Call 2019-N

COVER SHEET

Enclosure 3: Progress Report

SNSA rules for this enclosure

Mandatory Progress Report

If the application presents increased ambitions for a project with existing SNSA support, then it is mandatory to report progress of the project with the following content.

- Registration number (dnr) of previous research grant
- Summary of achievements so far
- A brief analysis of how the original goals of the project have been achieved and a discussion of the reasons for divergence with respect to original goals
- List of publications relevant to the running project
- List of the staff involved in the project so far
- Outreach activities

Optional Progress Report

If the above does not apply, then you may still include this enclosure on a voluntary basis to demonstrate past achievements of relevance to an assessment of the team's ability to carry out the proposed project.

Size of this enclosure (excluding this cover page)

Maximum 5 pages.

Progress report

Although this project has not been supported by SNSA, the discussion between Japanese and Sweden has started from 2015 through mail, web-meeting, and occasional meeting by person when Japanese visited Sweden or we happen to be in Japan for other purposes.

1. Japan as the long-term collaborating partner

Swedish space science teams have a long collaboration with Japanese space science teams in both planetary science (Mars, Moon, Venus, Mercury, and Jupiter) and auroral physics. We particularly had close collaboration with core members of the Japanese FACTORS project: Prof. Hirahara at Nagoya University (lead), Dr. Y. Saito at ISAS/JAXA (official manager), and Dr. Kojima at Kyoto University (coordinator for waves and field measurements). Collaboration with these core members started in 1993 through Japanese Martian mission Nozomi (IRF SSPT program provided IMI instrument, PI: Rickard Lundin with applicant being main contact), and is strengthened with BepiColombo Mercury mission and currently JUICE Jupiter mission, for both of which the collaboration is extended to IRF RPF program and KTH. Collaboration with IRF STAR program started with Japanese Reimei-ALIS conjugate observations.

2. FACTORS mission proposal

After successful Reimei (launch 2005) and Arase (launch 2016) missions, Japanese Solar-Terrestrial Physics program started to plan for the next plasma mission around the Earth. The mission pre-study started already in 2014 when the core team already received development funding toward formation flight similar to the FACTORS, but 2-4 spacecraft. After the mission was discussed in the ISAS Research Group (starting numbers of ideas to select representative 1-2 mission from each science community) during 2016-2018, the FACTORS is listed in the Japanese master plan of science targets and relevant missions (RFI document, see appendix) as one of the candidates.

