences including lithology, stratigraphy and structural deformation to reconstruct the variation of environments and climates through time. Although based on the same basic principles as on Earth, planetary geological - geomorphological mapping has some peculiarities which need to be addressed in order to standardize the technical and scientific approach.

The standards of planetary cartography have long been based on principles defined in the 1970s during the Apollo missions, while recently it is emerged the need to develop new cartographic guidelines in the light of advances in the understanding of geological processes that shape planetary surfaces. Furthermore, the plethora of new data derived from recent space missions and the possibility of identifying resources to be used in situ in view of permanent stations on the Moon and eventually Mars accentuate this need. This was recently faced by the USGS, which since the Apollo Era has continuously produced geological mapping of the surfaces of other planets and by a network of European scientific institutes involved in the pilot project H2020-PLANMAP (https://planmap.eu/).

In this framework, the Geological Survey of Italy, ISPRA, recently started a collaboration with the Italian Space Agency (ASI), the National Institute of Astrophysics (INAF) and the Universities of Chieti, Cagliari, Naples Federico II, Padua, Perugia and Jacobs University of Bremen. The aim of the project is the attempt to apply the cartographic standards rules used in the Italian Geological Mapping Project (CARG Project) for the realization of geological and geomorphological maps at various scales of detail even in the planetary environments. Thanks to the excellent coverage of high-resolution images of HiRISE (High Resolution Imaging Science Experiment) and the availability of medium and high resolution DTMs of some specific sectors of its surface, the applicability of the cartographic guidelines, published by the Geological Survey of Italy in the "Quaderni" series (http://www.isprambiente.gov.it/it/progetti/suolo-e-territorio-1/progetto-carg-cartografia-geologica-e-geotematica/linee-guida), is being tested. In this preliminary phase of the work, has been tested the production of geological and geomorphological maps of some sample areas of planet Mars.

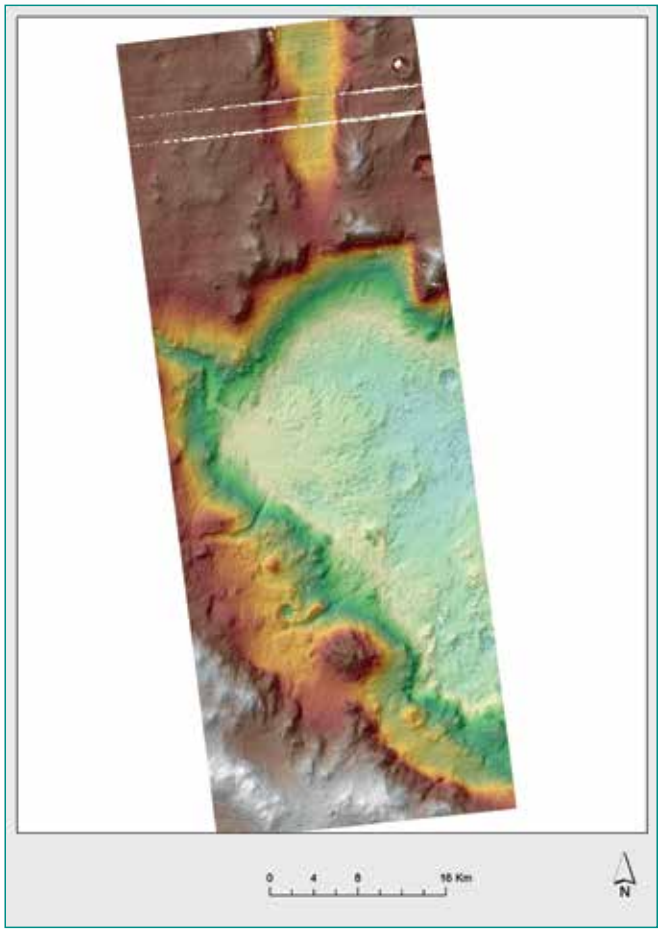

Fig. 1 - Topographic map of the western part of Eberswalde crater on Mars, chosen as a test area for the object of this study

The standards of planetary cartography have long been based on principles defined in the 1970s during the Apollo missions, while recently emerged the need to develop new cartographic guidelines in the light of advances in the understanding of geological processes that shape planetary surfaces. The plethora of new data derived from recent space missions and the possibility of identifying resources to be used in situ in view of permanent stations on

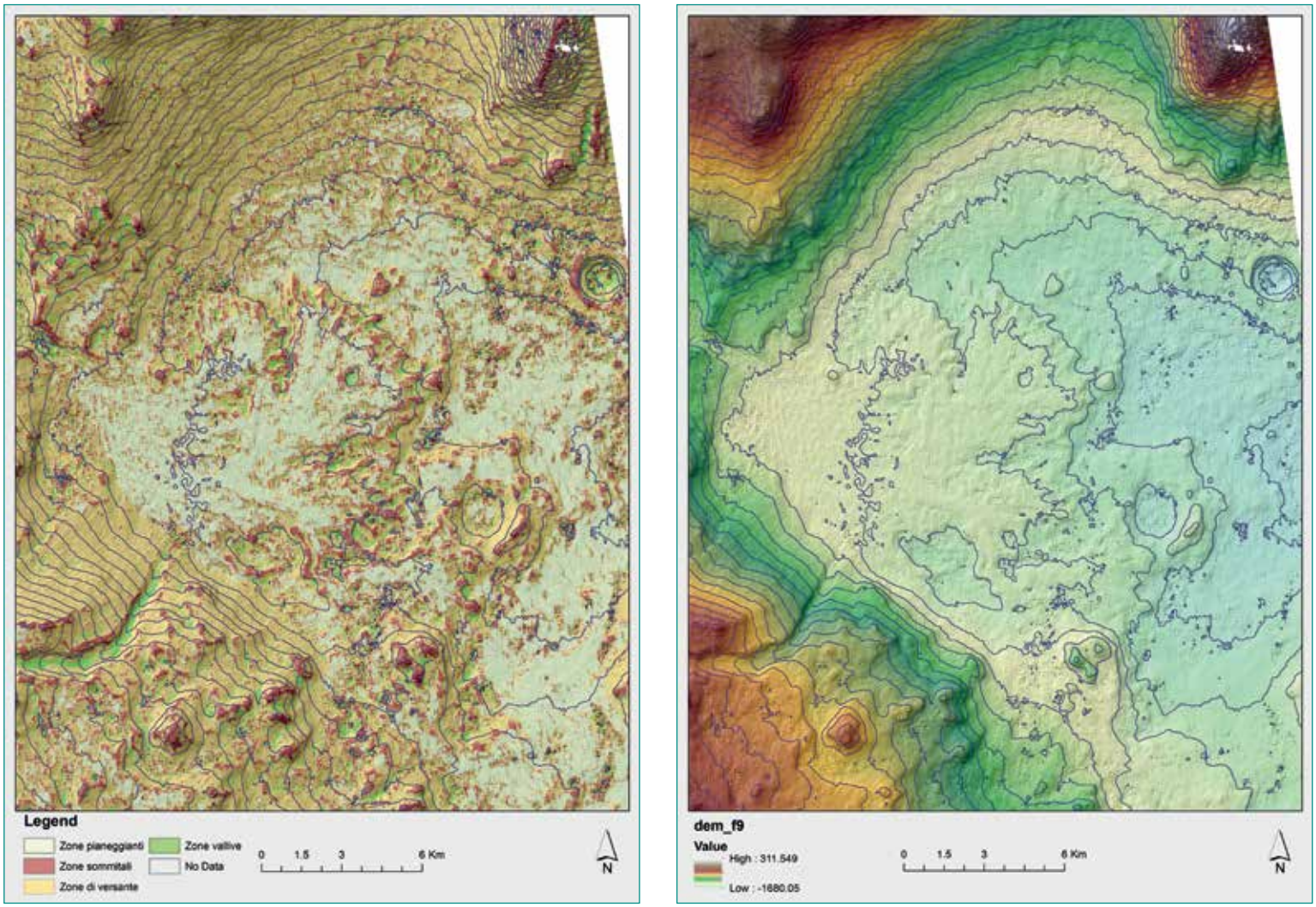

Fig. 2-3 - Thematic maps of the selected test area with slopes, exposure and landforms units

the Moon and eventually Mars accentuate this need. While USGS has been the reference for geological mapping and cartography of the surfaces of other planets, a network of European scientific institutes involved in the pilot project H2020-PLANMAP is aimed to define new rules for updating these products.

In a first experimental phase, the prototype area of the Eberswalde crater on Mars (Fig. 1) was chosen due to its great variability of forms of erosion and demolition and the conspicuous reference literature. It was possible to verify that some forms, morphostructures and depositional facies present in this area of the red planet are, in some ways, similar to those observed on Earth.

In planetary science, as well as in earth science, the geological map represents the most objective synthetic product; in it, the different rock units are distinguished based on observable physical parameters: texture, colour, sedimentary structures and geographical distribution. The stratigraphic relationships between the units are evaluated by applying the classic principles of stratigraphy used in the terrestrial environment, even if, sometimes, these principles do not seem to fully respect the extra-terrestrial geological dynamics. Moreover, the geological and geomorphological analysis carried out in the Martian area shows that geological units could be interpreted in terms of depositional environments, even if any change in genetic interpretation would not result in a change in representation in the geological map.

Planetary geological mapping is deeply linked to the availability and quality of data (resolution of images and DTMs, availability of spectral and elemental composition data, etc.), which implies great differences in the potential of the analysis between different planets but also between different parts of the same planet. Moreover, the presence of direct surface analyses

Some peculiar landforms of Mars

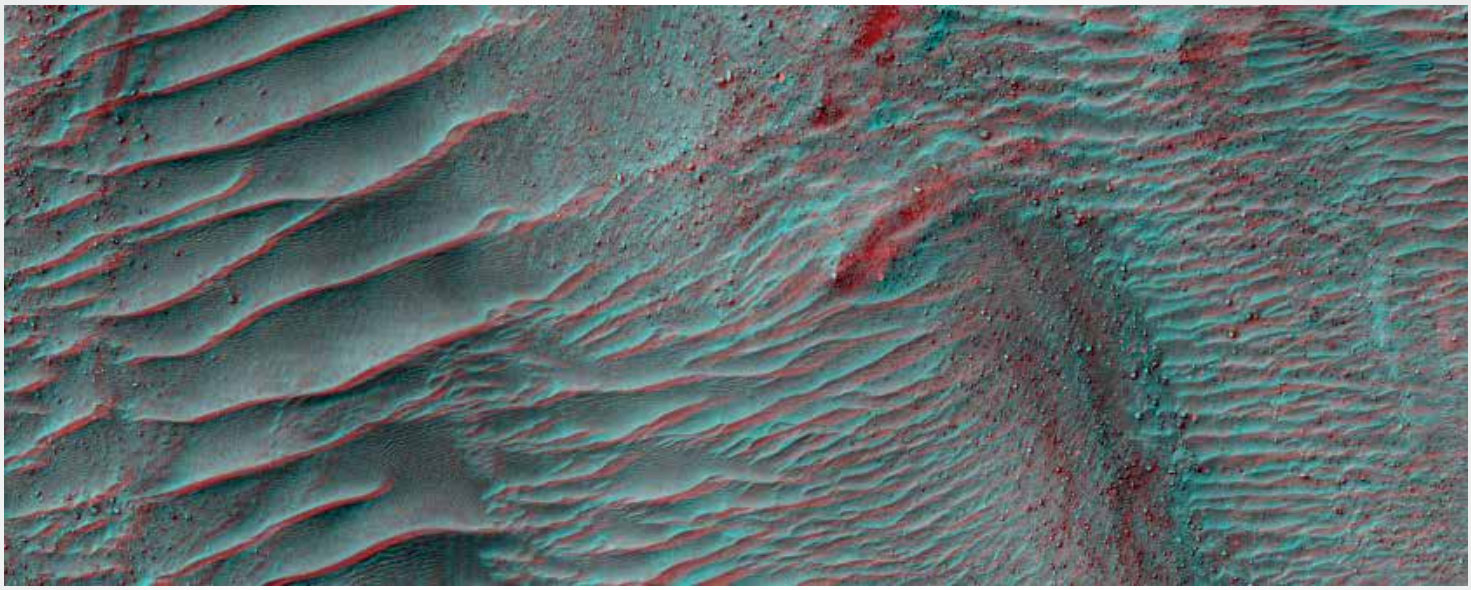

Fig. 4, 5 e 6 - The images show peculiar forms defined in literature as TARs (Transverse Aeolian Ridges). These forms are typical and very common on Mars; TARs are found in the flat bottom of craters, along the base of canyons, on large flat surfaces and at the base of vertical scarps. TARs are characterized by a great variability in their geometry (maximum ridge height, average height, wavelength, slope of the surfaces, etc.). These shapes vary in dimensions but above all very peculiar lateral contacts characterized by sudden transitions between morphotypes dissimilar in size. The direction of alignment of the TARs, on the other hand, is quite constant. Image credits: NASA/JPL/University of Arizona

