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NASA Science Mission Directorate SmallSat Coordination Group

State of NASA Science with SmallSats

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ABSTRACT

NASA recognizes the value and impact of SmallSats, from CubeSats to ESPA-class satellites, for high-value science missions to support exploration through innovative technologies. With SmallSats, we are able to, more nimbly, perform targeted science, prove out new technologies and innovation, and educate and train our engineers and scientists for the workforce of tomorrow. Across six divisions of the Science Mission Directorate (SMD), over 11 years, SMD has funded 73 CubeSat / SmallSat Missions and 56 Studies to date. Currently, SMD has 44 small spacecraft science missions (67 spacecraft) in implementation or formulation. The goal of this paper is to provide background of efforts to promote implementation of SmallSats within NASA as a balanced portfolio for the agency's science, technology and exploration analysis and to provide latest observations and trends of SmallSat missions and studies funded by NASA's Science Mission Directorate (SMD) through Research Opportunities in Space and Earth Sciences (ROSES), Small Innovative Missions for Planetary Exploration (SIMPLEx), as well as certain Small Explorer (SMEX) and Medium Explorer (MIDEX) calls over the last 11 years. The data source of this assessment is a subset of the NASA SmallSat Coordination Group Database, a collection of all known funded NASA SmallSat and CubeSat missions and studies. This paper recognizes the latest observations and trends of the NASA CubeSat / SmallSat Science missions with masses ranging between 1kg to 500kg.

Background and Definition

NASA recognizes the value and impact of SmallSats, from CubeSats to ESPA-class satellites, for high-value science missions to support exploration through innovative technologies. With SmallSats, we are able to, more nimbly, perform targeted science, prove out new technologies and innovation, and educate and train our engineers and scientists for the workforce of tomorrow.

For the purposes of this analysis, a SmallSat is defined in the SMD handbook, as "*A spacecraft that is interface compatible with an ESPA Ring, a dedicated small or medium-lift launch vehicle, or a containerized dispenser, and with an upper mass limit of approximately 500 kg*."

All data presented in this paper is from the time period 2010 to June 2021.

Since 2010, SMD has funded 73 CubeSat / SmallSat Missions and 56 Studies across six divisions. Currently, SMD has 44 small spacecraft science missions (67 spacecraft) in implementation or formulation.

The promise of SmallSats

Traditionally, NASA has used legacy class flagship missions – think Hubble, Cassini, or the Perseverance Rover – to achieve our goals of producing extraordinary science and supporting exploration through innovative technology. For NASA, there is a certainly a place for large flagship missions.

However, NASA acknowledges the value and impact of small satellites, from CubeSats to ESPA-class satellites in performing targeted science and making new observations that otherwise cannot be achieved. SmallSats are recognized as an advantageous platform to prove out new technologies and innovation, and to educate and train our future workforce.

As our Associate Administrator of Science, Thomas Zurbuchen said, "These missions will do big science, but they're also special because they come in small packages, which means that we can launch them together and get more research for the price of a single launch."

Role of Small Spacecraft Coordination Group (SSCG)

To this end, in 2017 and in response to recommendations from the National Academies of Science (NAS) "Achieving Science with CubeSats" report, NASA stood up the Small Spacecraft Coordination Group (SSCG).

The SSCG's goal is to improve coordination among the Science, Human Exploration and Operations, and Space Technology Mission Directorates and to place greater emphasis on an overarching integrated small satellite strategy to advance overall Agency objectives.

Policies to encourage and support implementation of SmallSats for NASA Science Missions

To actively engage the capabilities of SmallSats and exploit the risk-tolerant and lighter touch management process and approach toward the implementation of SmallSats, SMD released tailored class-D Mission Assurance Requirement (MAR) to class D Missions <$150M in 2017 (1). This MAR is especially tailored to SMD's SmallSats missions towards a streamlined implementation of these missions so as to not inadvertently suffocate the innovative potential of Class D missions, as compared to the traditional management processes of Class A to C missions. This MAR provided tailoring/streamlining of how we execute per NPR 8705.4, Risk Classification for NASA Payloads; NPR 7120.5, NASA Space Flight Program and Project Management Requirements; and the SMD Management Handbook.

