COLLECTION AND ANALYSIS OF FIELD DATA FOR DESIGN AND QUALITY IMPROVEMENTS

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Abstract

Field data often has the most relevant and useful information for improving the reliability of a product. The ability to collect and synthesize field information relies on having a good Failure Reporting Analysis and Corrective Action System (FRACAS) in place to capture the field data. However, setting up a FRACAS is not a simple task. Not capturing enough data will lead to confusion later on as to what the exact failure conditions were and the nature of the design or process deficiencies that caused them. Conversely, collecting information that is not needed will take more time, and not add to the value of the final reliability analysis. A balanced approach to FRACAS, which captures every failure accurately and quickly, is needed. This includes capturing information on field usage, time to failure, failure cause, and a variety of other information that is used to understand each failure and hopefully learn from them to improve the design. Each of these bits of information comes with their own challenge, with some being extremely difficult, if not sometimes impossible, to collect. This paper presents the methodology, challenges and successes that an organization encountered while developing its field reliability data program in the offshore industry.

1. Introduction

A Failure Reporting, Analysis and Corrective Action System (FRACAS) is one of the key components in an organization's reliability engineering program. In additions to assuring the customer of the reliability of the products, field data often provides vital information to improve the quality and reliability of products. This paper presents the methodology for setting up a FRACAS system, and challenges and successes in implementation. A case study from the reliability critical offshore industry is presented. The case study examines the key elements of the FRACAS, and some of the specific details in the challenges faced. The key elements discussed are goals of the FRACAS, failure classifications, field usage and time to failure, review of historical data, data analysis, reporting reliability results and reliability analysis applications.

2. Goals of the FRACAS

The first step in developing a FRACAS system is to clearly establish the goals and expectations from the project. All the stakeholders of the FRACAS system must be consulted at this stage. This may include the relevant departments in the organization and the customer. In our case study, several requests from customer for reliability data were compiled to create the core customer expectations from the FRACAS; this was used as a base line for discussions within the organization. The following set of primary and secondary expectations were established.

1) The FRACAS system must enable the estimation of field reliability metrics such as Mean Time Between Failure (MTBF) and Failures in Time (FIT). This must be achieved with minimal manual computations.
    a. Offshore Failures and Onshore Failures must be differentiated.
    b. Several types of Equipment in the different product families must have their own distinct reliability metric.
    c. Failure Causes chargeable to the organization must be identified.
    d. Time to Failure and Time to Repair must be established.
2) Critical Design Information on the failures must be made available to support design improvements and new product development.
    a. Information on the cause of the failures must identify type of design and process deficiency.
    b. Information on failures related to customer misuse must be compiled to gain an understanding of the customer use patterns

   c. and opportunities for improvements in creating a more robust design.
   d. Information on the field conditions must be collected to gain an understanding of harsh environments and stresses leading to failure.
3) In addition to the failure information, information on customer returns without failure must be captured.

Once the expectations were established, it helped the team establish the data requirements and output requirements of the project.

3. Failure Classifications

The clear set up expectations defined at the beginning of FRACAS development served as crucial input in developing standard failure classifications. This would allow each failure to be classified in the same way, so that sorting and analysis of the data would be made possible. The classification that was developed was a combination of the internal requirements, customer requirements, and industry standard classifications. Some fields were changed and added to capture information that was found to be relevant over time, this can however be minimized with proper planning. All the classifications were to be entered in by the respective engineers as they are performing a failure analysis of a product, and as such these engineers were consulted at every stage of the FRACAS development. The primary classifications of the failure classifies the phase during which the failure occurred and the criticality of the failure. For instance, this field may be “Post-Deployment – Non Critical”, indicating that failure happened after the unit was deployed, but was not a critical failure. Other examples of this field include “Pre-Deployment – Critical”, etc. As the post deployment (offshore) failures are more severe, additional classifications were established. This sub classification determined if the failures happened during deployment and if the product was active (powered on) or passive (powered off) when the failure occurred. Although this set of classification is specific to the offshore industry, similar requirements may exist for other industries. In addition to capturing information on failures, the FRACAS also collected information on customer requested changes, upgrades, refurbishments and recalls. Although these are not failures, they provide valuable product information for the design life. For example, the times for refurbishments provide insight on the degradation patterns and customer concerns. Table 1 shows the different failure classifications used by the organization.

