

Multi-Parameter Monitoring of the Potential Impact of the Exercise Asteroid 2024 PDC25

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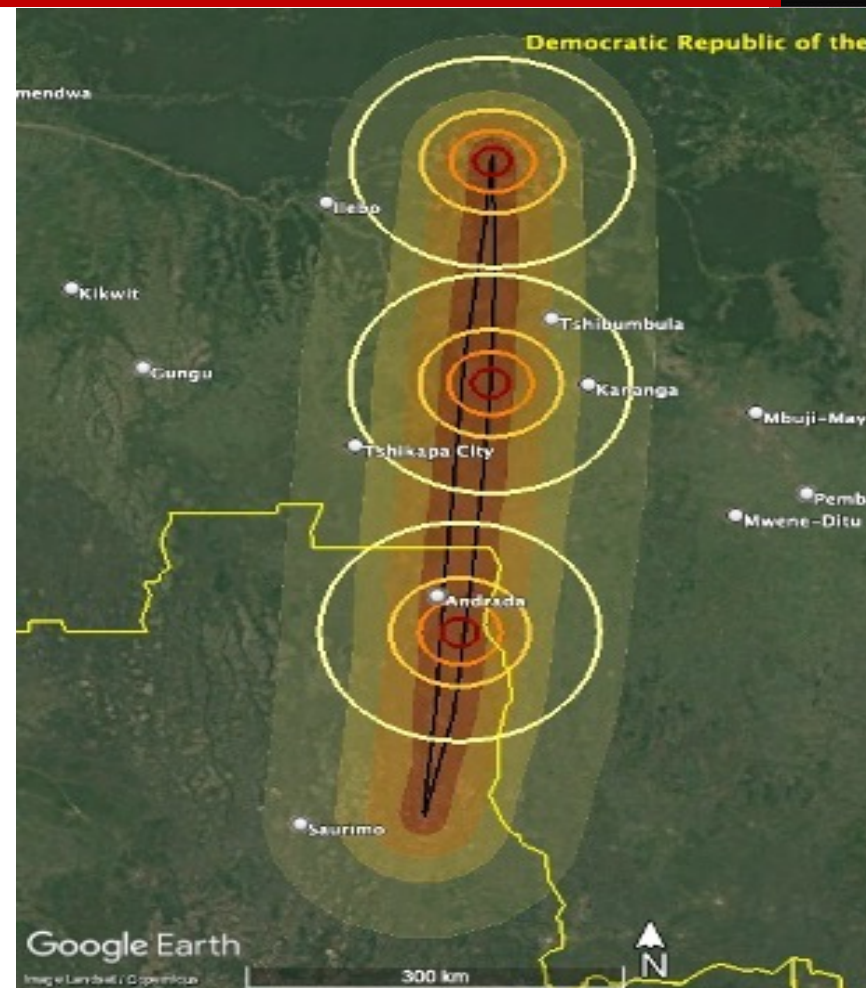


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Introduction and Background



- Simulation of the impact of 2024PDC25 around the border between Angola and the Democratic Republic of the Congo
- Up to 250 megatons of energy at impact, crater of up to 3 km in diameter.
- Populate the impact area with suitable sensors and probes, ranging from drones in various altitudes in the atmosphere to the surface and below.



The experimental set-up: on the ground



- As soon as the impact site is known an area of about 100 by 100 km around the site is to be covered by ground probes
- The sensor package contains
 - An all-sky camera
 - A seismometer and geophone
 - A microphone ranging from infra- to ultrasound
 - A meteorology package
 - Radar to measure the plasma trail distance
 - A communication package