To support regular access to space for SmallSats missions, in late 2018, SMD established Science Policy Directive 32, NASA-SPD-32 (2), which is a policy to enable rideshare or launch accommodation opportunities utilizing excess capacity, including excess ascent performance, by supporting the integration of an ESPA ring as part of the launch service procured for an SMD primary payload. In early 2020, during the Access to Space Workshop, we announced the establishment of a Rideshare office, within SMD, headed by Aly Mendoza-Hill to maximize science, exploration and technology returns by enabling accommodation opportunities for secondary payloads on SMD primary mission launches.

In August 2019, the SSCG released a NASA Small Spacecraft Strategic Plan. Our strategies are influenced by the NAS' report recommendations and add guidance to those recommendations to account for the future capability and growth in launch systems and Evolved Expendable Launch Vehicle (EELV) secondary payload adapter (ESPA)-class spacecraft.

Today, SMD's Heliophysics, Astrophysics, Earth, and Planetary divisions all have funded and flown CubeSats and SmallSats. At the time of this writing, SMD divisions are developing ESPA missions that take advantage of the rideshares available. Heliophysics's IMAP mission has manifested four rideshare missions: GLIDE, Lunar Trailblazer, Solar Cruiser, and SWFO-L1 and the Psyche Mission manifested the Janus spacecrafts. Several other SmallSat missions such as ESCAPADE, SUNRISE, PREFIRE, and others are actively working on rideshares (or dedicated rides) to their destinations.

SMD SmallSat Missions Statistics

Since 2010, across six divisions of SMD, we have funded 73 CubeSat and SmallSat Missions and 56 Studies totaling $2.2 billion. SMD has launched 29 smallsat science missions, 10 of which are still operating. Approximately two thirds of our missions are 6U or larger. The majority of SMD mission PIs are from universities (50%), followed by NASA centers (28%), and industry (10%). Over the 11 years, 80% of awarded missions' primary objective is science; the remaining missions have the goal of technology demonstration. Additionally, one in five of our missions are constellation missions. (*Figure 1*)

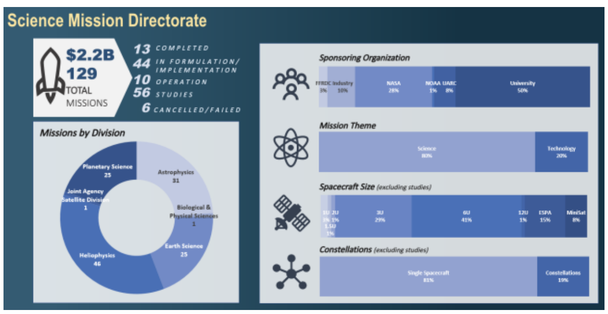

Figure 1 SMD SmallSat and CubeSat Missions a Glance

Currently, we have 44 small spacecraft science missions (67 spacecraft) in implementation or formulation. The full list of completed and future Science missions can be seen in the SmallSat/CubeSat Science Fleet Chart (*Figure 2*). The Fleet Chart depicts missions color coded by topic of study and Mission Directorate, with future missions notated in bold. Thirteen Science missions have completed over the last 11 years, while three missions have resulted in failure.

