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APPLICATIONS AND POTENTIALS OF INTELLIGENT SWARMS (APIS) FOR MAGNETOSPHERIC STUDIES

Abstract

The magnetosphere is vital for today's technologically dependent society. The energy transferred from the solar wind to the magnetosphere triggers electromagnetic storms on Earth, knocking out power grids and infrastructure, e.g., communication and navigation systems. Despite occurring on our astrophysical doorstep, numerous physical processes connecting the solar wind and our magnetosphere remain poorly understood. To date, over a dozen science missions have flown to study the magnetosphere, and many more design studies have been conducted. However, the majority of these solutions relied on large monolithic satellites, which limited the spatial resolution of these investigations, in addition to the technological limitations of the past. To counter these limitations, we propose the use of a satellite swarm, carrying numerous payloads for magnetospheric measurements. Our mission is named APIS – Applications and Potentials of Intelligent Swarms.

The APIS mission aims to characterize fundamental plasma processes in the magnetosphere and measure the effect of the solar wind on our magnetosphere. We propose a swarm of 40 cubesats in two highly-elliptical orbits around the Earth, which perform radio tomography in the magnetotail at 8-12 Earth radii (Re) downstream, and the subsolar magnetosphere at 8-12Re upstream. These maps will be made at both low-resolutions (at 0.5Re, 5s cadence) and high-resolutions (at 0.025Re, 2s cadence). In

addition, in-situ measurements of the magnetic and electric fields, and plasma density will be performed by on-board instruments.

In this publication, we present a comprehensive design study of the APIS mission, which includes the requirements for science, mission, spacecraft and the ground-segment. Extensive analysis has been done on the mission design, and the satellite operational phases, which include the science measurement periods and the data communication phases. The science requirements of the APIS mission levy stringent system requirements, which are addressed using commercially available off-the-shelf (COTS) technologies. The feasibility of the APIS mission using COTS technologies is demonstrated using link, power and mass budgets. Furthermore, a detailed CAD model of a single cubesat shows all the subsystems fit within a 12U configuration weighing 24kgs. Beyond the technological research, we also investigated the management, business, legal, and ethical considerations of the APIS mission.

The APIS design study was part of the International Space University Space Studies Program in 2019 (ISU-SSP-2019) Next Generation Space Systems: Swarms Team Project. The authors of this publication are the participants of the Project, which included 32 members from 17 nationalities, in addition to the Chairs and support staff.