NEWTON Deliverable D3.5

Final Design Report: NEWTON instrument prototype 2

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Authors:
TTI: Cristina Lavín, Laura González , Reinel Marante
INTA: Marina Díaz, José Luis Mesa, Javier de Frutos, Miguel Ángel Rivero, Amanda Ordoñez, Veracruz González
UPM: Claudio Aroca, Mar Sanz, Marco Maicas, Marina Pérez, Pedro Cobos
UT: Rolf Kilian

Abstract: As it is included in NEWTON DoA, D3.5 - Final design and validation report for the electronic control block should describe the final design and validation of the electronic control unit. However, during the first NEWTON periodic review it was agreed to modify the content and objectives of deliverables D3.4, D3.5 and D3.6 and to include in each of them the final design of NEWTON prototypes 1, 2 and 3 respectively. This was requested with the aim of improving the comprehensibility of the documents and the activities developed for the completion of the final design of each instrument. Due to this reason, this document, renamed as D3.5 - Final Design Report: NEWTON instrument prototype 2, describes the final design of the NEWTON instrument prototype 2 as well as the functional verification of its key building blocks, i.e. Sensor Unit, electronic Control Unit and the Power Distribution Unit.

Keyword list: Planetary Science, magnetometry, complex susceptibility, multi-sensor system, Mars, the Moon, susceptometer, magnetometer, magnetic amplifier, control unit, lock-in, power supply.

Executive Summary

As it is included in NEWTON DoA, D3.5 - Final design and validation report for the electronic control block should describe the final design and validation of the electronic control unit. However, during the first NEWTON periodic review it was agreed to modify the content and objectives of deliverables D3.4, D3.5 and D3.6 and to include in each of them the final design of NEWTON prototypes 1, 2 and 3 respectively. This was requested with the aim of improving the comprehensibility of the documents and the activities developed for the completion of the final design of each instrument. Due to this reason, this document, renamed as D3.5 - Final Design Report: NEWTON instrument prototype 2, describes the final design of the NEWTON instrument prototype 2 as well as the functional verification of its key building blocks.

With the aim of maximizing the impact of novel NEWTON technology, 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) will be developed in order to demonstrate the spin-off of the technology between space and non-space fields. 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). As already indicated, this document reports the final design of prototype 2, as well as the functional verification of its Sensor Unit, electronic Control Unit and Power Distribution Unit, while D3.4 and D3.6 describe the final design of NEWTON prototype 1 and 3 respectively, as well as the functional verification of their respective key blocks.

This document is structured in different sections. Section 2 gives an overview of the architecture and main features of NEWTON instrument prototype 2. Section 3 describes the final design of the Sensor Unit, electronic Control Unit and Power Distribution Unit. Finally, Section 4 presents a summary of the content included in this document, the main conclusions on the degree of advance obtained from it as well as the future lines of work, while Section 5 provides the referenced bibliography.

Authors

Partner	Name	Email
TTI	Cristina Lavín	clavin@ttinorte.es
	Laura González	lgonzalez@ttinorte.es
	Reinel Marante	rmarante@ttinorte.es
INTA	Marina Díaz	diazma@inta.es
	José Luis Mesa	mesaujl@inta.es
	Javier de Frutos	frutosfj@inta.es
	Miguel Ángel Rivero	riveroma.pers_externo@inta.es
	Amanda Ordoñez	arlensiuoca@inta.es
	Veracruz González	gonzalezgv@inta.es
UPM	Claudio Aroca	claudio.aroca@upm.es
	Mar Sanz	mar.sanz.lluch@upm.es
	Marco Maicas	marco.maicas@upm.es
	Marina Pérez	marina.perez@isom.upm.es
	Pedro Cobos	pedro.cobos@upm.es
UT	Rolf Kilian	kilian@uni-trier.de