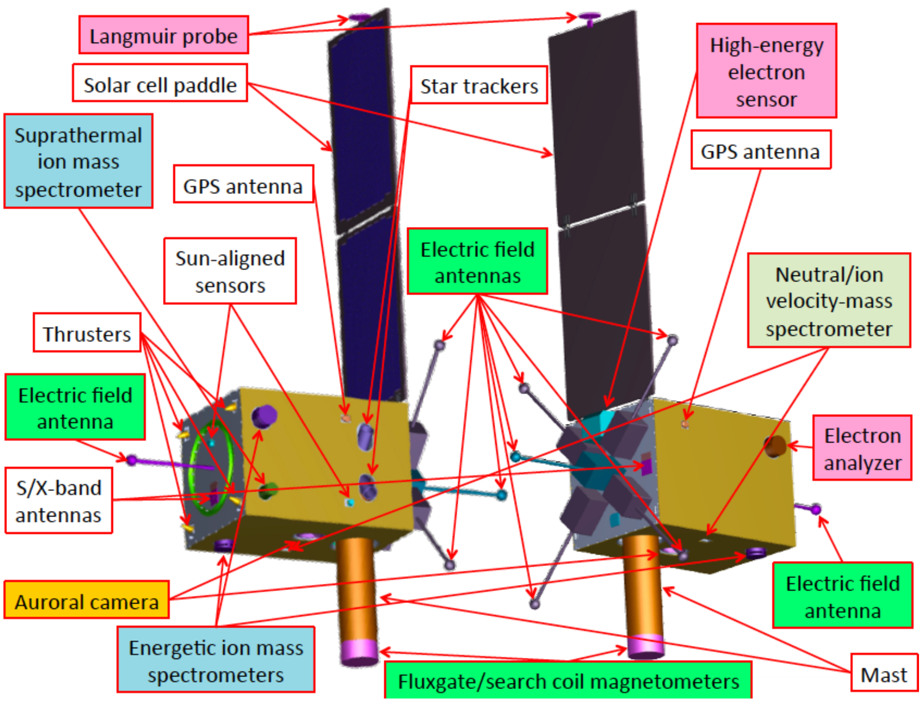

Figure 1. CAD model for main spacecraft for two Japanese spacecraft option: about 160-180 kg with about 60-70 kg payload each.

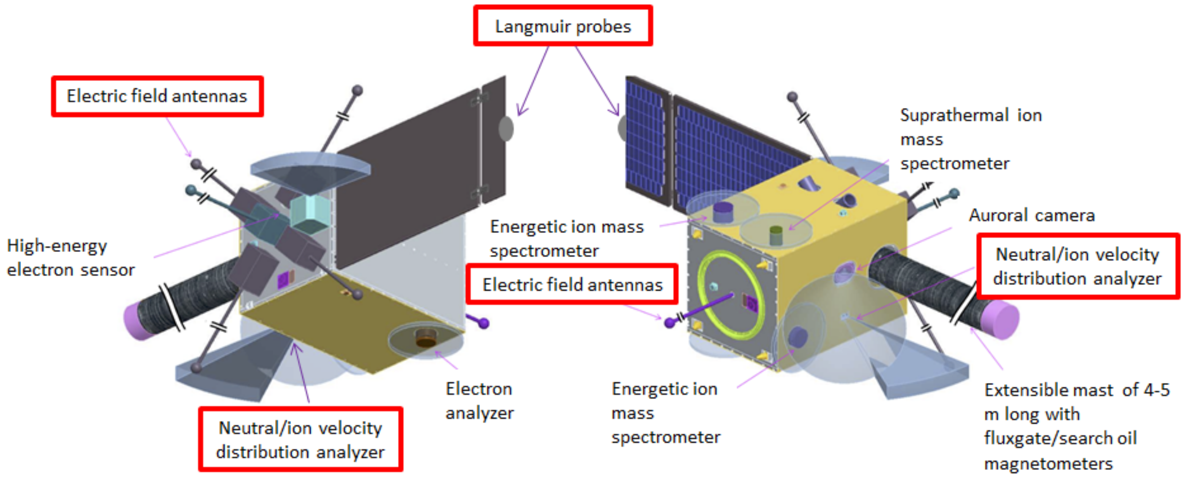

Figure 2. Scientific instruments onboard two spacecraft. The field-of-view of each instrument is also depicted. Swedish hardware contributions are marked by red boxes.

As the next step, FACTORS team proposed for Working Group (WG: pre-phase A and part of phase A study) October 2018, which was accepted December 2018 to officially start WG from April 2019. The applicant is listed as the member of proposing team as the only member from outside Japan. The WG is approved for "S-class" mission, that means the mission must fit into 1.3 billion JPY budget (≈ about 100 Meur) including instruments and launch (by Epsilon rocket which is much smaller than H2A rocket) but excluding operation. In the proposal, Japanese plans to build two spacecraft but also the possibility of externally-provided third spacecraft was mentioned (Innosat is strong candidate) to enhance the science. Figures 1 and 2 shows configuration and designs for Japanese spacecraft.

Unlike ESA mission that requires "proven technology", Japanese science mission requires technological challenge. Therefore, new development of neutral instrument (NIVA) and electric field measurement in three-axis stabilized satellite are highly sought by Japanese. To fit this challenges together with the formation flight (first time for Japanese) within the budget constraint, Japanese has been seeking possible collaborators including NIVA and electric field measurements. So far Japan has contacted LASP (U. Colorado), SSL (U.C. Berkeley), and U. Calgary as well as as Sweden as the possible collaborators.