This primary classification was one of the most difficult fields in the classification. The knowledge of field deployment was not always clear, and this topic will be discussed further in the next section. Criticality of a failure is also extremely hard to classify, as each engineers opinion of what constitutes a critical failure can, and more often than not, does vary. For instance, the same level of product failure may result in different levels of impact on the customer equipment based on the customer system configuration. Also the term “critical” may mean different things to different personnel. Engineers look at criticality from the technical point of view, based on the products ability to meet customer requirements. However Managers and Customer Service personnel seem to consider the criticality in terms of inconvenience caused to the customer in terms of project delays or costs. This led to some standard guidelines being established, and training being done to ensure that all personnel involved in classifying failure information are using the same criteria. The rule that was developed eventually stated that the criticality of the failure shall be determined by the ability of the product to meet the stated requirements and not based on the effects to customer system configuration or its effect on costs and schedule. This information is however captured as a part of the notes field. This ensures that good information is available for design improvements. The inconsistency in the availability of customer system impact information was also a factor in this standardization.

FAILURE CLASSIFICATIONS	CODE
POST DEPLOYMENT - CRITICAL	PODC
POST DEPLOYMENT - NON CRITICAL	PODN
PRE DEPLOYMENT - CRITICAL	PRDC
PRE DEPLOYMENT - NON CRITICAL	PRDN
PRE DEPLOYMENT - OTHER	PRDO
RECALL	RECL
UPGRADE / REFURBISHMENT	UPRF
CUSTOMER REQUESTED CHANGE	CRQC

Table 1 - Failure Classifications

The next important field captured information on the function/organization responsible for the failure. This could be the customer, manufacturing process, design, administrative error, vendor error, or operating conditions. “No failure” was used to classify a unit that was returned due to a customer requested change in a products configuration that was not related to a failure. The most common conflict occurs when determining whether the root cause of the failure was due to an error made by the customer or the manufacturer, especially during scenarios where problems exists both with the product and customer use, and determination of the predominant failure cause resulting in the failure is a concern. The classification of “Unknown” was used for failures that were found to be too ambiguous to be classified into a certain category. However, this was avoided as much as possible, as it made the data difficult to use in later analysis. In response to standard industry practices on how to classify this data, these classifications were eventually modified slightly. This modification both expanded and combined some of the cause classifications. These new classifications allowed more detailed information to be captured with additional analysis options. It is recommended that any organization setting up a FRCAS review any industry standards that may be available. This should help in consistent and quality data exchange between organizations in a given industry.

Another important piece of the puzzle is the equipment classification. It must be emphasized that this can vary significantly based on the industry and organizations. The solution for a company with fewer products and higher volume may be different from a company with many products and lower volume. In addition to categorizing the type of product, the equipment classification may need to address other elements. One common classification in the offshore industry is whether a product was electrical, optical, or hybrid, a combination of the two. Classifications specific to connectors such as the gender was also collected. There are some unique challenges in addressing the equipment classification. For instance, four different products, three of which were made by the company, all with different classifications, may be a part of a system that failed. It was therefore necessary to classify exactly which product failed, so that the failure would be charged only to that one product. Although more than one product in a system may be inoperable, it is important to identity the product that "caused" the failure and other products that may be simply affected by the cause and hence were only "victims". However, in some cases this was difficult, especially due to product interfaces which were not clearly defined. This led to the development of boundary diagrams to be set up showing exact interface and boundaries between products in a system. In addition, any difficulties in finding the exact failure location will also affect the ability to accurately map to an equipment classification.