Fig. 7 - This image shows a series of landforms that seem, at a first sight, similar to casting phenomena due to gravitational morphogenetic processes as on Earth. It is not possible to establish the exact origin of this phenomena (debris flow, mud flow or earth flow) not knowing the granulometry of the deposit and the density of the flow. As for the Earth landforms, also in this case we can identify a detachment zone, a transfer zone and an accumulation area. The flows seem to originate at the edge of the crater. The flows transfer zone follow a straight line, while it seems that the deposit expands in the accumulation area in peculiar lobed forms. Image credits: NASA/JPL/University of Arizona.

is only rarely available, with the exceptionof in situ landing and rovering missions on the Moon and Mars.
Regarding Mars, geological mapping is essential for the identification of landing and trafficability sites as well as to define the exploration areas for landers and rovers.
The geomorphological analysis and the related cartographic representation of the main forms of erosion and accumulation are based, in principle, on the same techniques and methodologies used for the geomorphological representation of landforms in the terrestrial environment.
Exceptions are the surveys on deposits associated with the forms of accumulation that require the collection of a series of specific data (grain size, texture, sedimentary structures, etc.) difficult to detect by remote observation techniques.
The development phases of the project start with the photo-interpretation of the available high-resolution images followed by the creation of DTMs as much detailed as possible and, finally, the production of thematic maps (slopes, exposure, basic topographic units, etc.). The data thus acquired and the morphometric analysis of the forms, carried out through the study of topographic profiles and the evaluation of the geometric relationships of the observed morphotypes, could help in understanding which have been in the past and which are currently the main processes and morphogenetic agents that have shaped the landscape of Mars.

Final remarks

This project involves different professionalities: geologists, geomorphologists, astronomers, physicists, chemists and mathematicians; the contribution of the Geological Survey of Italy is to adapt and update the cartographic protocols guidelines, developed for the cartographic representation of the Italian territory, to make them applicable to the production of geological - geomorphological maps of pilot areas of planet Mars. This contribution aims to expand the geological and cartographic information by including genetic considerations not currently provided by existing USGS

KEYWORDS

PLANETARY MAPPING, GEOLOGICAL MAPPING, MARS, GEOLOGICAL SURVEY

ABSTRACT

Planetary geological-geomorphological mapping has some peculiarities which need to be addressed in order to standardize the technical and scientific approach. The aim of this project is the attempt to apply the cartographic standards rules used in the Italian Geological Mapping Project (CARG Project) for the realization of geological and geomorphological maps at various scales of detail even in the planetary environment.

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This activity is also supported by the Planetary Geology Division of the Italian Geological Society.

Low Altitude Airspace: how Enterprises discover a new business dimension

by Chiara Mozzetti, Alberto DeVitis

Enterprises can offer new solutions and services in Low Altitude Airspace, as well as develop innovative business models. Drones will be used for Company needs but will also be a tool to develop new revenue. Enterprises will use powerful software platforms to manage fleets and enhance their assets and data.

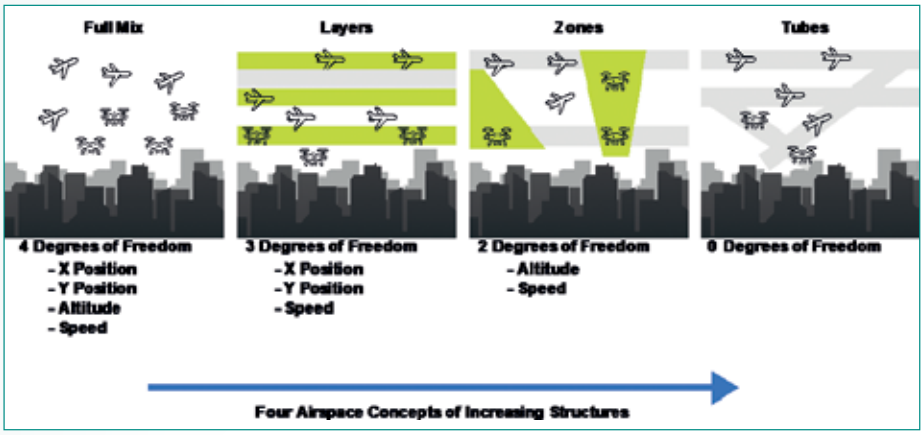

Fig. 1 - LAA – Four different concepts for Low Altitude Airspace access

There is a dimension of space, which surrounds us, that we are only now seeing through different eyes. Space that wasn't considered an asset or interesting by our communities.
On one hand, we have common human activities that take place on land; there are streets, shops, factories and fields. Whereas in the skies above us there are other activities and objects; airplanes, helicopters and satellites. There is a forgotten no-mans-land between these two dimensions; an uncharted place that is sparsely populated and underused even though it is so close to us.
Low altitude airspace is a thin shell that encloses our atmosphere, which goes from the ground up to 150 meters high.
In the past few years, intelligent and efficient objects have started moving around this space; at first out of curiosity or as a game, and later on with more challenging goals.
The great advancement of unmanned technologies, of drones, has suddenly changed our perspective. We have started to examine this new world as explorers. It's a new resource we can use, render safe and accessible, in which we can develop knowledge and activities.
Terra incognita. As for all new discoveries, we found ourselves having to address queries that all colonizers must face: who can enter the space and when? What are the rules? Will we plan-out routes? Will people be charged for access? We will need staging posts, energy posts and an efficient communication system. A long list of things to do, of things to learn, of great new opportunities.

UTM/U-Space

This new space borders and interacts with a more populated and regulated space that has already had to deal with, and solve, security and disciplinary issues. Civil and military aviation have existed here for over a hundred years developing a great set of regulations and standards. Low altitude air space must co-exist with this world and its rules; merging and integrating with it.
Now that our space, the LAA, is occupied with thousands of objects, guaranteeing coexistence with previous occupants such as airplanes, rescue vehicles and

recreational aviation becomes fundamental.
This required the merging of unmanned systems and drones, with manned Traffic. The UTM (Unmanned Traffic Management) project was born in the US for this exact purpose: outlining the division of airspace and the activities linked to them.
"UTM is a traffic management ecosystem for uncontrolled operations that is separate from, but complementary to, the FAA's Air Traffic Management (ATM) system. UTM development will ultimately identify services, roles and responsibilities, information architecture, data exchange protocols, software functions, infrastructure, and performance requirements for enabling the management of low-altitude uncontrolled drone operations" (source: Federal Aviation Administration).
Europe developed and launched a similar project with U-Space. There are common goals: laying down a set of rules and services that guarantee unmanned activity systems, trying to facilitate low altitude airspace access whilst staying in compliance with safety regulations. SESR states that "Drones are a growing business in Europe, delivering services in all environments, including urban areas. Mapping, infrastructure inspections, precision agriculture, delivery of goods and e-commerce are just some of the services possible using drones. A clear framework at EU level would allow the creation of a truly European market for drone services and aircraft, thereby harnessing potential for jobs and growth creation in this new sector of the economy. U-space is a set of new services relying on a high level of digitalization and automation of functions

Fig. 2 - DIODE U-Space project: concept of operations.

Fig. 3 - Architettura e tecnologie di TNO

and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones" (source: SESAR-JU)
A simple principle that corresponds to a long and articulated series of actions.
First of all, it is fundamental to know LAA status, the presence and location of UAV systems (as well as the manned systems obviously); this means that they should be registered and be identifiable when in use. Furthermore, it is crucial that these systems have access to information regarding the context in which their activities take place: if there are exclusion areas or if there are other mediums in the same space. This leads to the necessity to have updated maps, weather conditions and communication with air-personnel (NOTAM: notice to airmen).
LAA won't host only small and unimportant drones: we all known about Amazon's logistics projects, or the transportation of medicines in difficult geographical areas, or utilizing drones during great catastro-

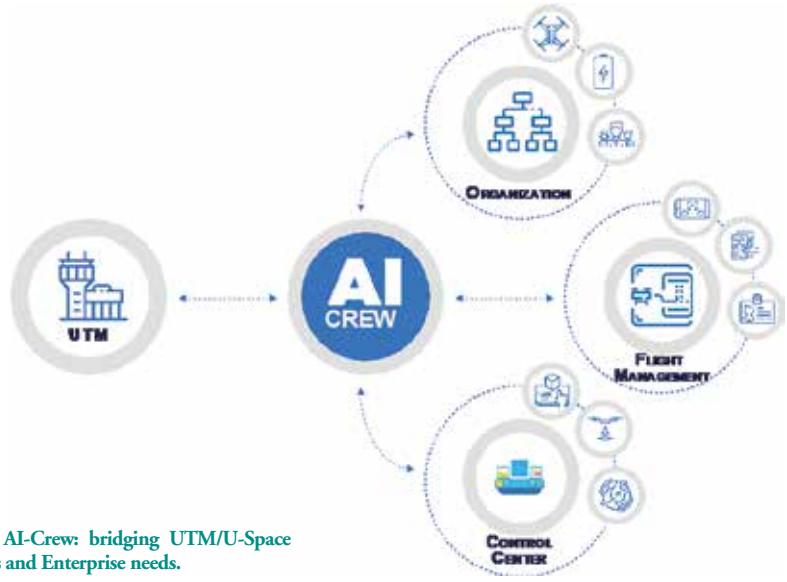

Fig. 3 - AI-Crew: bridging UTM/U-Space operations and Enterprise needs.

Fig. 4 - AI-Inspection, a complete workflow for UAV inspections.

phes. Uber is about to launch a new urban transportation service using unmanned vehicles. These are all missions with variable levels of importance and critical points. LAA access can't be completely democratic ("flat"), but must respond to the urgency and criticality of a mission. It will be necessary to outline fixed routes for exclusive usage for specific; either that or leaving the decisions to a referee, who will decide who to grant access to between those who apply.

To outline this set of rules and technologies one must verify that these can actually be carried out in reality. Experimental systems must be launched to simulate and study real conditions, with real drones that carry out different operations

Fig. 5 - UAV inspector manages drone operations and inspection data on-site

in airspace; interacting between themselves and with civil aviation. Based on the SESAR Joint Undertaking (SESAR-JU) input many European countries have started carrying out these types of trials.

