Implementation of FMECA in Small Satellite Development

Authors: Ada K.O. Moen, Eivind Sjøvold, Ola Jordheim

Summary:

A bachelor group consisting of three students from mechanical engineering at NTNU was brought into a satellite development project, the HYPSO project, to highlight and mitigate risk. This was done through Failure mode, effects and criticality analysis(FMECA). The situational analysis revealed missing documentation and control over potential failures. The FMECAs had to be adapted a rapid working environment, consisting of several fields of study. This led the FMECAs to be adapted to both hardware and functional aspects, due to much of the satellite being based on software functions. From two FMECAs the group found more than 220 failure modes, of which more than 20 were defined as critical. The FMECAs will help redefine the mission requirements.

Introduction:

The HYPSO-project is based on the development of a CubeSat, a small satellite. The satellite will contain, among other subsystems, a hyperspectral imager. The imager captures the spectral dimension. This means that it separates more frequencies of light in contrary to a regular camera. The satellite will monitor the Norwegian ocean territories. One of the purposes is to map algae growth, to help the fish farming industry prevent unexpected death of fish stocks, as some algae types can be harmful for the fish.

Due to lack of existing risk management in the HYPSO satellite development, three students from NTNU implemented an FMECA process in the project. The purpose of the engagement was to implement risk management in the HYPSO project, as a tool to highlight and mitigate potential risks. The group will also recommend how to utilize the FMECA tool for coming HYPSO-team members.

Objectives: To implement and utilize FMECA in the organization the group had to tailor a standardized approach for small satellites. Part of this process was to conduct an FMECA on the current satellite, preferable on those units where it still made sense.

Methods and theory: In order to reach these goals the group did a situational analysis, focusing on the structure of the organization, and the current situation of the risk management in the project. A technical description was included in the situational analysis. This was to build a base for the scope of the FMECA. Literature search and interviews with experienced people both in Norway and USA was done. The cloud storage of the satellite project was also available, providing existing documentation on the satellite.

Results: Two FMECAs were conducted. The first FMECA was a system-wide function analysis with a hardware structure, based on preset mission success criteria. The FMECA provided documentation of risk management, considering more than 120 failure modes. These failure modes was mostly software based, giving incentive to secure quality in the software development.

The second FMECA was a hardware analysis that target the mechanical parts and optics of the satellites self made subsystems. The analysis specifically pointed out the front objective of the imager as a critical component. Failure causes on the objective included darkening due to radiation, outgassing and shock from launch.

FMECA nr.	Failure modes found	Critical failure modes
1	142	25
2	92	7

Based on the experience from these two analyses, a customized approach for implementation of FMECA was suggested to the HYPSO team.

Discussion:

FMECA is a flexible but systematic method and exist in numerous different ways. The tailored approach and conduction was based on the literature search and situational analysis the group conducted. A weakness with this approach was that the group lacked former experience with FMECA and an understanding of advanced space technology. On the other hand, the group spent a lot of time gaining necessary knowledge about the field of study. In some situations, less specific competence makes it easier to take a step back and see the bigger picture. This way the lack of experience could be used as a strength.

The FMECAs were conducted in cooperation with students from different fields. A lot of the work was not peer reviewed, as time was limited. The numbers assigned to highlight risk, the risk priority numbers, were however peer-reviewed.

During the workshops and review, some of the failure modes were discussed and analysed in plenary. This secured quality and consistency in the analyzes. People with different fields of expertise got to analyze the failure modes, making the analysis yield accurate results. Most of the failure modes found were already known and the risk below the acceptance limit. Still, more than 20 failure modes were considered critical, emphasizing the benefits of the systematic approaches chosen in this assignment.

The group prioritized time to build a plan describing each step in the approach they developed. Test runs were also done before the workshops. This led to the workshops being more efficient and the results were good.

Conclusion:

Preparation is an integral part of implementing FMECA. What exact standard is being followed is less important than the approach itself being structured.

Most of the risks were already known, but the FMECAs helped quantify the risk, rank the failure modes and provided feedback on how to mitigate these consequences.

The FMECAs also provided a valuable overview of the risks across the subsystems and will be used as a tool for reviewing the mission requirements.

References:

Ada Moen, Eivind Sjovold and Ola Jordheim. Implementation of FMECA in small satellite development. Technical report, 2019.