Dr Alexei Lisitsa is a lecturer in the Logic and Computation group in the Department of Computer Science at the University of Liverpool.

Dr Louise Dennis is an expert in Multi-Agent Programming and Program Verification. She is a researcher in the Logic and Computation group at the University of Liverpool

Dr Nick Lincoln was a researcher in the Astronautics Research Group at the University of Southampton. He is an expert in the development of robotic and embedded systems, their programming and subsequently their testing. In summer 2012 he started work at IBM.

Professor Michael Fisher is Director of the Centre for Autonomous Systems Technology at the University of Liverpool, and head of the Logic and Computation group in the Department of Computer Science. He is also a Fellow of the BCS, a Fellow of the IET, and a member of the UK Computing Research Committee.

Professor Sandor Veres supervises and carries out research in the theory and practice of control engineering for autonomous systems. He was coordinator of the University of Southampton's Centre for Complex Autonomous System Engineering and head of the Autonomous Vehicle Control Systems Lab. In October 2012, Prof. Veres took up a chair in the Department of Automatic Control and Systems Engineering at the University of Sheffield.

FOR MORE INFORMATION:

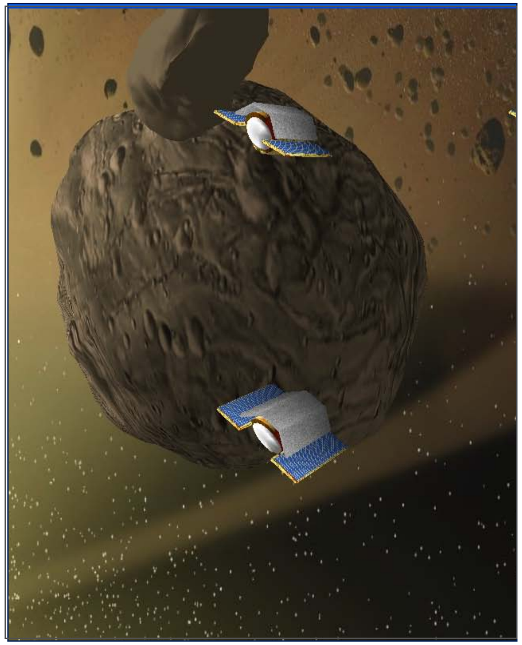
PROJECT WEB PAGE:

http://cgi.csc.liv.ac.uk/EASS/

CENTRE FOR AUTONOMOUS SYSTEMS:

http://www.liv.ac.uk/cast

ENGINEERING AUTONOMOUS SPACE SOFTWARE

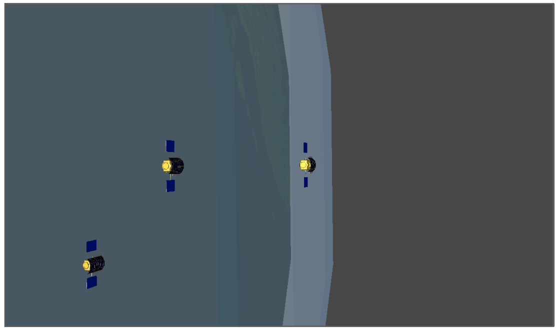


UNIVERSITY OF LIVERPOOL

University of Southampton

Engineering Autonomous Space Software

One of the problems faced by operations in space is the time taken for communications to reach Earth and for replies to be returned. Extending satellites with the capability to make simple decisions, such as to take evasive action or fix internal problems as they arise, should increase their effectiveness and robustness. It should also allow more ambitious missions to be planned in which satellites work in close proximity to each other or objects such as asteroids since they will have a much greater capacity for avoiding collisions.



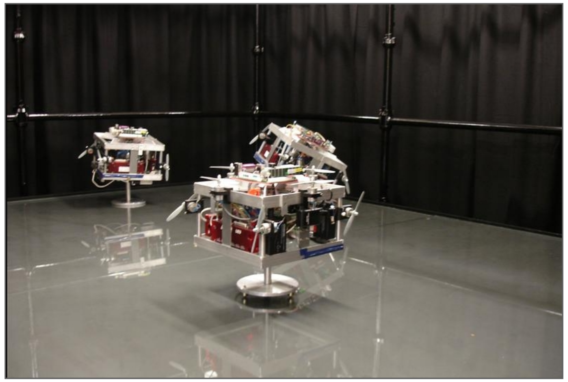
Satellite control is currently implemented using well understood technology from the field of Control Systems. At the heart of these systems is a *feedback loop controller* which monitors data from sensors and compares it to the data that is expected. The system then uses standard mathematical equations to tweak things such as output from the thrusters in order to make small corrections. In this way control systems can easily follow smooth paths, and compensate for minor irregularities. However these techniques do not work well in situations where dramatic changes are required, for instance taking sudden evasive action, or switching between internal components.

The field of Artificial Intelligence has developed many techniques for computer decision-making. One of the most successful of these has been *rational agents* which react to events based upon their "beliefs" about the state of the world and their current "goals" (e.g., mission objectives in the case of satellites). However these techniques are not well equipped for subtle fine-grained control.

This project aimed to combine current state-of-the-art control systems technology with rational agent technology to produce a system that could both perform fine-grained monitoring and make large-scale decisions.

We have done theoretical work to describe such a system in a general mathematical way which does not depend upon the particular tools (MatLab and the Gwendolen programming language) which we used to build a demonstrator. This allows the high level ideas developed by the project to be used for other satellite programming set-ups and in other autonomous vehicle control situations: for instance, deep-sea exploration is also hampered by unreliable communications; and in search and rescue situations there may be comparatively few human operators available but a short-term need for a lot of robots. Preliminary steps have also been taken towards understanding how guarantees can be given that the decision-making subsystem will always take the correct decisions given the information it receives from the sensors.

An actual system has been implemented and tested both in a simulated environment and on a hardware test bed at the University of Southampton. This system includes a number of experimental sub-systems such as a simulation engine, which can be used to assist in decision making by simulating possible outcomes of actions and events, and an abstraction engine which monitors incoming sensor data and can use it to deduce general facts such as "all the thrusters are working correctly". We have also examined how groups of satellites can make communal decisions about moving into and maintaining formations, or efficiently examining a set of objects such as asteroids. We have shown experimentally that the effort required to produce a program in this system scales very well as the application becomes more complicated. This compares favourably with the effort required using *hybrid automata* which form the major alternative approach to this kind of problem.



Satellite Test Bed at Southampton