

# Imperial College London; Adaptive communications and resource management for very large scale/very low cost space systems

## Executive Summary

This project aims to explore the core operating functions required by solar powered Thin-Film based wireless sensor networks (TFWSN) that can make them an effective solution for space exploration applications considering a launch scenario that uses a CubeSat class payload.

Relying on efficient energy harvesting, these systems are very resource constrained, and therefore require algorithms to manage low power, processing and both peer-to-peer and node to ground communications. In order to maximize the amount of data captured and reliably relayed by sensors hosted by these swarms of TFWSN devices, self-adaptive mechanisms are required.

Initially, we proposed that we would apply and extending the techniques we have developed for low power meshes of terrestrial wireless sensor networks to the TFWSN space systems, in the following ways by:

- a) Reducing the power required to perform peer-to-peer spacecraft transfers at a range of 3km or greater, space-to-earth transfers at 350km or greater, and generally extending range while remaining within existing power budgets,*
- b) Increasing and prioritizing sensing bit rates while staying within existing power budgets,*
- c) Achieving reliable data collection from a swarm of individually unreliable spacecraft*

We had envisaged that we would be able to map directly our current energy management and communications protocols to these devices, but soon learned that the *sudden death* of the node due to energy being abruptly unavailable meant that this vision was no longer viable. Instead we began examining alternatives that built on our prior work and have achieved a very simple yet effective solution that indeed fulfills our objectives of maximising the data sensed and communicated given the hostile environment, through elastic sensing regimes and communications power adaptation. The operating system scheduler that results from this learns the spin of the device that impacts the cycles of energy provided to the device and adapts its schedule based on this. Correspondingly, the power management function of the operating system also self-adapts based on the available energy, trading off small latencies to maximize the probability of communications success. Finally, understanding the energy cycle enables the '*suicide*' function to safely shut the device down, saving state before the sudden death situation, so that the system can reliably recover and continue its mission when energy returns.

We have carried out a number of analytical and physical experiments to understand and evaluate the behaviours of our schemes and show that we improve the system reliability and performance. As per the proposal, the work was developed using off the shelf spacecraft development kits and all outputs are now to be placed in the public domain for unrestricted access by members of the UK space community and beyond.