Improving Mission Success of CubeSats Product Overview

May 4, 2017

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Acknowledgments

This document has been produced as a collaborative effort of the Mission Assurance Improvement Workshop. The forum was organized to enhance mission assurance processes and supporting disciplines through collaboration between industry and government across the U.S. Space Program community utilizing an issue-based approach. The process is to engage the appropriate subject matter experts to share best practices across the community in order to produce valuable mission assurance guidance documentation.

The document was created by multiple authors throughout the government and the aerospace industry. For their content contributions, the following contributing authors are acknowledged for making this collaborative effort possible:

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Jeff Christensen  The Boeing Company
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Andrew Whiting  The Boeing Company
Tom Wiedenbauer  Harris Corporation
Gary Kushner  Lockheed Martin Corporation
Rick Gebbie  MIT Lincoln Laboratory
Renelito Delos Santos  SSL

A special thank you for co-leading this team and efforts to ensure completeness and quality of this document are extended to:

Catherine Venturini  The Aerospace Corporation
Mike Tolmasoff  The Boeing Company
Renelito Delos Santos  SSL
The topic team would also like to acknowledge the contributions and feedback from the subject matter experts who reviewed the product prior to publication:

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Improving Mission Success of CubeSats

Product Overview

Renelito Delos Santos, SSL
Mike Tolmasoff, The Boeing Company
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May 4, 2017
Agenda

• Motivation
• Historical causes of CubeSat failures
• Charter
• Interview process
• Themes
• Recommendations
• Target audience and intended users
• Team membership and recognition
Motivation for Improving Mission Success of CubeSats

- There has been a substantial increase in CubeSats launched since 2013
- University-led CubeSat projects lack the repeatable process rigor routinely found in industry
- Commercial off-the-shelf (COTS) solutions fall short of a space-qualified pedigree
- A recent National Academies report recommends that NASA and the National Science Foundation (NSF) make greater use of CubeSats for science missions
- As the importance of CubeSat payloads and missions increases, what aspects of mission assurance can significantly improve mission success rates?

Data Source: M. Swartwout CubeSat Database at Saint Louis University
Historical Causes of CubeSat Failures

- Over half of the CubeSat mission failures can be attributed to functional integration issues.
- Other causes of mission failures include:
  - *Lack of system-level testing due to schedule and budget constraints*
  - *Inadequate thermal design*
  - *Use of COTS electronics*

![Graph showing the time period 2000-2012 and the percentage of mission failures attributed to various causes](image)

Adapted from Swartwout, M. (2013): Journal of Small Satellites (JoSS), vol. 2, no. 2, p. 221 (Figure 9).
Improving Mission Success of CubeSats Charter

• Review design and manufacturing processes across industry, academia, and government CubeSat providers to identify best practices

• Interview CubeSat providers from industry, academia, and government to understand approaches taken to increase probability of mission success

• Identify important areas that CubeSat providers have focused on to improve probability of mission success
Interview Process

• Sub-divided topic team into four interview teams which were responsible for:
  – *Initiating contact with organizations*
  – *Scheduling and conducting interviews*
  – *Taking interview notes and generating interview summaries*

• Conducted 23 interviews
  – 10 from academia
  – 5 from industry
  – 8 from government/FFRDC/UARC

• Generated final interview summary for each interview
  – *Peer-reviewed and approved by topic team*
  – *Peer-reviewed and approved by organization that was interviewed*
Themes

• The recurring themes identified across the 23 interviews were grouped into 8 categories:
  – Setting the purpose and vision of the mission
  – Establishing the program structure
  – The risk process
  – Design and analysis
  – “Test, test, test”—the importance of testing
  – Common CubeSat failures
  – Parts quality, availability, and documentation
  – Launch is a significant driver
• These themes were used to develop the recommendations
Recommendations

1. Define your scope, goals, and success criteria at program start

Justify your ability to complete it within the available time using the available budget and resources. During the project lifecycle, aggressively defend it against growth, but have a plan to de-scope, if necessary.
Recommendations

2. Plan for ample integration, verification, and test (IV&T) time

Stick to the baseline IV&T of 1/3 to 1/2 of the overall schedule.
Recommendations

3. Conduct risk-based mission assurance

Perform a risk assessment at the beginning of the program to prioritize analyses, tests, reviews, and activities.
Recommendations

4. Design for simplicity and robustness

Assume designs will fail and then prove they will work. Design the satellite for easy assembly and disassembly. Have respectable margins, robust safe modes, few deployables, graceful performance degradation, and frequent preventative satellite resets.
5. Build an experienced team—it matters

A successful team has veteran member(s) and frequent informal peer reviews (discussions) with proven subject matter experts.
Recommendations

6. Stock spare components

Extra boards support parallel software development and are flight spares. Extra hardware protects schedule during mechanical testing.
Recommendations

Mission assurance tests:
1. Day-in-the-life (or longer) testing
2. Communication link test with the ground station
3. Power system charge/discharge testing
4. Thermal testing (in vacuum if at all possible)
7. At a minimum, perform the four mission assurance tests
Recommendations

8. Maintain a healthy skepticism on vendor subsystem datasheets

Hold margin on all performance numbers during design and verify after receipt.
Recommendations

1. Define your scope, goals, and success criteria at program start
2. Plan for ample IV&T time
3. Conduct risk-based mission assurance
4. Design for simplicity and robustness
5. Build an experienced team—it matters
6. Stock spare components
7. At a minimum, perform the four mission assurance tests
8. Maintain a healthy skepticism on vendor subsystem datasheets
Target Audience and Intended Product Users

• The target audience for this product consists of:
  – CubeSat designers and developers (academia, industry)
  – CubeSat product suppliers (hardware, software)
  – CubeSat customers (government, others)

• This product is intended to address needs of producers and consumers
  – CubeSat designers/developers and subsystem suppliers will use this product to improve their design, manufacturing, and IV&T processes
  – Government and other customers will use this product to improve their requirements and statement of work documentation
# Team Members – Topic Team

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<tr>
<th>Company</th>
<th>Participant</th>
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<tr>
<td>The Aerospace Corporation</td>
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# Team Members – Additional SMEs

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