The experimental set-up: in the atmosphere

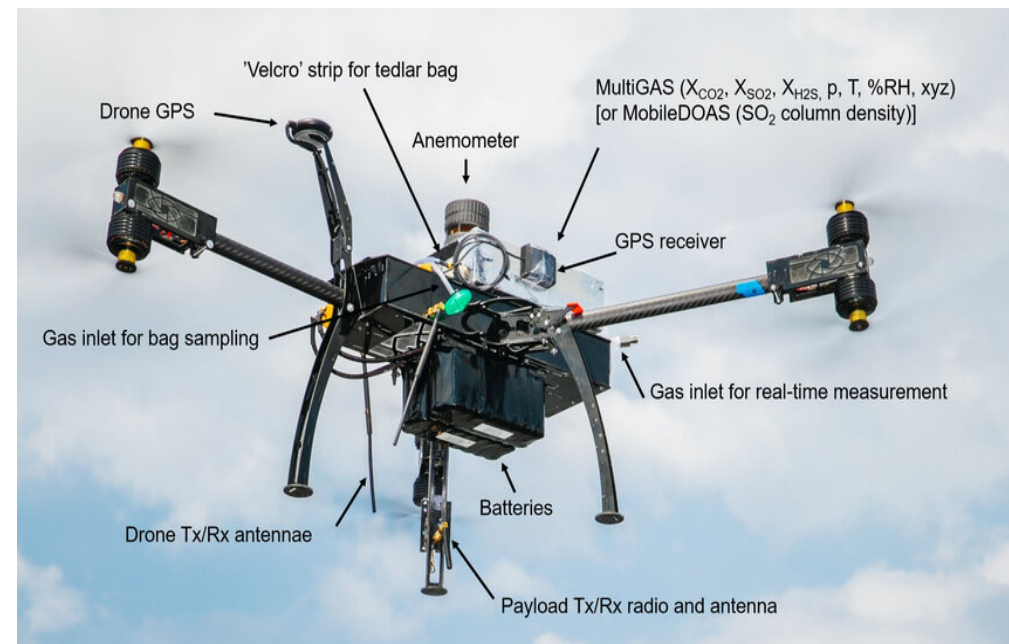


- Drones launched at a suitable time before impact,
- ascending to 5.5 km (half of atmospheric ground pressure) and 11 km (one quarter ground pressure)
- The asteroid will traverse the atmosphere very quickly. The ion trail will persist for some time

Airborne sensor package:

- An all-sky camera
- A GNSS sensor
- A microphone ranging from infra- to ultrasound
- An EM spectrum scanner
- An IR to UV spectrum scanner
- Radar to measure the plasma trail distance
- A communications package

Ref. 1



Operational Drone



Drone with payload package developed by MW and OK

Scanning and monitoring the EM spectrum

Determine signal strength and origin/location of echoes of plasma cloud

Spoofing/jamming protection

Secure data transmission



Global considerations



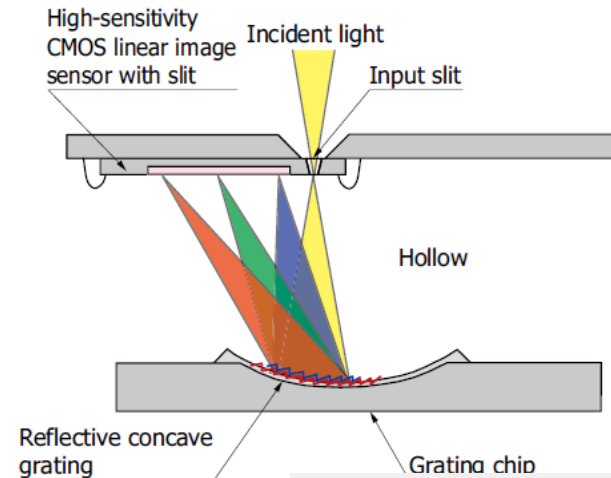
- Large number of ground (100) and airborne (200) probes
- Usage of off-the-shelf low cost technology
- Easy to transport and to install, when impact area known at short notice
- All sensors with battery-buffered solar arrays
- Data transmitted in real time, using communication satellite networks.
- For redundancy usage of 5G cellphone technology.
- Relay drones receiving these signals around the impact area
- Data stored locally in the probes, using a ring-buffer strategy
- Precise location by GNSS
- Surviving probes located, data buffers read out
- All terrain vehicles/helicopters to distribute/collect the probes before/after



