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# OPTIMAL DESIGN OF SPACECRAFT FORMATION SYSTEMS FOR AUSTRALIA

**Abstract**

Interest in satellite formation flight technologies is growing due to its potential to improve performance and reliability while reducing costs. Satellite formations often require precise relative geometry to realize these benefits. In spacecraft dynamics it is popular – due to its simplicity – to model the Earth as a perfect sphere. Earth's non-spherical shape introduces distortions in its gravity that affect the motion of satellites – the largest of which is known as the J2 perturbation. Satellite formation models were developed to model the exact motion of the spacecraft under the J2 perturbation so that the optimal design and control could be determined to meet mission requirements. The key feature of this paper is design of formation missions that would benefit Australia.

Australia's need for satellite communications and Earth Observation from Space (EOS) capabilities is growing rapidly. Satellite systems are essential for national challenges in climate change, water, disaster mitigation, transport, energy, infrastructure, agriculture, environment and security. Despite this, Australia is fully dependent on foreign satellites that are not designed to meet our specific requirements. Using the optimization models, this paper explored suitable orbits for Australian satellite systems and formations.

Satellite formation applications often require precise spacing or high shape quality for mission functionality and perturbations may impair these quality factors or introduce a high fuel consumption penalty. While this J2 perturbation is small relative to the magnitude of Earth's gravity, it has a cumulative effect over time. Without efficient station keeping or careful orbit design, the orbits of satellites within formations will disperse or rotate beyond their useful range.

An exact form of the equations of motion considering J2 was used to capture this effect in the model. The model was implemented within DIRECT, a general reusable software package for solving optimum control problems. DIRECT translate the described problem into an appropriate non-linear problem using the selected discretization method. The resulting non-linear problem is solved by the general purpose optimization package SNOPT.

The model was applied to identify suitable orbits to meet Australia's current and future challenges. Formation dynamics for a conceptual synthetic aperture radar system for Australia using satellite formation flight was designed. Other formations were designed within a geosynchronous orbit with unique Australian ground coverage. The resulting formations present orbits that will prove valuable to Australia to meet both its current and future EOS requirements, humanitarian and national challenges.