2019 IAA Symposium on Small Satellites for Earth Observation

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Esteemed Members of the Academy and Colleagues,

With the successful conclusion of the 12th International Academy of Astronautics Symposium on Small Satellites for Earth Observation, held the 6-10th of May 2019, as the Chief Rapporteur I am pleased to provide the following summary report. Gathering again at the Berlin Brandenburg Academy of Sciences, we enjoyed not only great hospitality and accommodation, but another successful gathering of 270 representatives from across the industry, government, and academic institutions of 37 countries. The symposium was opened by an illuminating keynote address, followed by not only a rich technical program with more than 60 paper presentations across 15 sessions, a special panel discussion, two poster sessions comprised of more than 40 summaries, but also an exhibition with a wide array of system and subsystem offerings needed for developing small satellite missions, launch accommodation, ground services, and information processing. A highly competitive student conference again highlighted exciting new contributors to the space community, featuring six finalists from three continents. Awards were given for both best papers and posters, as determined by committee and participant voting. Finally, not to be missed were also the many enjoyable social opportunities and local excursions made possible by the symposium and supporting organizations, including a hosted "floating" reception as part of a delightful riverboat tour of Berlin.

The symposium was convened and warmly welcomed to Berlin by several distinguished guests, beginning with Bernd Lietzau, representing the State of Berlin Senate, who noted the fitting location of the symposium in a city with a long history and diverse community of traditional and NewSpace companies. On behalf of the conference Chairmen and Secretary General of the IAA, Rainer Sandau noted that when the symposium first started, small satellites were regarded as toys, but much has changed since, and they are now considered invaluable tools. Moreover, the forum has served as means for invaluable exchange between established, global experts in the field and upcoming ones. The Executive Board Chair of the German Space Agency, Prof. Dr. Pascale Ehrenfreund, emphasized the broad use of small satellites for making impactful scientific contributions and the importance of seeking ways to collaborate. From her executive perspective, she highlighted DLR contributions to space research across their 47 globally distributed research facilities, and noted the increasing significance—and opportunity—for the space mission developer community to leverage artificial intelligence, New Space capabilities, services of pending mega constellations, and cutting-edge remote sensing techniques like hyperspectral imagery.

The symposium was then honored to receive the Department Head for Systems at ESA/ESTEC, Mr. Frederic Teston, for his keynote address titled, "Small(er) Satellites at ESA." In his remarks he touched upon highlights of a rich history of ESA science missions beginning with its first small satellite in 1968 (ESRO-1), with now routine use of the mission class, best exemplified with its PROBA technology program. Remarkably, since PROBA-1 launched 20 years ago, the average mass of ESA satellites has dramatically decreased with more satellites being launched in even smaller form-factors. These have targeted scientific applications (e.g., Smart-1, Lisa Pathfinder, and CHEOPS), as well as driven the capabilities and industries of member states. Today, small satellites can be relied upon to provide critical science and observation data, such as with PROBA-2 for space weather monitoring.

ESA employs a disciplined process for "Discovery, Preparation, and Development" to capture and mature disruptive ideas, concepts for future missions, and enabling technologies. Typically, beginning with foundational elements, technology readiness level mapping and enabler roadmaps are considered (e.g., propulsion, star trackers, reflectarray flat antenna, vision based navigation, and hyperspectral imagers) which might first be validated using cubesat missions spanning 2U-12U. In conjunction, this progressively matriculating framework commonly utilizes studies, leading to broad competitions to identify compelling missions, which are then matured into flight programs. It is notable, that in addition to pursuing a broad portfolio of core science and exploration initiatives, ESA has recently expanded its focus to also address Space Safety, including increasingly topical considerations pertaining to space weather, space protection, debris remediation, and automated collision avoidance.

With an eye to the future, ESA has undertaken a strategic exercise entitled Space19+ to define and direct Europe's "next generation" ambitions in space. As part of this exercise, a roadmap is being developed that now formally includes constellation missions, close proximity operations

missions, and beyond LEO missions (e.g., M-ARGO 12U cubesat). Pursuant to these goals, the PROBA-3 mission will demonstrate formation flying small satellites to overcome the physical limitations of single platform. Additionally, ESA is seeking the means by which small satellites can further enhance the ecosystem of science/application/service capabilities. In this regard, ESA is enabling industrial partners to "Fast Fly Forward," through a host of new SmallSat challenges, such as the Sentinel Small Sat (S^3) in Copernicus Master Challenge and Scout Missions. In doing so, Mr. Teston believes, they will help strengthen the competiveness of European smallsat operations, while also contributing to the shared equities of the global community.

In the technical sessions that followed, a diverse array of papers were presented spanning missions, instruments, lessons learned, programmatics, new spacecraft platforms, and enabling subsystem designs. These talks—along with a special roundtable panel—were all of high quality and relevance, received by a full auditorium with many good question-and-answer exchanges. Moreover, the collective body of topics addressed also had strong linkages to many of the remarks shared by the Chairmen's welcome and in the keynote address. When considered in their full context, four important, topical points were made that served to frame the current state of the community from both a capabilities and enabler's perspective, as well new expanded scopes of attention and expectations for increased access to the myriad uses of space supported by small satellites:

1. Small satellites are executing important missions that are directly contributing to the global understanding of our world and beyond.

