



Focus Session On International Programs and Cooperation

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The Space Studies Board of the National Academies of Sciences, Engineering and Medicine held its annual Space Science Week from March 29-31, 2016 involving the five SSB standing committees, several of which are operated in conjunction with other boards of the Academies. A plenary session for all of the committees was held on March 29, including a panel discussion on international programs and cooperation. That panel discussion is summarized in these notes.

After a briefing by NASA Associate Administrator for Science Mission Directorate John Grunsfeld summarizing NASA's science programs, Space Studies Board Chair and panel moderator David Spergel invited foreign space agency panel members to join Grunsfeld at the panel table.

These representatives were:

- Fabio Favata for European Space Agency (ESA) space science programs
- Maurice Borgeaud for ESA Earth science and applications programs
- Chi Wang of the Chinese Academy of Sciences (CAS),
- Masaki Fujimoto for the Japan Aerospace Exploration Agency (JAXA), and
- Pascale Ehrenfreund of the German Aerospace Center (DLR).

The panelists gave brief individual presentations on their agencies' programs, deferring Q&A until afterwards.

Speaking first, Favata described ESA's mandatory program and its characteristics. The ESA space science budget is approximately EUR 500 million per year, not allocated a priori among science themes. All of their missions are partnerships with their member states. He showed a list of current and future missions, noting that a Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) mission will be joint

with CAS. ESA has four candidates in hand for M4 (4th Medium-class mission) in hand, and there will be solicitations for M5 and M6 on two-year intervals. They expect to initiate larger (L-class) missions at a rate of three every two decades. Favata showed some pictures from the Rosetta Philae comet lander, and reflected that the recent exciting results from the Laser Interferometer Gravitational-wave Observatory (LIGO) provides a great affirmation for ESA's selection of the Laser Interferometer Space Antenna (LISA) as their L3 mission.

Borgeaud spoke next. ESA's Earth observation strategy is to "Observe, Understand, and Decide." He briefly described the Biomass carbon cycle mission, FLEX for photosynthesis measurements via vegetation fluorescence, and the Sentinel family, followed by ESA's role on spacecraft development with EUMETSAT. He noted that the ESA released an Earth observation strategy in 2014, and cited collaborations on a number of spacecraft. Regarding international cooperation generally, Borgeaud remarked that it is not only an opportunity but a "must," adding that cooperation in Earth observation between ESA and NASA is now established but could be firmed up in the future. In conclusion, there are strong synergies between NASA and ESA future Earth observation priorities, suggesting obvious cooperation opportunities.

Speaking for the Chinese program, Wang said that it has three components. They have four flight missions currently under development: the Hard X-ray Modulation Telescope (HXMT), the QUantum Experiments at Space Scale (QUESS) quantum entanglement experiment, the Dark Matter Particle Explorer (DAMPE—already launched last December), and the SJ-10 recoverable microgravity experiment spacecraft. They are currently conducting intensive studies for eight varied missions, including the collaboration with ESA on SMILE. Summarizing: they are planning three more launches in 2016 with additional missions to launch in the 2016-2020 period, open to international collaboration.

The next presenter was JAXA's Fujimoto, who began his remarks by providing an update on the status of their new Hitomi x-ray observatory, formerly called Astro-H. The spacecraft was successfully launched but has lost communications with the ground. Because a beacon signal has been received, JAXA believes that the problem is a loss of attitude control rather than the spacecraft having broken up. They are currently attempting to restore communications; while they do not believe the mission has been lost, Fujimoto acknowledged that even if they can get the observatory into safe mode recovery might take months. He also mentioned two current missions in flight. Hayabusa-2, a comet mission sample return like NASA's OSIRIS-ReX, will rendezvous with a different comet, but the time frames of the two missions are similar, so they expect to cooperate scientifically. Akatsuki, the JAXA Venus mission, failed in its first attempt at orbit insertion, but after orbiting the Sun for five years has successfully achieved orbit on a second effort using attitude control thrusters.

The JAXA program consists of three classes of flight missions. A strategic large mission line budgeted at \$300 million on H-IIA launchers, three per decade; a

competed mid-class line at \$150 million on the Epsilon launcher, one every two years; and missions of opportunity at \$10 million on partner platforms. Fujimoto explained that their overall strategy for expensive missions is to be part of partner projects, e.g., ESA L-class or NASA strategic and New Frontiers class missions. In conclusion, he said that Hitomi is a model for aligning their program via allocating their large mission expenditures with international partners' priorities.

The final agency briefing was given by DLR's Ehrenfreund. She began with an overview of DLR: 8000 employees at 16 sites with a budget of EUR 3 billion per annum. After describing the capabilities of the TerraSAR-X high-resolution radar mission, she introduced two missions in planning, the Methane Remote sensing Lidar mission (MERLIN) in partnership with the Centre National d'Etudes Spatiales and the Environmental Mapping and Analysis Program (EnMAP) hyperspectral observatory for terrestrial ecosystems research. Also under consideration is the Tandem-L twin satellite synthetic aperture radar mission for measurement of 7-8 climate variables, currently seeking international partners. Ehrenfreund went on to list nine current and future missions featuring significant DLR cooperations with NASA, JAXA, and European agencies. She finished with a short film commemorating the 10th anniversary of the ESA Mars Express mission.

With the formal presentations concluded, moderator Spergel thanked the panelists and opened the floor for Q&A from microphones in the aisles of the auditorium.

