Chapter | fourteen

Summary and Future Prospects

What surety is there
That we will meet again,
On other worlds some
Future time undated.

Maya Angelou (1928–)

Given the advantages that can be gained by flying spacecraft in formations and all the associated research into the topic, a natural question to ask would be: Why are there no spacecraft formations on orbit currently?

Are we confident in our models to maintain 10–100 m separations? Can we foresee a collision and take evasive action before it is too late? With increased miniaturization and the advent of nano-satellites, the problem of navigating the jungle will become more complex. A scientific mission can be carried out for long durations if the satellites do not thrust while collecting images. For thrust-free operations, we must find good natural solutions, which allow very long-term drift-free formation flying. Even though the satellites of the future will become smaller and cheaper to build, the launch costs are still too high to make formation flying affordable. These are the main research issues; progress must be made in all fronts before we develop enough confidence to go on with real missions. But there is no doubt regarding the payoffs.

14.1 RISK REDUCTION

No formations have ever been flown and a formation is by definition multiple spacecraft in close proximity. The leap in complexity and cost from controlling a single spacecraft to multiple spacecraft incurs a large quantity of risk. In particular, verifying and validating the control system algorithms is expected to be a key barrier and cost driver. Communications reliability will also need to be considered from both the perspective of the control system performance in off-nominal communication conditions and the feasibility of the control requirements on the communications system.

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14.2 FUEL REQUIREMENTS

Unlike a monolithic spacecraft, the component spacecraft in a formation are expected to require regular on-orbit corrections to prevent drift within the formation. These regular corrections are expected to use more fuel per satellite than that required for maintaining the orbit of a satellite which is not part of a formation. Furthermore, when any one satellite runs out of fuel, the entire formation flying mission will be over. One can argue, however, that the remaining satellites will still be able to perform the mission, albeit with a degradation in performance.

Thus, either a high degree of confidence must be placed in a fuel-minimizing control system or a great deal of extra fuel will be required for each satellite on orbit. Raising the redundant fuel margin for each satellite will raise the mission cost considerably.

14.3 MISSION OPERATIONS

Although many control approaches for spacecraft formations have been proposed in the literature, few papers discuss the methods and costs involved in operating a spacecraft formation. A balance will need to be found between guidance conducted by human-monitored ground systems and fully autonomous control on-orbit. Furthermore, the culture between spacecraft autonomy and spacecraft automatic control must be bridged to collect the best ideas from both areas of research. Although the presentation in this book has focused on control systems, a large quantity of research exists in the areas of spacecraft fault detection, automated command sequence generation, and future software architectures [189–192]. The future of implementing, verifying, and validating higher level control systems on board satellites will depend critically on successful integration with the spacecraft software community.