DIODE

To answer these needs, Europe has created a roadmap that integrates drone safety in LAA, as well as different finance programs, for air traffic control organizations (Eurocontrol, ENAV, Frequentis) on one hand; and for technology and information industries on the other, that include big corporations (Leonardo, Airbus, Boeing) and small-medium companies that operate in the airspace field.

Europe aims to build a defined and rational architecture of necessary services to access U-Space safely and efficiently, keeping in mind the huge growth that is foreseen for the drone market in the next few years: A 10 billion-euro annual market in 2035 has been estimated.

The DIODE project (D-Flight Internet of Drones Environment) is one of ten Demonstration Projects co-funded by the SESAR Joint Undertaking within the Horizon 2020 project to define and develop European U-Space. DIODE fits in the evolving context of U-Space services with its own approach on the matter, based on U-Space demonstrations in realistic scenarios characterized by simultaneous, interacting missions between unmanned vehicles and traditional aviation.

DIODEs aim is to demonstrate how U-Space services grant unmanned system users LAA access to carry out professional or recreational operations in

a scenario where multiple unmanned missions take place in the same airspace, at the same time, in complete compliance with regulations, with the correct levels of safety for the people involved and the land and air users. The provision of U-space services will be given to the D-flight platform, that is a provider and manager of U-Space foundation services in Italy since 2016.
The project is made up of various phases that go from outlining a plan, studying the demonstration activities and their execution, to the final report on the results and data achieved, including discussion points for possible future developments.
The main phase of the project is the Live Demonstrations that will take place from June to September 2019. It consists of a Trial session first, where the single missions will be tested, followed by the Demonstration Days where all the missions will be carried out simultaneously.
All these Live Demonstrations will take place in the airspace of the city of Rieti.
There are ten unmanned missions in the DIODE project, with different characteristics and goals. From infrastructure inspections, to postal delivery, from traffic patrolling and archeological sites detection, from precision agriculture to search and rescue investigations. These demonstrations also include the interaction with manned aviation through a light aircraft emergency landing simulation.
During the live demonstrations, all airspace users involved will be able to use the UTM D-Flight platform through which they can access U-Space services as well as receive and give information on their operations workflow. Registration and identification, flight planning, strategic management of conflicts and interactions, flight execution and management, emergency management, and communicating with airport authorities, are just a few examples of services available through DIODE.
The Italian involvement in the DIODE project allows us to take part in a technological, juridical, managerial and procedural evolution. It is important to highlight the great opportunity DIODE is for Italy, to be a part of the European undertaking in unmanned system management; keeping in mind that new EASA Regulations will unify activities and regulations of Unmanned Systems in all of Europe starting from 2021.
The results achieved from the DIODE project will be the foundation on which to build ever-ambitious projects that will reap the benefits of U-Space services and functions, allowing stakeholders to exploit the great potential that is Low Altitude Airspace.

Enterprise LAA

Platforms and solutions

At the same time, Enterprises have finished experimenting on drone application for their own operation and maintenance processes. The past two years have given companies in telco, oil & gas, utilities, railways and highways, the opportunity to discover the potential and the business use-cases in which it is possible to reduce costs of activities such as inspections, monitoring, measuring and transportation.
Many of these companies started purchasing commercial or custom drones from different providers, or in some cases to manufacture them internally; followed by the precise execution of operation's simulations, carried out by internal drone communities or relying on a variety of external expert consultants.
Enterprises now fully understand the advantages of using drones for their activities and incorporating this technology as a tool in their everyday operations.
Electrical distribution Companies use them to check up on their power plants and their distribution lines.
Railroads and highways companies for the inspection of bridges and flyovers, rest areas, rock fall barriers etc.
Other companies such as Autostrade per L'Italia have launched campaigns that include up to 400 inspections of bridges and viaducts.
Nowadays many Enterprises own a relevant number of drones, creating what can be described as fleets.
In the digital transformation process Enterprises are going through, drones are part of an IoT system that collect information. Therefore, there is a need to merge Staff and Fleet coordination with data from the company information systems, in order to protect brand responsibilities and for the valorization of data.
Since Enterprises are starting to own not only few, but hundreds of flying drones, the risk of uncoordinated and unauthorized actions and operations increases, as well as the risk of accidents. UAV Regulations imply that organizations must be certified with well-defined roles and responsibilities, and must have operation and maintenance procedures in place for pilots and fleets.
The Accountable Manager of an Enterprise, often a top-level manager, must have full control over a fleet of hundreds of

drones, the people who operates them, the internal authorization process for the mission etc. When a pilot in a company division carries out a mission, it has to be planned in compliance with national regulations, No-flight-zones, Notams, and other relevant criteria.
Thus, Enterprises need a platform with which they can manage their fleets, the organization and operations. These platforms allow operational planning, internal authorizations of missions, requesting the reservation of airspace to UTM systems, managing activity logs of pilots, fleets and payloads.
Drones create a great amount of data: 4k optical sensors record gigabytes of information during each mission. This must be combined to the structural features, quality indicators and measurement of the inspected asset.
Enterprises need platforms that can manage a workflow of data capture, classification, analysis and reporting. All of this completely integrated with an up-stream pre-existing Asset Management, and downstream Predictive or Order Management.
This is because the main information retrieved from an inspection is not only a series of photos or videos, but contains different parameters that indicate the conservation status of the asset, obtained by applying a specific defect catalogue and evaluation weights (intensity, extension and evolution) that are unique to the asset.
AIviewgroup (www.aiviewgroup.com) supports Enterprises in the introduction of drones into their Operation & Maintenance processes, with an impressive track record, both for the number of companies and also for the great variety of activities of inspection and reporting carried out. We also support our clients in BVLOS experimentations, remotely piloted and autonomous flights.
Ai-Crew - Drone Operations Management and Airspace Access
AI-CREW (www.ai-crew.com) is a drone-management-platform that supports UAV Organizations for National Authorities' regulation compliance. It also manages the fleets, the documentation and personnel.
Through the Control Center module, AI-CREW allows an Enterprise to monitor an operation both from a synoptic point of view, as well as on a map with the possibility of communicating with pilots on the field. All data and videos can be seen real-time from the Control Center.
Interactive airspace map allows you to visualize real-time regulated areas and temporary flight restrictions, plan flights, interact with operators, and fly drones safely.
We tailor flights and operations to our clients' needs using standardized flight procedures and operation checklists, with the aim to meet companies' safety requirements while ensuring efficiency.
Pilots, flight hours, authorizations, aircrafts and flight plans, all in one place. AI-Crew is a drone operation complete system that makes it easy to manage systems, people and missions. Every planned mission undergoes in-depth validation from the Enterprises control center and the integrated UTM system.

Ai-Inspection - Operational intelligence and predictive maintenance

AI-Inspection (https://www.ai-inspection.com/) platform was created to manage the workflow of UAV operations in inspections and monitoring, optimizing the cataloguing and predictive maintenance through defect analysis using algorithms in image processing, machine learning, and data consultation.
All the data acquired during an inspection (photos, videos, lidar data or parametric sensors) is collected by AI-Inspection, catalogued based on the key plan of the operation and its rules, and analyzed using machine learning & image recognition algorithms that automatically produce an inspection report.
All this information can be temporally cross-checked and compared with the analytical and visual results obtained with previous inspections.
AI-Inspection allows the management of different types of data (images, videos, point clouds, 3D models, CAD, etc.) for the purpose of inspections, documentation and maintenance by linking them to single structural elements.
The information can be exported to external systems for predictive maintenance, order management, etc.
The combined adoption of these powerful tools allows the Enterprise to fully exploit the potential of Low Altitude Airspace.

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ABSTRACT

The development of Low Altitude Airspace activities is a great opportunity for many companies. Work carried-out by drones (inspections, surveillance and control, mapping etc.) will be supported by other new activities and services that will pave the way for new business models and revenues.
A new set of rules must be set up to allow the correct use of LAAs; UTM projects and U-Space were created for this purpose. Europe is very active in this regard and the Italian U-space project DIODE is an example of highly advanced experimentation.
Enterprises are already building large fleets; managing the drones, the people and procedures using advanced platforms that utilize the collected data effectively. Working in compliance with LAA rules is fundamental for success. AI-Crew and AI-Inspection are two innovative platforms born to help Enterprises capitalize on LAA, maximizing their assets.

KEYWORDS

Low altitude Airspaces; drones; surveillance; inspections; mapping; UTM projects; U-space; DIODE

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L'AEROFOTOTECA NAZIONALE RACCONTA.....MULTI-TEMPORAL PHOTOINTERPRETATION

by Roberto Graciotti

Aerial photographs, if taken to allow a stereoscopic vision, can increase the physical and anthropic information of terrestrial survey acquired by means of direct field surveying.
The synoptic view from above even of vast areas shows, almost immediately, the configuration of the terrain, the mutual relationships of the elements and objects present and the main forms of erosion and accumulation that characterize it.
The observation of aerial photos allows to investigate even inaccessible areas, characterized by steep slopes, high altitude, little or no traffic, where access is difficult, or areas where access is impossible.
It is therefore clear that photointerpretation is a particularly useful investigation technique in the field of Earth Sciences, especially for geological and geomorphological studies. In some university courses, geological photo-interpretation or photogeology has been, and still is, a teaching discipline in its own right.

Multi-temporal photointerpretation

Photointerpretation can be defined multi-temporal when observation concerns photograms covering the same portion of territory in different periods. The study of the various photograms allows us to evaluate the natural and anthropogenic changes in a given territory, in a precise time interval and also to estimate their evolution in terms of speed.
Multi-temporal photointerpretation is particularly useful in geomorphology, when certain morphotypes must be monitored, such as geometry and morpho-evolutive characteristics of landslides, damage caused by intense flood events, amount of volcanic eruptions and forms of accumulation and erosion that they generate in the landscape, area and volumetric variations of the glaciers, extension deltas, retreat of high cliffs and evolution of the aeolian dunes, etc.
Finally, the increasingly growing use of multi-temporal photointerpretation in the estimation of landscape changes following anthropic morphogenetic processes (such as earthworks, terracing, mining activities and so on) is worth mentioning.
Of course, the study of a given territory or of a single morphotype will be the more accurate and detailed the more images will be available, and the larger the time span they embrace will be.

MAPRW (RAF and USAAF) and GAI flights

It should be noted that with Google Earth imagery the changes in landscape and its evolution can be observed only since 2001. However, if we consider the aerial photos taken by the Gruppo Aerofotogrammetrico Italiano (GAI) we might observe the whole Italian territory in the years 1954-1955; and if we add to them those taken during World War II by the Allied Forces on a large part of central-northern Italy it is even possible to go back in time up to the years 1943-1945.
These two distinct sets of photographs are very important, precisely because they allow us to examine the territory respectively around 65 and 75 years ago, establishing comparisons and differences in its structure. The GAI flight is available at the Istituto Geografico Militare, based in Florence; the Allied coverage of Italy (collectively known as MAPRW, Mediterranean Allied Photo Reconnaissance Wing, and mainly taken by RAF and USAAF air forces) are available from Aerofototeca Nazionale (AFN), based in Rome, and from the National Collection of Aerial Photography (NCAP), based in Edinburgh.

Two case studies

a) *The delta of the Tiber river*

Fig. 1 - AFN, MAPRW collection, frame 3076 of mission no.26, taken by 23rd Squadron RAF on August 20, 1943, 8,30 a.m.; 24" focal, altitude 31,500 feet.

