Intelligent Space Systems Laboratory,
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The University of Tokyo

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Kawakatsu Laboratory,
Institute of Space and Astronautical Science,
Japan Aerospace Exploration Agency

Mission Analysis and Orbital Maneuver Experiment for Interplanetary Micro-spacecraft PROCYON

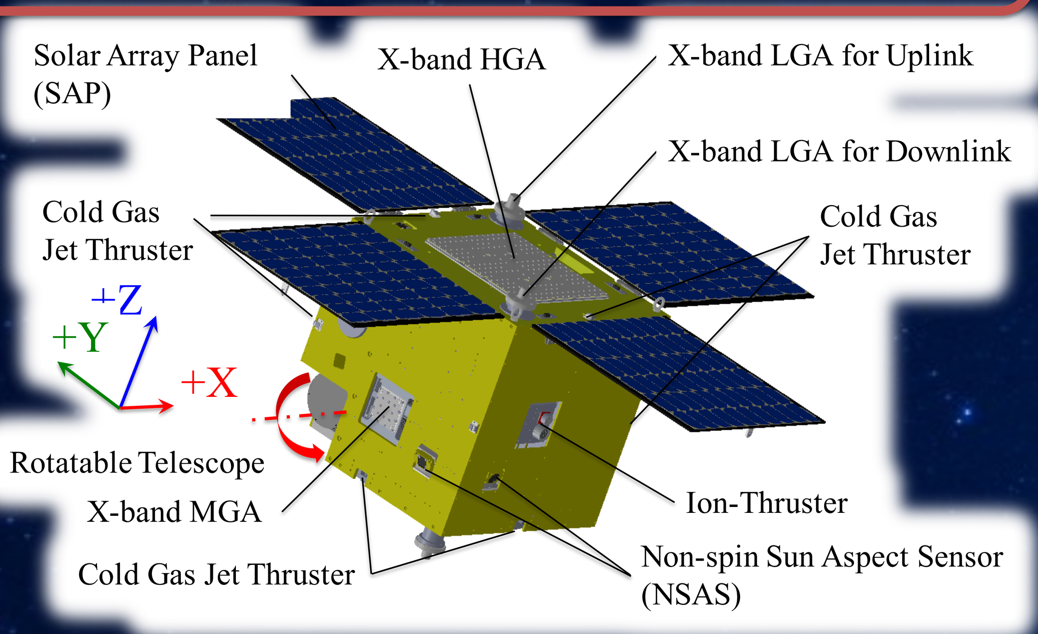
Naoya Ozaki*, Yosuke Kawabata** (the University of Tokyo),
Makoto Horikawa, Yuuki Kayama, Satoshi, Ogura, Kaito Ariu, Stefano Campagnola, Chit Hong Yam,
Bruno Victrino Sarli, Hongru Chen, Hiroshi Takeuchi, Tsutomu Ichikawa, Ryu Funase, Yasuhiro Kawakatsu.

What is PROCYON?

