NEWTON Deliverable D1.2

First Project Period Report Summary
Reference Period: 1st November 2016 - 31st October 2017

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**

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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

CNRS	Centre Nacional de la Reserche Scientifique
CU	Control Unit
EU	European Union
IGU	Institut für Industriellen und Geotechechnische Unweltshutz
INTA	Instituto Nacional Técnica Aeroespacial “Esteban Terradas”
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
SME	Small and Medium Enterprise
SU	Sensor Unit
TTI	Tecnologías de Telecomunicaciones e Información
UPM	Universidad Politécnica Madrid
UT	University of Trier
WP	Work Package

PERIODIC REPORT

Grant Agreement number:	730041
Project Acronym:	NEWTON
Project Title	New portable multi-sensor scientific instrument for non-invasive on-site characterisation of rock from planetary surface and sub-surfaces
Start date of the project:	01/11/2016
Duration of the project:	36 months
Period covered by the report:	From 01/11/2016 to 31/10/2017
Periodic report:	1st
Version:	1.0
Project website address:	www.h2020-newton.eu

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 characterisation of rock from planetary surface and sub-surfaces (NEWTON) aims at developing a new portable and compact multi-sensor instrument for ground breaking high resolution magnetic characterisation of planetary surfaces and sub-surfaces through the combination of complex susceptibility and vector measurements. This novel technology can be used to solve some of the open key question related to the Solar System exploration.

In space instrumentation, there is currently no instrument dedicated to susceptibly measurement and neither to complete magnetization measurement of rocks. This is among other things because the magnetic instruments considered so far for the measurements are magnetometers and the motors used with rovers for relatively recent planetary exploration produce a strong magnetic contamination, which make it difficult to reap the benefits from the inclusion of magnetometer. However, magnetic characterisation is essential to understand key aspects of the present and past history of the celestial bodies. For instance, the combination of magnetometers and susceptometers can give important information about the rocks composition, history and evolution of the planetary magnetic field. With this regard, vector magnetometers with gradiometric measurements can distinguish between rover and environmental magnetic field while susceptometers are intrinsically immune to the magnetic contaminations of the rover.

NEWTON multi-sensor instrument combines novel portable susceptometer with a vector magnetometer. The novel technology applied to NEWTON instrument provides significant improvements in instrument performance while at the same time making possible to include the instrument in rovers for planetary exploration. With this, NEWTON gives the first opportunity to perform high resolution and complete non-invasive in-situ magnetic characterization of planetary surfaces and subsurfaces. This non-invasive characterization will provide unique scientific information on some of the main objectives related to the Solar System exploration roadmap such 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 outcoming instrument would represent a real advantage over existing products.

The final objective of NEWTON project is to provide a first and unique technology capable of performing a complete characterisation of the rocks based on magnetic measurements. 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 a real environment. The instrument will include a recurrent vector magnetometer, a susceptometer, the power supply, the electronics and features for the mechanical assembly. To this end, the following concrete objectives have been defined:

- **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) novel 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 has a duration of 36 months. The work is divided into six work packages:

- WP1 is devoted to management and technical/administrative coordination of the project.
- WP2 is devoted for defining the technical specifications of the system and the architecture of the solution considering the different scenarios over which the system will be validated.
- WP3 is devoted to technical analysis, design and implementation of the different key building blocks which integrate the overall system.
- WP4 is devoted to the integration of the prototypes, their calibration and their functional verification in the laboratory.
- WP5 is devoted to the validation of the multi-sensor instruments in relevant environments.
- WP6 is devoted to dissemination and exploitation of project results.

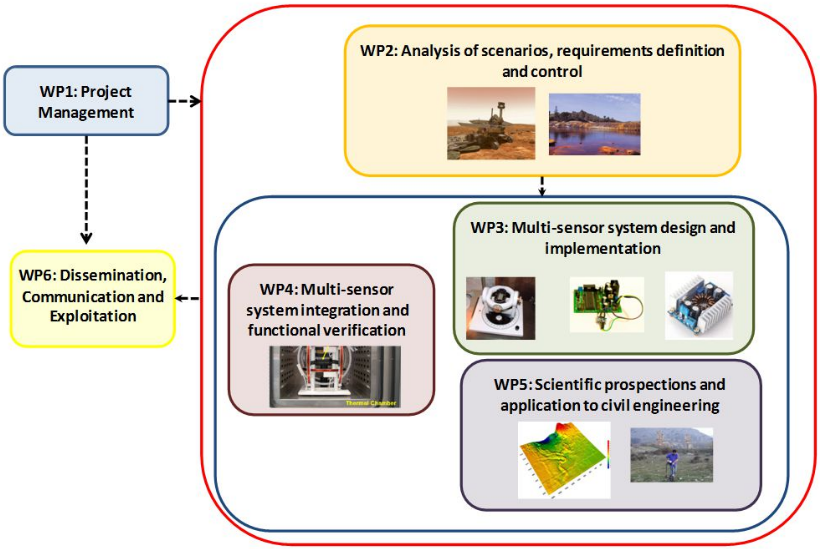

FIGURE 1. NEWTON methodology.

