FLYRADAR: A MULTIMODE/MULTIBAND RADAR ON BOARD OF AN UAV TO EXPLORE MARS AND THE EARTH. F. Mancini[1&6], G.G. Ori[1], G. Alberti[2], P. Allemand[3], P. Grandjean[3&4], A. Kreszturi[5], D. Mège[7], A.Tullo[8&1] , S. Augier[1], W. Kofman[7], E. Mariani,[1], C. Orlanducci[1], T. Senez[4], V. Steinman[5], K. Villavicencio[1], [1] International Research School of Planetary Sciences, Università Gabriele D'Annunzio, Viale Pindaro 42, Pescara, Italy, [2] CO.RI.S.T.A., 80143 Naples, Italy, [3] UCBL, CNRS, UMR 5276 LGL-TPE, France, [4] Hyperion Seven, Claix, F-38640, [5] CSFK Sopron 9400, Hungary, [6] Departimento Ingenieria e geologia, Università "G. D'Annunzio" of Chieti-Pescara, Viale Pindaro 42, Pescara, Italy, [7] Centrum Badań Kosmicznych Polskiej Akademii Nauk (CBK PAN), Bartycka 18A, 00-716 Warszawa, Poland, [8] Exploration Sarlau, Marrakech, Morocco.

Introduction: The aim of the FlyRadar project (H2020-MSCA-RISE-2020 project of European Commission) is to develop a multimode (GPR and SAR) multi-frequency radar installed on board a UAV dimensioned for Martian exploration and tested on Earth. A GPR is an active remote sensing probe that emits electromagnetic waves and receives the waves reflected by discontinuities that can be the surface of the planet or permittivity contrasts in the interior. Echo analysis provides geometrical and geological information on the surface features to a depth about 100 m that depends on the permittivity of material.

Mars is particularly suitable for exploration with such an instrument. The upper crust of Mars is composed of rocks of various origins (volcanic, sedimentary, impact, etc.) clearly visible at the surface of the planet. Mars also presents two permanent polar caps and a range of shallow subsurface buried ice masses in the middle latitude region. The shallow 3D subsurface geometry of these geological features is generally poorly known, but will be accessible using a GPR-SAR instrument. The efficiency of GPR has already been demonstrated on Mars (figure 1). Two orbital radar sounders that work as GPR (MARSIS on Mars Express and SHARAD on MRO) have successfully operated in the last 20 years [1, 2]. These two instruments provided the first images of the subsurface of Mars. The RimFax instrument [3] on board the Perseverance rover is currently in operation to provide high resolution sections of the underground of the Jezero impact crater on Mars.

The FlyRadar system will operate several tenth of meters above ground on board a UAV, providing precise and high resolution data, which will be critically needed for example, for future Mars sample return initiatives and human missions.

The FlyRadar project is organized around technical, scientific and qualification work packages.

Technical Work Packages: The aim of these work packages is to provide a fully operational system that will be tested on Earth in analog environments.

The characteristics of the radar will be first defined according to scientific expectations. The radar will be a 435 MHz frequency multimode/multi-band radar for short-range operation and adapted to UAV installation. Sounder and SAR modes will be implemented. Foreseen application is mainly in the field of geology, because the intrinsic capability of low frequency radar in revealing and characterizing shallow sub-surface layers, in both Earth and planetary environments. The FlyRadar instrument will have a penetration depth lower, but a resolution higher, than SHARAD and MARSIS, the frequency of which are much lower than the FlyRadar instrument. This should make it possible to characterize shallower features in the crust (tens of meters). However, the geographic coverage is anticipated to be significantly larger than RimFax, owing to intrinsic higher UAV mobility than rover mobility. All the design aspects will be considered, namely mechanical, electrical, electronics, optics, sensors, control s/w, thermal analysis, along with the scientific and operational aspects, and a final technological trade-off analysis will be carried out. An adapted data processing chain will also be defined and implemented.

A UAV will be designed in parallel, what will be able to carry the mass and volume of the FlyRadar instrument. The aerial and ground segments, namely mechanical, electrical, electronics, sensors, will be considered along with the scientific and operational aspects. A Validation Plan for both the planetary and Earth science applications will be then specified.

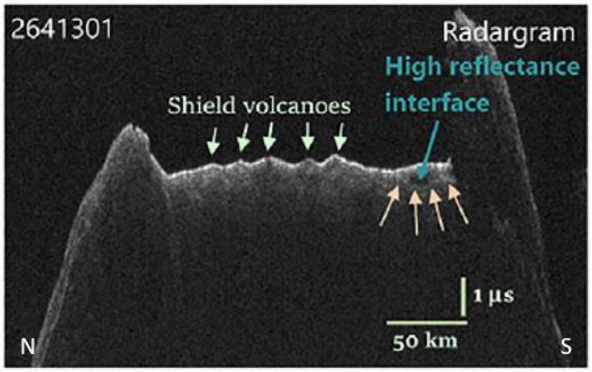

Figure 1: Radargram generated using SHARAD echoes [4] showing layers on the top of Arsia Mons, a Martian shield volcano. These reflectors are interpreted as the interfaces of buried volcanic layers.

Scientific Work Packages: Models of the Martian surface and subsurface environment will be developed and extended beyond the current state of the art. In parallel, terrestrial analogs will be selected and described in order to define the scientific and technical objectives of the radar surveys.

As part of the exploitation of the results, a requirement engineering analysis will be performed in order for end-user to assemble the FlyRadar products and match the scientific objectives. The requirements necessary to address the Research and Technical Development activities will be defined. This process of definition, followed by control and verification processes will be carried out at scientific level as well as on components and verification levels to enable the achievement of an efficient system architecture. This requirement analysis is divided into two steps: (i) defining scientific goals and technical requirements relevant to the overall performance of the instrument; (ii) determining the instrument requirements for planetary, missions and terrestrial applications.

Qualification Tests: The qualification of the instrument will ensure that radar, UAV and their integration will comply with the FlyRadar specific requirements for scientific efficiency. The fulfilment of the user requirements will be verified. This activity includes: (i) selection and use of appropriate targets for radar calibration and instruments performance; (ii) update of the software for data acquisition and analysis; (iii) identification of a technology development roadmap for planetary exploration and for Earth science. A validation plan for both the planetary and Earth science applications will be then specified.

Conclusion

The aim of the FlyRadar project is to develop, to test and to build a radar system able to work in both GPR and SAR mode installed on board a UAV. This instrument will be a demonstrator of a system that could operate on Mars in assistance with a rover for the exploration of the Martian environment in the vicinity of the rover at high spatial resolution. The planned tests at analog sites on Earth will help to improve and fine tune the instrument with a workflow to prepare and optimize the system to Martian usage. Because radar technologies have a strong potential for Earth exploration in arid areas too, the FlyRadar system will also be useful for archeological and geological exploration on Earth.

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