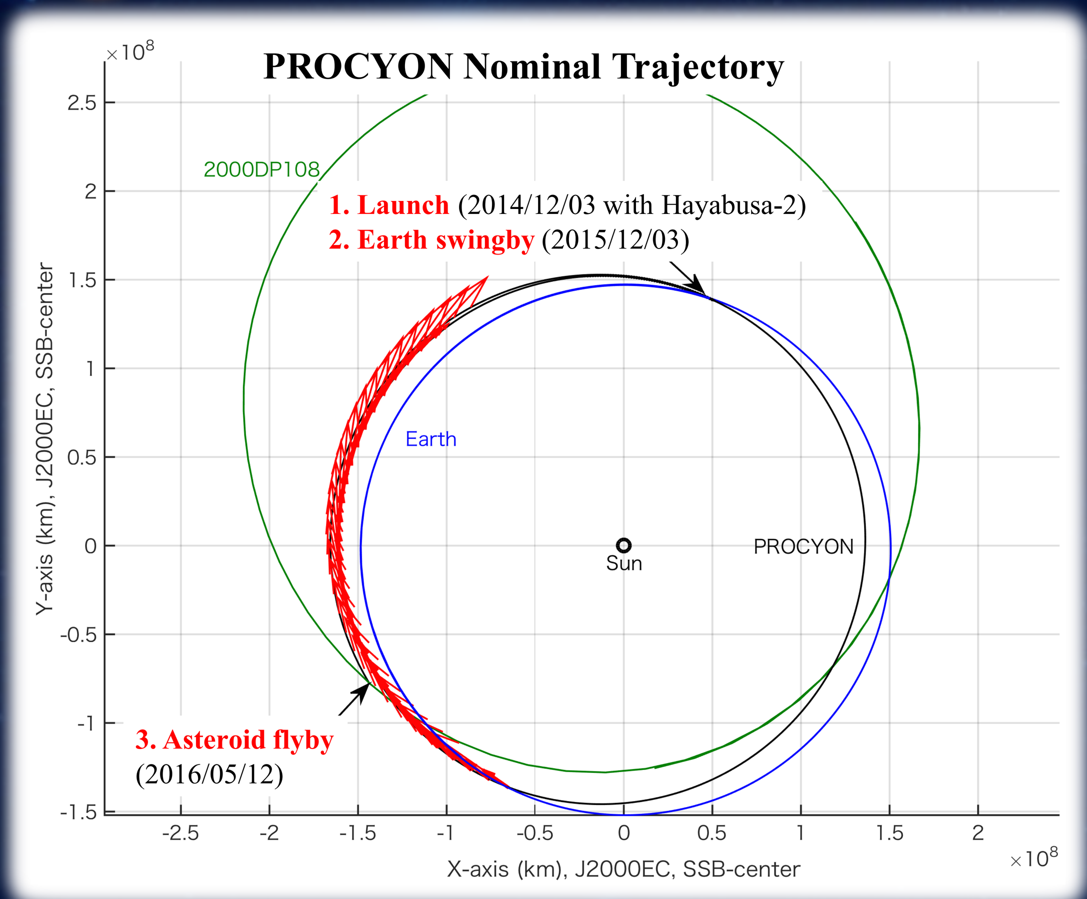
The spacecraft PROCYON (PRoximate Object Close flYby with Optical Navigation), which was jointly developed by the University of Tokyo and Japan Aerospace Exploration Agency (JAXA) is **the first deep-space micro-spacecraft in the world**; mainly university students developed the spacecraft, with a very short development time of about 1 year.

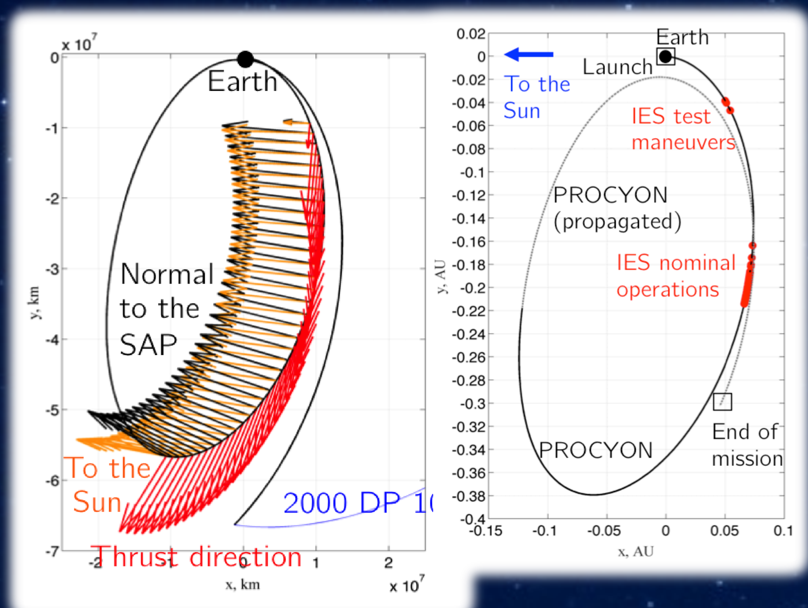
Launch Date:	3 December 2014, 04:22:04 (UTC)
Rocket:	H-IIA 202 (Primary payload is Hayabusa 2)
Mass:	67 [kg] (Launch), 65.5[kg] (Dry) = 1/9 of Hayabusa-2 spacecraft
Dimensions:	0.55(m)×0.55(m)×0.67(m) (SAPs closed) = about 1/10 of Hayabusa-2 spacecraft
Mission Objective:	PRIMARY: Technology demonstration of micro-spacecraft bus system for deep space mission SECONDARY: High resolution observation of Near Earth Asteroids (NEAs) by proximate flyby

- PROCYON has sufficient functions for the deep space exploration.
- The combined propulsion system is used to satisfy the requirement of weight & trajectory control methods (MIPS & Cold Gas Jet).