NEWTON consortium is comprised by six partners from three European countries: TTI, leading the project, National Institute for Aerospace Technology Esteban Terradas (INTA) and Polytechnic University of Madrid (UPM) from Spain, University of Trier (UT) and Institut für Industriellen und Geotechnischen Umweltschutz (IGU) from Germany and the Laboratoire de Planétologie et Géodynamique (LPG) from France. The feasibility of the project is based on the experience of the members of the consortium on the NEWTON key areas, with complementary profiles and their good interrelation. The achievements of NEWTON objectives is subject to a good coordination of the interdisciplinary groups, and an optimum conception and development of magnetometric instrumentation (UPM) and power supply systems (TTI) to space applications (INTA), the demonstration of the instrumentation capabilities in a relevant environment (UT) and the precursory work to include the instrument on board in planetary mission (LPG), as well as the exploitation of the instrument technological advances in the civil engineering field (IGU).

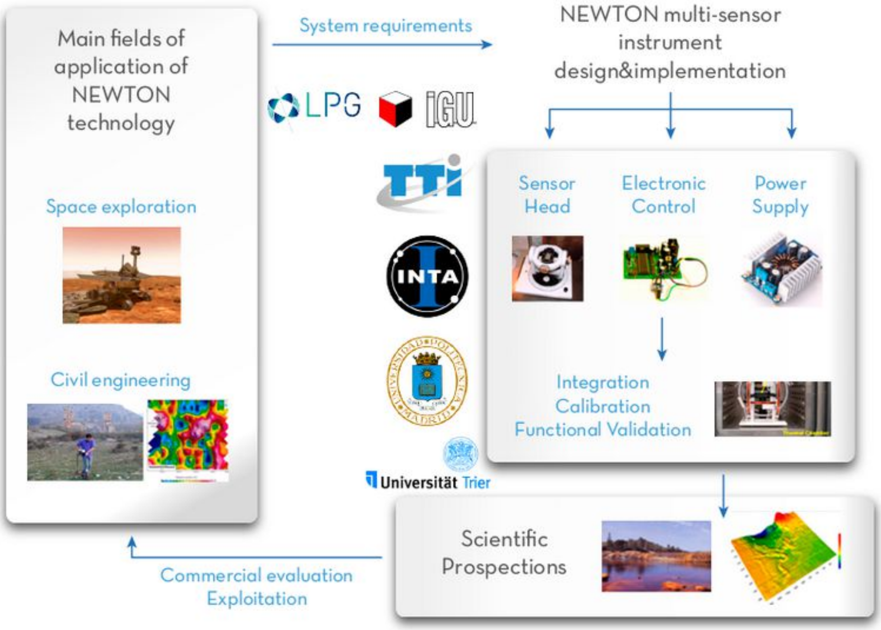

FIGURE 2. NEWTON consortium.

NEWTON project was split into two reporting periods. The first one from M1 until M12, i.e. from 01.11.2016 till 31.10.2017, and the second one from M13 till the end of the project in M36. This document details the work undertaken during the first period of NEWTON.

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

The reporting period covers from 01.11.2016 till 31.10.2017. The technical activities developed within this period have been focused on the definition of the scenarios and requirements of NEWTON multi-sensor instrument, as well as the preliminary design of its key building blocks.

NEWTON project aims to develop a new instrument with no precedent. Therefore, it is not a matter of meeting specifications, but to set the specifications. For this purpose, an exhaustive analysis of scenarios has been developed during the first months of the project. This analysis has served to define the requirements which NEWTON instrument should met to operate on the selected use cases. NEWTON multi-sensor instrument provides new technology for non-invasive in-situ planetary exploration. The instrument can be applied to obtain detailed magnetic information of planets, asteroids and other celestial bodies. With this regard, and considering the Solar System future exploration roadmap, the Moon and Mars have been selected as the possible scenarios of application of NEWTON technology. With the aim of maximizing the impact of NEWTON, different prototypes are being developed within the project. Two prototypes (named prototype 1 and 3) are being developed for planetary application, while a slightly (reduced) adapted version of prototype 1 (named prototype 2) is developed in order to demonstrate the spin-off of the technology between space and non-space fields.

