NEWTON Deliverable D1.4

Second Project Period Report Summary
Reference Period: 1st November 2017 - 31st October 2018

Project Number:	**730041**
Project Title	**New portable multi-sensor scientific instrument for non-invasive on-site characterisation of rock from planetary surface and sub-surfaces**
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Consortium Partners

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3	Universidad Politécnica de Madrid	UPM	Spain
4	Universitat Trier	UT	Germany
5	Centre National de la Recherche Scientifique CNRS	CNRS	France
6	IGU Institut fur Industriellen Undgeotechnischen Umweltschutz GMBH	IGU	Germany

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ABBREVIATIONS

AC	Alternating Current
CNRS	Centre Nacional de la Reserche Scientifique
CU	Control Unit
DC	Direct Current
DoA	Description of Action
EU	European Union
IGU	Institut für Industriellen und Geotechechnische Unweltshutz
INTA	Instituto Nacional Técnica Aeroespacial “Esteban Terradas”
ISECG	International Space Exploration Coordination Group
LPG	Laboratoire de Planétologie et Géodynamique
NEWTON	New portable multi-sensor scientific instrument for non-invasive on-site characterization of rock from planetary surface and sub-surface
PDU	Power Distribution Unit
SU	Sensor Unit
TTI	Tecnologías de Telecomunicaciones e Información
UPM	Universidad Politécnica Madrid
UT	University of Trier

1. SUMMARY FOR PUBLICATION

1.1. Summary of the context and overall objectives of the project

NEWTON is an international research project co-funded from EU H2020 programme funds. The project NEW portable multi-sensor scienTific instrument for non-invasive ON-site characterization of rock from planetary surface and sub-surfaces (NEWTON) is developing a new portable and compact multi-sensor instrument for ground breaking high-resolution magnetic characterization of planetary surfaces and sub-surfaces, being the Moon and Mars the main scenarios of application of the instrument. This non-invasive technology provides unique scientific information on some of the main objectives related to the Solar System exploration roadmap as the intense magnetic crustal anomalies of Mars and the strongly discussed formation of its moons.

NEWTON is developing a susceptometry instrument which is combined with a compact vector magnetometer. While the latter only represents a modification of still existing magnetometers, the susceptometer will be able to measure in-situ for the first time both, the real and imaginary magnetic susceptibilities of minerals and rocks. With this, NEWTON provides a first opportunity to perform a widely complete in situ, non-invasive and high-resolution measurement of the different and complex magnetic properties of rocks at planetary surfaces (including the Earth). The NEWTON instrument delivers critical and unique information on the past and present magnetic signatures of the analysed rocks. By analysing both remanent vector magnetic data together with the susceptibilities, the surface characteristics (orientation and intensity) as well as paleodynamos can be constrained for different periods of the geological history, on the Earth and on other planets and moons. This provides important new insights concerning planetary formation processes and their further dynamic evolution, as well as internal structure, and relations with the space environment. Moreover, the benefits of NEWTON technology provide ample opportunities for spin-in/spin-out effects between space and non-space technology fields, where the out-coming instrument would represent a real advantage over existing products.

To this end, three main objectives have been defined within the framework of the project:

- **Objective 1:** Establish general requirements and use cases for two different scenarios of the planetary exploration: on board rovers (short term) and on-board laboratory stations (medium term) for the exploration of Mars and the Moon. Due to the fact that there is not any precedent of such an instrument on Earth, it will be analysed its applicability to Earth sciences and applied geology.
- **Objective 2:** Implementation of a novel multisensory instrument for in-situ non-invasive planetary prospecting with three main innovations: 1) a compact susceptibility technology capable to measure real and imaginary parts at different frequencies, 2) efficient designs of power systems and 3) highly accurate frequency generation and detection.
- **Objective 3:** To introduce the potential of the multi-sensor instrument in the next planetary mission forums and start the actions for its inclusion as a new payload in the medium-term rovers. The appropriateness of the multi-sensor system will be demonstrated through measurement campaigns in relevant geological sites. Regarding the spin-off of the technology for the society, the consortium has selected the civil engineering as an example of application and an extra demonstration of NEWTON potential will be carried out with geophysical prospections.