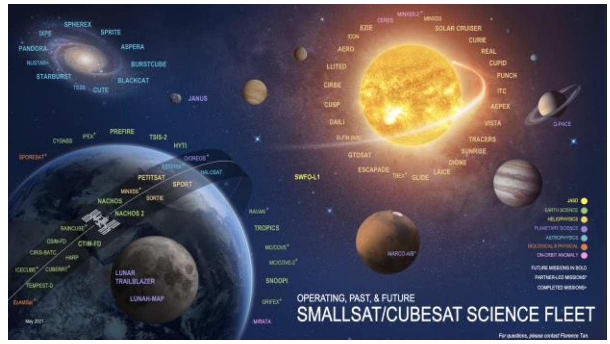

Figure 2 SmallSat/CubeSat Science Fleet

Looking forward, we expect to launch 13 missions for the rest of 2021 comprising of 15 spacecraft and 13 missions in 2022 comprising of 20 spacecraft. (*Figure 3*)

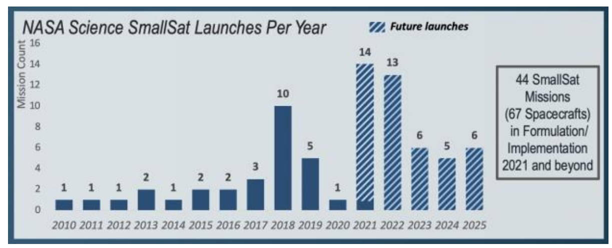

Figure 3 SMD SmallSat and CubeSat launches per year

From an investment perspective, there is a consistent trend of two or three missions accounting for about 50-75% of total funds invested within each Division. Although the Earth Science Division (ESD) was the first division to fly CubeSats, the Heliophysics Division (HPD) has funded the highest number as well as invested in the highest aggregate cost towards SmallSat and CubeSat missions among of all SMD divisions. (*Figure 4*) Heliophysics awards are concentrated within the SMEX program, funding large missions such as ICON, PUNCH, and TRACERS. Astrophysics also invests largely through the SMEX program (32%), but about 60% of investment is in MIDEX. Earth Science funds missions largely through the Earth Ventures (EV) program, at over 50%, while Planetary Science is largely through SIMPLEx (61%).

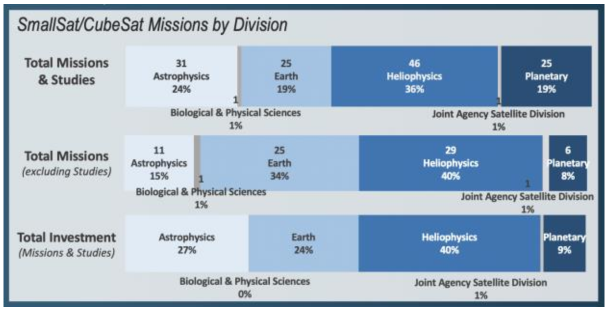

Figure 4 NASA Science SmallSat and CubeSat Missions and Studies Awards by Division

In addition, over the last 11 years, SMD has shifted from deploying 3U or smaller CubeSats towards 6U or larger satellites, and has also employed constellation missions as the unique mission architecture to achieve our science measurements. Since 2016, 20-38% of SMD missions awarded are constellation missions. A constellation mission is defined a mission consisting of two or more spacecraft. (*Figure 5*)

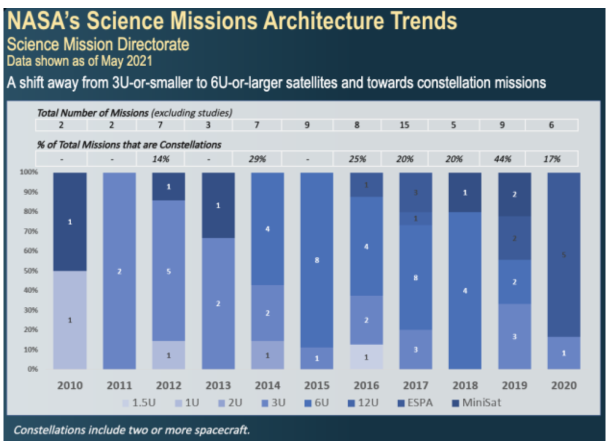

Figure 5 SMD SmallSat and CubeSat Missions Architecture Trends

Since the adoption of NASA-SPD-32, awards of missions comprising of ESPA Class spacecraft have also greatly increased over the last five years; Astrophysics and Heliophysics missions total to greater than 77% of all SMD ESPA class missions. (*Figure 6*)

