Optimal Design of Integrated Systems Health Management (ISHM) Systems for improving safety in NASA's Exploration Vehicles: A Two-Level Multidisciplinary Design Approach

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1. Background

Integrated Vehicle Health Management (ISHM) systems are used to detect, assess, and isolate functional failures in order to improve safety of space systems such as Orbital Space Planes (OSP's). An ISHM system, as a whole, consists of several subsystems that monitor different components of an OSP including[1]: Spacecraft, Launch Vehicle, Ground Control, and the International Space Station. In this research, therefore, we propose a new methodology to design and optimize ISHM as a distributed system with multiple disciplines (that correspond to different subsystems of OSP safety). A paramount amount of interest has been given in the literature to the multidisciplinary design optimization of problems with such architecture[2] (as will be reviewed in the full paper).

Keywords: Two-level Optimization, Integrated Systems Health Management, Orbital Space Planes

2. Objective and Contributions

In this paper, a two-level multidisciplinary design approach is described to optimize the effectiveness of ISHM's. At the top level, the overall safety of the mission consists of system-level variables, parameters, objectives, and constraints that are shared throughout the system and

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[1] D. Maclise, S. Wilson, "Orbital Space Plane Integrated Health Management Summit Results, Recommendations and Lessons Learned", working paper, NASA Ames Research Center, Moffett Field CA 94035
[2] J. S. Sobieski, R. Haftka, 1996, "Multidisciplinary Aerospace Design Optimization: Survey of Recent Developments," 34th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada, AIAA Paper No. 96-0711

by all subsystems. Each subsystem level will then comprise of these shared values in addition to subsystem-specific variables, parameters, objectives and constraints. A hierarchical structure will be established to pass up or down shared values between the two levels with system-level and subsystem-level optimization routines.

3. Status and Plan

An ISHM Summit meeting held at NASA Ames Research Center in August 2003 established a benchmark for a universal definition, system architecture, and components of ISHM systems[2]. A further study resulted in a set of correlated variables and parameters and a group of models to quantify the performance of an ISHM. We are currently crafting a two-level system-subsystem breakdown of these models to form a multidisciplinary design problem.

4. Impacts of this Research

Once the architecture of the ISHM design problem is established, we can conduct a series of studies to determine the impact of an ISHM on the overall safety of OSP, as follows.

Safety Improvement: This research will provide a quantifiable measure for the effect of an optimized IHM on the overall safety of a given mission.

Tradeoff Study: By modifying the subsystem-level constraints, a tradeoff study can be performed.

What-if Scenarios (robustness of the optimal design): Decisions that are made based on ISHM's assessment of the system health are often extremely crucial and can sometimes determine the success or failure of a mission (Taken to the extreme, consider the decision of continuing or aborting a mission). It is therefore of extreme importance to determine the robustness of the obtained IHM design. This can be done by conducting what-if scenarios (at the subsystem-level) and observing the impact (at the system-level).