Ground based sensors, specs



- **Seismometer**, geophone 1 m deep
- **All sky camera** (fish-eye) package
 - Visible spectrum CCD sensor
 - Wideband spectrometer (UV to IR)
 - IR CCD sensor
- **RADAR sensor** package
 - 20 cm (typ.) printed antennas
 - CW ranging based pn-sequences (26 GHz)
 - Measured distance to plasma trail with high precision
- **Communications** package
 - 20 cm (typ.) printed antennas
 - Connectivity to LEO/MEO satellites in Ku/Ka-band
 - 10 Mbit/s (typ.) uplink data rate



Airborne sensors, specifications

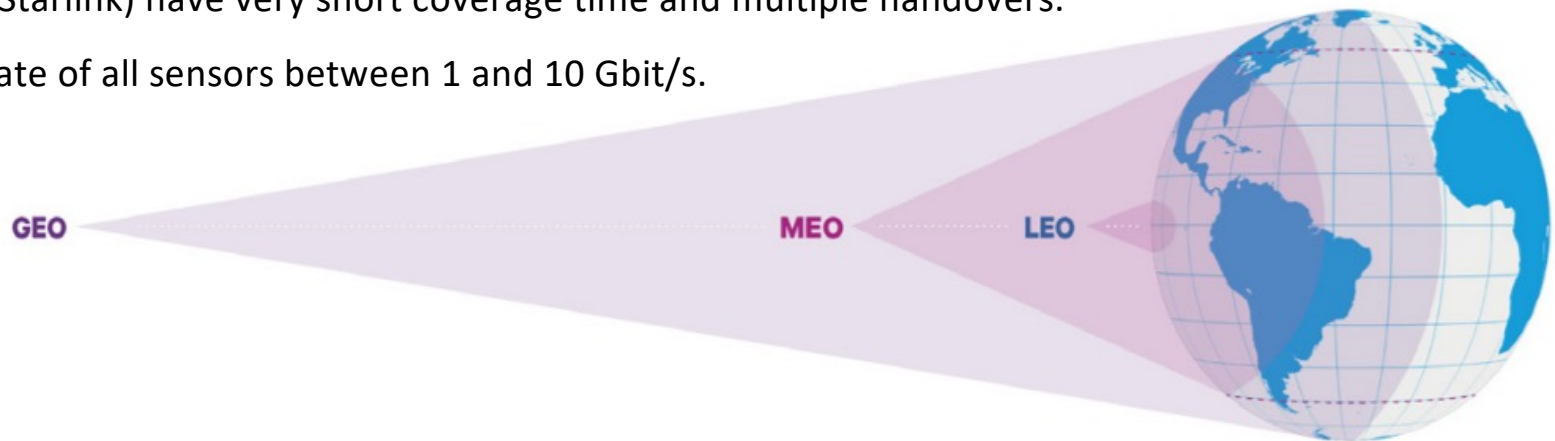


- The drones are **launched before impact** and ascend to their assigned altitudes
- Suggested instrumentation:
- **All sky camera package** consisting of
 - Visible spectrum CCD sensor
 - Wideband spectrometer
 - IR CCD sensor
- **Radar sensor package** consisting of
 - 20 cm printed antennas
 - CW ranging based on pn-sequences (26 GHz)
 - Measured distance to plasma trail with error in the cm range
- **Communications package** consisting of
 - 20 cm printed antennas
 - Connectivity to LEO/MEO satellites in Ku/Ka-band
 - Real-time data links via MEO, LEO satellite networks

Satellite Communication Network



- Existing communication satellite networks in a redundant manner.
- MEO orbit satellite (such as O3b mPower @ Ka-band): large coverage for observation and gateway links.
- LEO networks for redundancy.
- Simultaneous transmission in Ku and Ka-band for required capacity and reliability.
- GEO satellites are demanding regarding sensor transmit power needs.
- VLEO satellites (such as Starlink) have very short coverage time and multiple handovers.
- The accumulated data rate of all sensors between 1 and 10 Gbit/s.