Fig. 2 - © Google Earth, 2004

Fig. 4 - © Google Earth, anno 2019

Fig. 3 - AFN, MAPRW collection, frame 3112 of mission no.12S-175, taken by 3rd Photo Group USAAF on August 26, 1943, 9,30 a.m.; focal 24", altitude 29,000 feet.

Image n. 3076, taken on August 20, 1943 (fig. 1), shows the mouth of the Tiber river and the various systems of beach ridge, marked by light-colored arched bands formed during the progradation of the delta alternating with darker bands of beach ridge, showing the presence of finer sediments and organic matter.
The image in fig. 2 roughly covers the same area shown in fig. 1. We immediately notice the great anthropic changes that have affected and transformed the environmental context of this area.
The part where the beach ridge were earlier clearly visible is now notably reduced, due to urban expansion; both river banks near the mouth have been completely invaded by residential settlement and harbor works that have modified and altered the coastal morphodynamics of this particular natural ecosystem.

b) *Ostiense district - via della Villa di Lucina*
The area represented in the image in fig. 3 includes a part of the urban territory between the Basilica of San Paolo fuori le mura and the Via Cristoforo Colombo, that appears still under construction.
In earlier IGM maps the area circled in red is named as "Marrana di Grotta Perfetta", from the name of the homonymous tributary of the Tiber river on its left side. Until the early 1960s this was a depression, consisting of palustrine deposits, of poor consistency and poor geotechnical characteristics.
The image in fig. 4 points out the deep anthropic changes brought in the area, highlighted with the red ellipse in the previous image, between Via Ostiense (left) and Via Cristoforo Colombo (right). This area of "marrana", characterized palustrine deposits with poor physical and mechanical characteristics, has been reclaimed by filling with large quantities of landfill. The reclaimed area was then urbanized, with the construction of several buildings of considerable size, whose excessive weight on unsuitable terrains caused, in a short time, prolonged and significant subsidence that caused their heavy inclination.

Conclusions

The two case studies described above clearly show the great importance of multi-temporal photointerpretation, particularly if performed with the aid of historical aerial photos, taken in times when the territorial context was nearly everywhere profoundly different compared to the current one.
In the first case the progradation of the Tiber delta can be studied in its natural geo-environmental context and the morphodynamic evolution of the coastline can be compared before and after the anthropic expansion of the 1960s.
In the second case it is evident that the timely use of this survey technique would have provided a better physical knowledge of the territory, and the serious damages suffered by the anthropic works carried out on unsuitable foundation terrains could have been avoided.

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KEYWORDS

MULTI-TEMPORAL PHOTOINTERPRETATION; AERIAL IMAGERY; MORPHODYNAMIC EVOLUTION

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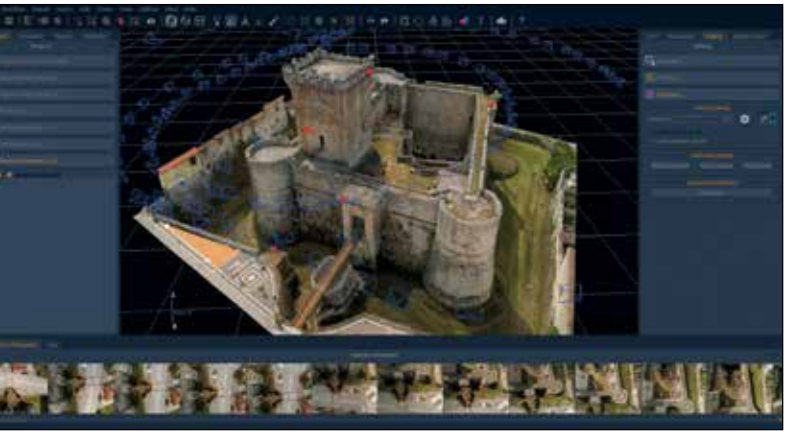

APPROACHING THE NEW RELEASE OF 3DF ZEPHYR, VERSION 4.5

3DF Zephyr, the complete software photogrammetry suite provided by the Italian company 3Dflow srl, has gone through a lot of improvements and new features. The software is one of the leading packages for 3D reconstruction of both terrestrial and aerial photogrammetry and includes an unbeatable toolset for professional surveyors.
Let's have a quick review of the main features of 3DF Zephyr and the updates of the brand-new build of the software, version 4.5 (Codename Clementine)!

Faster processing – Both the Structure from Motion and the Multiview Stereo phases have been significantly improved: during the SfM phase, the bundle adjustment can deal with massive datasets.
Better detail – The Multiview Stereo routine can recover even more detail than before. Developments have also been made in the Photoconsistency algorithm, which can now better reconstruct thin structures.
Improved UI – Many tools have been reorganized for a much more efficient workflow and an even cleaner UI, more user-friendly and intuitive.
Speaking of survey features, 3DF Zephyr Aerial also gets new exclusive improvements along with the release of Clementine:
New orthophoto internal algorithm – With the latest version, the processing speed has also improved a lot, plus there is no longer any limitation in the maximum orthophoto resolution output that can now be exported as a single BigTiff file. Other minor improvements include the smart auto crop borders feature and improved interoperability with many viewers.
Planar surface drawing element – Planar surface drawing elements can be added and saved in the workspace and exported as CAD elements.
DXF cad import: Users can now import polylines and points as dxf inside the workspace.
Support for custom geoids – 3DF Zephyr Aerial is now supporting custom geoid for improved georeferencing capabilities.

The team is also working on a novel registration tool for laser scan data, that will be unveiled at the next Intergeo exhibition.

www.3dflow.net
www.microgeo.it

STONEX AT INTERGEO 2019

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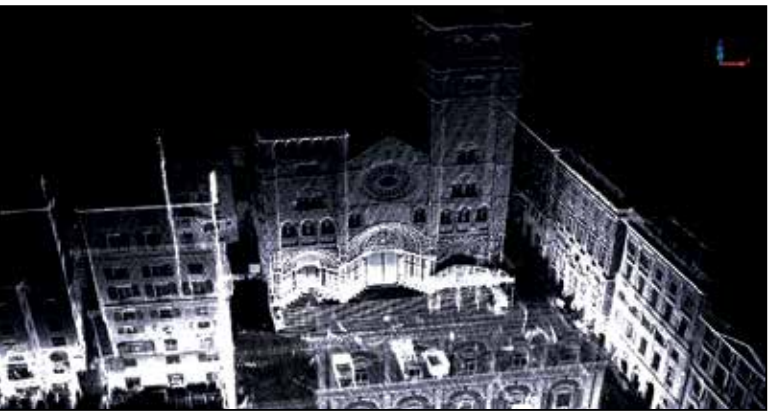

THE POTENTIAL OF LIDAR SYSTEMS AND POST-PROCESSING SOFTWARE

The potential of the LiDAR systems and the post-processing software increases day by day. The industry is always looking for new technologies and new solutions to improve productivity and efficiency. LiDAR sensor provide speed, accuracy, processing automation and the ability to easily integrate into existing engineering and GIS workflows.

The most known applications are in aerial, UAV or automotive systems. But what about using LiDAR in a terrestrial system, specifically, handheld mobile lidar systems? To answer this question, we performed a quick test in the urban center of Genova city, to investigate the potential of utilizing mobile LiDAR in urban environments.

Gter is a reseller of Greenvalley International, so we used the LiBackpack DG50, the newest HW produced by the Californian company. This system includes a VLP-16 laser sensor from Velodyne, can generate up 300.000 pulses per second and integrates SLAM (simultaneous localization and mapping) technology, allowing the system to continuously generate real time 3D point cloud with trajectory, loop and timestamp information. The scan was completed in approximately 20 minutes for two loop, due to the operator get into each significant building. The point cloud obtained after the scan does not require any raw conversion, it is ready to be used. The results were processed in LiDAR360 a software solution that provides tools for efficiently visualizing, generating & manipulating LiDAR data. We classified the point cloud and eliminated the noise due to the people flow. LIDAR 360 contains complex machine learning algorithms that facilitate the classification process. Buildings and ground got perfectly defined. This quick test allowed us to appreciate the potential of using a LiBackpack system. The results were surprisingly satisfactory even inside the buildings for a breve's 15 minutes scan, so is possible to capture good urban environment data with a mobile handheld LiDAR solution like the GVI LiBackpack.

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LANDVIEWER NOW FEATURES CHANGE DETECTION THAT RUNS IN BROWSER

The major utilization of remote sensing data has been to compare images of an area taken at different times and identify the changes it underwent. With a wealth of long-term satellite imagery currently in open use, detecting such changes manually would be time-consuming and most likely inaccurate. EOS Data Analytics stepped in by introducing the automated Change Detection tool to its flagship product LandViewer, which ranks among the most capable cloud tools for satellite imagery search and analysis in today's market.

Unlike the methods involving neural networks that identify changes in the previously extracted features, the change detection algorithm implemented by EOS is using a pixel-based strategy, meaning that changes between two raster multi-band images are mathematically calculated by subtracting the pixel values for one date from the pixel values of the same coordinates for another date. This new signature feature is designed to automate your change detection task and deliver accurate results in fewer steps and in a fraction of the time needed for change detection with ArcGIS, QGIS or another image-processing GIS software.

Change detection interface. Images of Beirut city coastline selected for tracing the developments of the past years.

Unlimited scope of applications – from farming to environmental monitoring

One of the main goals set by EOS team was to make the complex process of change detection in remote sensing data equally accessible and easy for non-expert users coming from non-GIS industries.

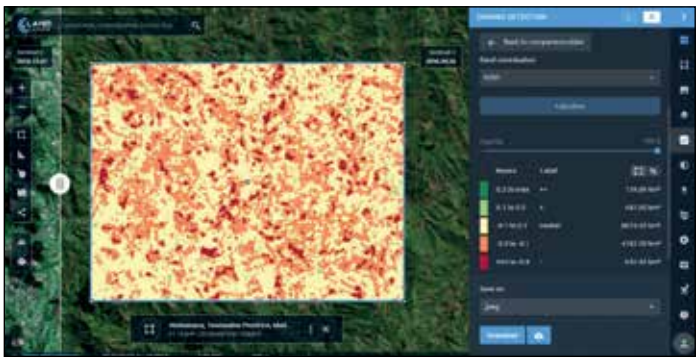
With LandViewer's change detection tool, farmers can quickly identify the areas on their fields that were damaged by hail, storm or flooding. In forest management, satellite image detection of changes will come in handy for estimation of the burned areas following the wildfire and spotting the illegal logging or encroachment on forest lands. Observing the rate and extent of climate changes occurring to the planet (such as polar ice melt, air and water pollution, natural habitat loss due to urban expansion) is an ongoing task of environmental scientists, who may now have it done online in a matter of minutes. By studying the differences between the past and present using the change detection tool and years of satellite data in LandViewer, all these industries can also forecast future changes.

Top change detection use cases: flood damage and deforestation

A picture is worth a thousand words, and the capabilities of satellite image change detection in LandViewer can be best demonstrated on real-life examples.

