UNIVERSITÀ DEGLI STUDI DI PADOVA

Legged drone for underground cave exploration

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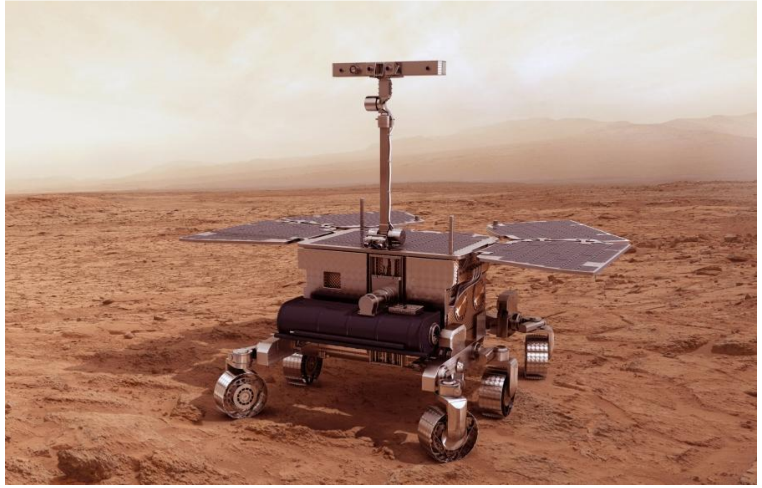
Introduction:

- Drones and rovers have always been an essential element for space exploration to perform scientific tasks on lunar or planetary objects.
- Over the years, technological development has given birth to numerous mobile systems, some of which are spin-offs of terrestrial applications, such as wheeled cars, military tanks and balloons.
- Others have been developed for space applications, such as hoppers.

NASA's Perseverance rover and Ingenuity drone

JAXA's Smart Lander Investigating the Moon



ESA's ExoMars

Project description:

The purpose of this research is to design a legged drone, that maximizes the benefits offered by both ground and aerial systems:

- Support lunar and planetary exploration by venturing into Martian and Lunar lava tubes
- Assisting in terrestrial operations like search and rescue or analyzing underground at-risk environments.

Both are environment of unknown features as slopes, dimensions and terrains.

The drone will be designed to be as compact as possible, paving the way for new assembly methods for drones of this kind, such as 3D printing or additive manufacturing.

Mission context (1):

- Lava tubes are caves created by flows of low-viscosity basaltic lava from a nonexplosive volcano → the outer surfaces of lava cool faster than the core forming a crust with a hollow tube covered with lava on the floors, walls and ceiling.
- On Earth, these pyroducts are present in various volcanic areas such as *USA* (Kilauea Volcano in Hawaii), *Italy* (Mount Etna), *Australia* (Undara Volcano), *Iceland, the Canary Islands, Azores, India, Vietnam, Korea, Japan, Galapagos Islands, Easter Island, Mexico, Kenya, Saudi Arabia and Jordan*.
- They are studied and their morphological characteristics are well known: their length vary from a few meters to tens of kilometres, their width and height go from 0.5 m up to a few dozen of meters, with a slope superior to 4°

Thurston lava tube, Hawaii Volcanoes National Park, Big Island of Hawaii, U.S.A. - Michael Oswald

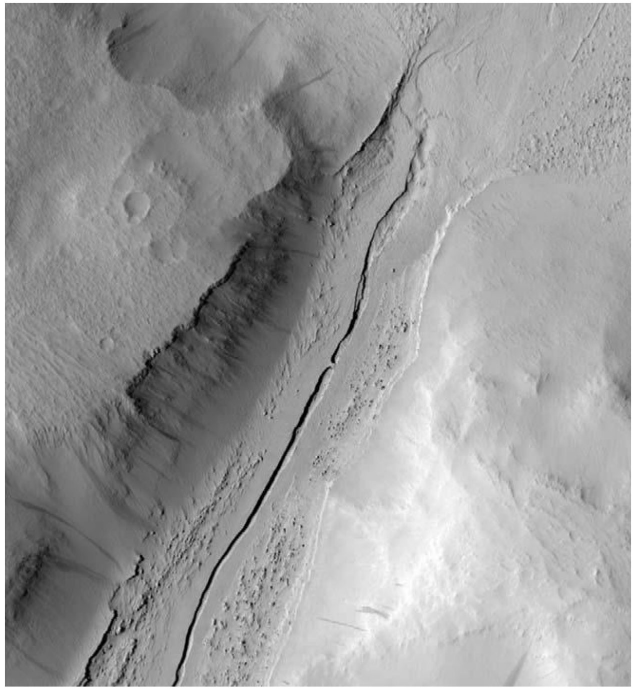
Mission context (2):

On Mars and the Moon they have been identified by the presence of skylights which are openings formed when a section of the ceiling collapses.

They may be the best place on Mars and the Moon for future habitats.

- Due to the lower gravity these caves could be an order of magnitude larger.
- Shelter from dust and extra-planetary radiation
- Daily and seasonal temperature variations would be more controlled than on the surface
- Increase our knowledge of geology, climate and biology.

Since their identification is mainly performed by orbiters, their morphological characteristics remain only hypotheses.

