

**PDC2013
Flagstaff, AZ, USA**

IAA-PDC-13-03-15P

- Planetary Defense – Recent Progress & Plans
- NEO Discovery
- NEO Characterization
- Mitigation Techniques & Missions
- Impact Effects that Inform Warning, Mitigation & Costs
- Consequence Management & Education

APOPHIS 2029 MISSION, CNES ENGINEERING STUDY

**Emmanuel Hinglais⁽¹⁾, Louise Lopes⁽²⁾, Jean-Yves Prado⁽³⁾,
and the Apophis Mission Science group⁽⁴⁾, CNES team⁽⁵⁾**

⁽¹⁾⁽²⁾⁽³⁾⁽⁵⁾ *CNES, 18 Av E. Belin 31401 TOULOUSE cedex 9, FRANCE,*

⁽¹⁾ *+33 5 61 27 46 94, emmanuel.hinglais@cnes.fr*

⁽²⁾ *+33 5 61 28 18 89, louise.lopes@cnes.fr*

⁽³⁾ *+33 5 61 27 37 04, jean-yves.prado@cnes.fr*

⁽⁴⁾ *LESIA, OCA, LAM, IMCCE, IRAP, IPAG, ISAE, ONERA french laboratories*

Keywords: asteroid, Apophis, sounding, seismology, radar tomography

ABSTRACT

Apophis is a Potential Hazardous Asteroid, hence it must be watched closely and its physical properties should be well characterized. Indeed, it is generally admitted today that a mitigation action success cannot be guaranteed if it is not defined and sized in relation with the internal and subsurface asteroid structure knowledge. The passage of Apophis close to the Earth in 2029 offers a great opportunity to better characterize this object, possibly in an international effort.

The Apophis 2029 mission is studied by CNES in this purpose, and would greatly help to choose and size a reliable future mitigation mission if it becomes mandatory in the future.

At the same time, such a mission would greatly serve planetology science objectives because the knowledge of asteroids is fundamental to understand the formation and history of the solar system.

No mission so far has made a dedicated investigation of asteroid interior using seismic or radar sounding techniques.

Two European missions already use radar techniques; MarsExpress uses MARSIS as orbital radar for Mars subsurface sounding and Rosetta implements bi-static radar CONSERT to sound the comet Churyumov-Gerasimenko in 2014.

Planetary interior probing using seismology is implemented in the InSight mission with the help of the European SEIS seismometer, which includes short period geophones. This technique was also implemented in the ALSEP experiments in several Apollo missions on the Moon in the early seventies.

Nowadays and relying on this background, a new generation of instruments using these two techniques should be very efficient for Apophis sounding.

An instrument such as ASSERT, ASteroid Sounding Experiment by Radiowave Transmission between on board and on asteroid ground antennas, provides real internal tomography sections.

Two or three micro stations, containing short period geophones coupled with accelerometers are foreseen for seismologic sounding. Natural or external excitations, such as micro-meteoritic flux, thermo-elastic cracks, gravity gradient tidal effects or artificial explosions, may allow multi layers sounding using respectively cross correlation technique and direct deep waves speed measurements.

Of course, if the internal and subsurface sounding is the motivation of the Apophis 2029 mission, the surface study is also mandatory and will also be studied.

An additional goal of such a mission is to leave an emitter or reflectors, allowing tracking accurately the asteroid during several decades for trajectory propagation correction purpose.

It can be noticed that mitigation request is more constraining in term of measurement accuracy than scientific need for solar system study. It is explained by the necessity to best quantify the resolution need to be able to accurately size a mitigation action as a ΔV on the asteroid velocity for instance.

The sounding instrumentation has to be operated on the asteroid soil, requesting proximity manoeuvres of the probe to dump instrumentation micro stations which must guarantee reliable contact with the asteroid ground.

Definitely, these last aspects are the most challenging in this engineering study. High precision Doppler techniques, guidance, autonomous navigation, command, lander and anchoring technologies are clearly the most important tasks to perform.

In regard to the important societal and scientific issue, a broad board of scientists, instrumentalists and representatives of European policy, drives this technical CNES study.

Such a mission is basically aimed at being an international one. Similarly, it has to be seen both as a demonstrative mission and as an operational mission preparing a possible future Apophis mitigating mission. Therefore, CNES study covers a full range of scenarios with the aim to highlight all the critical aspects to be deeply investigated afterwards.