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Abbreviations

AC	Alternating Current
ADC	Analog to Digital Converter
CU	Control Unit
D	Deliverable
DAC	Digital to Analog Converter
DC	Direct Current
DoA	Description of Action
g	grams
INTA	Instituto Nacional Técnica Aeroespacial "Esteban Terradas"
IRM	Isothermal Remanent Magnetization
kHz	Kiloherts
LPF	Low Pass Filter
mA	milliAmpere
MHz	Megahertz
NEWTON	New portable multi-sensor scientific instrument for non-invasive on-site characterization of rock from planetary surface and sub-surfaces.
NRM	Natural Remanent Magnetisation
nT	nanoTesla
PDU	Power Distribution Unit
R	Resistance
RS	Recommended Standard
SPI	Serial Peripheral Interface
SU	Sensor Unit
TBC	To Be Completed
TBD	To Be Determined
TTI	Tecnologías de Telecomunicaciones e Información
µC	Microcontroller
UPM	Universidad Politécnica Madrid
UT	University of Trier
µT	MicroTesla
V	Volts
W	Watts
WP	Work Package

1. INTRODUCTION

NEWTON project targets to provide a fist opportunity to perform high resolution and complete non-invasive in-situ magnetic characterization of planetary surfaces and subsurfaces by means of developing a new portable and compact multi-sensor instrument which combines complex susceptibility and vector measurements. This instrument includes a magnetometer, a novel portable susceptometer, a power supply system and an electronic control with a frequency generation system.

The combination of magnetometers and susceptometers gives relevant information about the rocks composition, the history and the evolution of the planetary magnetic fields. This data will contribute to open a new via in the understanding of key questions related to the Solar System exploration which are still open. Questions as the intense magnetic anomalies of Mars, the characteristics of its past field, the origin of its moons, i.e. Phobos and Deimos, or even whether comets brought the life to the Earth can find some answers with the new data provided by NEWTON instrument. In addition to this, NEWTON provides also advantages in non-space technology fields among the ones it could be highlighted the application in civil engineering, in particular in the construction industry. NEWTON technology can be used for the soil, sediment and rock characterization in geotechnical works, the characterization of constructions materials such as concrete and bricks, to the detection of contamination soils and soft rocks with metals and the presence of cobalt and other contaminants particles in the concrete. With this regard, NEWTON instrument delivers better measurements interpretation which allows to reduce the time and cost of the prospections.

As already mentioned, with the aim of maximizing the impact of novel NEWTON technology, three different prototypes are being developed within the project. The prototypes which share the same architecture and provide different performance capabilities adapted to different scenarios are:

- Prototype 1: This prototype 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 complex susceptibility in a planetary environment combined with vector Natural Remanent Magnetization (NRM) data. This prototype will work in a sweep of continuous frequencies.

- Prototype 2: This prototype 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 a discrete frequency. It will be employed to demonstrate the industrial spin-off of NEWTON technology in civil engineering applications.

- Prototype 3: This prototype 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 measurement of the susceptibility, demagnetization and isothermal remanent magnetization (IRM) acquisition experiments.

This document describes the final design of NEWTON instrument prototype 2. The final design of NEWTON instrument prototype 1 and 3 are respectively reported in deliverables D3.4 [1] and D3.6 [2]. As NEWTON prototype 2 is a reduced version of NEWTON prototype 1, both instruments share many parts of the design. Due to this reason, and with the objective of not repeating the same information in different documents, many parts of this deliverables make reference to deliverable D3.4 where all the details of the design have been included.

2. NEWTON PROTOTYPE 2

The block diagram of the NEWTON instrument prototype 2 is illustrated in FIGURE 1. The architecture has been updated from the architecture previously reported in deliverable D3.1 [3].

