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The Apollo program and the rockets that took humanity to the moon (9-D6.2)

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THE ENDURING LEGACY OF SATURN-V LAUNCH VEHICLE FLIGHT DYNAMICS AND CONTROL DESIGN PRINCIPLES & PRACTICES

Abstract

It has been over 50 years since the first launch of the Saturn-V launch vehicle on November 9th 1967 called Apollo 4. Developed at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama the Saturn-V was a multistage liquid-fuel expendable rocket used by NASA's Apollo and Skylab Programs. It safely flew 24 American astronauts to the Moon blazing the trail for all American heavy lift launch vehicles to follow. The Saturn-V remains the only launch vehicle to carry humans beyond low Earth orbit. Although the last flight of the Saturn-V was nearly 50 years ago, on May 14th 1973 launching the Skylab space station, there is still a strong enduring launch vehicle Guidance, Navigation and Control (GNC) technical legacy that continues on to this day from the Saturn program. For example, the Saturn Program developed the now-common launch vehicle flight control design and analysis principles such as in-flight load relief and best practices for structural bending mode stabilization. The Saturn I/IB project was the origin for the model-based approach for flight control design systematic employing for the first time mathematically rigorous flight dynamics models for stability analysis, particularly with respect to structural bending and propellant slosh dynamics. There was also the noteworthy development of precision, high-power mechanical feedback hydraulic Thrust Vector Control (TVC) system, which laid the groundwork for the advent of the quad-redundant actuators used for both the Space Transportation System (STS) Shuttle Orbiter vehicle and the on-going Space Launch System (SLS) heavy lift core stage. As will be described in this paper the NASA MSFC managed, and provided the technical leadership, for the entire Saturn Program evolving it from the earlier Jupiter launch vehicle program previously conducted at MSFC. While the majority of the Saturn technical work was performed at MSFC other NASA Centers provided support to the Saturn Program to create this iconic heavy lift launch vehicle which enabled the historic Apollo lunar landings. This paper will provide an overview of the Saturn-V fight dynamics and control design and analysis process. It will also highlight the multiple flight dynamics and control related technical innovations that emerged from the Saturn-V launch vehicle project. The paper will also summarize and describe the particular launch vehicle flight dynamics and control design principles and practices that have endured since the 1960s citing specific examples of their application in the GNC design process for the on-going SLS Program.