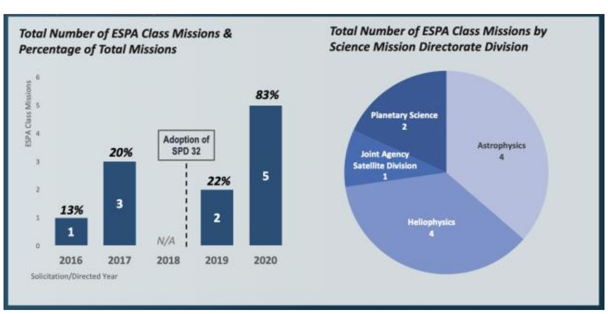

Figure 6 SMD ESPA Class Missions Trends

For the 29 SMD SmallSat and CubeSat missions that have been launched, the period of time between solicitation and launch vary by division. ESD awards are the fastest at launching missions from the year of solicitation [3.5 years], followed by Planetary Science [4.3 years]. However, the Biological and Physical Sciences SporeSat mission, the only BPS mission solicited since 2010, took only two years to launch from solicitation. (*Figure 7*)

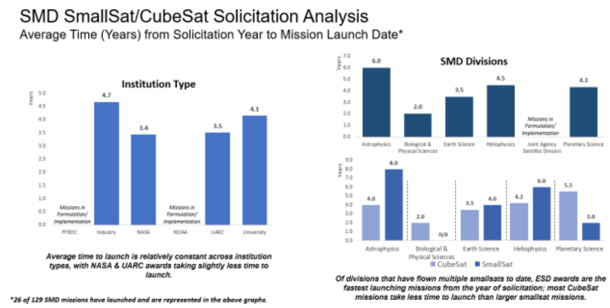

Figure 7 SMD SmallSat and CubeSat Solicitation to Launch

Only eight percent of our SmallSat and CubeSat PIs are within 10 years of their academic age or years since their highest degree. Forty one percent are within 20 years of earning their highest degree. 14% of our PI's inferred gender is female. (*Figure 8)*

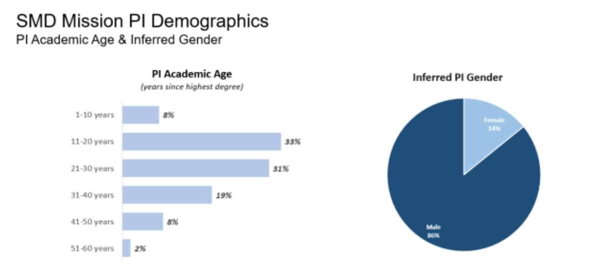

Figure 8 SMD SmallSat and CubeSat PI Demographics

Conclusion/Observations

As NASA's story of the use of SmallSats and CubeSats unfolds, we will continue to provide more such data and perform more analysis. It will also be valuable to compare large sat statistics to SmallSat statistics in a later paper especially to test the premise of SmallSats being better, faster, and cheaper. As we continue our discoveries with SmallSats and collect the data, we will be able to update this analysis especially when we begin flying larger and more capable ESPA class missions.

References

1. ***SMD Standard Mission Assurance Requirements for Payload Classification D, SMD Policy Document SPD-39, April 2021***: https://explorers.larc.nasa.gov/2021APMIDEX/MO/pdf_files/48722_SMD_Class_D_MAR_(OSMA_Final)_04-01-21_SMD_Final_rev2.pdf
2. ***SMD policy document SPD-32 - ESPA Secondary Payloads Rideshare*** https://explorers.larc.nasa.gov/2021APMIDEX/pdf_files/47151_SMD_Rideshare_Policy_SPD-32_Rev_2_Dec_2020_Final.pdf