CLUSTER FLIGHT APPLICATION ON SYSTEM F6

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ABSTRACT

The Cluster Flight Application (CFA) is a critical infrastructure application developed under the DARPA System F6 Program to provide guidance, navigation and control (GN&C) services to a cluster of spacecraft modules. System F6 seeks to "demonstrate the feasibility and benefits of fractionated space architectures, wherein the functionality traditionally co-resident within a single, large, 'monolithic' satellite is delivered by a cluster of wirelessly-interconnected modules capable of sharing their resources and utilizing resources found elsewhere in the cluster" [Ref 1]. The CFA, when deployed on a spacecraft, would enable it to safely participate in the F6 fractionated cluster by providing coordinated services that the modules could not provide for themselves, such as relative navigation and cluster-coordinated maneuvers, to maintain the cluster safely and efficiently without extensive ground crew support.

Key F6 objectives to be met by the CFA include semi-autonomous long-term cluster maintenance, ingress, egress, passive safety, autonomous scatter and re-gather of the cluster, and reconfiguration. One of the underlying goals is also to provide a framework whereby future enhancements to the CFA can be easily injected. To this end, the major CFA functionalities are designed as services that can reside on any processing node on any module, even on a ground node, that has sufficient computational resource and can communicate wirelessly with the rest of the cluster. Major services provided by the CFA are Maneuver Planning Service (MPS), Navigation Service (NAV), Orbit Maintenance Service (OMS) and Cluster Flight Manager (CFM). In addition, cross-cutting across all services is a CFA fault detection, isolation, and recovery function. A summary description of the CFA is shown in Figure 1. In this paper, the basic functionalities of the CFA are summarized.

Two fundamental services provided by the CFA are the Maneuver Planning Service (MPS) and the Navigation Service (NAV). The MPS generates multi-burn maneuver plans that satisfy the constraints and objectives of a particular orbit control request. Its flexible algorithm is designed to compute the delta-V maneuvers for all the orbit control scenarios required by F6. Through a robust heuristic search method based on simulated annealing, MPS finds the optimal maneuver times and targets that satisfy the cluster control objectives and constraints. An underlying efficient multi-burn solver based on linear programming generates the optimum delta-V plans for a given set of initial and final conditions selected by the heuristic search.

The second fundamental service is NAV which provides position and velocity information for all the modules in the cluster. Because of the criticality of the navigation information, robustness and reliability are the main driving factors of the NAV architecture. Although the NAV framework is being built to accept any measurements of type range, range rate, and angles, its nominal mode of operation is using GPS pseudo-range measurements. The NAV

filter solutions based on these GPS measurements provide sufficiently accurate relative navigation for efficient orbit control. The NAV architecture is designed to provide robustness to failures in either the wireless communication or in the GPS information through its fault detection, isolation, and recovery function.

There are two additional services that make up the CFA: Orbit Maintenance Service (OMS) and Cluster Flight Manager (CFM). OMS is responsible for planning and executing on the guidance and control strategies during the various operational scenarios required by the cluster. For example, for cluster orbit maintenance, it specifies the target relative orbit elements that are desired and those that are free, the frequency of the control loop, and the constraints associated with the spacecraft such as minimum and maximum delta-V and time. OMS is also responsible for managing the pre-calculation of maneuvers required for rapid response scenarios like scatter.

CFM is responsible for the coordination of all the CFA services, and it maintains an inventory of all the modules that are members of the F6 cluster and manages the state machine of the cluster and of each module. Other key functionalities of CFM include the monitoring of the cluster collision probability and the management of maneuver distribution to the spacecraft in the cluster.

The functionalities of the CFA are being verified using MATLAB simulations as well as a high-fidelity embedded FSW simulation based on NASA's Trick simulation framework and environment models.

[Ref. 1] BAA, System F6, TTO, DARPA-BAA-11-01, 20 Oct 2010.

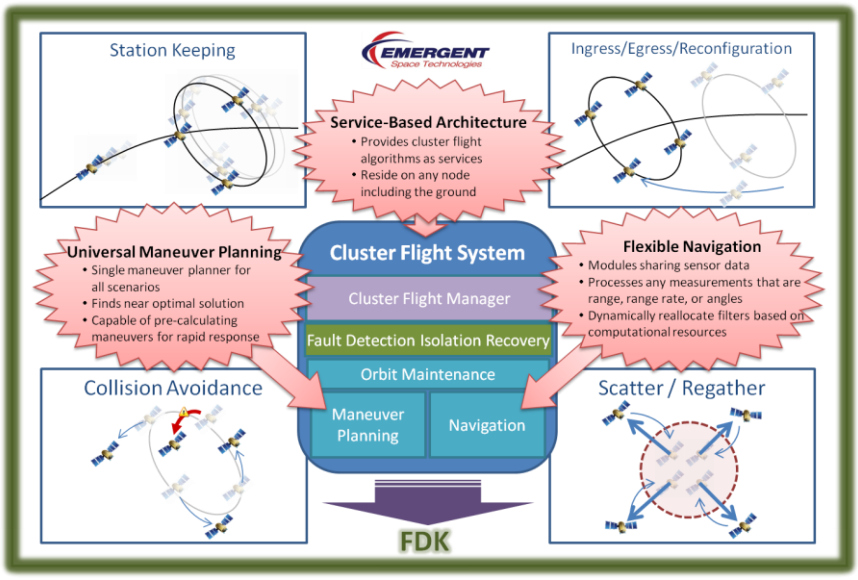

Figure 1. Summary of Cluster Flight Application