Mission Scenario and IES Operation Result





On 10th March 2015, IES was suddenly stopped because of malfunction of propulsion system. Therefore, PROCYON cannot target to 2000DP107 (nominal candidate)

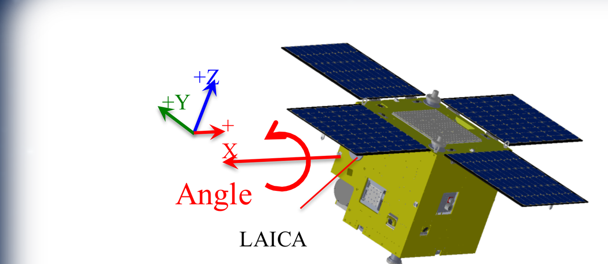
For Interplanetary Operation: IES & RARR
For Proximate Operation: CGJ/RCS & RARR and Optical Image

Mission Analysis for Comet Observation

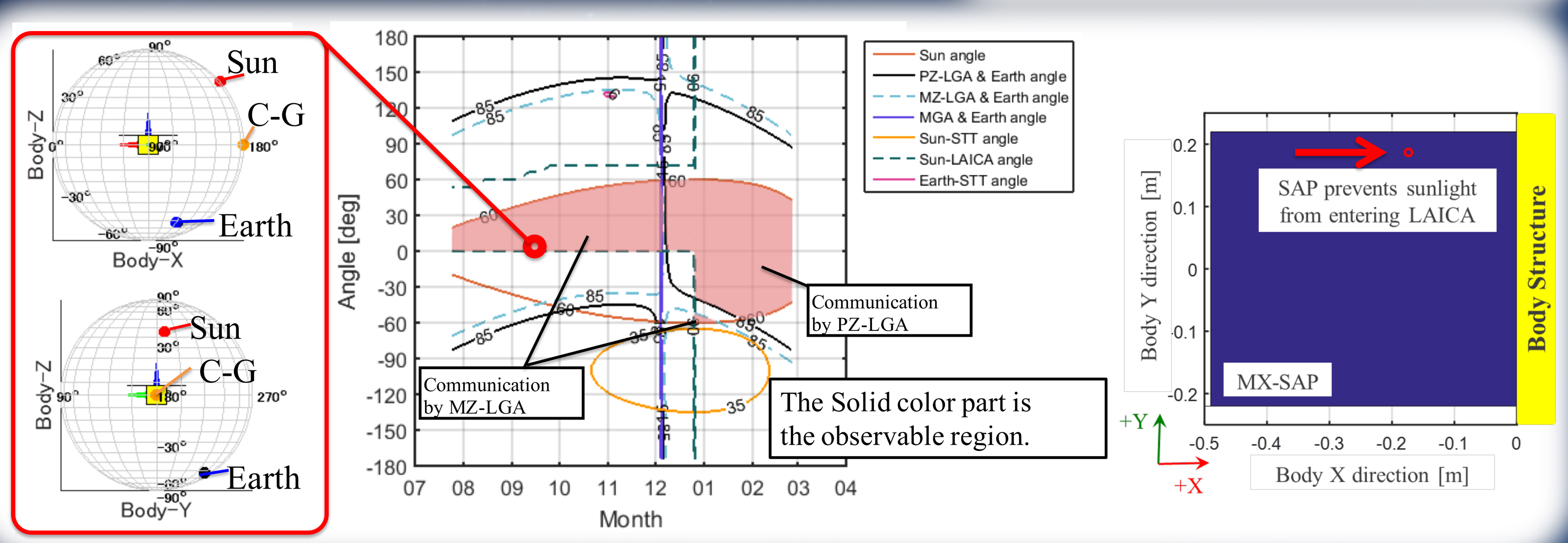
The comet observation by LAICA (Lyman Alpha Imaging CAmera), which can observe the geocoron, is one of various orbit experiments except initial plans. "Churyumov-Gerasimenko" which is famous for Rosetta Misson was chosen as the observation object.

There are many constraints for the observation, and in PROCYON mission, the observable period and observation Attitude are chosen on a contour basis because it's easy to grasp the dominant constraints and possibility.

Although it's necessary to prevent sunlight from entering LAICA, the angle between the boresight of LAICA and the sun is less than 90 degree constraint until the end of December. Therefore we made use of the shade of a solar array panel to avoid direct sunlight entering LAICA.