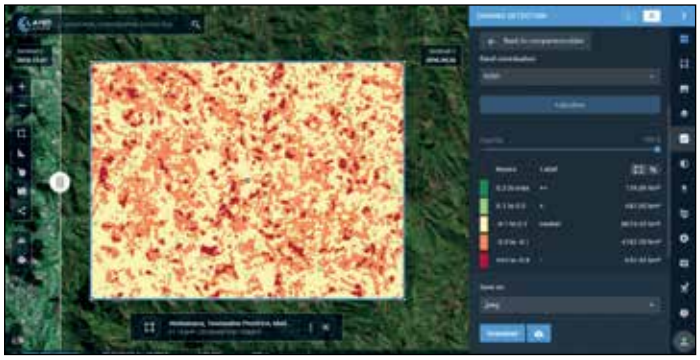
Forests that still cover around a third of the world's area are disappearing at an alarming rate, mostly due to human activities such as farming, mining, grazing of livestock, logging, and also the natural factors like wildfires. Instead of massive ground surveying of thousands of forest acres, a forestry technician can regularly monitor the forest safety with a pair of satellite images and the automated change detection based on NDVI (Normalized Difference Vegetation Index).

How does it work? NDVI is a known means of determining vegetation health. By comparing the satellite image of the intact forest with the recent one acquired after the trees were cut down, LandViewer will detect the changes and generate a difference image highlighting the deforestation spots, which can further be downloaded by users in .jpg, .png or .tiff format. The surviving forest cover will have positive values, while the cleared areas will have negative ones and be shown in red hues indicating there's no vegetation present.



A difference image showing the extent of deforestation in Madagascar between 2016 and 2018; generated from two Sentinel-2 satellite images.

Another widespread use case for change detection would be agricultural flood damage assessment, which is of most interest to crop growers and insurance companies. Whenever flooding has taken a heavy toll on your harvest, the damage can be quickly mapped and measured with the help of NDWI-based change detection algorithms.



Results of Sentinel-2 scene change detection: the red and orange areas represent the flooded part of the field; the surrounding fields are green, meaning they avoided the damage. California flooding, February 2017.

How to run change detection in LandViewer

There are two ways you can launch the tool and start finding differences on multi-temporal satellite images: by clicking the right menu icon "Analysis tools" or from the Comparison slider €whichever is more convenient. Currently, change detection is performed on optical (passive) satellite data only; addition of the algorithms for active remote sensing data is scheduled for future updates.

For more details, please read this guide to LandViewer's change detection tool.

Or start exploring the latest capabilities of LandViewer on your own.

Here to find more info and links:
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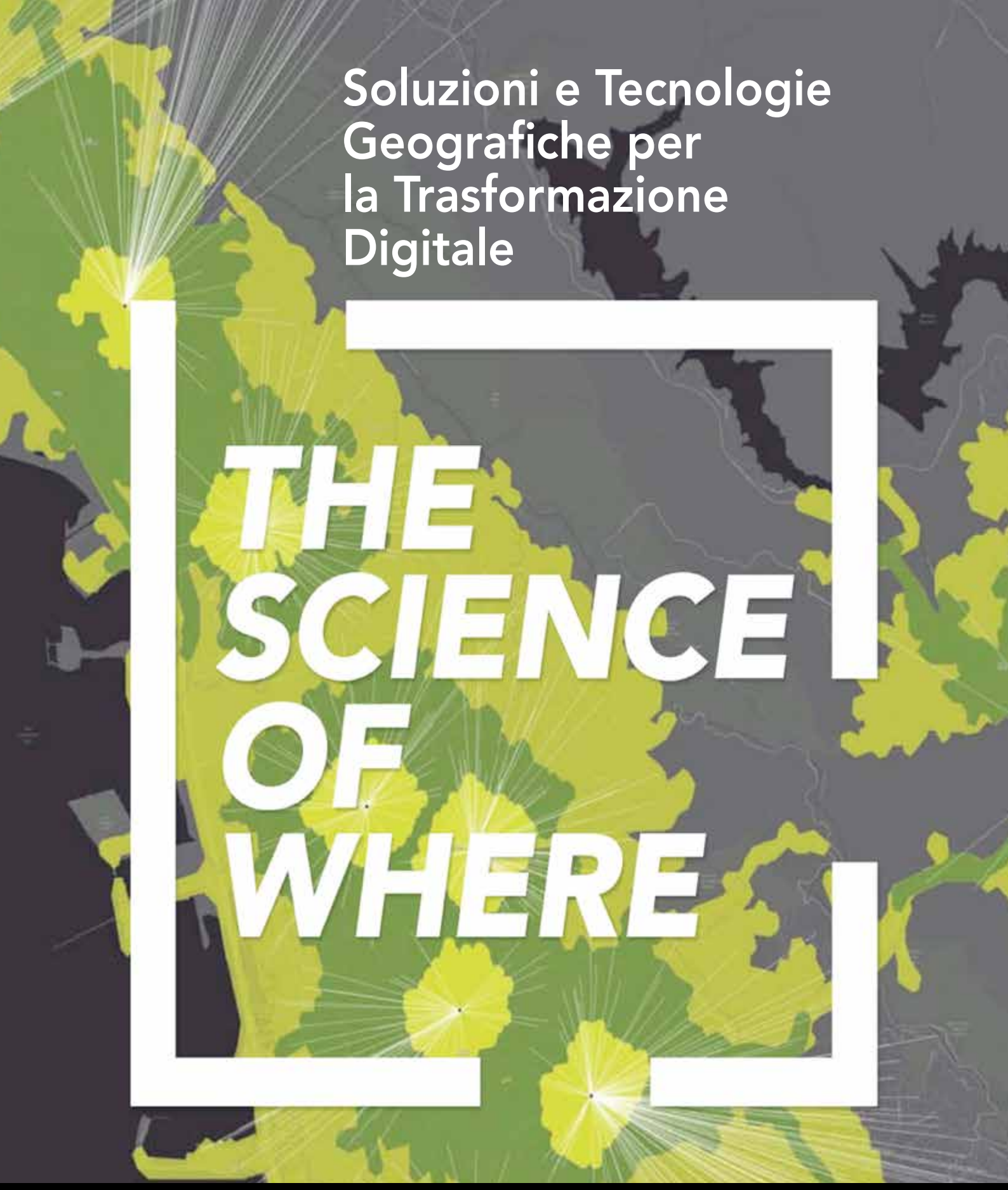

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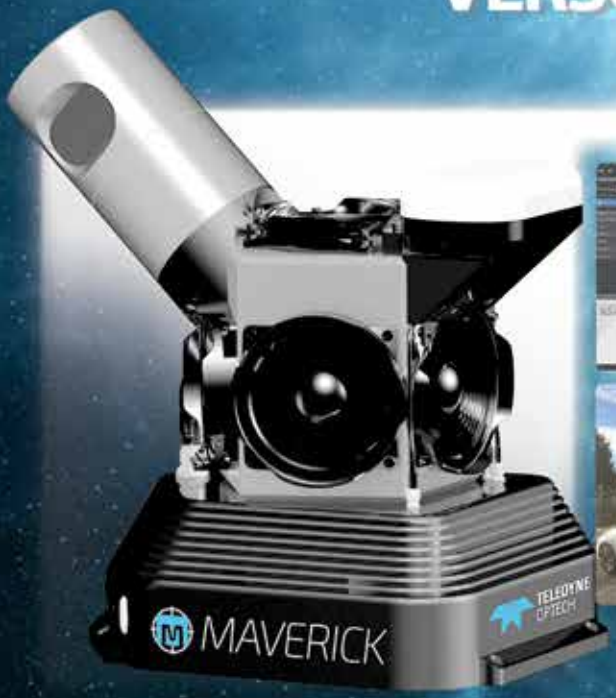

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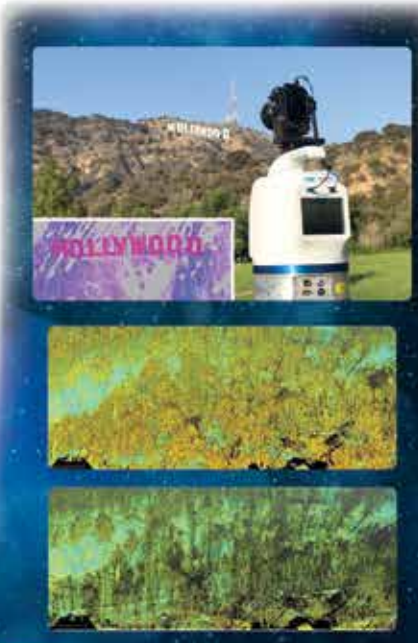

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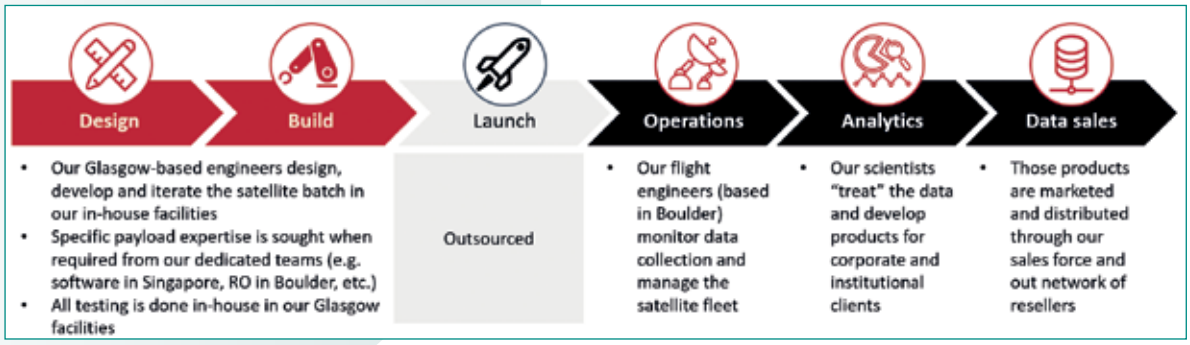
GNSS Radio Occultation in Advanced Numerical Weather Prediction Models

by Guillermo Bosch



Radio Occultation (RO) is a well-proven technique that goes back to the mid 1960's, when the satellite Mariner IV transmitted data while it was approaching Mars. In the moments as it disappeared behind the Red Planet, the transmitted signal, as viewed from Earth, passed through the thin Martian atmosphere, from its upper layers down to its surface. This represented history's first inter-planetary atmospheric and ionospheric radio occultation experiment. Minutes later, as the signal reappeared on the other side of Mars, the first rising radio occultation was observed from Earth.

After the Mars experiment, several other planets, as well as many bodies of the solar system, were studied through RO, until GPS-RO was used to study the Earth's atmosphere. Many experiments and proofs-of-concept followed, such as GPS/MET (April 1995), and NASA-sponsored international missions from 1998 through 2005 (SAC-C of Argentina, SUNSAT of South Africa, Oersted of Denmark, CHAMP of Germany, and GRACE of US and Germany). In April 2006, COSMIC-1 (Constellation Observing System for Meteorology, Ionosphere, and Climate), a fleet of six Low-Earth-Orbit (LEO) satellites mission, sponsored primarily by Taiwan's National Space Organization and managed in the U.S. by the University Corporation for Atmospheric Research (UCAR), become the first dedicated constellation for assessing the operational use of GPS-RO data in NWP models. When COSMIC-1 RO profiles were first used as a data source for NWP - they were providing about 150 occultations per day (eventually it would reach 3000 per day), several other small constellations or single satellites were launched for the same purpose. Today, METOP (3 satellites) are contributing with circa 600 ROs per day, KOMPSAT-5 with about 350 ROs/day and GNOS-FY3D with an estimated 800 ROs/day.

