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ADVANCED MICRO-GN&C TECHNOLOGY FOR LOW-COST PLANETARY MISSIONS

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ABSTRACT

The new NASA paradigm calls for more frequent, low cost, small spacecraft missions capable of returning high - value planetary science. This challenge also extends to the rapid insertion of advanced technologies across all spacecraft subsystems as an enabling tool for building these highly capable miniaturized science platforms in the spirit of "faster, better, and cheaper." This paper presents the JPL vision of near-term and emerging Guidance, Navigation, and Control (GN&C) subsystem technologies that will help fashion the future of low-cost planetary missions.

INTRODUCTION

The major GN&C mission support roles for future planetary spacecraft include attitude stabilization, Δ-V trajectory corrections, science instrument pointing, target feature tracking and image motion compensation, radar/lidar and gravity-field mapping maneuvers, aerobraking control, and disturbance compensation. To achieve low cost missions will require a radical change from the current dependence on real-time, hands-on ground support in mission operations. Low operational costs can be realized through greatly increased onboard autonomy and reliance on the adaptability we build into control systems. Future missions to explore planets, comets, and asteroids will emphasize fast-flying, agile spacecraft that are capable of insuring mission success in the face of a wide range of uncertainties, both on-board and in the external environment. Whether the mission is a fast flyby, rendezvous and stationkeeping, orbiter, surface probe, or lander, the issues of component degradation and failure, disturbance interactions, ephemeris uncertainty, and unknown target features will always be present.

Likewise, as block redundancy is traded for lower cost and mass, new ways of introducing fault tolerance and maintaining performance will be needed. For example, functional and analytic redundancy through smart-sensor data fusion or mixed use of impulsive and proportional momentum-exchange effectors will provide a graceful loss of performance rather than failure. In these "design-to cost" spacecraft, tightly regulated power, fuel, computation, and data storage resource management will be needed. This simply means that future missions need self-reconfigurability to manage without costly human intervention and the attendant interruption and possible loss of mission return. This has motivated JPL's development of miniaturized attitude sensors with embedded processors and smart software, advanced actuators, and Intelligent Control technology.

AUTONOMOUS CONTROL TECHNOLOGIES

Intelligent Control

In contrast to conventional feedback control, where the error signal is the main way to assure control stability and performance, Intelligent Control offers autonomy through self learning, self reconfigurability, approximate reasoning, planning and decision making, and the ability to extract the most valuable information from unstructured and noisy data. These attributes may be realized by the merger of neural networks and fuzzy logic in support of uncertainty-tolerant robust control systems.

1. Automated Modeling and Control Synthesis [1,2,3]

The three generic design issues for any control system are stability, robustness to modeling uncertainties, and performance. The automated design technology of *Modeling and Control Synthesis (MACSYN) [1]* addresses these issues directly via a deterministic model-based approach. Figure 1 shows the basic concept of MACSYN. This provides the technology for the *inner loop (or first layer)* of the Intelligent Control architecture discussed later.

First, the plant input/output (I/O) data from prescribed excitations of the system are processed by system identification (ID) algorithms to generate a mathematical model of the multivariable plant and any disturbances. Based on system ID data, additive and multiplicative uncertainty models are created to capture system variations in rigid-body mass properties, flexible body modal frequencies and damping, plant parameter drift, nonlinearities, noise, and disturbances. Finally, the plant and uncertainty models are passed to the robust control design algorithms to generate a controller (either H-Infinity or LQG methods) that can perform robustly under the defined uncertainties and to the prescribed margins.. This particular approach is referred to as a *model-based* design technique. MACSYN can provide guaranteed stability and robustness since identification and uncertainty modeling are true for in-flight conditions. During the mission, a fully automated onboard MACSYN process would provide periodic non-real-time self tuning of the control system nominal design. In the event of equipment failures, MACSYN could also enable autonomous reconfiguration of control loops for the best performance using the available control channels.

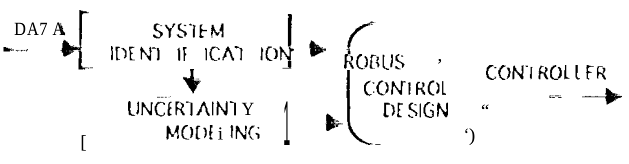

Figure 1. Modeling and Control Synthesis (MACSYN) basic concept.