The work is conducted following three main steps: the first one is to make the design and development of the instrument; the second is to assess its performance in the laboratory; finally, the third one is to validate the instrument in real terrestrial analogues. NEWTON project started in November 2016 and has a duration of 36 months. This document makes reference to the work undertaken during the second year of the project.

1.2. Work performed during the period covered by the report and main results achieved so far

The reporting period covers from 1st November 2017 till 31st October 2018. Within this period, the main effort has been devoted to the finalization of the design of the NEWTON instrument, its implementation, and its calibration and functional verification in the laboratory.

NEWTON project is developing three different prototypes adapted to different scenarios. Two prototypes (named prototype 1 and 3) are being developed for planetary application, while a slightly reduced version of prototype 1 (named prototype 2) is being developed in order to demonstrate the spin-off of the technology between space and non-space fields. Prototype 1 is designed for planetary exploration missions with the particular case of Martian and Moon's system with an envelope adapted to a rover-mounted payload. Prototype 3 is an advanced system for the in-situ analysis and full magnetic characterization of drilled samples in the long-term missions with more powerful rovers or to be part of base stations with the particular case of Martian and Moon's systems. The three prototypes share the same architecture while they provide different performance capabilities adapted to different scenarios. The key building blocks of the three prototypes are the same, i.e. Power Distribution Unit (PDU), the electronic Control Unit (CU) and the Sensor Unit (SU).

During the reporting period, the final design of the NEWTON prototypes has been concluded. With regard to the prototype 1, it is integrated by the magnetometer and the susceptometer. The magnetometer is an HMC1023 3-axis magnetic sensor manufactured by Honeywell. It is a high performance three-axis magneto-resistive sensor design in a single package. The susceptometer is an induction-based device, consisting on a ferrite core with H shape. In addition to this, temperature sensors have been included in the design to reduce the error in the measurement due to T dependence. Prototype 1 also integrates an electronic Control Unit with highly accurate frequency generation and detection capability, and an efficient and compact-size Power Distribution System. NEWTON prototype 1 allows to perform in-situ measurement of the susceptibility at different frequencies combined with Natural Remanent Magnetization data. With regard to the Prototype 2, it is a reduced version of prototype 1 for a rapid and preliminary analysis of the surface during prospections on Earth.

NEWTON instrument prototype 3 is an advance system that provides susceptibility measurements, and demagnetization and isothermal remanent magnetization acquisition experiments. This prototype is based on two designs for different range of frequencies that have been named prototype 3A (P3A) and prototype 3B (P3B). P3A is designed for medium-high frequencies and it performs magnetic flux measurements to characterize the magnetic properties of the materials. This kind of measurement is not frequency dependant and has very good sensitivity. The sample is moved by means of a linear actuator within a secondary (pick up) coil system which measures the flux changes produced by the presence of an alternating magnetic field set by a primary coil. P3B is defined to work with DC intense fields. It consists on a DC-ultra low frequency intense magnetic field production system based on a mechanical vibrating system, which limits the working frequency, and a big electromagnet to achieve the high field. The Prototype 3 also includes an electronic Control Unit able to perform the magnetic measurement and to generate the signal used to produce the exciting field. In addition to this, an AC current source has been developed to generate the required magnetic field.

As already mentioned, the design of the instruments has been completed during the second year of the project. Moreover, the different blocks have been integrated and then the performance of the HW has been validated in the laboratory. Moreover, the calibration of the instrumentation has been also performed with different patterns and samples. NEWTON technology has been also tested under space environmental conditions by means of submitting the susceptometer to vibration and thermo-vacuum tests. The results obtained during this stage prove the capability of NEWTON technology to be part of future exploration missions.

Furthermore, during the reporting period, magnetic measurements have been performed on different terrestrial analogues, i.e. Barda Negra Crater (Neoquen Province, Argentina), Pali Alike Volcanic field in Chile and recently formed volcanic field on Lanzarote Island, as well as field campaigns performed at applied geological sites in Germany. In order to perform these field measurements, it has been developed a portable field measurement system for in-situ acquisition of georeferenciated data with an innovative navigation system which provides a complete orientation control in a 3-D XYZ system with uncertainties of less than ± 1° for each axis. These field measurements allow, on one hand to reduce the risk of the field works planned for the last year of the project which are really ambitious and challenging, and on the other hand, they have allowed to validate on an early state the designs of the instrumentation and identify any possible improvements during its development. During our on-going practical field work, we have also tested the capacity and potential of NEWTON technology for geophysical exploration in the context of long-term space exploration missions.

