EPSC Abstracts
Vol. 5, EPSC2010-544, 2010
European Planetary Science Congress 2010

Strategies for improving the science-to-cost ratio when exploring dwarf planets and TNOs

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Abstract

Dwarf planets and TNOs can be explored at a distance or in situ. A dedicated telescope can better constrain the properties of distant objects. For in situ exploration, apart from "nearby" Ceres that is already accessible to orbiters and landers, the other dwarves can only be visited by fly-by missions with the current state of the art. In that context increasing the science return–to-cost ratio of a fly-by is vital to justify such missions to TNOs. Thales Alenia Space discusses here how advances in technology and industrial maturity enable such improvements, whether by standardization of the spacecraft and their instruments (decreasing cost) or by use of ancillaries characterizing the various physical fields (increasing science return).

1. Introduction

The last decade has suddenly seen the doubling of the number of known bodies above 500km in diameter in the Solar System, from 35 to about 70. Combined with predictions of differentiated states for a large fraction of the largest newcomers, this calls for a better knowledge of these bodies, not just as massless dots in n-body codes simulations or as a cloud of objects to be classified in taxa, but also as full-fledged planetary bodies with an evolution, a structure and sometimes an extant geological or atmospheric activity. The recent white paper from Grundy, McKinnon et al. reporting the SBAG community recommendations for the decadal survey [1] has stressed the importance of advances in the field. However, getting such an enhanced knowledge for those planetary science targets represents huge challenges mainly due to their large distance from the Earth and due to their number. Whether at-a-distance or in-situ, their exploration requires innovative thinking to address those needs in a cost-efficient manner.

2. Can we have more than a fly-by?

Thales Alenia Space has explored the different possible paths in recent preliminary studies. Observation at a distance from Earth's orbit has been considered, including strategies for chasing stellar occultations [2], which bring highly valuable results on a large list of targets. As far as in-situ exploration is concerned, the only dwarf planet for which a mid-term landing is achievable is Ceres in the asteroid belt, where a post-Dawn polar lander mission has been studied by Thales Alenia Space [3]. In-situ exploration of more distant targets would be best served by orbiters rather than by fly-by, but our study of what an orbiter around Haumea [4] would mean on the performance of propulsion and mainly power generation specific mass has confirmed that such a mission lies beyond the next decade. For the transneptunian dwarves, a fly-by still represents the most efficient in-situ exploration strategy in the short term.

3. Improving the science-to-cost ratio of fly-by missions

Any "fly-by only" mission raises the issue of its science return-to-cost ratio. NASA's New Horizons sets a precedent as such a mission to a transneptunian dwarf planet. New Horizons had to battle to exist despite its quite modest size and the study of 4 to 6 unexplored bodies (at least the 4 identified bodies of the plutonian system, plus potentially one or two TNOs). Future missions to TNOs will need to sharply reduce cost and/or increase the science return to pass the budgetary hurdles. But advances in technology and industrial maturity enable to improve the ratio by:

- standardization of the spacecraft and their instruments (decreasing cost)

• and/or use of ancillaries characterizing the various physical fields (increasing science return).

We have investigated strategies enabling a significant enhancement of science return with respect to a New Horizons-like mission. We dwell in particular on how a mid-sized spacecraft can be efficiently complemented by ancillary micro-satellites so as to provide for a considerably increased spatial and/or time coverage and probing of the magnetic field, gravitational field, atmosphere or exosphere of the targets, as illustrated by figure 1.

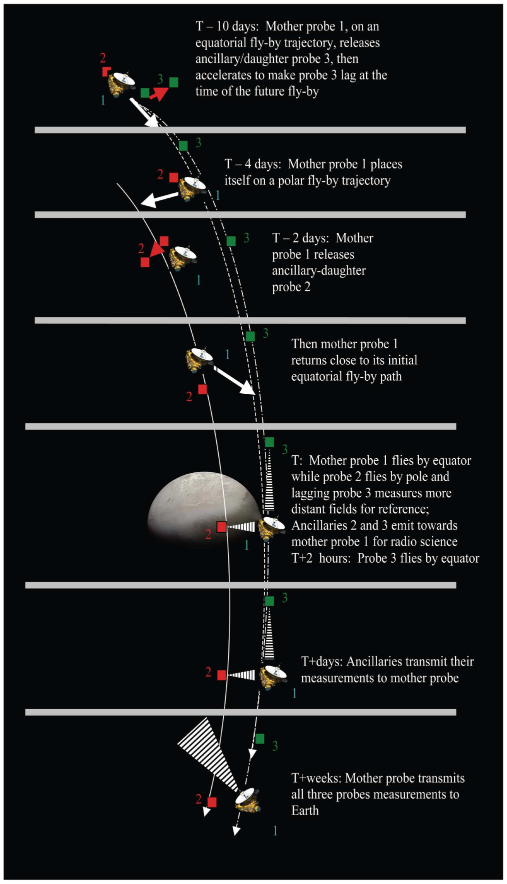

Figure 1: *We illustrate the typical timeline of such an enhanced fly-by mission, in the example of 2 micro-satellites in addition to the mother ship.*

How a multiple measurement of magnetic field would improve the knowledge of the visited body has been discussed e.g. by Saur et al. ([5], [6]). We have run parametric studies to assess delta-V as a function of the time at which such ancillaries would be released, so as to cope with navigation uncertainties and power supply considerations. The ancillaries are low-cost, low-mass items (50kg typ. each) as they have no need for orbit control and can survive their short lifetime as independent items through primary batteries (Huygens-like e.g.). We have computed, in the example of a New Horizons-like fly-by of dwarf planet Makemake, the needed delta-V as a function of release time and fly-by altitude for both probes #2 and #3 of figure 1.

4. Summary and conclusions

Exploring dwarf planets and TNOs “at-a-distance” is well served by dedicated space observatories monitoring objects or chasing occultations. Apart from “nearby” Ceres, in-situ exploration can only be achieved in the short term through fly-by missions. The large number of targets and their diversity call for many New Horizons-like missions. But they require improving the science-to-cost ratio for getting approval. This ratio can be considerably increased by standardizing the mission on the one hand and by complementing spacecraft with ancillary micro-satellites on the other so as to cover all physical fields in a comprehensive way, and answer questions such as “does the object have a subsurface ocean?”. In addition, such mission designs have valuable spin-off for other targets in the Solar System.

References

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