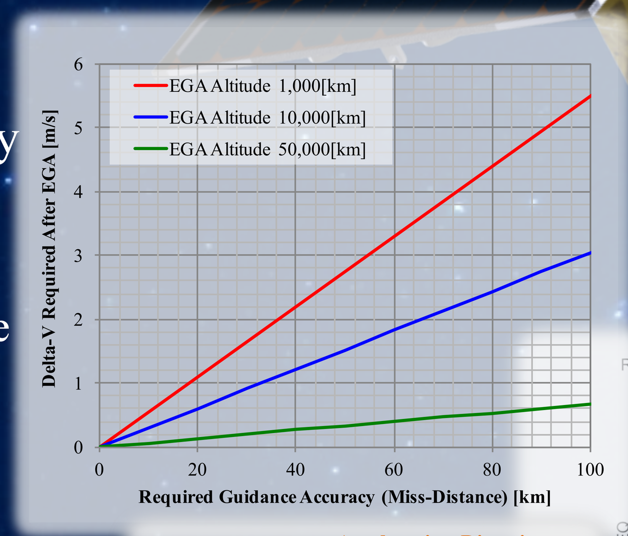
There is 1DOF around the line of sight of LAICA.



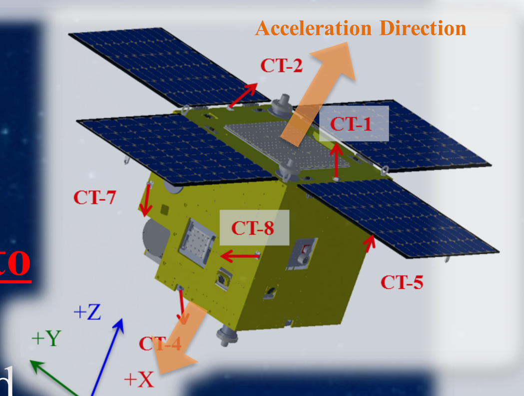
RCS Orbital Maneuver Experiments

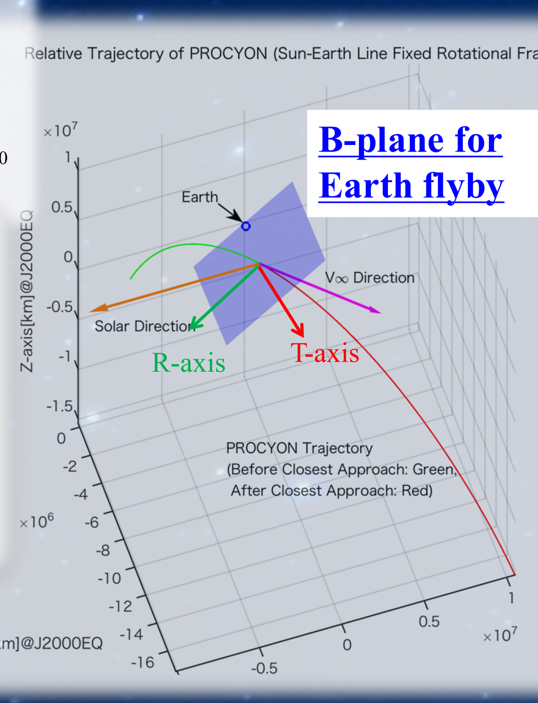
Objectives of Cold-Gas Jet/RCS orbital maneuver experiments are:
1) Evaluate the performance of CGJ/RCS
2) Evaluate the guidance accuracy on the B-plane for Earth flyby.

Required guidance accuracy: < **100[km]** for 50,000[km] altitude flyby, 1[m/s] clean-up maneuver (r.f. 500,000[km] altitude flyby for 2000DP107)