3. Japan needs foreign contribution and Sweden is the first priority

These backgrounds ignited the idea of having collaboration with Sweden through both instrument provision and Innosat as one of the formation flight fleet. This idea already started October 2015 and November 2016 when the applicant met Hirahara in Japan.

To develop the collaboration at a more technical level, both Hirahara and Saito visited Sweden in February 2017 (SNSA and IRF Kiruna), and August 2018 (OHB-Sweden and KTH). Responding to a request from OHB-Sweden, orbit information and radiation dose estimate of FACTORS are already sent to OHB-Sweden. Also, Dr. Sakanoi, as a representative of FACTORS has visited Kiruna for the SRS meeting in 2017, where he also discussed with team members from Stockholm and Uppsala.

As the FACTORS concept became more solid, Japanese became more keen about having Swedish contribution to the Japanese spacecraft at a more solid level. By the end of March 2019, Japanese decided to ask Sweden to provide NIVA and some key parts of the electric field measurement, both of which are key instruments for FACTORS. Japanese also asked Sweden to build the entire Langmuir probe (LP). To express strong wish of the FACTORS team for the development of neutral instrument by IRF SSPT program, Dr. Asamura also visited Kiruna in January 2019. In addition, a member of the STAR team (co-applicant Sergienko) met Hirahara in May 2017 in Tokyo, the applicant attended the core team meeting in January 2018 and in November 2018 in Japan. Aside these physical meetings, the applicants has attended many web-meetings (monthly in 2018, and nearly bi-weekly in 2019).

While the instrument level collaboration became more or less clear during the first quarter of 2019, how to include Innosat in the fleet needs more discussion during WG. Currently, both Japanese side and Swedish side have now common recognition that we have to manage two different competitive selections for the Japanese spacecraft (Evaluation by Space Science Committee in Japan) and InnoSat (Evaluation by SNSA). In the meeting between IRF, KTH, and Japanese when Hirahara and Saito visited KTH August 2018, we agreed that Swedish side will propose InnoSat as the part of FACTORS fleet (which means automatic rejection of Innosat proposal in case FACTORS final proposal failed).

4. Technological challenges for Swedish contributions

4.1. Innosat

In the August 2018 meeting, we also preliminary agreed on how the Innosat will be proposed in the context of FACTORS mission

<u>Technical summary</u>

- InnoSat formation to be horizontal rather than vertical
- Innosat flies without propulsion and control is done only for FACTORS
- Nominal time for InnoSat is 1 year
- Perigee = 400 km for the first year, and FACTORS decreases perigee afterward
- Allowed mass for InnoSat depends on the capability of new launcher
- With extra mass allowance, spot-shielding solves the radiation problem

<u>Priority of the feasibility study to fit InnoSat into FACTORS</u>

1a. Radiation harness for 1 year
1b. Battery for eclipse (< 50 min): to survive only spacecraft without observation
2. Spin stabilising
3. Propulsion (so far we do not plan to have)

<u>Logistic summary</u>

- Improvements are possible but they cost extra
- TBD whether FACTORS final proposal must/must not rely on InnoSat
- WG will discuss whether FACTORS proposal should address three cases regarding Innosat, (no Innosat, Innosat without propulsion, Innosat with propulsion).
- When FACTORS phase-A study starts, OHB personal is ready to attend necessary meeting
- Uplink and downlink information of FACTORS will be sent to OHB (to make common operation)
- Mass and size allowance for InnoSat for launch will be sent to OHB (as soon as the new launchers ability is fixed).

<u>Preliminary payload (much less solid for plans for now)</u>

4.2. Neutral and Ion Velocity Analyser (NIVA)

The aim of this section is to provide a current status of Neutral and Ion Velocity Analyser (NIVA) development and clarify technical challenges.