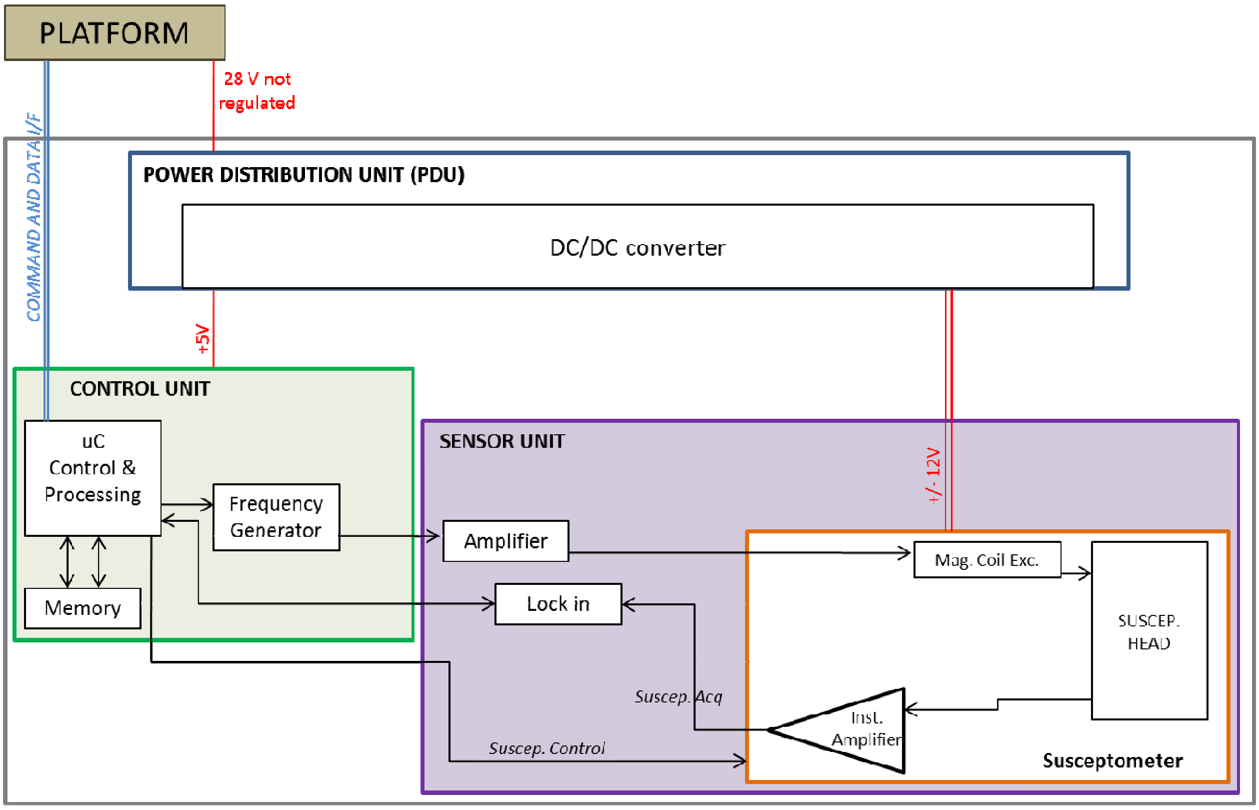


FIGURE 1. Block Diagram of the NEWTON multi-sensor instrument for prototype 2.

NEWTON instrument prototype 2 is integrated by the same three key building blocks which integrate prototype 1, i.e. the Sensor Unit (SU), the electronic Control Unit (CU) and the Power Distribution Unit (PDU). However, there are some differences between prototype 1 and prototype 2, in particular, in the case of the Sensor Unit. NEWTON prototype 2 is conceived for a rapid and preliminary analysis of the surface during geological prospections on Earth. To that purpose, the instrument includes only a susceptometer capable of measuring the complex susceptibility at one frequency, i.e. 15 kHz / 40 kHz TBC, while the magnetometer incorporated in NEWTON prototype 1 has been removed from the design. The thermometer which has been integrated in the prototype 1 has been also removed from NEWTON instrument prototype 2. This simplified architecture will facilitate the integration of the multi-sensor instrument reducing its volume and weight. In addition to this, it allows the use of NEWTON prototype 2 for quick complex susceptibility measurements of the Earth's surface and its combination with other magnetic instrumentation in case of more detailed field measurements were required.

3. DETAILED DESIGN OF NEWTON PROTOTYPE 2

3.1. Sensor Unit

As already indicated in the previous section, the Sensor Unit of the prototype 2 is integrated by the susceptometer. The susceptometer is the same as the susceptometer of NEWTON prototype 1. It is an induction based device based on a ferrite core with H shape implemented by means of a couple of U ferrite cores and with a primary coil on each of the four arms of the H, as illustrated in FIGURE 2. The H shaped ferrite core of the susceptometer allows to perform a differential measurement of the susceptibility of the atmosphere and the susceptibility of the rock. In addition to this, two primary coils are placed in two of the ferrite arms in order to pick up the electromotive force signal of the magnetic field.

