NEWTON Deliverable D1.6

Project Final Report Summary

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**
Deliverable Type:	**Public**

Project Coordinator
Cristina Lavín
TTI
Tel: +34 942 29 12 12
Fax: +34 942 27 01 39
Email: clavin@ttinorte.es

Consortium Partners

Beneficiary Number	Beneficiary Name	Beneficiary Short Name	Country
1 (Coordinator)	TTI	TTI	Spain
2	Instituto Nacional de Técnica Aeroespacial Esteban Terradas	INTA	Spain
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

CU	Control Unit
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
TRL	Technology Readiness Level

1. SUMMARY FOR PUBLICATION

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

The project NEW portable multi-sensor scienTific instrument for non-invasive ON-site characterization of rock from planetary surface and sub-surfaces (NEWTON) provides a first opportunity to perform a widely in situ, non-invasive and high resolution measurement of the complex magnetic properties of rocks at planetary surfaces. This is achieved by means of a new portable and compact multi-sensor instrument which combines susceptometer with compact vector magnetometer. While the latter only represents a modification of still existing magnetometers, the susceptometer is a novel design which allows to measure in-situ for the first time both, the real and the imaginary susceptibilities of minerals and rocks.

The overall objectives of NEWTON project are:

- **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.

NEWTON project started in November 2016 and it has finalized in January 2020. During its lifetime, the work has been conducted following three main stages: a) to perform the design and development of the instrument; b) to assess its performance in the laboratory; c) to validate the instrument in representative terrestrial analogues.

Within the framework of NEWTON project, three prototypes have been designed, implemented and validated. The three prototypes share the same architecture while they provide different performance capabilities adapted to different scenarios. Two prototypes (named prototype 1 and 3) have been developed for planetary exploration, being the Moon and Mars the main scenarios of application, while a slightly (reduced) adapted version of prototype 1 (named prototype 2) has been developed in order to demonstrate the spin-off of the technology between space and non-space fields. The instruments have been manufactured and validated in the laboratory, as well as in terrestrial analogues representative of the scenarios of application of NEWTON. In addition to this, NEWTON instrument prototype 1 has been verified under space environment conditions. With this regard, the sensor head has been proved to stand representative qualification levels of ExoMars 2020 mission, considering the design validated for a TRL 6. In addition to this, the performance capability of the instrument to operate on rover platforms has been also demonstrated within the framework of the project.

NEWTON project non-invasive technology delivers unique information on the past and present magnetic signatures of the rocks, which provides relevant new insights concerning planetary formation processes and their further dynamic evolution. This can give answers to 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. 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.

FIGURE 1. Photograph of NEWTON instrument prototype 1.

1.2. Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

NEWTON project has designed, implemented a validated three different prototypes of NEWTON multi-sensor instrument adapted to different scenarios of application. Prototypes 1 and 3 have been developed for planetary application, while a slightly reduced version of prototype 1, named prototype 2 has being developed in order to demonstrate the capability of NEWTON to operate on Earth's surface. 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).

NEWTON instruments have been manufactured and validated in the laboratory and also in different terrestrial analogues. Different field prospections campaigns have been carried out in selected analogue sites for lunar and martian areas such as: Pali Aike volcanic field in southernmost Chile, Barda Negra basaltic plateau located in Argentina, basaltic lava fields in Lanzarote island and the Rio Tinto region in southern Spain. Applied geological sites in Germany have been also selected to demonstrate the innovation gained from NEWTON for civil engineering applications. In addition to this, NEWTON prototype 1 has been also validated under representation qualification levels of ExoMars 2020 mission conditions.

The results achieved by NEWTON project have been disseminated through different channels, targeting a wide audience, with the final aim of achieving the inclusion of NEWTON in medium term space exploration missions. Between the actions and material for the dissemination of the technical and scientific outcomes, it can be highlighted the following ones: NEWTON public website and participation in social media networks, publication of scientific articles in international conference and journals, participation in international events and national public exhibitions and organization of two Workshops oriented to disseminate project activities and main achievements.