Spire's Technology, expertise and value chain

Spire Global is a company that started operations in 2012, with the mission to collect and to analyze advanced datasets from space. With almost complete control over its value chain, from the design of its satellites to the creation of innovative products that are designed from the data constantly generated by its growing satellite constel-

lation, it is one of the only two non-government companies in existence to manage a fleet of more than eighty satellites, and constantly relay their data to its cloud infrastructure through its integrated network of ground stations.
Manufacturing capacity is close to one satellite per week at its facilities. Spire has built on this hardware base an extensive series of key software and services, offering its clients a set of strong assets and differentiators based on global, straight-from-space data. This suite of products is analyzed and maintained by teams of scientists, distributed across our global offices, that have an ability to build unique, differentiating products, and to leverage unique data sets and decades of fundamental research in their given scientific field of expertise.

GNSS-RO. The Key to precise atmospheric Measurementes

Figure 1 shows a conceptual diagram of the principles of GNSS-RO. A GNSS satellite generates an L-band radio signal that is received by Spire's Low Earth Multi Unit Receiver (LEMUR) Satellites from the opposite side of the Earth. Both satellites need to have descending orbits relative to each other to be able to 'slice' the atmosphere as they reciprocally disappear over the horizon. Due to the refractivity of the atmosphere, radio waves experience bending during propagation from the GNSS satellite to Spire's LEMUR. Since atmospheric refractivity depends on temperature, pressure, and water vapor, measurement (called "soundings") of the bending angle (an absolute measurement, with no need for calibration), GNSS-RO allows us to retrieve accurate atmospheric profiles that are used in advanced NWP models. Once the bending angle and other geometric parameters are measured in a specific point in the atmosphere, data is pre-processed on-board and downloaded to Spire's proprietary current ground network of 32 stations. Once data is available for further processing, a climatology model is used to compensate for ionospheric effects and to calculate the ionosphere's Total Electron Content (TEC). At this point in the process, the refractivity profile and the associated temperature profile at the specific sounding point is obtained. While by their very nature and reach, other constellations or single satellites contribute to different NWP models with a smaller numbers of RO profiles, Spire's unique fleet of more than eighty LEMURs is currently measuring about 4000 RO profiles/day, with increasing numbers as Spire launches more satellites and uses the satellites of additional GNSS fleets. Today, Spire performs RO though the GPS and Galileo fleets. Incidentally, Spire is the only company in the world that preforms RO soundings using Galileo. Spire's GNSS-RO capability provides vertical profiles with high vertical resolution of 100m and 0.1oc temperature accuracy from the Mesopause (about 70 kilometers in the atmosphere) down to near the surface of the earth. This unique data set has been proven, according to studies by the European Centre for Medium-Range Weather Forecasting (ECMWF), to have a high impact on forecast accuracy and is a data set that Spire collects globally, including all land masses, oceans, poles, and extremely remote areas. The quality, accuracy and resolution of Spire's RO soundings are a new key dataset for any NWP. The two diagrams in Figure 2 below, show the quality of Spire's GNSS-RO temperature profiles (measured in K) taken by two independent Spire satellites at nearly the same location (mid-Pacific). Both show that there is an error in the National Weather Service (NWS) Global Forecast Service (GFS) model analysis in

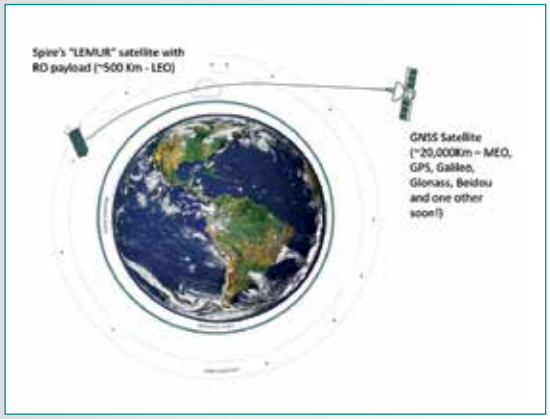


Fig. 1 - Conceptual diagram of the principles of GNSS-RO.

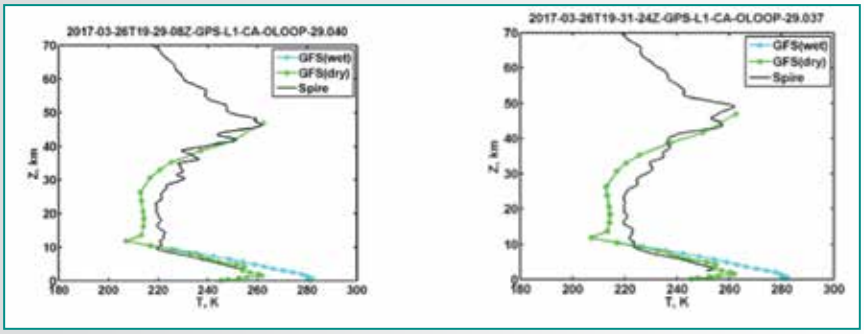


Fig. 2 - Quality of Spire's RO profiles.

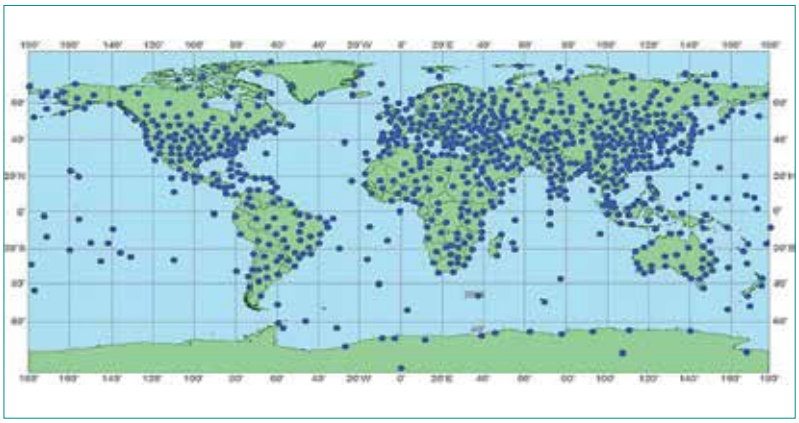


Fig. 3 - Global Network of radiosondes.

this geographic area. The GFS has a tropopause of about 12 km, and a colder stratosphere, whereas Spire RO measurements show that the actual low is much deeper, with characteristic lower tropopause at 10 km, and a warmer stratosphere. Such theoretical model errors can amplify into large errors in prediction downstream.

Comparison of capabilities of GNSS-Radio Occultation to Radiosondes

Currently the main source of accurate atmospheric data is a network of about 1,300 radiosondes that are launched twice a day (Figure 3). They are expensive to operate, and they provide a poor coverage over the oceans and unpopulated areas. On the other hand, a single Spire LEMUR satellite is capable of producing from a number of 500 to 1000 RO-based atmospheric profiles (based solely on the GPS constellation) per day with a global distribution. If we multiply the number of ROs per satellite by the number of Spire's LEMUR satellites available today and scheduled in the near future, and we also take in consideration other GNSS fleets (e.g. Galileo), we obtain a number close to 120,000 atmospheric profiles per day (Figure 4), thus contributing immensely to the atmospheric data available to NWS models. In Figure 5 are depicted a radiosonde and a three-unit (measuring 3 dm3) LEMUR GNSS-RO enabled satellite.

Operational use of GNS-RO in NWP models

As previously discussed, GNSS-RO is a dependable source of high-quality real time data for global and regional weather models. Previous academic programs like COSMIC, demonstrated the high quality of RO atmospheric profiles and their value for weather forecasts. Spire has taken the COSMIC experience to the next level, by operating a current fleet of more than eighty LEO satellites (increasing in number every three months) with unique atmospheric sounding capabilities.

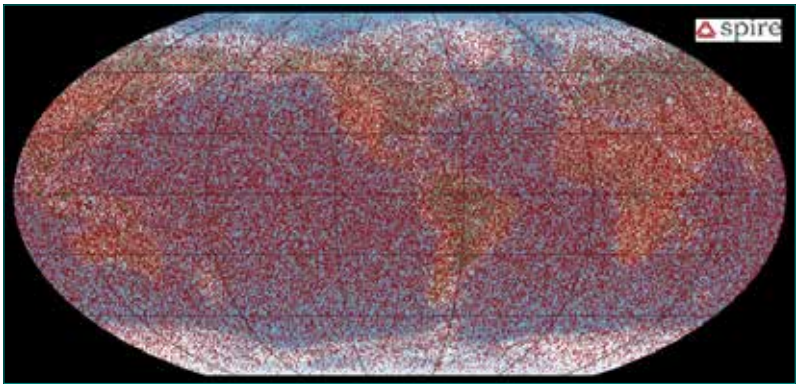


Fig. 4 - Spire's ROatmospheric profiles at full constellation.

Figure 6 below depicts the conceptual block diagram of a generic advanced NWP weather model that takes advantage of RO data. From left to right, data is collected from many existing atmospheric standard sources, as well as many RO profiles as they become available. Both RO data and standard atmospheric data are ingested into a data assimilation filter that generates very precise initial conditions of the atmosphere at a specific moment in time. Such initial conditions are the input to the advanced NWP model that, at a certain number of times per day, and more typically as often as possible, outputs a certain number of Forecast Products. Such products are then stored in a data server and cloud services that are the basis for delivery of the final forecast (Output Data) to Customers, under the form of GRIB2 files and APIs. Optional fully customized products for specific vertical markets may also be provided.

Apart from being specifically designed to assimilate RO data and other weather data available from third-party sources, advanced NWPs core features are often based upon the following underlying principles:

- They are non-hydrostatic models (featuring a dynamic core) that resolves weather below 10 miles.
- Have a higher vertical and horizontal resolution by virtue of highly efficient computing

Fig. 5 - A radiosonde features a balloon and a payload capable of one vertical atmospheric profile/launch (right) and a LEMUR satellite (above) is capable of measuring 1000 atmospheric profiles/day.

there are plans to implement operational short-range weather models in the near future. They will have an inherent advantage against other options because no national center currently runs a global short-range model. Many countries use regional models (WRF) over their area of the world, but there is compelling evidence that these limited domain models are not as accurate as global models in producing short-term weather forecasts.

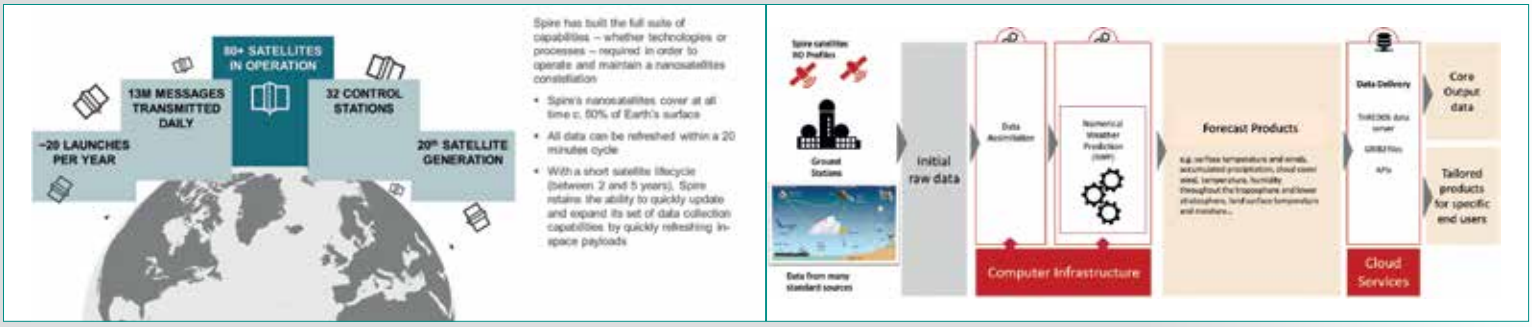


Fig. 6 - Weather Prediction System block diagram.

