Summary

This report provides an overview and assessment of state-of-the-art small spacecraft technologies publicly available as of September 2023. Technology maturation and miniaturization continues to expand small spacecraft capabilities, giving rise to more complex SmallSat mission designs. These improved capabilities have broadened the common SmallSat platform with larger CubeSats and smaller SmallSats; the traditional CubeSat platforms of 1U and 3U volume now include up to 16U form factors, and SmallSats once designed as <400 kg are now <100 kg with similar capability for less cost. The larger surface area of more capable SmallSat platforms can be more equipped with solar panels and subsystem arrangement options. The SmallSat industry is thinking outside the box to maximize usage of the full spacecraft volume and design increasingly complex future SmallSat missions.

While still fairly dominated by the traditional CubeSat form factor, this report is starting to reflect increased interest in the more capable SmallSat platforms. The surge in SmallSat launch opportunities and increased availability of services such as rideshares, hosted payloads, dedicated launchers, and orbital transportation is modernizing the SmallSat paradigm. Hosted payload services are increasingly available for larger SmallSats and other commercial satellites. Several SmallSat missions are actively working on rideshares (or dedicated rides) to destinations in years 2024-2026,and there is an increased interest in orbital maneuvering vehicles (OMV) that provide some autonomy from predetermined rideshares. Dedicated launches provide rapid integration and greater mission design flexibility, allowing spacecraft designers to better dictate mission parameters. A wide variety of integration and deployment systems are now available for constellations of small spacecraft, with SmallSat constellations recently launched by Starlink and OneWeb.

The pace of SmallSat technology advancement overall is rapidly accelerating and varies per subsystem. There has been significant subsystem growth in enhanced ground station support, improved technical efficiency, emerging sensor technology, and in rideshare opportunities. Recent flight missions have demonstrated innovative SmallSat technologies; the successful flights of Starling, CAPSTONE, PTD-3 and CLICK A spacecraft have each significantly contributed to SmallSat technology development. Starling successfully demonstrated intersatellite communication; CAPSTONE completed its six-month primary mission of testing the stability of the near-rectilinear halo orbit for Lunar Gateway; PTD-3 achieved a downlink of 200 gigabits per second via optical communication; and CLICK A tested the optical communication hardware that will be implemented on the second CLICK B/C mission, slated to launch later in 2024. DiskSat, expected to launch in 2024, with its revolutionary circular configuration and larger surface area will challenge the way SmallSat's are perceived. LiDAR sensor technology development is ongoing with applications for improved altimetry and relative navigation for rendezvous, docking, and formation flying. There has been particular consideration to deployment mechanisms for small spacecraft subsystems such as antennas booms, gravity gradients, stabilization, sensors, sails, and solar panels, and these technologies are gaining space heritage through operations. ACS3 is an ongoing NASA mission slated for launch in 2024 that will use a new composite boom solar sail in low-Earth orbit (LEO) for propellant-less propulsion. There is a spike in position, navigation, and timing technology progression in inertial sensors and atomic clocks, and magnetic navigation for near-Earth environments.

NASA's new Indefinite Delivery/Indefinite Quantity (IDIQ) mechanism–the Venture Class Acquisition of Dedicated and Rideshare (VADR) launch services–was developed to accommodate very low complexity CubeSats (up to more complex Class D missions) and provide FAA licensed launch services to deliver payloads to a variety of orbits. The 2023 NASA solicitation for Suborbital/Hosted Orbital Flight and Payload Integration Services included opportunities for hosted payloads on commercial orbital platforms (1). IDIQ contracts for these services will replace

existing Flight Opportunities IDIQ contracts when those expire, and are expected to be in place with commercial providers in early 2024. While the deadlines for the latest opportunities recently passed in Q4 2023, readers are strongly encouraged to subscribe to the Flight Opportunities newsletter in reference 1.

There are ongoing policy measures being developed to mitigate and remove space debris. In 2022, the FCC adopted a new “5 year“ rule to reduce the lifetime requirement for all FCC-licensed satellites in LEO to 5 years after launch. These new regulations have incorporated spacecraft decay capabilities into mission design. As of 2023, there are discussions at the agency and federal level to determine the final policies. To comply with new orbital lifetime requirements, satellite operators are employing strategies such as decreasing the spacecraft ballistic coefficient or mass to area ratio. Deorbit technologies such as drag devices that can effectively increase the spacecraft’s drag area may become even more important for future spacecraft operations in LEO.

NASA is working with several American companies to deliver science and technology to the lunar surface through the Commercial Lunar Payload Services (CLPS) initiative. Under the Artemis program, these commercial deliveries present SmallSat designers with opportunities to perform science experiments, test technologies and demonstrate capabilities to help NASA explore the Moon and prepare for human missions. NASA has initially selected 14 companies to deliver payloads for NASA, including payload integration and operations and launch services to the surface of the Moon. The NASA CLPS program will begin delivering science payloads to the Moon in 2024. CLPS contracts are indefinite delivery, indefinite quantity contracts with a cumulative maximum contract value of $2.6 billion through 2028. Companies of varying sizes can work with selected vendors and are encouraged to fly commercial payloads in addition to the NASA payloads (2).

This report will be updated annually as emerging technologies mature and become state of the art. Any current technologies that were inadvertently overlooked in this version may be included in subsequent editions. Updates to technologies listed in this report could be also modified in subsequent revisions. This report is also available online at: https://www.nasa.gov/smallsat-institute/sst-soa. Technology inputs, updates, or corrections can be made by reaching out to the editor of this report at arc-sst-soa@mail.nasa.gov.

References

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