CHAPTER 2

Literature Survey

Automated Planning and Scheduling Technology for Autonomous Spacecrafts has several benefits. A team of engineers working continuously for the various aspects covering all the activities enumerated in the handbook of Satellite Mission Operations Best Practices Working Group [1-2] on Mission Operations is found to be a very complex process. New Millennium Remote Agent (NMRA) architecture [3] has been reported for autonomous spacecraft control systems of Deep Space 1 mission. The current trends and future tendency of sensors for earth observing satellites has been provided by Chou et. al. [4, 5]. PROBA [6] is a technology demonstration of onboard autonomy missions from European Space Agency. In PROBA-2 mission “hardware-in-the loop simulations in a signal simulator testbed are used to demonstrate the feasibility of 1 m level real-time navigation using a single-frequency GPS receiver and to demonstrate the overall robustness of the onboard navigation [7]”. On the other hand, demands of science missions such as SWIFT [8], unlike earth observing missions, has also require specific autonomous features built-in in order to ease science observations effectively. This work explores the challenges associated with mission operations automation and autonomy for the Swift mission. An information technology organization [9] is structured to support mission operations and general users, while protecting resources for the development and deployment of changes to the technology infrastructure. FUSE spacecraft had four actuator wheels and only one of them was functioning at one stage. The team has come out with procedures to keep the mission going further and the details are as given in reference [10].

The demand for low cost satellite operations has arisen due to financial pressure faced by space faring nations all over the world. Feasibility study revealed that the system life cycle involving, design, development, installation, tests, operations, maintenance, dismantlement and reuse of Ground Network elements has the potential to cutting the budget sensibly. A feasibility study on low cost autonomous ground terminals and tracking network has been reported by NASDA [11]. NASDA has planned to upgrade its old-age, big and complicated ground equipment to state-of-art, small and simple systems in order to reduce operational costs. Some Flight Dynamics Systems (FDS) on the large-scale computers, with maintenance services soon to expire, have already been migrated into engineering
workstations. Also, NASDA had initiated a migration program of Spacecraft Management and Control System (SMACS) and the tracking Ground Network (GN).

It will be more effective to cut the cost further if it is possible to automate the mission planning and scheduling of spacecraft operations without much of ground engineers’ support. The idea was in vogue as early as 1960’s with several space mission operational stations. NASA / GSFC worked on the pathfinders for future self-managing sensor constellations [12]. In such a system, futuristic constellation components, whether they are orbiting satellites, unmanned systems, or ground components, will autonomously optimize their operational activities. For accomplishing coordinated observations, these systems will act independently in such a way they satisfy complex scientific objectives. When taken together, such a system enables more cost-effective management of future satellite constellations and other sensor platforms. In pursuance of this technology, an Autonomous Sciencecraft Experiment (ASE) Onboard the EO-1 Spacecraft [13-16], wherein several autonomy software technologies enabling autonomous science analysis and mission planning is integrated and demonstrated. The experiment demonstrated the potential for future space missions to use onboard decision-making to respond autonomously to capture short-lived science phenomena. The software demonstration consisted of two sections: a real-time display of an ASE-commanded ground contact from the EO-1 spacecraft, and a simulation of the full ASE autonomous science-response scenario.

Autonomous Science craft Experiment [ASE] team from JPL has demonstrated the utility of this advanced technology with EO-1 team [15]. Automated Planning and Scheduling Technology [16] for Autonomous Spacecrafts has several benefits viz. (i) reduction of costs (ii) Increased responsiveness (iii) Increased interactivity (iv) increased productivity and (v) simplified self-monitoring. The technology covers a wide spectrum of spaceflight missions – some of them with limited onboard computational capabilities and others with highly sophisticated software.

In another experiment by NASA, an autonomous control strategy on the Low Energy Neutral Atom (LENA) instrument flying in IMAGE spacecraft [17] has been applied using model based reasoning wherein explicit models of instrument subsystem responses are constructed and are used to dynamically adapt to the spacecrafts environment. In yet another experiment conducted by NASA, TOPEX-POSEIDON Autonomous Maneuver
Experiment (TAME) has been designed, implemented and executed in flight [18]. TAME is an experiment to provide the necessary algorithms for planning and executing attitude maneuvers and a thrusting Orbital Maintenance Maneuver (OMM) autonomously. This experiment not only provides the challenge of developing the autonomy algorithm but also implementing them on an operational satellite that is not designed to accommodate autonomous attitude or propulsive maneuvers. Another experiment named Microcosm Autonomous Navigation System (MANS) was launched as part of the Space Test Experiment Platform (STEP)[19] Mission zero. The purpose of MANS was to supply accurate values of the host spacecraft position, velocity, attitude, attitude rate, ground look point, and lighting conditions with an inexpensive fully autonomous navigation system. The experiment was successful and meaningful results were obtained and gave lots of confidence. In testing the model based operations system concept, a mission planning system to develop and execute a validated plan of ground and spacecraft activities has also been tested for a mission called ST5 [20]. Here, an Automated Mission Planning and Scheduling (AMPS) Support of Autonomous Operations for a constellation called ST5 is presented. During operations it is clearly demonstrated that the utility of this architectural and operational approach caters to radical changes in operational requirements. Also, the operations team was able to easily meet mission requirements with relatively minor changes in ground implementation details. An architecture called SWAMO [21] that enables a future generation of coordinated science collection, collaboration and calibration was implemented that is suitable for Spacecrafts which is a piece of sensor web puzzle.

Spacecraft designers drawn into the idea of increasing the level of flight system autonomy of spacecrafts which ensures robust operation after faults, faster decision making and thus reducing the spacecraft operational costs. On the other hand, mission controllers though interested in the mission autonomy, but bring a number of concerns and requirements like that they are in a position to control the spacecraft even when the autonomy features goes wrong. Usually they would prefer to demonstrate new capabilities first on the ground and then plan onboard the spacecraft. For this purpose, a new concept based on remote agent approach [22] is demonstrated that shows promise for meeting the autonomous system aspirations of the spacecraft designers while also meeting the needs of the mission controllers. Herein, it is claimed that “the mission controllers can communicate at a high level of abstraction to an agent that is remotely located on the spacecraft and the agent understands the abstract goals, creates and executes robust plans to carry them out.
For specific Radio Science experiments, such as the Mars Global Surveyor atmospheric occultation occurring every two hours for many years, project-funded science staff configures the RSR with the appropriate tuning files derived from navigation information, the event-timing file, and acquisition configuration in advance. Autonomous operations need only spot checks, as opposed to constant monitoring needed on previous missions. This pioneering and visionary development on the part of the Deep Space Network was reported in [23] has resulted in statistics above 95 percent of valid data acquisition for MGS over several thousands of occultation to date. This paper describes the Radio Science Receiver system and the savings it has brought to mission operations. Of late several student satellites are flown and operating the small satellites with student community requires specific autonomous features. Some attempts were made in this field [24-25]. In these references, J. L. Anderson introduces a framework of developing different artificial intelligent aspects to conduct autonomous satellite operations.

Research in NOAA [26] has chartered plans for (i) Eco Mission Systems (ii) Climatic Mission Systems and (iii) Weather and Water Missions Systems and India cannot fall back in its efforts to maintain the environment This means several near earth satellite missions for studying earth environment along with existing fleet of missions in orbit need to be maintained by an operational centre. The need of the hour has been felt so seriously a monograph [27] on this topic “Autonomous and Autonomic Systems: With Applications to NASA Intelligent Spacecraft operations

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