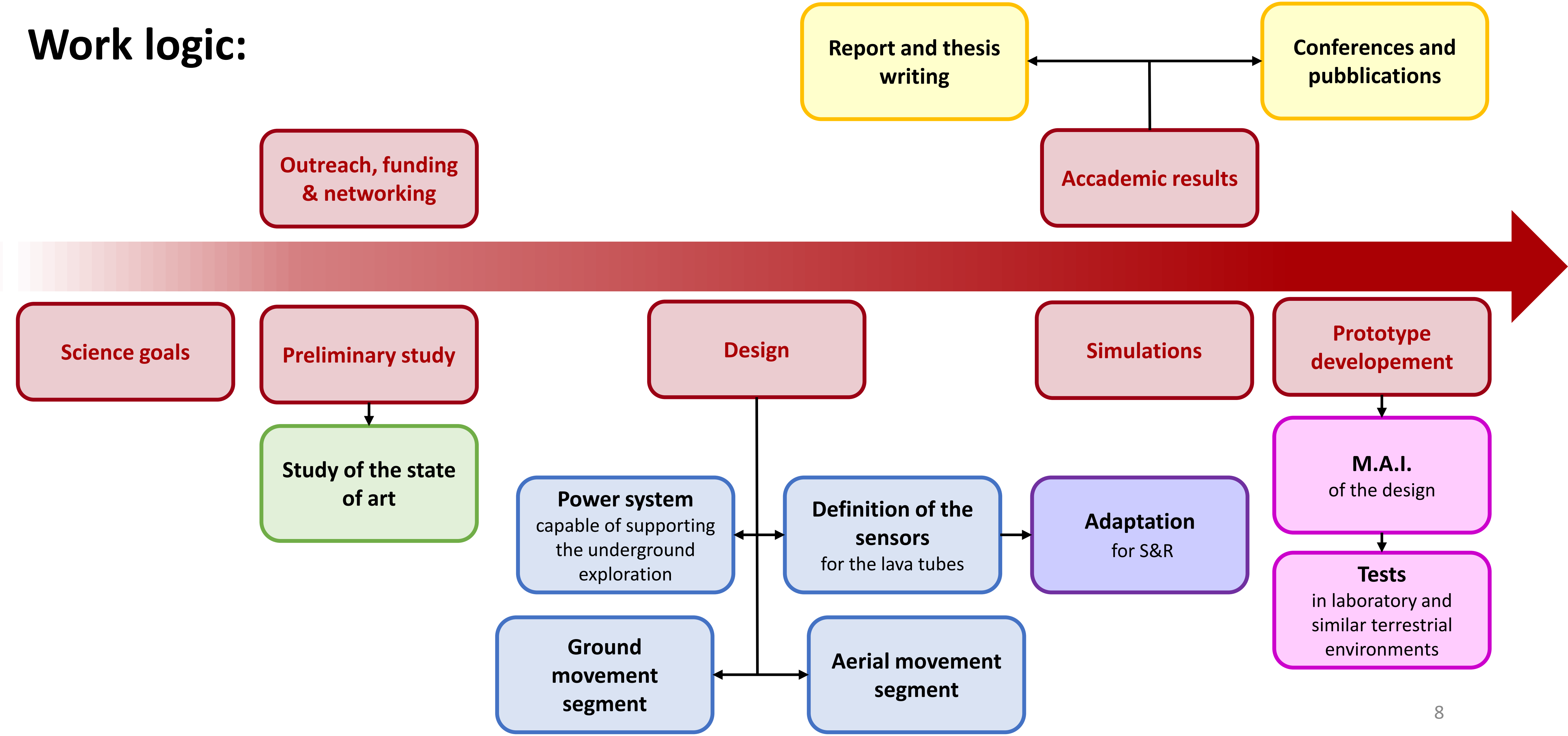


Portion of MRO/HiRiSE image of a channel-like conduit in Tartarus Colles. Credit: NASA/JPL/University of Arizona

Science goals:

- *Mapping of conduits:* to create a detailed maps and 3D models of underground conduits; to help understand structure, dimensions and potential pathways of these underground features.
- *Quantification of radiation penetration through basaltic layer:* measuring and quantifying the levels of radiation that pass through the basaltic layer, to assess potential habitability or radiation exposure risks underground.
- *Quantification of relative humidity and temperature variations:* understanding these variations can provide insight about the micro climatic conditions and potential habitats within.
- *Analysis of subsurface soil:* to study the properties and the composition of the soil found beneath the surface, which can provide more knowledge about the geological history, potential resources and potential habitability of the lava tubes.

Work logic:


Report and thesis writing
Conferences and pubblications
Outreach, funding & networking
Accademic results
Science goals
Preliminary study
Design
Simulations
Prototype developement
Study of the state of art
Power system capable of supporting the underground exploration
Definition of the sensors for the lava tubes
Adaptation for S&R
M.A.I. of the design
Tests in laboratory and similar terrestrial environments
Ground movement segment
Aerial movement segment

Expected results:

- Compactness
- Effective navigation, obstacle avoidance and integration between the two modes of movement
- Opportunity to produce the drone quickly on-site
- Power system capable of supporting underground exploration
- Versatility

Thank you for the attention

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