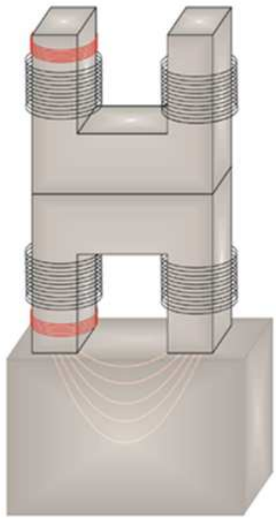


FIGURE 2. Ferrite core with H shape.

TABLE 2 depicts the updated requirements for the design of the susceptometer of NEWTON prototype 2. As mentioned before the same design is adopted for the susceptometer of NEWTON prototype 1 and 2, the only difference resides in the magnetic amplifier employed to perform measurements at different frequencies. Prototype 2 will operate at only one frequency point so magnetic amplifier has been removed from the design. With regard to the rest of the element which integrate the sensor unit, i.e. ferrite H core and the electrical resonant circuit, their detailed design and functional verification have been detailed described in deliverable D3.4 [1].

TABLE 1. Common design operational requirements for prototype 2.

ELECTRICAL CHARACTERISTICS	
Power supply (W) Voltage (V) Ripple voltage (mVpp) (f: 0 - 30 MHz)	≤1.5 TBC 5 .00 ≤ V ≤ 5.40 TBC 150
MAGNETIC CHARACTERISTICS	
Susceptibility Range (χ)	$10^{-6} \leq \chi \leq 10^{3}$ TBC
Frequency: f(kHz)	15 / 40 TBC
Magnetic Field, at 3 cm from head: B (µT)	30 ≤ B ≤ 300 TBC
Resolution	$1 \cdot 10^{-6}$
Sensitivity	$1 \cdot 10^{-6}$
Noise	$2 \cdot 10^{-7}$
Sensitivity Temp. Coeff.	1% full scale

Magnetic field dynamic range	± 200 µT
Magnetic field resolution	1 nT
Bandwidth	10 Hz
Stability	1 ‰
PHYSICAL CHARACTERISTICS	
Head Dimensions maximum (mm)	70 x 40 x 85 mm
Mass (g)	≤400 TBC

3.2. Electronic Control Unit

The block diagram of the electronic Control Unit developed for the NEWTON prototype 2 is illustrated in FIGURE 3. Same design has been adopted for the CU of prototypes 1 and 2. Those parts which are not used in prototype 2, i.e. the control block of the magnetometer and thermometer will not be mounted in the board. The details related to the design of the CU and its functional verification can be found in deliverable D3.4 [1].

