Integrating Software Technologies in RAXEM AI Meets Information Technology

Giulio Bernardi, Amedeo Cesta and Gabriella Cortellessa

***Abstract*—This paper describes aspects of RAXEM, an intelligent software system developed to support human mission planners in the daily task to plan uplink commands for an interplanetary spacecraft. A first release of RAXEM is in operational use at the ESA-ESOC mission control center since Summer 2007. During this year an enhanced version of the tool has been delivered, able to capture the entire life-cycle of the uplink plan problem, and incorporating new functionalities for data management. The new tool combines a flexible AI based automated algorithm, a user-friendly interaction tool, and functionalities for information management, overall guaranteeing continuity of work practice. The paper touches upon all these aspects and comments on how a key factor for success has been the integration of such different modules in a unique comprehensive support environment.**

***Index Terms*—Intelligent systems, User interfaces, Data communication, Knowledge Engineering, Information systems.**

THE space domain is one of those in which AI technology has demonstrated maturity and effectiveness. A significant effort has been directed to have advanced examples of autonomy, see Remote Agent [5] and EO-1 [4]. Other very interesting success stories have addressed daily problems at ground segments to support either payload scientists' negotiation, like in MAPGEN [1], or mission planners' activities, like in MEXAR2 [2]. This paper describes a system developed to support the command uplink problem (formalized as MEX-UP) for the MARS EXPRESS probe, which is currently operational in Mars orbit. A first version of the system, named RAXEM [3], has been developed to support daily mission planners' activities. A new enhanced version has been recently deployed to support the entire *life cycle* of the uplink activities. This new version is the focus of this paper. RAXEM has been designed and engineered to optimize the safety and timeliness of more than fifty command timelines sent to MARS EXPRESS each week. It uses an AI constraint-based modeling and solving approach to plan each command file for uplink, retaining a backup window wherever possible, keeping the on-board timeline as full as feasible, and ensuring the safety of the spacecraft at all times (see left part of Fig.1).

A key point in RAXEM is to support the continuity of work of mission planners. They are in continuous contact with payload

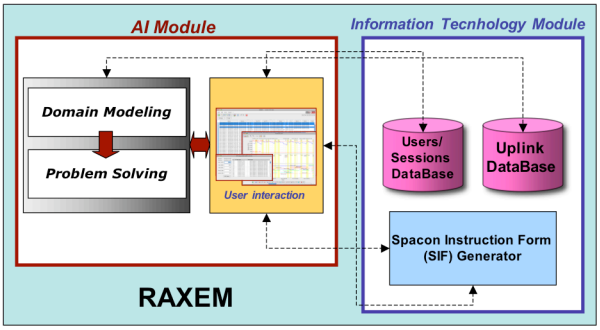

Fig. 1. RAXEM is composed of two modules: an AI-based module to model the domain, solve the problem and interact with the users. A second module completes the system, allowing the management of the entire uplink plan *life cycle*.

PIs and may receive commands to be unlinked distributed over time including the possibility of having to accommodate new activities in a short notice. As a consequence RAXEM has been endowed with an interaction layer that supports incremental plan definition and management.

The AI module and the user interaction layer have been then integrated with an additional module that ensures a complete and continuous management of the uplink problem. The first version of RAXEM was indeed part of a loop which entailed the use of an external semi-manual procedure in order to produce the Spacon Instruction Form (SIF Generator module), needed to the operator to execute the uplink plan and to maintain an updated information of the status of each MDAF (Multi-Detailed Agenda File). The new version of RAXEM integrates an enhanced module for the generation of the SIFs and populates databases, which allows numerous *queries* on the uplink history and users' responsibility on the operation guaranteeing a continuous complete control on the uplink responsibilities. The paper underscores how the end-to-end features and the overall management of the problem are contributing not only to support mission operations but also to increasingly inject innovative ideas about more flexible ways of managing operations and data during mission. The paper will specifically focus on the new RAXEM with the aim of showing how integrating flexible innovative techniques with standard robust solutions creates innovative software services.

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G. Bernardi is with the University of Rome "Roma Tre".
A. Cesta, is with ISTC-CNR, Rome, Italy (e-mail: amedeo.cesta@istc.cnr.it).
G. Cortellessa, is with ISTC-CNR, Rome, Italy (e-mail: gabriella.cortellessa@istc.cnr.it).

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