The first question dealt with the SOFIA program. Reporting concern in the U.S. community about the scientific productivity of SOFIA, the speaker asked for DLR's perspective on its cost versus scientific benefits, citing hearsay about effects at NASA of decisions at "higher levels and political considerations." Ehrenfreund responded as a scientist in infrared astronomy that it's a "fantastic endeavor" due to its wavelength range and mission flexibility for new instrumentation. She does believe that its results should be more strongly promoted. Speaking as the DLR executive board chair, she added that, since money is always a problem, everything must be political. SOFIA has a disadvantage in that it must support both scientists and future instrumentation. She said she couldn't project the future, but funding presently comes also from other German institutions. We should all "fight together" to keep the observatory.

Spergel added his own comments. SOFIA will go through NASA Senior Review. If its productivity turns out to be low, "hard choices will have to be made . . . we don't want to continue operating missions solely because they are international." Grunsfeld added that in the wavelengths it covers, SOFIA is unique. He invited listeners to consider, Hubble, JWST, SOFIA, and the Atacama Large Millimeter/submillimeter Array (ALMA) combining in the near future for unprecedented wavelength coverage. He also warned that funding in strategic budget lines can't necessarily be transferred to other programs.

The next question was addressed to ESA and JAXA. The speaker was struck by the absence in ESA's plans of a follow-on to Giotto and Rosetta. Favata reminded him that ESA's program is defined bottom-up, based on community proposals. Comet missions are not small, so they should be responses to the L-class call; none were received that passed the peer review. "Peer review, sometimes it is crueller than one would like." MIT's Rick Binzel stepped to the microphone and commented that it would be nice to keep the momentum but there was interest in comet sample return missions in other agencies too. NASA's Planetary Science Division Director Jim Green added that there will be a NASA New Frontiers solicitation in early 2017 open to comet surface sample return proposals.

A third question pointed out that there are three U.S. satellite companies set up to deliver radio occultation atmospheric science measurements with NOAA. Directed to ESA, JAXA, and DPL, he wondered what investments are being made in Europe and Japan in private sector satellites that do Earth observation work? Borgeaud observed that this is regarding operational systems. Commercial partners are interested because of the long series of data; there are more and more small and medium companies using these data and he expects growth. Ehrenfreund stated that Tandem-L is being implemented as a public-private partnership. Fujimoto added that in Japan a weather channel has purchased a microsatellite to get its own data.

A fourth question came from a member of the Academies' Committee on Astronomy and Astrophysics. Considering the current model of independent processes for assessment and selection of future investments in each of the various space agencies, do the panelists think this model is sustainable and do they have any comments about modifications and on what scale?

Spergel thought this was a very good question and asked each of the panelists to respond in turn, beginning with Ehrenfreund. We should think about this in terms of both prioritization and implementation, he added.

Ehrenfreund began by saying that the scientific community is very international, e.g., both the Mars Exploration Planning and Analysis Group (MEPAG) and the astrobiology community use a bottom-up structure. Now, with less money, there needs to be a more regular dialogue. She noted that for human spaceflight, the International Space Exploration Coordination Group (ISECG) of space agency leaders is very active, but the higher level group of ministers who convene in the International Space Exploration Forum will do so only every second or third year. There is a need to strengthen the higher level dialogues.

Fujimoto said JAXA is reformulating its science program now. The process used to be totally bottom-up, but with more options there are new modes of cooperation. Agencies have the most information on international opportunities and try to push this into the community. For larger, strategic missions using the H-IIA rocket, it is

smarter to be international with 1/3 of instruments contributed by other countries. This is JAXA's new guideline.

Wang acknowledged that China is a newcomer and stated that international cooperation is strongly encouraged. There are three levels. The first, easiest, is data exchange. The second level is exchange of payloads. The third level is mission level cooperation, like the ESA-China Double Star-Cluster approach. These are good models for the different agencies. He pointed to the SMILE mission. The key roles should be played by agencies.

Borgeaud started by saying that ESA wants to make its own merit assessments—using science panels, etc. He is convinced of the value of synergy between different agencies' program, but it does involve constraints, e.g., budget cycles may be out of phase and other programmatic issues. ESA's Earth science program gets proposals from U.S. scientists and they are welcome, but one must also consider the potential for problems arising on one side or the other. For a 50-50 partnership, a problem on one side might seriously impact the other partner, so senior-junior partnerships are preferable. Plus, there can be political constraints. Thus, for carbon dioxide, it might be useful for both partners to have their own measurements.

Favata expressed a more positive view, the opinion that "we are doing outstandingly well." He wanted to dispel the aura of the "good old days." However, we should not forget that the funding comes from taxpayers, which results in political constraints between sovereign entities. This needs to be respected, but agencies have done a good job of working within these constraints. It may be easier to proceed alone because then there is only one selection process, only one political system, but in the end we cooperate because there is really only one scientific community.

Grunsfeld observed that the great opportunity in science is that scientists don't see the same boundaries that others see. Political and military leaders may have a different perspective. Humans seem to still have a genetically based tribal instinct—that's our challenge. Perhaps having the most efficient market for science is not the right goal: diversity in timing, phasing, etc., offers opportunity to lean on partners when necessary. The current arrangement may be the most effective. He added that he thought that "the [panel] table really should be much longer," with other European countries and emerging new space entrants—India, Brazil, or Argentina for example. In the ebb and flow between countries, a totally coordinated process might not be optimal.

Spergel agreed, in closing, that we may do best when we have as many informed, independent decisions as possible. Thus, perhaps it is best that NASA's decadal survey processes and ESA's L4 and L5 decisions take place out of phase.