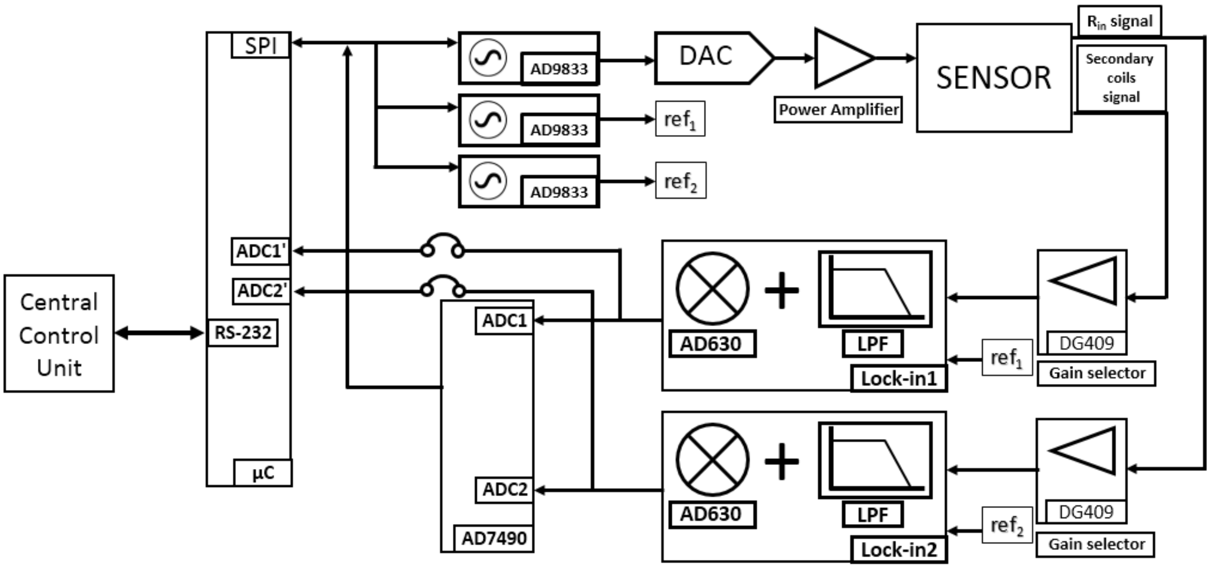


FIGURE 3. Block diagram of the control unit of NEWTON prototype 2.

3.1. Power Distribution Unit

The Power Distribution Unit of NEWTON instrument (for the three prototypes) supplies energy to the Control Unit and to the Sensor Unit and it is integrated by the AC current source and the power module, i.e. DC/DC converter.

With regard to the AC current source, it drives the primary winding of the Sensor Unit. In the case of prototype 2, the AC current source has been implemented as part of the Electronic Control Unit by means of using a frequency generator and an external amplifier which is placed in the Sensor Unit. This design is the same as for NEWTON prototype 1, so further details about its design and implementation can be found in deliverable D3.4 [1].

With regard to the DC/DC converter, the DC/DC converter provides three different output voltages from the main primary power which consists on external batteries in the case of NEWTON prototype 2. The requirements of the DC/DC converter for NEWTON prototype 2 are listed in TABLE 2. There has been no modification with respect to the requirements initially defined and reported in D3.3 [4].

TABLE 2. Requirements for the design of the DC/DC converter.

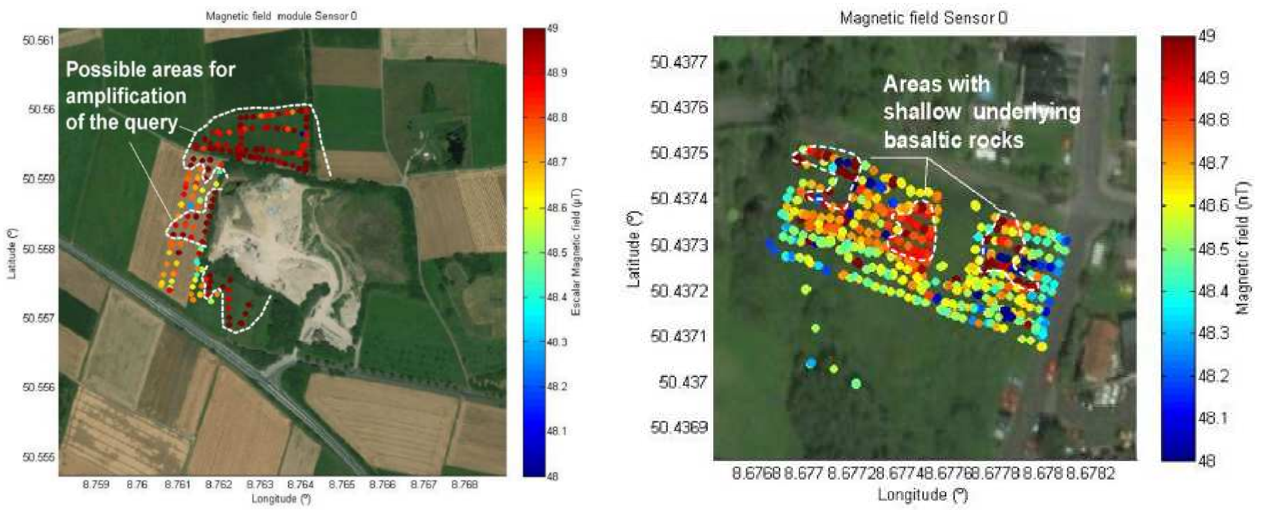
Parameter	Prototype 2	Observations
ELECTRICAL		
Input DC Voltage	+28 V (not regulated)	From external batteries
Output DC Voltages	+5 V +12 V -12 V	+5 V are dedicated to supply general electronics (digital output) +12 V and -12 V should supply the amplifiers of the susceptometer (analogue output)
Output ripple	≤ ±0.5 %	Implies a maximum ripple of 120 mVpp at the +12 V and -12 V outputs, and 50 mVpp at the +5 V output
Output regulation	±0.1 V	Maximum deviation of the output voltages from their nominal values
Steady current consumption from ±12V	500 mA (max)	Current to be consumed by the susceptometer
Steady current consumption from 5V	200 mA (max)	Current to be consumed by the digital electronics
Inrush current per output	2 A	Peak current demanded to the PSU when the devices hanging from its outputs are powered on
ON/OFF feature	Yes	NEWTON instrument operation is enabled after +5 V POWER ON of the Control Unit. Magnetometer operation is disabled by removing the +5 V (switching OFF) of the PDU to the Control Unit
ISOLATION		
Isolation (Prim. – Sec.)	-	Different isolated and non-isolated topologies have been analyzed in order to evaluate the main advantages and drawbacks of them
Isolation (outputs)	Isolation required	Two different grounds should be considered, referring the +12 V and the -12 V outputs to an analogue ground, and the +5 V output to a digital one (ground isolation)
EFFICIENCY		
Efficiency	≥ 90 %	Efficiency in a steady stage, calculated as the ratio between the total amount of power delivered and the input rms power
TEMPERATURE		
Operational Temperature	-40°C to 85°C	
SIZE AND WEIGHT		
Area / Height	-	Including base plate (or other mechanical parts). The target is to achieve a reduced size.
Weight	-	Including base plate (or other mechanical parts). The target is to achieve a reduced weight.

