5th Annual Assurance Technology Conference

Presentation: Historic and Current Launcher Success Rates

Technology Topic: Analysis

Presentation Abstract: This presentation reviews historic and current space launcher success rates from all nations with a mature launcher industry. Data from the 1950’s through present day is reviewed for possible trends such as when in the launch timeline a failure occurred, which stages had the highest failure rate, overall launcher reliability, a decade by decade look at launcher reliability, when in a launchers history did failures occur, and the reliability of United States human-rated launchers. This information is useful in determining where launcher reliability can be improved and where additional measures for crew survival (i.e., Crew Escape systems) will have the greatest emphasis.

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Historic and Current Launcher Success Rates

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- Johnson Space Center’s 2nd Generation Reusable Launch Vehicle Program role
- NASA Unique Task
- Program Requirement of <1 loss of crew per 5,000 missions (.9998)
- Crew Transfer Vehicle
- Study purpose

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This study sought to answer following questions:

- What is the overall success rate of launch boosters (all launchers and the top 10% most successful)?
- On what stage did most of the failures occur (all launchers and the top 10% most successful)?
- At what time in the mission timeline did the failures occur (all launchers and top 10% most successful)?
- When, in the launcher history, did most of the failures occur?
- What is launcher success rate for United States human rated launchers?

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[Bar chart showing success rates by decade from 1950's through 2000's with success rates of 61% in the 1950's, 82% in the 1960's, 94% in the 1970's, 96% in the 1980's, 93% in the 1990's, and 100% through 2001.]

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Historic and Current Launcher Success Rates

Failure percentages by stage for all launchers:

- Solid failures: 38%
- First Stage failures: 20%
- 2nd Stage failures: 14%
- 3rd Stage failures: 6%
- Fourth stage failures: 22%
Historic and Current Launcher Success Rates

1st stage failure breakdown

- Main engine failure: 25%
- SW error: 5%
- Flight dynamics: 5%
- Loss of gimbal control: 4%
- Fuel system: 4%
- Flight control failure: 8%
- Electrical failure: 7%
- Ground guidance failure: 1%
- Structural failure: 5%
- Sustainer engine failure: 2%
- Guidance failure: 7%
- Gas gen failure: 1%
- Ululation failure: 1%
- Misc: 6%
- Pogo: 4%
- Flight safety system failure: 1%

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- Early shut down: 9%
- Prop leak: 2%
- Hydraulics: 4%
- Misc: 33%
- Structural failure: 2%
- 2nd stage failure breakdown: 22%
- Altitude control mech failure: 9%
- Excessive velocity: 2%
- Incorrect orientation for payload release: 2%
- Gas thruster malfunction: 2%
- Payload fairing fails to separate: 4%
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3rd stage failure breakdown

- Staging failure: 3%
- Failure to separate payload: 10%
- Early shut down: 24%
- Misc: 21%
- 3rd stage engine: 42%
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4th stage failure breakdown

- Misc 21%
- 4th stage engine 46%
- Early shut down 24%
- Control system failure 9%
Historic and Current Launcher Success Rates

Failure percentages by stage for top ten most reliable launchers

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Failure %'s by time for all launchers

- Greater than 7 min.: 23%
- 1st min.: 22%
- 2nd min.: 14%
- 3rd min.: 13%
- 4th min.: 6%
- 5th min.: 4%
- 6th min.: 3%
- 7th min.: 2%

Failures occurring within:
- 1 minute: □ 1
- 2 minutes: □ 2
- 3 minutes: □ 3
- 4 minutes: □ 4
- 5 minutes: □ 5
- 6 minutes: □ 6
- 7 minutes: □ 7
- >7 minutes: □ 8

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Failure percentages by time for top 10 most reliable launchers

- 24% Greater than 7 min.
- 19% 1st min.
- 17% 2nd min.
- 15% 3rd min.
- 14% 5th min.
- 7% 4th min.
- 3% 6th min.
- 1% 7th min.

Failures occurring within:
- 1st minute
- 2nd minute
- 3rd minute
- 4th minute
- 5th minute
- 6th minute
- 7th minute
- > 7 minutes

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When failures occurred

<table>
<thead>
<tr>
<th>Total % of launches</th>
<th>Percentage of failures occurring</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>67.40%</td>
</tr>
<tr>
<td>2</td>
<td>39.85%</td>
</tr>
<tr>
<td>3</td>
<td>25.00%</td>
</tr>
<tr>
<td>4</td>
<td>12.00%</td>
</tr>
</tbody>
</table>

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U.S. Human Rated Launchers

Success Rate

1 Vehicle Type

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Conclusions:

• The average historic launcher success rate is less than 99%, however success rates as high as 100% have been achieved.
• The majority of failures for both all launchers in this study and the top ten most successful launchers occurred on the first stage. Most of these failures occurred on the main engines.
• Over 50% of all launcher failures occurred within the first three minutes of the launch, and 70% within the first five minutes of the launch.

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References:

- Encyclopedia Astronautica, Astronautix.com, Mark Wade
- History of the Delta Launch Vehicle, Kevin Forsyth
- NASA Glenn Launch Vehicle History, NASA Glenn website
- DOD Assessment of Space Launch Failures, Summary of Recommendations, Appendix C, Failures and Anomalies, Nov. 4 1999