Ares I-X First Flight Loss of Vehicle Probability Analysis

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As part of the Constellation (Cx) Program development effort, several test flights were planned to prove concepts and operational capabilities of the new vehicles being developed. The first test, involving the Eastern Test Range, is the Ares I-X launched in 2009. As part of this test, the risk to the general public was addressed to ensure it is within Air Force requirements. This paper describes the methodology used to develop first flight estimates of overall loss of vehicle (LOV) failure probability, specifically for the Ares I-X. The method described in this report starts with the Air Force's generic failure probability estimate for first flight and adjusts the value based on the complexity of the vehicle as compared to the complexity of a generic vehicle. The results estimate a 1 in 9 probability of failure. The paper also describes traditional PRA methods used in this assessment, which were then combined with the updated first flight risk methodology to generate inputs required by the malfunction turn analysis to support estimate of casualty (E_c) calculations as part of the Final Flight Data Package (FFDP) delivered to the Eastern Range for Final Flight Plan Approval.

I. Introduction

The Air Force methodology for estimating first flight probability of failure is based on statistics for the first launches of new vehicles and accounting for the experience of the vehicle developer. Their methodology is based on a paper produced by the Common Standards Working Group (CSWG) composed of representatives from the Air Force, the Federal Aviation Administration, and National Aeronautics and Space Administration (NASA). While the Air Force's current method for estimating first flight failure probabilities is objective, it does not account for the relative complexity of a specific vehicle. Previously, NASA risk assessment methods involved developing a PRA model for a specific vehicle at a mature state in terms of risk. Since mature vehicle risk and the risk of the first or early flights are significantly different based on historical launch records, the direct output from a PRA is not acceptable for estimating early flight risk. Therefore, a method was needed to combine the Air Force method that accounts for first flight risk with the NASA PRA methods that account for the specific complexity of the particular vehicle in question. This paper provides an overview of the assumptions, methodology, and results used to develop the Ares I-X failure probability estimates, along with a description of how the results were used as inputs to the malfunction turn analysis to support the (E_c) calculations.

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II. Ares 1-X Design and Mission Overview

This section will provide a brief overview of the design of the vehicle, including major systems and components, along with a description of the flight profile for the test flight.

III. Ares 1-X First Flight Failure Probability Methodology

This section will provide an overview of how the current Air Force methodology for generating first flight failure probability estimates for a generic launch vehicle was adapted using launch vehicle failure history since 1980 to adjust the generic Air Force value based on the complexity of the vehicle being considered, in this case Ares 1-X, compared to the complexity of a generic vehicle representing the Air Force value based on a system vulnerability approach.

IV. Ares 1-X PRA Methodology

This section will provide an overview of the assumptions, methodology and results of the PRA. It also describes how the PRA results were categorized based on the type of expected vehicle response (i.e. type of failure trajectory) and the time distribution that describes the likelihood of failure as a function of time in flight.

V. Ares 1-X Risk Assessment Results

This section will provide an overview of the results of the Ares I-X analysis at the overall LOV level, including associated uncertainty. It further describes how the PRA results developed in section III were used to flow down the first flight failure probability developed in Section II to individual failure modes so they could be used with the malfunction turn trajectory information for purposes of the range safety assessment. Also provide a comparison of how the well the model predicted the actual performance and comparison of Ares 1-X with other launch vehicles using this method.

VI. Conclusions

This section will provide a summary of the main points of the paper and thoughts on future improvements to the method and status of working with Air Force or CSWG on establishing a PRA based first flight.

References