The requirements of the DC/DC converter for the three NEWTON prototypes are the same. The only difference is that NEWTON prototype 2 is not devoted for space application but it will be used for field prospections on Earth to demonstrate the spin-off capabilities of NEWTON technology in the field of civil engineering applications. However, the requirements in terms of efficiency and volume are the same. NEWTON prototype 2 will operate also in a limited energy scenario in which the aim is to save a maximum electrical power by means of maximizing the efficiency of the power supply. In addition to this, the target is to integrate NEWTON prototype 2 in a hand-held device, therefore the weight and volume of the source must be reduced. Due to this reasons, the same design is adopted for the three prototypes. The detail information about the final design of the DC/DC converter and its verification has can be found in D3.4 [1].

4. SUMMARY AND CONCLUSIONS

This document reports the final design of NEWTON instrument prototype 2 which has been conceived to demonstrate the industrial spin-off capabilities of NEWTON technology in civil engineering applications. The NEWTON prototype 2 is a reduced version of prototype 1 implemented on a hand-held device for a rapid and preliminary analysis of the surface of Earth. The design is similar to prototype 1 with only two minor modifications. On one hand, the magnetometer and thermometer, included in prototype 1, have been removed from the sensor unit. On the other hand, NEWTON prototype 1 performs measurements of the complex susceptibility at different frequencies while NEWTON prototype 2 operates at only one frequency point, due to this, the magnetic amplifier which forms part of the susceptometer sensor has been also removed from the design. The design of the other parts of the susceptometer sensor, i.e. ferrite H core and resonant circuit are the same as in the case of NEWTON prototype 1. In addition to this, the design of the electronic Control Unit and the Power Distribution Unit are also equal to the ones developed for the prototype 1. In the case of the CU, those parts not used in prototype 2, i.e. the control block of the magnetometer and thermometer will not be mounted in the printed board.

NEWTON instrument prototype 2 will be used to demonstrate the advances gained from NEWTON project in non-space technology fields such in civil engineering applications on Earth. With this regard, some sites have been selected for the evaluation of local geological structures with respect to building ground properties, characterization of construction materials, e.g. concrete and bricks, as well as the detection of contamination of soils and soft rocks with metals, cobalt or other contaminants. FIGURE 4 shows the first magnetic mapping results obtained from the field prospections performed in two different applied geological sites in Germany. Magnetic maps show significant local variations in the magnetic flied strength. More details about these activities can be found in NEWTON deliverable D2.2 [5]. This work will continue in the framework of WP5.



(A) (B)

FIGURE 4. (A) Basalt query next to Lich in Hessen, Germany. (B) Future building ground in the city of Butzbach, Germany.

5. REFERENCES

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