The 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. This prototype performs in-situ measurements of the susceptibility in a planetary environment combined with Natural Remanent Magnetization data. Prototype 2 is a reduced version of prototype 1 implemented on a hand-held device for a rapid and preliminary analysis of surface during prospections on Earth. This prototype performs in-situ measurements of the susceptibility at discrete frequencies. It will be employed to potentiate the impact of NEWTON technology not only in space sector, but also on Earth for civil engineering applications. Prototype 3 is an advanced system for the in-situ analysis and full magnetic characterization of drilled samples in the medium term missions with more powerful rovers or to be part of base stations with the particular case of Martian and Moon's systems. This prototype performs in-situ measurements of the susceptibility, demagnetization and isothermal remanent magnetization acquisition experiments.

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 and the Sensor Unit (SU). The SU is at the same time divided in the sensor head, which includes magnetometer and susceptometer, and the electronics for the generation and processing of the excitation and measurement signals.

During this reporting period, the architecture of the three prototypes has been defined and the key building blocks have been preliminary designed. In addition to this, some preliminary validation tests have been already performed to analyze the feasibility of these initial designs. In this sense, some field campaigns have been carried out in Barda Negra crater (Argentina) and in Lanzarote (Spain) with part of the hardware developed for the preliminary design.

In addition to this, a significant effort has been dedicated to the communication, dissemination and exploitation of NEWTON. The project aims to provide a strong impact through the wide dissemination of its outcomes and the active communication of its achievements and activities. The major aim during the first year of the project has been to make the project well-known, to achieve the largest possible audience and to present and to publish first research results. At the start of the project when no results were available, the communication activities have been focused on the public disclosure of the project and its main objectives. The main communication channels used to implement this have been the NEWTON official web site and social networks. After first results were obtained, the activities have been devoted to disseminate these achievements and to promote the technological advances in scientific conferences and journals, along with the creation of a broader awareness of the developed technologies and results in academic and business forums. During this period, dissemination, communication and exploitation plans have been also defined for their implementation in the incoming years of the project. These plans have been defined with the objective of establishing the strategy to efficiently communicate the project activities and also to disseminate project results and achievements targeting two different fields of application, on one hand to the application of NEWTON instrument and results in next space exploration programmes and on the other hand to exploit the spin-in/spin-out opportunities of NEWTON in non-space fields, in particular, in civil engineering applications.

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 schedule.

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)

NEWTON project will bring new technology for space exploration. The objective of the project is the development and validation of a new portable and compact multi-sensor instrument for ground breaking high-resolution magnetic characterisation of planetary surfaces and sub-surfaces through the combination of complex susceptibility and vector measurements. This technology opens new horizons for the in-situ characterisation of materials with the determination of the real and imaginary components of the susceptibility based for the first time on time measurements, which is a very sensitive and accurate method. Moreover, NEWTON technology will relax the need of sample preparation in the sensor head thanks to its innovative field generation system.

NEWTON goes beyond the state-of-the-art technology by introducing magnetic susceptometry as a complement to existing compact vector magnetometers for planetary exploration. With this, NEWTON provides a first opportunity to perform high resolution and complete non-invasive in-situ magnetic characterisation of planetary surfaces and subsurfaces. The NEWTON instrument will deliver unique information on the magnetic structure stored during the formation of the measured rocks and thus information on the primigenial global magnetising field. Moreover, NEWTON measures will give information related to the past geological history and well as tectonically-induced changes and their orientation and thus on the planet history.

The innovation provided by NEWTON project open a new via in the understanding of key questions of the Solar System exploration which cannot be solved with the present affordable technology. To date, systematic magnetic surveys on Mars, Mercury and the Moon have been only performed by satellites in orbit. Surface measurements were only performed on the Moon during the Apollo era, and revealed dramatically varying magnetic fields over kilometre scales. A possible explanation of the Lunar field is that magnetic anomalies formed at the antipodes of large impact craters, as a result of the convergence of plasma-generated magnetic fields. A Lunar dynamo origin can however not being ruled out, as recent studies on Lunar samples showed an age variability of the recorded magnetic field. For Mars, satellite measurements have shown a very large signature, up to 1500 nT at 90-km altitude. Strong and localized field are mostly located over the southern hemisphere, where the crust is thought to be thicker. The largest impact craters, as well as the most recent volcanic structures are devoid of significant magnetic features. However, their origin remains highly disputed despite the on ground magnetic experiments by Viking Pathfinder mission. Worldwide experts in planetary magnetism strongly recommend magnetic prospections on ground with rovers to obtain detailed magnetic signatures and rocks susceptibilities prior to sample-return mission. However, they have not been performed so far for the incompatibility of magnetic instrumentation with the magnetic noise of the landed platforms. NEWTON will overcome this limitation and will shed light on questions as the intense magnetic anomalies of Mars, the characteristics of its past field, the origin of Phobos and Deimos and whether comets brought the life to the Earth.

Furthermore, NEWTON project lead 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. One of the fields in which the project could have greater impacts is in the geophysical engineering. 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.