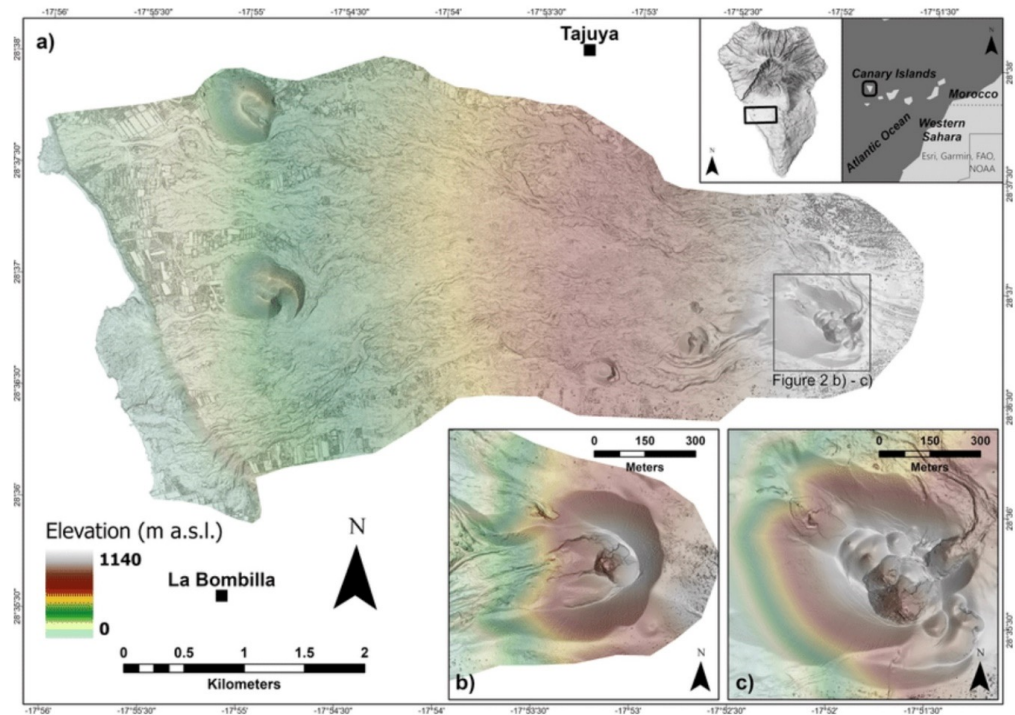


Building a digital model



- Several other sources of data
- Radar tracking for location and velocity data
- Seismometer data from many stations
- GTBTO will register the impact
- The impact might be observed from space
- Suitable AM, VHF and UHF stations can be monitored and examined for signal strength and variation
- The ultimate goal is to create a three-dimensional multi-parameter model of the impact
- This will include the evolution over time, from entering the atmosphere, creation of the plasma trail to the creation of the impact crater

Ref 2:



Digital Surface Model (DSM) of the 2021 eruption deposit of Cumbre Vieja volcano. (a) Multidirectional hillshade of the DSM. The inset at the top right of the figure shows the location of La Palma island and the survey area. The grey square in the eastern portion of the study area marks the extent of Fig. 2b,c; (b) detailed view of the cone on 27 September 2021²⁶ and (c) in January 2022, respectively.

References and links



Ref 1: Galle, Bo & Arellano, Santiago & Bobrowski, Nicole & Conde, Vladimir & Fischer, Tobias & Gerdes, Gustav & Gutmann, Alexandra & Hoffmann, Thorsten & Itikarai, Ima & Krejci, Tomas & Nicholson, Emma & Mulina, Kila & Nowicki, Scott & Richardson, Tom & Rüdiger, Julian & Wood, Kieran & Xu, Jiazhi. (2021). A multi-purpose, multi-rotor drone system for long-range and high-altitude volcanic gas plume measurements. *Atmospheric Measurement Techniques*. 14. 4255-4277. 10.5194/amt-14-4255-2021.

<https://www.researchgate.net/publication/347863168> A multi-purpose multi-rotor drone system for long range and high altitude volcanic gas plume measurements

Ref 2: Civico, R., Ricci, T., Scarlato, P. *et al.* High-resolution Digital Surface Model of the 2021 eruption deposit of Cumbre Vieja volcano, La Palma, Spain. *Sci Data* **9**, 435 (2022).

<https://doi.org/10.1038/s41597-022-01551-8>

<https://www.nature.com/articles/s41597-022-01551-8>

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