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MASSIVELY PARALLEL IN-SITU SENSING USING FEMTO-SPACECRAFT CLOUDS

Abstract

Many physical phenomena in the near-Earth space environment such as the geomagnetic/gravitational field and the evolution of atmospheric phenomena are characterised by significant spatial and/or temporal dynamics and ambiguities. While satellite clusters can be utilised to sense such phenomena in a distributed manner, massively parallel simultaneous multi-point sensing with sensor clouds can in principle deliver new insights. Clouds of sensor nodes would also help deconvolve such measurements. Such an architecture can facilitate sampling at a range of spatial length scales, thereby improving understanding of many phenomena.

In this paper we propose a strategy for sensing the near-Earth space environment using clouds of centimetre-scale femto-spacecraft that could be dispersed from a carrier platform. This is now feasible as a result of ongoing miniaturisation in commercial-off-the-shelf technology. Active femto-spacecraft with inertial measurement units, attitude determination and control systems, radio communications and sensor suites, all contained within a 3.5x3.5 cm printed circuit board are now possible [1].

We investigate the qualitative and quantitative trade-offs in utilising thousands of femto-spacecraft dispersed from a carrier platform to improve the spatial measurement of phenomena across the volume of space that the cloud forms. This contrasts with traditional distributed cluster architectures which would use fewer, although more capable, expensive and larger sensing platforms but offer far fewer simultaneous measurements. We examine how these trade-offs scale as the number of sensor nodes increases versus lower quality sensor performance and poorer position localisation, including effects on the reconstruction of scalar/vector fields. We also explore communication architectures for femto-spacecraft wireless sensor networks as a means of extending the reach of the carrier platform they are deployed from.

Use cases considered include operational data services from the in-situ monitoring of space weather phenomena [2] and improving the understanding of the structure of the upper atmosphere [3]. Such examples highlight use-cases where massively parallel multi-point sensing could provide data at new scales to improve understanding of the near-Earth space environment, both for space science and for operational applications.

[1] Hu, Z. et al. “Development of a 10g Femto-satellite with Active Attitude Control”, 17th Reinventing Space Conference, 2019.

[2] Parham, J.B. et al., “Networked Small Satellite Magnetometers for Auroral Plasma Science”, JoSS, 2019.

[3] Clausen, L. et al., “Dynamics of the Region-1 Birkeland Current Oval Derived From AMPERE”, JGCD, Vol. 28, 2012.