THE MARS SCIENCE LABORATORY SKY-CRANE LANDING ARCHITECTURE
A GUIDANCE, NAVIGATION, AND CONTROL PERSPECTIVE

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ABSTRACT

The return to Mars by the Mars Pathfinder Mission (MPF) in the 90's marked the beginning of an exciting period in the development of new Mars landing system architectures. Driven by the need to reduce development costs while improving system robustness to terrain slopes and rocks, the evolution of these architectures started with the primarily passive MPF airbag landing system, in which the function of the GN&C subsystem was limited to the timing of the airbag inflation and of the retro-rockets firing. It continued with the Mars Exploration Rovers (MER), where the increase of the landed mass coupled with a changing mission risk posture, resulted in the augmentation of the heritage MPF airbag landing system with the GN&C TIRS/DIMES wind compensation system. The Mars Science Laboratory (MSL) Sky-Crane represents the current state of this landing architecture evolution. The dramatic increase in the MSL rover mass over its predecessors, MER validation and verification challenges, and the resulting increase in GN&C complexity necessary to deal with environmental uncertainties, resulted on a new landing approach that in many ways is the antithesis of MPF's, the starting point of this architectural journey. In the Sky-Crane design, high performance 6-axis active control is the enabling factor around which engineering challenges of a mechanical type (e.g. rover egress, touchdown stability, landing loads, terrain slope and rock landing robustness) are dealt with efficiently and with certainty. In principle, with high performance active control, the balance of risks shifts from the uncertain environment that Mars can present during landing day, to the technical and programmatic challenges during the project development phase. In this paper, the GN&C technical challenges associated with the Sky-Crane landing architecture are described, starting with the requirements imposed by the system on GN&C, and vice versa, followed by a description and motivation of the design elements and themes derived in response to such challenge, the evolution of these principles through the implementation phase, current status of GN&C performance, ending with lessons learned so far, and proposed GN&C related Sky-Crane enhancements for future missions.