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APOPHIS EXPRESS, A UNIQUE OPPORTUNITY FOR A HUMAN VISIT TO A NEO IN 2029

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ABSTRACT

The purpose of the paper is to present an original mission design that can be applied to any human visit to a NEO making a close approach to Earth, with a first implementation in 2029 with a visit to Apophis.

The asteroid Apophis, discovered in 2004, is a 250 meter wide asteroid that will come very close to the Earth on April 13, 2029.
During its 2029 pass, Apophis will be easily visible from the Earth and it can be expected that its geometry and thermal properties will be well determined from ground based observations. However, the characterization of its interior will not be achievable from purely terrestrial observations. Such a characterization is essential for planning any mitigation operation, should it be necessary in the future.

This can be done only through a dedicated space mission where a set of instruments for probing the interior of Apophis will be softly laid down on its surface. But a purely robotic mission cannot pretend to provide a complete understanding of the asteroid core. A human presence for a smart characterization of the asteroid is definitely needed.

The mission scenario that is proposed in the paper is based on a sequence of two missions:
- a few years in advance of the 2029 close approach, a robotic mission is launched on a traditional heliocentric orbit that will reach Apophis several months before its close approach. The robotic element will make a first survey of the asteroid surface and finally land scientific and logistics payload. Part of this payload will consist of a navigation support system that can be used from the Earth to improve the Apophis ephemerides and by the visiting crew to secure its final approach and landing.
- in March 2029, just a few weeks before Apophis is coming close to the Earth, a

crewed mission is launched into a highly eccentric orbit. The trajectory of this mission will be an interception type, the direction of the launch being towards the incoming asteroid. A ΔV of about 6 km/s will have to be delivered for the crew to land on Apophis but only a few hundreds of meter per second ΔV is required to come home, when leaving Apophis a couple of days before the close approach so the total amount of required ΔV is kept acceptably low. The astronauts will spend only a few days on Apophis, using the equipments that will have been laid down by the pathfinder mission and be back on the Earth on April 13.

The crewed mission is designed to be compliant with the presently known characteristics of the SLS (Space Launch System). At first, a Cargo Launch Vehicle is launched, placing the EDS (Earth Departure Stage) into a Low Earth Orbit. This takes place around mid-March 2029, one month before the Apophis pass.
A few days after, a Crew Launch Vehicle places on the same orbit the MPCV (Muti-Purpose Crew Vehicle). They rendezvous and link together.

Then the ignition of the EDS provides a ΔV of 3300 m/s that places the MPCV on a highly eccentric orbit of apogee around 1 Million kilometers. After its burn, the EDS is jettisoned, leaving in orbit the Crew Launch Vehicle Upper Stage carrying the MPCV.
It takes about three weeks for the crew to raise from LEO to the apogee of this orbit.
At the apogee of this eccentric orbit, the MPCV is close to the natural path of Apophis. The MPCV velocity with respect to the Earth is very low, just a few tens of meter/second. Apophis is approaching with a velocity of 5900 m/s. The Upper Stage is then ignited and delivers a ΔV around 6000 m/s so that when Apophis catches up the MPCV, their relative velocity is only a few tens of m/s. The Upper Stage is then jettisoned and the close navigation phase can start. This phase ends when the crew module is at reach of the surface of Apophis.

The visit of one or two of the crew members can then begin. One can imagine two different scenarios, depending on the capacity of the MPCV to land on Apophis or not. If it is not expected to land, one astronaut has to stay onboard the Crew Module while his/her mates are walking and working on Apophis.
The Earth will approach very rapidly (more than 6 km/s one day before the closest approach). The visiting astronaut(s) will have only less than one day to perform its scientific programme and, very likely, to accomplish some highly spectacular media duties.
One day before the closest approach, at the latest, everybody has to be in the Crew Module to get ready for the return to Earth. Two kinds of maneuver have to be performed then:

- a reorientation of the trajectory to provide an altitude change at perigee around 38,000 km (difference between the Apophis perigee altitude and the altitude of 125 km that is required for an atmospheric reentry),
- a braking maneuver so that the speed at 125 km be less than 12 km/s for a safe atmospheric reentry.

Beyond the science and mitigation objectives, it is obvious that such a mission would have a global coverage from the media, 60 years after the first step on the Moon.