During this period, a significant effort has been also dedicated to the communication, dissemination and exploitation of NEWTON. Space exploration programs of different agencies around the world are being reviewed in order to find new possibilities for NEWTON technology as well as new scenarios of application. Moreover, NEWTON results have been disseminated through NEWTON official web-site and social networks, as well as through the participation on relevant scientific and general-public events, and also by means of the publication of the main outcomes of the project in specialised journals. The fist NEWTON workshop has been also organized on the 22-24 October 2018. Different sessions were organized with the aim of discussing about the latest state-of-art regarding in-situ instrumentation for planetary surface characterization, with particular focus on magnetometric devices and their application to planetary exploration. In addition to this, the workshop served as a showcase to disseminate the activities developed within the NEWTON project and the latest advances regarding the design and validation of NEWTON instrumentation.

From a management point of view, the work has been devoted to the coordination of the work among the NEWTON consortium in order to ensure the successful completion of the project objectives in accordance with the project plan.

1.3. Progress beyond the state of the art, expected results until de end of the project and potential impacts (including the socio-economic impact and the wider societal implications of the project so far)

The ultimate objective of NEWTON project is the development of a magnetic instrument combining susceptometer and vector magnetometer for planetary scientific exploration. It aims to provide a complete in-situ, non-invasive and high-resolution characterization of the distinct magnetic properties of rocks and their constituting minerals, which will open a new via in the understanding of the Solar System.

The last edition of the Global Exploration Roadmap published by the Space Exploration Coordination Group (ISECG, 2018) in January 2018, documents the ambitious goals of worldwide space agencies roadmaps concerning the expansion of human presence into the Solar System including particularly surface explorations on Mars and the Moon. Preparatory missions include robotic missions to both celestial bodies and also to near-Earth asteroids. Future space exploration programs aim a better understanding of (1) the origin and geological history of celestial bodies as well as their magnetization histories with related shielding effects, (2) exploration of extra-terrestrial volatile and water resources which can be used during future missions and (3) investigation of elemental enrichment processes and related formation of extra-terrestrial resources and ore deposits. However, recent multi-instrument suites do not provide devices to measure magnetic susceptibilities, which represent an important tool in the context of the previously described exploration aims. NEWTON sensor is a key element to provide a detailed characterization of rock composition at future landing suites and surrounding areas by e.g. rover or robotic mapping. In particular, the potential regional magnetic shielding, due to a remanent magnetic rock behaviour, must be estimated with respect to possible past life formation as well as future habitability. Furthermore, such local to regional mineralogical and geophysical rock characterization will be important to detect and consider the potential of extra-terrestrial raw materials and ore deposits.

The prospections campaigns performed so far within the framework of NEWTON project, have allowed to test the NEWTON technology on many distinct crustal analogue rock suites as well as to prove its capacity for geophysical exploration in the context of next space exploration missions.

It should be also highlighted that despite all the emerging work, either on commercial devices and on research area, NEWTON device is at the forefront of technological innovation, given that none of the current commercial or state of the art devices, although they could have better performances in terms of resolution, sensitivity or frequency range, are oriented to a hand-held device for the measurement of the complex magnetic susceptibility without the need of sample preparation in a space environment. Furthermore, NEWTON project provides potential opportunities for spin-in/spin-out effects between space and non-space field technologies. With this regard, NEWTON novel technologies can be applied in different fields being the geophysical engineering one of the most relevant. High resolution mapping of distinct magnetic properties might provide a characterization of most distinct natural rocks and their complex three-dimensional geological structure which allows a better in-situ interpretation with the consequent time and cost savings. With this regard, magnetic field mappings with components of the NEWTON multi-sensor unit have been also performed at applied geological sites, and the first results document the appropriateness of the NEWTON instrument to be exploited also for applied geological topics.