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The study of Ice/Volcano interactions on Earth and Mars with a P-Band airborne radar designed for subsurface mapping

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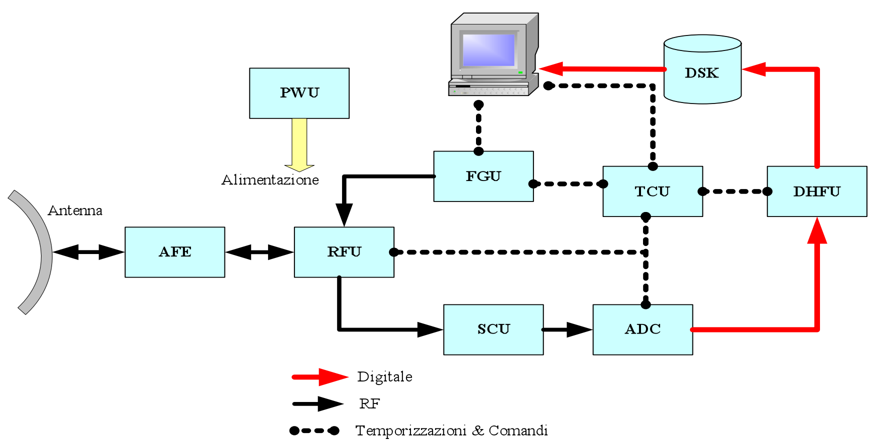
The use of ground penetrating radar from a planetary orbit it is nowadays a well proven technique. The first planetary radar sounder (the ALSE experiment) was embarked on the Apollo 17 orbiter with the aim of mapping the moon subsurface. But only in 2005 when the Italian PI experiment MARSIS embarked on Mars Express deployed its 40 meters long antenna, the potential of a radar sounder was completely understood. Today two sounding radars are operating at Mars, MARSIS and SHARAD, both led by Italian PI's and developed in strong collaboration with US institutions. On a planet like Mars, where the soil contains a low amount of moisture (the detection of liquid water would be a remarkable discovery), the penetration is generally higher than those achievable on Earth at the same frequencies. Low frequency (HF and below) radio waves have the capability to penetrate both soil (especially dry soil, due to its low conductivity) and ice. Ground penetrating radars, usually known as GPR, are used for Earth applications such as locating buried pipes, archeological surveys and forensic searches. GPR's are very limited for subsurface mapping of large areas, or non-accessible regions. Operating a low frequency GPR from orbit, with a limited directivity antenna due to the low operating frequency and to the constrained resources on a spacecraft, generates problems of "clutter" discrimination. Narrowing the antenna footprint, without increasing dramatically the size of the antenna in order to improve the resolution in the along-track direction, requires the use of the Synthetic Aperture technique. This technique utilizes the relative motion between the radar and the target. For Earth applications the use of airborne radars appears to be most promising. Airplanes, helicopters or aerobots may flight at different altitudes and allow multiple crossed passages over selected areas, increasing the capacity of identifying different geological layers and features. Selection of the radar's central frequency, bandwidth and pulse duration is the most critical aspect in the design of sounding radars with respect to their scientific goals.
Currently ASI is developing a new prototype of radar operating in the P-band:



This radar is being developed for airborne utilization. It appears to be an ideal tool for geological studies of volcanic areas. Its mains characteristics are reported here below:

	Sounder	SAR - Low	SAR - High
Altitude	500-8000 m	3000-8000 m	
Central frequency	~ 150 MHz	~ 450 MHz	~ 900 MHz
Transmitted Bandwidth	10 MHz	40 MHz	80 MHz
Frequency Steps	1 x 10 MHz	4 x 10 MHz	8 x 10 MHz
Swath		40 – 80 Km	5 – 12 Km
PRF equivalent	500 Hz		
Pulse Duration (min & max relative to flight altitude)	3 ms	20-50 ms (Nota 1)	
Receiving Window	86 ms	250-500 ms	25 – 65 ms
Resolution range (swath center)		5 m	2.5 m
Azimuth Resolution		5 m (8 looks)	2.5 m (4 looks)
Antenna TYPE	Log periodic	Planar array 2 x 1 patch	Planar array 4 x 2 patch
Antenna Pointing	Nadir	45 °	
Antenna size (cm)	58x108x20	120x50x15	
Sampling Frequency	50 MHz		
Transmitted Peak Power	100 W	150 W	

A very promising platform to operate such radar on Earth would be the transportable JPL Blimp.
The JPL Aerobot is a conventional twin-engine blimp with an ellipsoidal hull, internal ballonet and cross tail as shown in Fig. X. The blimp has two MVVS 58 engines that burn a gasoline and oil mixture. The vehicle is a commercially procured Minizepp MZ-13000 blimp to which has been added custom JPL avionics for navigation, autonomous flight control and telemetry. Basic vehicle parameters are listed in Table Y. There are separate communications links for digital control/telemetry (900 MHz radio link), pilot teleoperation (2.4 GHz) and real-time television (427 MHz). The standard aerobot avionics system includes:

- Dual PC 104 stack processors
- An inertial measurement unit (IMU) which provides angular rates and linear accelerations
- A magnetic compass and inclinometer (yaw, roll and pitch angles)
- A differential GPS (DGPS) system for absolute 3D position
- A laser altimeter (surface relative altitude)
- A barometric altimeter (absolute altitude above sea level)
- An ultrasonic anemometer (for relative wind field measurements)
- Two down-looking imaging cameras (narrow and wide angle)
- A forward-looking TV camera.

This sensor suite combined with an onboard software system (known as “FIREFLY”) allows the vehicle to fly autonomously, typically through waypoint navigation, trajectory following or image-based navigation. The teleoperation pilot can retake control from and the onboard autopilot at any time. All telemetry is displayed in real time at a ground station.
On Earth as well on Mars ice and volcanoes appear to have a symbiotic life: they interact in a number of ways that might have been and still are critical to large-scale planetary climate. There is more and more evidence that volcanic eruptions can occur as result of unloading ice from a volcano (*Tuffen H., Phil. Trans. R. Soc., 368, 2010*). In terrestrial geological record there is a strong correlation between warming climates and the frequency of volcanic explosions (*Huybers P. and Langmuir C., Earth Planet Sci Lett., 286, 2009*). On Mars such a correlation is still unproven due to lack of in situ measurements. However, it would be difficult to imagine different geological mechanisms and climatic correlation with Mars. Eruptions of any type can become explosive if water comes into contact with magma: that is way ice-capped volcanoes tend to erupt explosively (F.B. Wadsworth, 2011). Thinning of ice sheets, due to climatic warming on Earth or dramatic sublimation of volatiles on Mars, promotes explosive eruptions. We may state that in general the presence of ice in the surrounding of an active volcano exacerbates the physical hazards related to volcanic activity. The future of volcanic research will be determining the deep structure of volcanic edifices and localizing possible deep ice and/or water deposits in their surroundings with a goal to document sub-glacially erupted successions and comparing them with contemporaneous ice-thickness predications. This will allow us to build a model of ice-eruption interplay at a single volcano. The terrestrial data will be used in turn to infer volcanoes-climate interactions on Mars.