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NETWORKED PICO-SATELLITE FORMATIONS

Abstract

So far multi-satellite systems in orbit have only been realized in form of constellations, where all satellites are controlled separately from ground control stations without autonomous control capability onboard to correct relative distances and orientations. Such constellations are established in telecommunication (Iridium, Globalstar, Orbcom, Teledesic), Earth observation (rapid eye, ERS-1/-2,Tandem X), navigation (GPS, Glonass, Galileo) and scientific exploration (Cluster, planet finder / Darwin, LISA). Here control approaches are investigated to move from established hierarchical satellite control implementations like constellations towards distributed systems of cooperating very small multi-satellites, using mainly autonomous formation keeping. The objective is to establish a network composed of many small spacecrafts integrated with an appropriate ground segment to provide a robust distributed satellite system. Specific technologies addressed in this contribution include:

- sensor systems for navigation, in particular for determination of relative distances and orientations based on laser scanner and photonic mixer device (PMD) cameras,
- relative attitude and position modeling of the formation, taking advantage of the specific Earth orbit dynamic properties, on basis of sensor data fusion with extended Kalman filters,
- reliable data exchange between the satellites in-orbit, on basis of mobile ad-hoc networks to adapt to changing communication topologies in the formation,
- networked control of the overall satellite formation, combining supervisory control from the teleoperator with autonomous control approaches in the space segment,
- integration of the multi-satellite space segment with a network of ground stations on basis of advanced planning and scheduling algorithms.

Essential features have already been implemented by our team for pico-satellites (complete satellites at a mass of about 1 kg):

• UWE-1 (launched 2005): communication based on Internet Protocols,
• UWE-2 (launched 2009): attitude determination techniques.

Related results will from these missions will be summarized and related to the context of pico-satellite formations. Such distributed services exhibit higher availability (when one satellite moves out of the field of view soon the next one will enter) and higher fault tolerance (if one satellite out of several fails there is a graceful degradation, not a complete loss of services) compared to traditional satellites. These satellite formations could well contribute to low-bandwidth telecommunication, as well as to Earth and space weather observations.