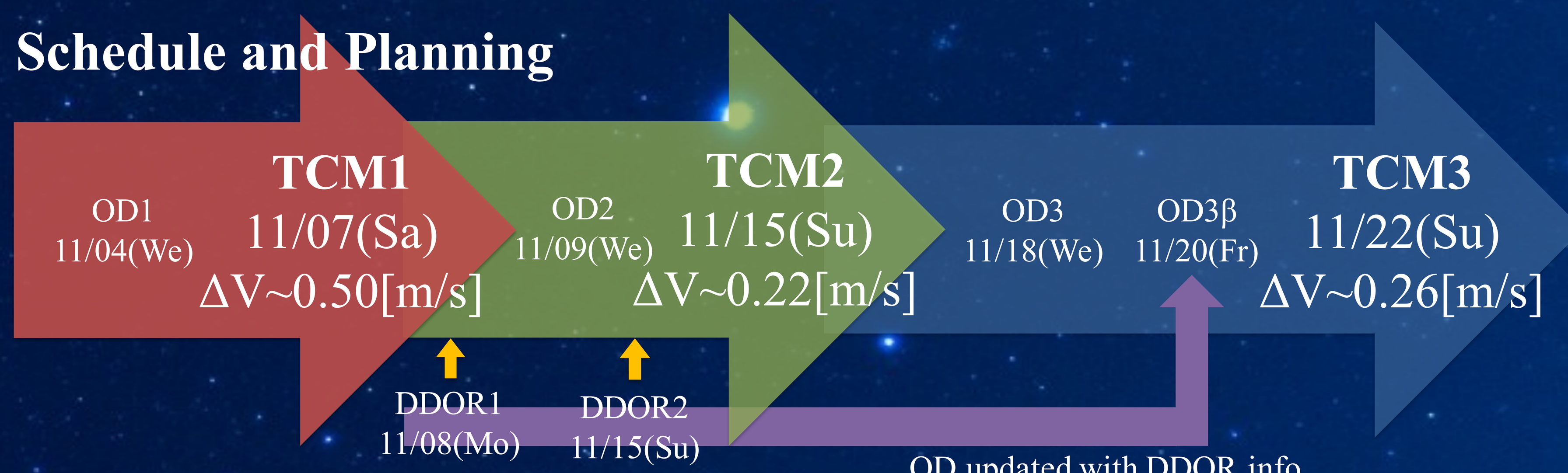


Using 8 CGJ thruster, S/C can control 2-DOF translational acceleration (±X, ±Z); however, **only 1-DOF thruster (±Z) is able to be used for guidance experiments**, because of disturbance torque caused by CGJ plume interference on solar array panels.

