SPACE SYSTEMS SYMPOSIUM (D1)
Lessons Learned in Space Systems (5)

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51 YEARS OF SPACE LAUNCHES AND FAILURES

Abstract

Purpose: This is a follow-on paper to the following papers that the authors presented at the International Symposia on Space Technology and Science (ISTS) in Japan and at the International Astronautical Congresses (IAC) in Spain and in Scotland, U.K. • ISTS 2006-a-22 "Survey of U.S. Small Launch Vehicle Failures" • ISTS 2006-a-23 "Survey of Non-U.S. Small Launch Vehicle Failures" • ISTS 2008-g-11 "U.S. Human Space Transportation Failures" • ISTS 2008-g-12 "Non-U.S. Human Space Transportation Failures" • IAC-06-D2.4.10 "Assessment of U.S. Human Space Launch and Flight Programs" • IAC-08-D1.5.3 "Heavy Launch Vehicle Failure History" Since successful launch to deliver satellites or humans to Earth orbit and beyond is the most important step in space exploration, mitigating launch risks and improving launch reliability and cost should be the top priority of any space endeavor. This paper reviews the space launch reliability and discusses the lessons learned from the launch failures during last 51 years and 88 days (1957-10-04 through 2008-12-31). The study is a portion of a continuing effort to investigate the failure causes and corrective actions of the world space launch vehicles. The purpose is to provide lessons learned from the past in order to mitigate launch failures in the future.

Methodology: A comprehensive database has been developed by The Aerospace Corporation that will eventually log the entire space flight launch history. Data has been compiled from multiple sources including information available in the public domain. Space launch failure history data is a part of the comprehensive database highlighting launch failure description and corrective action explanation for all launch vehicles. According to their performance, launch vehicles in the world can be grouped into four distinctive classes, namely super-heavy, heavy, medium, and small launch vehicles (SHLVs, HLVs, MLVs, and SLVs). Chronologically, however, world space launch vehicle development trends can be divided into three periods, namely first generation (1st-G, from 1957 through 1978), second generation (2nd-G, from 1979 through 1997), and third generation (3rd-G, from 1998 through 2008). The paper discusses the analysis results of the demonstrated orbital launch reliability and yearly successes and failures of all space launch vehicles in the world for the four LV classes and for the three LV generations.

Results: Analysis of the demonstrated orbital launch reliability and yearly successes and failures for the four LV classes has been completed. Launch vehicle classes are seemingly, readily identifiable but not easily defined. A unique, unambiguous classification method, which considers the lift capability growth over time, was introduced by the authors. The method is based on a non-linear regression analysis of the historical growth data of published lifting capabilities to LEO for the U.S. vehicles and the results show that, for example, in 1960's the HLV could be defined as having a lift capability of at least 8,000-kg (17,640-lbm) to LEO, whereas today's HLV has a lift capability of more than 17,310-kg (38,162-lbm). The elite SHLV class consists of only U.S. Saturn V and CIS/USSR N-1 and is considered a special class in the study. There were 4,517 successes and 419 failures during the last 51 years and 88 days of world orbital space launches. Out of these launches, 12 successes and 5 failures were in SHLV class, 583 successes and 58 failures in HLV class, 3,116 successes and 222 failures in MLV class, and 806 successes and 134 failures in SLV class. The demonstrated reliability is 91.5

Analysis of the demonstrated orbital launch reliability and yearly successes and failures for the three LV generations has also been completed. The 1st-G exemplifies early vehicle development and many unsuccessful initial orbital launch attempts by different countries during the space race dominated by the US and USSR programs. The 2nd-G characterizes vehicle stretch, propulsion modernization upgrades, composite use, fault-tolerant avionics, partial reusability, commercial space, and improved launch developments in space-faring nations. The 3rd-G concerns the newly-developed vehicles entering the service since 1998 in the U.S. (Atlas IIIA, Atlas IIIB, Delta III, Minotaur I, Falcon 1 and EELVs) and elsewhere in the world and is characterized by high performance propulsion, reduced numbers of stages, and advanced guidance. There were 3,296 successes and 323 failures in the 1st-G LVs, 1,046 successes and 78 failures in the 2nd-G LVs, and 175 successes and 18 failures in the 3rd-G LVs. The demonstrated reliability is 91.1

Conclusions: The final manuscript will include comparison of launch reliabilities from every space-faring nation of the world. The failure root causes and failures by function of the four LV classes will be examined, and the lessons learned from space launches for the vehicles developed in the three LV generations will be discussed. The study is essentially complete, and a presentation package with substantive technical content will be forthcoming in the coming months. The compilation of data from the different space programs and analysis of launch failures and their mitigation strategy make the material in this IAC paper new and original. This paper is the result of research based on information available in public domain and has not been presented or submitted for publication elsewhere. Financing the attendance of at least one author at the 60th IAC in the Republic of Korea to present the paper is assured.