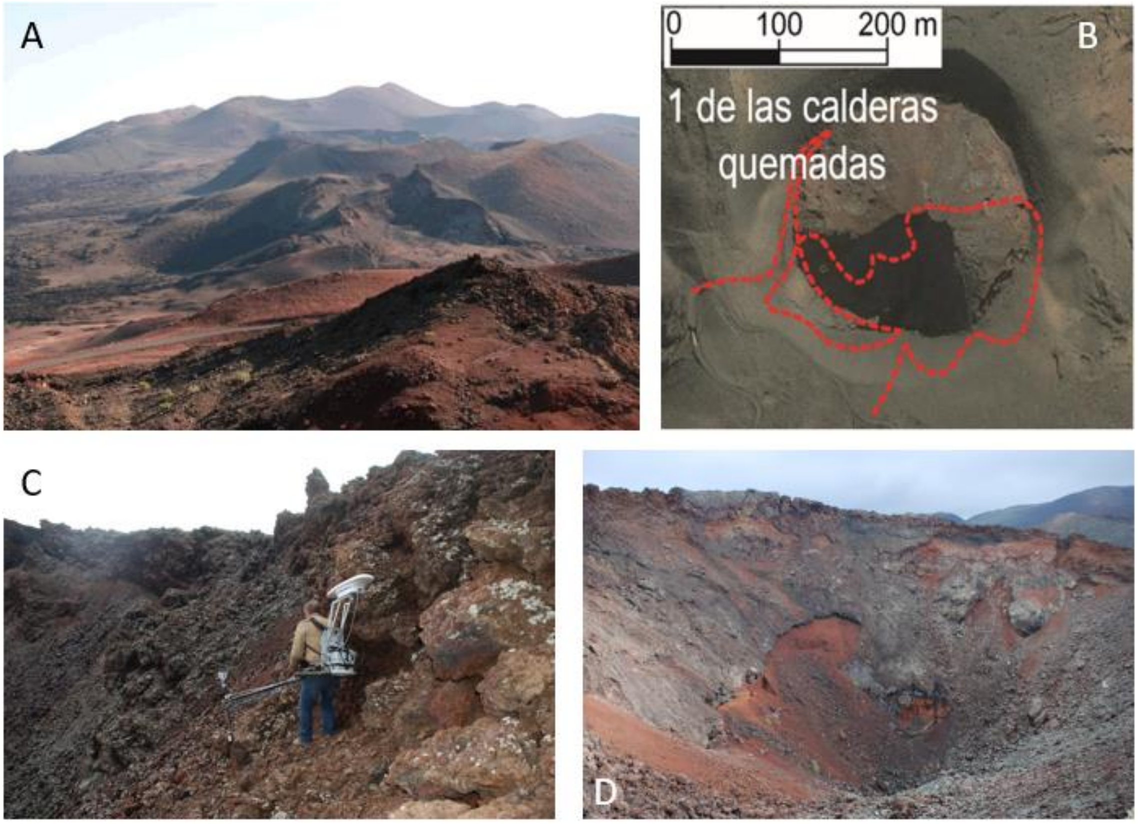

FIGURE 2. Prospection campaign with NEWTON instrument in Calderas Quedamas volcano located in Timanfaya National Park (Lanzarote Island, Spain). (A) View of the Calderas Quemadas. (B) Track performed in one of the volcanoes of Calderas Quemadas. (C) Picture during the prospection. (D) Panoramic picture of the cone.

1.3. Progress beyond the state of the art, expected results until de end of the project and potential impacts

Space Exploration Roadmap has the ambitious goal of expanding the human presence into the Solar System including particularly the surface exploration of Mars and the Moon. 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.

NEWTON device is at the forefront of technological innovation, given that, as far as NEWTON consortium knows, 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 compact 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.

FIGURE 3. NEWTON instrument integrated into LUVMI rover platform (LUVMI H2020 project, Grant Agreement: 727220).