The NIVA is a quite innovative instrument to measure mass-resolved neutral particle velocity distribution function by combining several key technologies. The conceptual design of the NIVA has been already studied and feasibility analyses have been carried out using a simplified ion optical model at U. Calgary in Canada and Nagoya U. in Japan when one of the applicants (Dr. Shimoyama) had been working there (Figure 3). The instrument comprises several functional elements: a slit-shaped particle collimator, an electron impact ionization, an initial ion acceleration for mass analyses, a radio-frequency (RF) mass spectroscopy and a micro channel plate based ion detector. Among these elements, we identified RF electronics and an electron gun for ionization as key technologies. Collaboration with U. Bern is under discussion with Prof. P. Wurz, particularly on the ionisation part (electron gun). We also found that U. Calgary can be a good collaborator in development of the RF electronics if necessary (not yet contacted, though). IRF will lead the whole development and the team structure will be defined after analyses of the detailed design because the detailed design affects the performance required for each element.

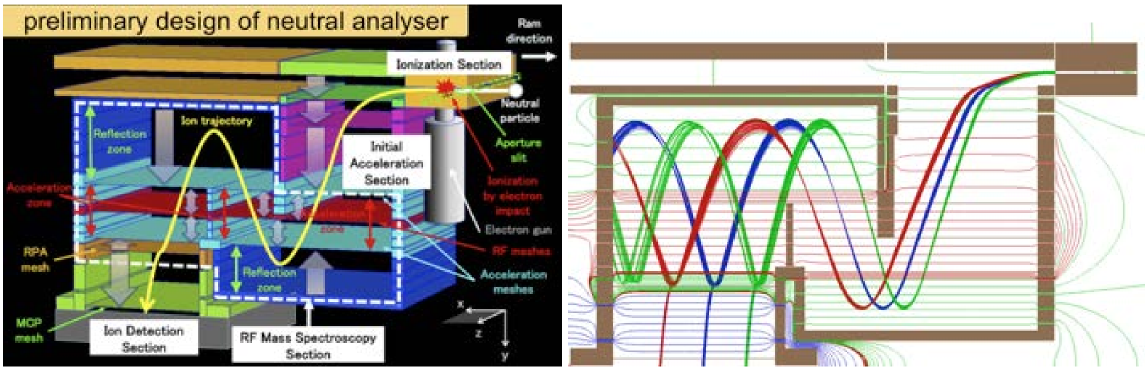

Figure 3. Preliminary design of NIVA instrument. (Left) Principle of measurement. (Right) An example of ion optical simulations. Simulated particle trajectories with equipotential lines are shown.

Ground-support: ALIS_4D and combination with other measurements

ALIS_4D, a significant improvement toward high time-resolution from ALIS that was used in collaboration with Japanese missions Reimei and Arase. New cameras were installed in fall 2018, and first test image were taken in 2019. Full operation is expected from 2020. In addition, the Kiruna observatory is under way to be upgraded, including new fluxgate magnetometer (test operation started spring 2019) and new riometer (under process) with IRF basic fund. EISCAT_3D has also started construction from fall 2017, and will start test operation 2021 and nominal operation 2022.

The Japanese team values these ground-based supports at Kiruna, because the ALIS_4D and EISCAT_3D are unique systems that provide 3D snapshots at high time resolution. In fact, the FACTORS proposal toward WG listed ALIS_4D, EISCAT_3D, and magnetometer network like IMAGE (Kiruna magnetometer by IRF is a member of it) as top three foreign collaborators of the ground segment. In addition, Japanese plans to have Esrange as one of downlink stations to facilitate operations over the target area of ALIS_4D and EISCAT_3D.

Although EISCAT_3D is very important for FACTORS, and Japan is a member of EISCAT, Japan has not yet financially supported EISCAT_3D, failing to approve the construction cost 2018 and 2019. Japanese EISCAT team are still working to realize the Japanese contribution., while at least FACTORS can collaborate with EISCAT_3D through for official request for operation and data taking.