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
Historic and Current Launcher Success Rates

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?
Historic and Current Launcher Success Rates

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Historic and Current Launcher Success Rates

Launcher Success % based on decade data

<table>
<thead>
<tr>
<th>Decade when launches occurred</th>
<th>Success %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950's</td>
<td>61%</td>
</tr>
<tr>
<td>1960's</td>
<td>82%</td>
</tr>
<tr>
<td>1970's</td>
<td>94%</td>
</tr>
<tr>
<td>1980's</td>
<td>96%</td>
</tr>
<tr>
<td>1990's</td>
<td>93%</td>
</tr>
<tr>
<td>2000 Through 4-01</td>
<td>100%</td>
</tr>
</tbody>
</table>

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Historic and Current Launcher Success Rates

Failure percentages by stage for all launchers

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

1st stage failure breakdown

- Main engine failure: 25%
- SW error: 1%
- Flight dynamics: 5%
- Loss of gimbal control: 4%
- Fuel system: 4%
- Flight control failure: 8%
- Electrical failure: 7%
- Ground guidance failure: 1%
- Hydraulics: 7%
- Sustainer engine failure: 2%
- Structural failure: 5%
- Guidance failure: 7%
- Gas gen failure: 1%
- Solid failure: 12%
- Misc: 6%
- Pogo: 4%
- Flight safety system failure: 1%

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- 2nd stage failure breakdown
  - Incorrect orientation for payload release 2%
  - Gas thruster malfunction 2%
  - Payload fairing fails to separate 4%

- Excessive velocity 2%
- Altitude control mechanism failure 9%
- 2nd stage engine failure 22%
- Staging failure 9%
- Prop leak 4%
- Early shut down 9%
- Misc 33%
- Structural failure 2%

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3rd stage failure breakdown

- Staging failure: 3%
- Failure to separate payload: 10%
- Early shut down: 24%
- 3rd stage engine: 42%
- Misc: 21%
Historic and Current Launcher Success Rates

4th stage failure breakdown

- Misc: 21%
- Early shut down: 24%
- 4th stage engine: 46%
- Control system failure: 9%

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Failure percentages by stage for top ten most reliable launchers

- 39% Solid boosters
- 21% 1st stage
- 12% 2nd stage
- 21% 3rd stage
- 7% 4th stage

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Failure %'s by time for all launchers

22% 1st min.
23% Greater than 7 min.
15% 2nd min.
14% 3rd min.
6% 4th min.
13% 5th min.
6% 6th min.
4% 7th min.

Failures occurring within:
1 minute
2 minutes
3 minutes
4 minutes
5 minutes
6 minutes
7 minutes
>7 minutes
Historic and Current Launcher Success Rates

Failure percentages by time for top 10 most reliable launchers

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

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

Percentage of failures occurring

67.40%

39.85%

25.00%

12.00%

50% of launches

30% of launches

20% of launches

10% of launches

Total % of launches

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U.S. Human Rated Launchers

- Redstone-Mercury: 83%
- Atlas D: 64.94%
- Titan-Gemini: 87.50%
- Saturn
- Shuttle

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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.
Historic and Current Launcher Success Rates

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