- They are optimized for short-term (0-36 hour) predictions with frequent assimilation that often allows for prediction up to 7 days.

From a study published by Carla Cardinali et al. [CAR1], in Figure 7 is shown the importance of Spire's GNSS-RO as a contributing dataset to NWP models, in terms of comparison of the performance percentage increase of weather models depending on the data source in use against cost. Most datasets shown in the picture are provided by missions that cost hundreds of millions of dollars. For example, datasets provided by the MetOP program (e.g. through the IASI Infrared sounder) cost 756 M Euros, while the Aqua satellites with AIRS infrared sounder run over 900 million dollars.

While most available soundings datasets are inefficient in terms of NWP model percentage performance increase against mission cost, Spire's GNSS-RO soundings contribute enormously to NWP models performance, at a mere fraction of the cost of other options.

In terms of forecasting capabilities,

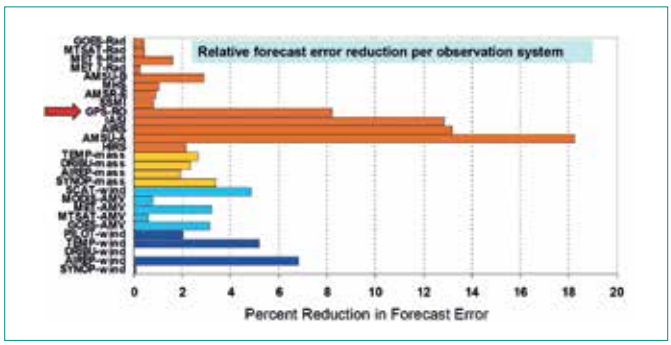


Fig. 7 - RO contribution to performance increase of NWPs.

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[CAR1] Carla Cardinali and Sean Healy. "Impact of GPS radio occultation measurements in the ECMWF system using adjoint based diagnostics." Q.J.R Meteorol. Soc. 140(684), 2315-2320, doi:10.1002/qj.2300

KEYWORDS

Spire; GNSS Radio Occultation; smallsats; cubesats; LEO; TEC; NWP

ABSTRACT

GPS-Radio Occultation (GPS-RO), and generally, Global Navigation Satellite System Radio Occultation (GNSS-RO), is a technique that measures the refractivity of the Earth's atmosphere as a Low Earth Orbit (LEO) satellite listens to the radio signal of a GNSS satellite. As the signal between the two satellites travels through the different levels of the Earth's atmosphere, temperature and water vapor content can be derived at each occultation point, allowing for a new weather dataset to be available to meteorologists.

In this article we describe the benefits of large-scale GNSS-Radio Occultation (GNSS-RO) as a method of gathering large amounts of extremely accurate atmospheric data that exceptionally contributes to the performance of advanced numerical weather prediction (NWP) models.

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Galileo helps increasing the European Union cooperation with the Grand Caribbean, Central and South Americas

by Marco Lisi

Galileo and Copernicus are not only flagship technology programs of the European Union: they can be the ambassadors of European cooperation in other continents, an effective opportunity for growth and development together.

On February 14th and 15th this year, a post-graduate course on satellites technologies and applications was held in Santo Domingo, Dominican Republic, at the Universidad Nacional Pedro Henríquez Ureña (UNPHU).

The activity, supported by the Delegation of the European Union to the Dominican Republic, was organized by Dr. ing. Marco Lisi and by the UNPHU professors Jose Gustavo Rodriguez Mejia, Director of the "Escuela de Ingenieria Geomatica", and Eugenio Leopoldo Taveras Polanco.

After a general introduction to artificial satellites and their applications (e.g. to telecommunications and Earth remote sensing), the course focussed on global satellite navigation systems (GNSS's) and on Galileo, the European system, in particular.

UNPHU, Santo Domingo, Dominican Republic

European Union and Dominican Republic Cooperation

The Dominican Republic is an upper/middle-income country, with the largest economy of Central America and the Caribbean. Since the early nineties, the Dominican Republic experienced sustained economic growth (7.3% GDP in 2014) with relatively low inflation rates. Progress has been made towards Millennium Development Goals and extreme poverty has dropped, however, challenges to inclusive growth persist. The Dominican Republic is member of both the Central American Integration System (SICA) and the Cariforum Group of ACP Countries. The country is also a signatory of the EU-Caribbean Partnership Agreement (EPA), a comprehensive free trade agreement.

Under the 10th and 11th European Development Funds (EDF), that is in the periods 2007-2013 and 2014-2020, the European Union allocation for the Dominican Republic totalled €179 million and €72 million respectively.

Cooperation focused on poverty reduction, human development and social cohesion (notably education), institution building (mainly modernisation of the public administration), and enhancing competitiveness. EU cooperation was instrumental in introducing strategic planning in key institutions in the country, such as the Ministry of Industry and Trade, Consumers' Commission, National Competitiveness Council, as well as creating

and initiating the operations of the National Quality System (SIDOCAL).
Dominican Republic is signatory of the EU-Central America Association Agreement, a comprehensive free trade agreement with a strong focus on development cooperation.
Dominican Republic will benefit during 2014-2020 from the EU sub-regional programme for Central America (€120 million).
It must be noted that the focal sectors of cooperation for the sub-regional have evolved for this period. In the past, cooperation was mainly focused on social cohesion and economic growth, while the new programming exercise responds to the emerging needs of the region, namely security and impunity, climate change and private sector development as a vehicle for generating employment opportunities.

La Universidad Nacional Pedro Henríquez Ureña (UNPHU)

UNPHU is the first private non-profit University in the Dominican Republic, founded in 1966. The founders were, and still are, acknowledged representatives of important entrepreneurial organizations in the country, who created the Dominican University Foundation "Fundación Universitaria Dominicana Pedro Henriquez Ureña (FUDPHU)". "Pedro Henríquez Ureña" was chosen as the name of the university to honor the great Dominican philosopher and humanist known and respected throughout the Americas and worldwide, as a brilliant figure in the humanities.
The UNPHU campus of more than 250,000 square meters is the most privileged campus in the Country (Figures 1 and 2).
The university has other facilities in the city of La Vega, an Experimental Agricultural Farm with 7,536,000 square meters, and a facility in New York City-USA.
The Department of Higher Education, Science and Technology, the government organ ruling the higher education in Dominican Republic, duly accredit UNPHU as well as all of its schools.
Seven faculties compose UNPHU: Health Sciences; Agriculture Sciences and Natural Resources; Education and Humanities: Legal and Political Sciences; Economics and Social; Architecture and Arts; Science and technology.
UNPHU has been acknowledged through its existence for the important contributions to the national development through scientific investigation, in special Agronomy, Medicine and Engineering.
The UNPHU Geomatics Department ("Escuela de Ingeniería Geomática"), managed by prof. Jose Gustavo Rodriguez Mejia, is focussed on the management of geographic information through the use of information and communication technologies.This includes the acquisition, modelling, treatment, storage, recovery, analysis, exploitation, representation and dissemination of geodesy, photogrammetry and remote sensing, Geographic

Fig. 1 - UNPHU main building.

Fig. 2 - overview of the UNPHU campus.

Fig. 3 - From left to right: prof. Jose Gustavo Rodriguez Mejia, the Author, prof. dr. José Rafael Espaillat Muñoz (vice-Rector), Soledad Veronica Perez-Gautier (PRAE), prof. Eugenio Leopoldo Taveras Polanco, Pedro Manuel Cabrera Objio (PRAE)

Information Systems and Spatial Data Infrastructure, and is related to any science that involves processing of geographic information.
The department is a vital reference on geomatics for all the Dominican Republic and has a close relationship with many institutional and private organizations. It is worth noting that UNPHU is the only university in the Country providing an academic curriculum in the Geomatics field.

The UNPHU-IDAC "Air and Space Project Office"

UNPHU and the "Instituto Dominicano de Aviacion Civil (IDAC)" have recently created the "Air and Space Project Office" ("Oficina Coordinadora de Proyectos del Aire y del Espacio, PRAE"), unifying their efforts to work towards the aviation industry in the academic and research fields.
The Dominican Republic Civil Aviation Institute (IDAC) is the civil aviation authority of the Dominican Republic. It was a founding member state of the International Civil Aviation Organization (ICAO). IDAC is an autonomous State agency that regulates and promotes civil aviation in the Dominican Republic; it is the air navigation service provider, contributing to the economic development of the Dominican nation.
The UNPHU Geomatics Department is heavily involved in the PRAE activities because of the growing interest in the applications of aerial drones (UAV's) to remote sensing. GNSS technologies and in particular the new possibilities offered by Galileo (multi-constellation and dual-frequency receivers) play a fundamental role in the adoption of drones to remote sensing, in a wide range of applications, spanning from agriculture to infrastructures management, natural disasters management and recovery, environmental control, surveillance and borders control. All these applications are considered critical by the Dominican government for the future development of the country.

Fig. 4 - The Author with UNPHU Dean, Prof. Miguel Fiallo Calderón

The Course/Workshop "Las Technologías de Satélites y sus Applicaciones"

The course, the first of this kind at UNPHU and probably one of the first in Dominican Republic, aimed at providing a general overview about artificial satellites and their applications, with a special focus on GNSS.
The initiative was organized by the Department of Geomatics and by PRAE, with the close support by Prof. Dr. José Rafael Espaillat Muñoz, Vice-Rector of UNPHU (Figure 3).
The course was also very welcomed by the university dean (Rector), prof. Miguel Fiallo Calderón (Figure 4).

More than fifty university students and professionals, coming from a variety of civilian and military institutions, followed the course:

1. Servicio Geológico Nacional (SGN).
2. Instituto Geográfico Nacional, Hungría Morel (IGN)
3. Unidad de Electrificación Rural y Sub-Urbana (UERS)
4. Instituto Cartográfico Militar (ICM)
5. Instituto Geográfico Universitario (IGU)
6. Dirección Nacional de Mensuras Catastrales (DNMC)
7. Colegio Dominicano de Ingenieros, Arquitectos y Agrimensores (CODIA)
8. Saint Lawrence School
9. Universidad Autónoma de Santo Domingo (UASD) Estudiantes de Geografía y Cartografía
10. Universidad Nacional Pedro Henríquez Ureña (UNPHU)

Estudiantes de Geomática y Topografía

The audience interacted actively with the speakers (Figures 5 and 6) and, during the discussions, it emerged clearly the interest in satellite technologies, mainly for applications in remote sensing and positioning.
It was also clear the high potential role these technologies will play in the future development of the Dominican Republic,

which is the largest economy in the Caribbean and Central American region. As a matter of fact, over the last two decades, the Dominican Republic have been standing out as one of the fastest-growing economies in the Americas, with an average real GDP growth rate getting above 7%, the highest in the Western Hemisphere.
It is now the right time to give the Dominican economy a qualitative boost, taking advantage of the information and communications technologies (ICT). The integration and fusion of telecommunications (satellites and 5G), high accuracy positioning (GNSS) and remote sensing (satellites, Internet of Things) will be at the core of this leap forward of the Dominican economy.

Fig. 5 – Prof. Jose Gustavo Rodriguez Mejia presenting the course to the audience.