Setting an important baseline, we expanded our present understanding of current ESA program highlights, with an overview of the portfolio led by NASA, many of which are discriminately using small satellites to provide broad, critical contributions to Earth science and to improve our understanding of climate, weather, and other natural events. In related capacities, we also learned of other demonstration programs seeking to make critical contributions to our global understanding of climate change, such as Green House Gas Sat (SFL), PRETTY (TU Graz), RAVAN (APL), and SHACS (SSC). Underpinning these and other programs are a number of international collaborations, such as the 10-satellite CloudCT constellation for coordinated photogrammetric cloud observation to create 3D imaging solutions for climate prediction. Fundamental to all of these programs and others that were presented, was a mature design baseline of small satellites that have progressively moved the technology risk away from the platform themselves, to instead rightly place the "new endeavor" on the payload. Among many offerors reporting continued development progress in this regard, was Technical University Berlin who've now built 16 satellites for Earth observation, communication, and technology demonstration. By implicit consensus, it is clear that small satellites will continue to be utilized for missions requiring distributed measurements to drive temporal and spatial knowledge, while supporting affordable and responsive programmatics.

2. Continued investments are being made in mission-enabling technologies and integrated capabilities

We enjoyed a strong host of talks pertaining to enhanced and innovative subsystems, such as optical downlinks, as well as ground networks to support expected scaling of future small satellite constellation missions. With the latter in mind, there were several updates on successfully demonstrated capabilities for executing formation flight, including the coordinated operation of BIROS and BEESAT-4, as well as the S-Net mission. Additionally, we addressed the greater integration and efficacy of autonomous fault detection isolation and recovery (FDIR) techniques that are being explored in programs like Eu: CROPIS, as well as onboard target validation and dynamic re-tasking based upon imposing external factors, like cloud obscuration on the Diwata-2 mission. With a similar focus on seeking ways to further reduce operational latencies and risk from human-in-loop of the fault recovery process, the SONATE technology demonstration mission will seek to flight qualify two highly autonomous processing payloads for on-orbit scheduling and diagnostic / fault management algorithms. The application and merits of applying modular open-system architecture (MOSA) approaches to the satellite design and development lifecycle were also discussed.

Beyond the capabilities of individual sensor systems, the forum converged to agreement that integrated applications are not only a matter of data nor earth observation, but combining satellite systems with other sensor systems, across both commercial and government institutions. In this respect, ESA is developing broad, cross-domain business collaborations for applications spanning communications, navigation, earth observation, and others. To evaluate how disparate, yet complementary systems may be effectively integrated, we were introduced to the concept of an Observing System Simulation Experiment (OSSE) that can integrate a heterogeneous system of data sources, to provide a more informed basis for decision making on courses of action and where additional measurements using small satellites might be smartly added to improve assimilative models for forward-looking projections.

3. The world is expanding the obligations and scope of space operations

With greater cognizance and concern for the preservation of our space environment, there is now global attention and emphasis on becoming better stewards of the domain, through space debris mitigation, management, and remediation. The keynote provided several remarks on ESA's Space Safety initiative, where the specific anthropogenic hazards have also been broadly considered by the United Nations Committee on the Peaceful Uses of Outer Space (COPOUS) resulting in 21 non-binding guidelines. The COPOUS working group noted several distinctions between the design and operation of small satellites relative to larger ones, most notably their reduced ability for ground-based tracking and means for safe end of life disposal. Regarding the latter, to provide subject matter based guidance to developers of small satellites, the IAA has created a "Handbook for Post-Mission Disposal of Satellites Less Than 100 kg." Among the viable courses of action and engineering options to satisfy post-mission disposal requirements, drag augmentation was again effectively flight validated by the recently completed InflateSail

mission. In all, the forum discussion was focused on the pragmatic, considerate methods by which future missions should be executed with concern for responsibly preserving our collective access-to and use-of the space environment.

4. There is an evolving outlook on the roles & responsibilities for driving future capabilities in Earth observation

As we look to the future, it is worth contemplating who holds the mantle of responsibility for making the investments of both treasure and talent to advance our collective understanding of the world. A special roundtable panel directly discussed this topic as it pertains to space-based earth observation, convening informed representatives from both business and government sectors. It was foremost noted that Earth observation (EO) is driven by having satellites and, in this regard, Governments are currently the largest consumer of EO data and remain essential to all businesses working with EO products across the raw data (pixels) to knowledge/analytics value chain. While Governments do own and operate their own earth observation systems, there are many existing commercial providers (e.g., Planet, Digital Globe, and Airbus). In all cases, EO is driven by the capabilities of information technology, with cloud services and emerging machine learning tools coming online to transform imagery into actionable products. Among other remote sensing techniques that are being actively pursued, is synthetic aperture radar (SAR). With several demonstrations underway globally, programs such as the Japanese Strix-α X-band SAR among others, are seeking to leverage initial Government investments to then deploy large commercially operated constellations within the next five years.

While the use of space is not globally ubiquitous, during the symposium we were witness to a number of new paper and poster contributions from previously under- or non-represented nations, such as Algeria and Bangladesh. We received a timely update on African space policy and strategy, with emphasis on 17 Sustainable Development Goals that could be furthered through space capabilities. Whereas there are now multiple African nations with active national space programs and several with supporting initiatives, like other emerging actors, we must collectively seek a sustainable ecosystem that can address the equities and stakeholders of Africa, including an eventual sovereign capability to develop necessary space capabilities.

In conclusion, the symposium was another success, providing a great opportunity for technical exchange, broad community engagement, and communication across a diverse international representation. More importantly, it brought forward both new ideas and the opportunity to discuss perspectives on developing important earth observation missions using small satellites. As we have now reflected upon the accomplishments and lessons learned, I would like to again invoke an appropriate question and challenge from my predecessor Chief Rapporteur, Dr. Eberhard Gill, who asked “Quo vadis? Where are we going?” To conclude this symposium, I believe we have again provided an exciting roadmap for future endeavors and I look forward to seeing where we are upon our return to Berlin two years hence.