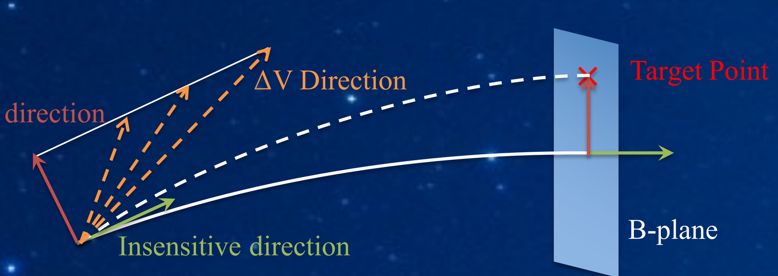




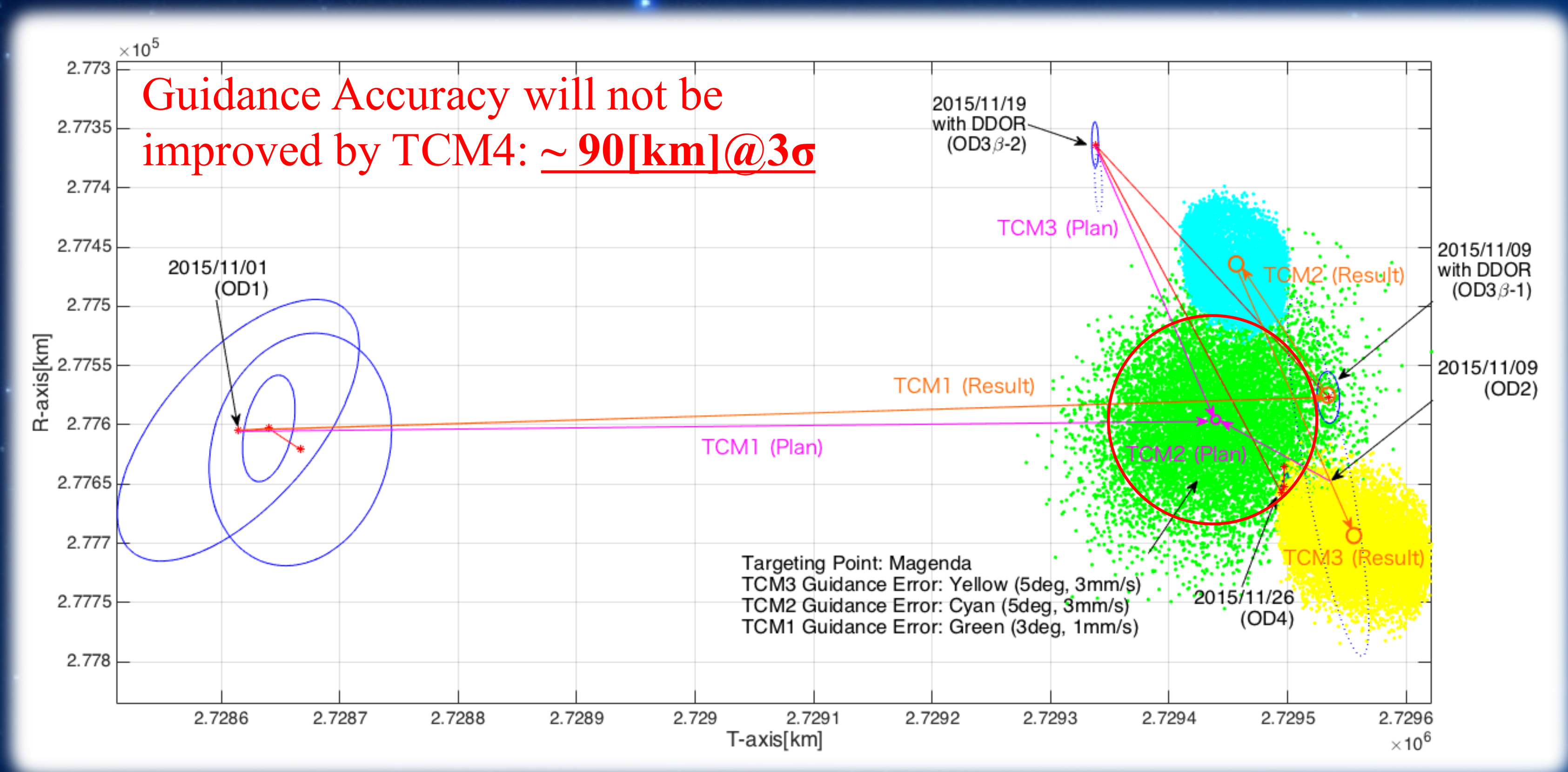
Schedule and Planning



ΔV direction is designed considering:
1) Power budget/ Thermal condition (Necessary)
2) Doppler sensitivity (If possible)
with guidance insensitive direction as parameter.



Orbital Maneuvering Results



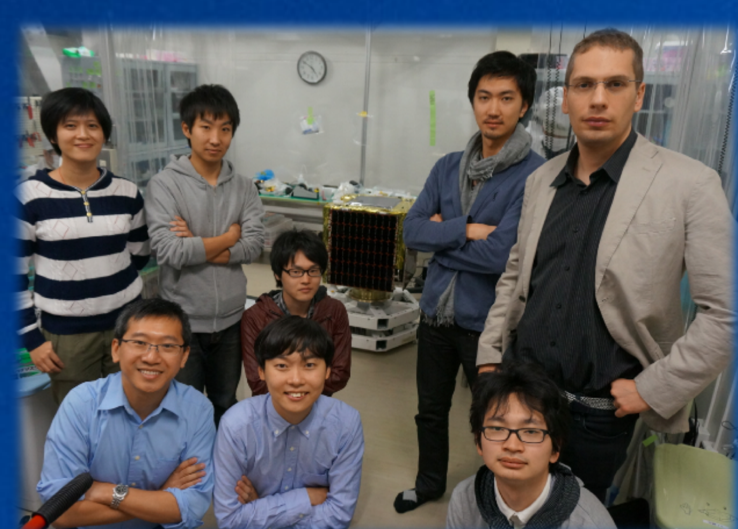
TCM 1: 0.50[m/s] by CT-1/2 (-Z acceleration)
TCM 2: 0.29[m/s] by CT-3/4 (+Z acceleration)
TCM 3: 0.26[m/s] by CT-3/4 (+Z acceleration)

Throughout post-analysis, we have noticed that PROCYON could not be successfully guided at TCM3, since OD3 is not reliable. **Finally, we have achieved guidance accuracy on position is about 90[km] @ 3-sigma.**

Lessons Learned

We had some discrepancy through experiments. Therefore, We must improve the reliability of:
1) OD (increasing number of ranging operation, using precise model of SRP in propagator)
2) In-house propagator
3) Orbital maneuver (alignment of DV and Star Sensor, magnitude of DV).

Because thrust direction is highly constrained, we should apply stochastic optimal control method considering the guidance error.



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