Future activities and plans (and one dream)

UNPHU, together with public Dominican institutions and private industries, seems eager to be at the forefront of technology and innovation.
Their efforts will leverage on the cooperation programs of the European Union, starting with Horizon 2020 and its follow-on. The Geomatics department and PRAE are part of a team presenting a proposal for the management of infrastructures using aerial surveying in association with high accuracy GNSS positioning.
A technical paper on the effect of antenna phase center errors in high accuracy geodetic measurements will be presented at the 25th Ka and Broadband Communications Conference, to be held at Sorrento (Italy) in October 2019.

New courses on satellites and GNSS are being planned in the near future. One dream, discussed with excitement by students and participants: the development and launch of the first satellite of the Dominican Republic.

Fig. 5 – xxxxx.

KEYWORDS
GNSS; UNPHU; Geomatics; accuracy positioning; satellites; education

ABSTRACT
Galileo and Copernicus are not only flagship technology programs of the European Union: they can be the ambassadors of European cooperation in other continents, an effective opportunity for growth and development together. On February 14th and 15th this year, a post-graduate course on satellites technologies and applications was held in Santo Domingo, Dominican Republic, at the Universidad Nacional Pedro Henríquez Ureña (UNPHU).

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Earth like you've never seen it before: PRISMA reveals the state of our planet's health

by Giuseppina Piccirilli

The first images from the Italian Space Agency satellite are now available. Captured by the hyperspectral sensor, they have been received in Matera and processed by a team of engineers and scientists. This "first look" confirms the outstanding performance of PRISMA and its hyperspectral sensor.

Fig. 1 PRISMA image of Trasimeno lake in Italy

The amazing pictures were captured in Italy, Peru and Iraq during the Commissioning of the system. This phase, managed by the Space Centre in Fucino, Italy, involves in-orbit satellite and instrumentation testing, until the satellite is fully operational and its data available to the scientific community. The images were received by Matera Space Centre, where a team of experts from ASI, Leonardo, Planetek, Telespazio/e-GEOS and OHB Italia processed them with the support of scientists from the National Research Council of Italy (IREA/CNR) and the University of Milano-Bicocca.

Launched on the 22nd March 2019, PRISMA, a satellite of ASI developed by an industrial consortium led by OHB Italia and Leonardo, is the first European Earth Observation system with innovative hyperspectral optical instrumentation able to perform chemical and physical analysis from Space. The first data from the mission confirms the ability of the Italian space system, which developed advanced expertise for future hyperspectral missions in Europe and the rest of the world.

The first PRISMA image features Trasimeno, the fourth largest Italian lake, with a surface of 128 square Km. The water resource is key for tourism, agriculture and fisheries. In less than 2 seconds, PRISMA measured the turbidity of every single spot in the lake, identifying the clearest waters and algae colonies. Water is the most precious resource we have on our Planet and its wise ma-

nagement – in line with SDGs "clean water" and "life below water" – is, in this era signed by climate change, a commitment to future generations.
In the second image, PRISMA detected vegetation water content in Perù, recognizing well-irrigated fields and droughts. Sustainable agriculture is a major challenge for mankind: aiming at "zero hunger" and "sustainable production and consumption" United Nations SDGs, PRISMA allows unprecedented accuracy monitoring water scarcity in crops, offering new instruments to precision agriculture and resource management.
Every year about 65,000 fires occur in Europe with 85% of them in the Mediterranean area. Water monitoring, when applied to forests, can provide a precursor signs of wildfire risk. The third image shows an example where state of the art technology can be effectively used to save human and animal lives, to protect biodiversity and preserve soil against hydrogeological risks due to fires. In Castel Fusano (Italy), a naturalistic area put at risk by frequent fires, PRISMA performed two analyses: the vegetation status, with an evaluation of chlorophyll, and the water content in forest areas, identifying drier areas with higher fires risk.
Gas flaring from oil production in Bassora/Basra (Iraq) has been captured by PRISMA as well. In addition to precisely determining the fire extent, hyperspectral technology allows the recognition of the chemical substances generated by combustion: CO2 and other hydrocarbons have a "hyperspectral fingerprint – PRISMA measures air pollution and characterizes it.
PRISMA is able to monitor the delicate terrestrial ecosystem: it recognizes not only water and soil conditions worldwide, but also atmosphere status and the chemical substances in it,

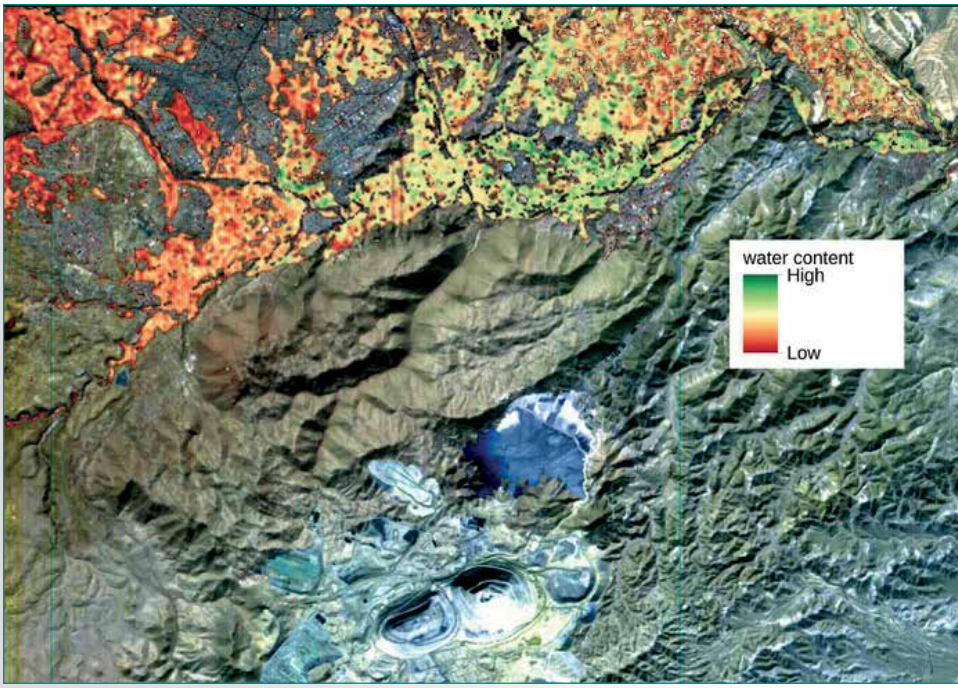

Fig. 2 PRISMA image of vegetation water content in Perù

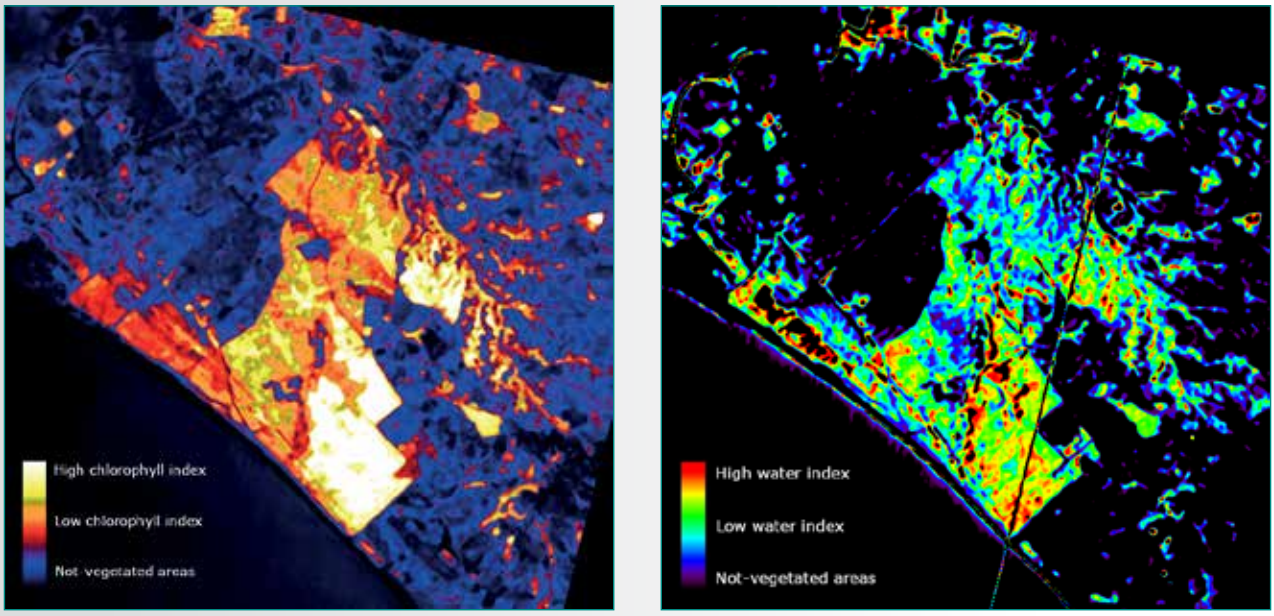

Fig. 3a 3b PRISMA image of vegetation status in the naturalistic area of Castel Fusano (Italy)

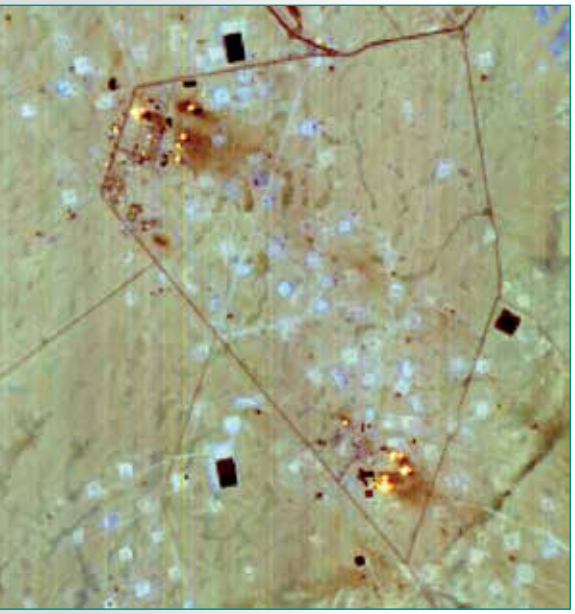

Fig. 4 PRISMA image of oil spill in Basra (Iraq)

which is extremely valuable for evaluating natural disasters. The amazing pictures released today are just a small sample of what to expect when the system is fully operational: a crucial contribution to the controlling pollution, studying climatic and environment changes, and unprecedented support to resource and emergency management.

ABSTRACT

Water quality, crops monitoring, drought and wildfire risk, air pollution: the Italian Space Agency started to release new images from the PRISMA satellite, which reveal the state of our planet's health and contributes to the United Nations Sustainable Development Goals. Thanks to its hyperspectral sensor, developed by Leonardo and the first of its kind ever launched in Europe, PRISMA proves to be a versatile guard to protect the environment.

KEYWORDS

ASI, PRISMA, environmental monitoring, earth observation, hyperspectral

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PRISMA AND INDUSTRIAL CONSORTIUM

PRISMA, a satellite of the Italian Space Agency (ASI), is the first European Earth Observation system with electro-optical instrumentation that combines a hyperspectral sensor with a medium-resolution panchromatic camera. Launched on 22 March 2019 with a VEGA rocket, produced by AVIO, PRISMA was developed by a Temporary Joint Venture of companies, led by OHB Italia, responsible for the mission and management of the three main segments (ground, flight and launch) and Leonardo, which built the electro-optical hyperspectral instrumentation in addition to on-board equipment such as attitude sensors and solar panel. Telespazio (Leonardo 67%, Thales 33%) set up the mission control centre at Fucino Space Centre, while data acquisition and processing will take place at the ASI Matera Space Centre.

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