Another useful piece of information (especially for design/quality improvements) is the maintainable unit that failed. This was, in essence, the lowest level part that the failure could be attributed to. This level of detail is often ignored by organizations, however the benefits are plenty. This provides, among other things, the ability to estimate the failure rate of the components which could be used in future products. The failure estimates are useful in reliability predictions of similar designs. Other information of interest to the engineer is the failure mode. It is important again to capture the necessary level of detail. For instance, electrical failures could be broken down further, into classifications such as "open circuit" and "short circuit". This data can prove useful in determining if similar failures are being seen repeatedly, and was set up in a way compatible with industry standards. It is also important to have a free text field, where the engineer can enter a short failure description. This can be extremely useful for later research into a failure, as it often provides useful information on the failure. Table 2 on the next page provides the partial list of failure modes used in the case study; the list can be modified appropriately for the organization.

These classifications together provide extremely useful information that can be used in corrective actions and redesigns of products. It must however be emphasized that the classifications must be modified for the given organization or industry, what works in one organizations may not work in another.

MECHANICAL FAILURE - GENERAL	**MECH00**
LEAKAGE	MECH01
CLEARANCE/ALIGNMENT FAILURE	MECH02
DEFORMATION	MECH03
LOOSENESS	MECH04
STICKING	MECH05
MATERIAL FAILURE - GENERAL	**MAT00**
CORROSION	MAT01
WEAR	MAT02
BREAKAGE AND FATIGUE	MAT03
OVERHEATING	MAT04
OPTICS FAILURE - GENERAL	**OPT00**
OPEN CIRCUIT	OPT01
INSERTION LOSS	OPT02
RETURN LOSS	OPT03
ELECTRICAL FAILURE - GENERAL	**ELEC00**
SHORT CIRCUITING	ELEC01
OPEN CIRCUIT	ELEC02
EARTH/ISOLATION FAULT	ELEC03

Table 2 - List of Failure Modes

4. Field Usage and Time to Failure

Field usage and time to failure are two of the most difficult and most critical pieces of information to obtain. Field usage refers to whether or not the product was actually used in its intended function by the customer, when the failure had occurred. In the offshore industry, this would pertain to whether or not the failure occurred during subsea use or during the testing prior to failure subsea. In reliability critical applications, failure of any part of a system can cause delays that can easily cost the customer millions of dollars. Therefore, every product is tested by the customer before it is deployed in the field. This testing can take months under the best of conditions, and often products will fail, whether due to customer or manufacturer caused reasons, during testing. It is sometimes hard to determine whether or not the product was actually deployed. This can be important, as it is vital to understand whether the product failed during operation or not. This is closely related to time to failure. "Time to Failure" is the most basic and critical measure of reliability and forms the bedrock of all the other metrics. It also helps us to understand the failure mechanisms, the applied stress conditions, and their relationship which leads to failure. This information is not always effectively transferred to the manufacturer, especially in a supply chain that involves several organizations. This requires assumptions to be made in order to find the time to failure of each product. Based on the industry norms, assumptions on date of deployment and date of failure can be made based on the date the product was shipped and the date the product was returned, respectively. These assumptions are to be made only when the other methods of obtaining the precise time to failure are exhausted, and every attempt must be made in order to accurately capture this information from the customer.

As mentioned earlier, the time to failure information is used in the estimation of reliability metrics. This includes common metrics like Mean Time between Failures and Failures in Time. Such metrics are often used by the customer in selecting between competing suppliers and designs. There is, however, an increased scrutiny by the customers on how these metrics are computed and the data that forms the basis of the metrics. It is important to note that a MTBF or FIT metric may be obtained by simply using the number of failures and cumulative service time. This however makes the assumption that the failure rates are constant. This is not a good assumption for most modern products which often see early infant mortality failures and late wear out failures. With the help of actual time to failure and tools such as Weibull analysis, more accurate metrics can be estimated.

5. Review of Historic Data

One of the decisions to be made when establishing a comprehensive FRACAS is to decide how to handle past data. It may be useful to review the historic data based on the classifications established and reclassify the historic data. Some organizations can afford to start "fresh" from a given point. In other cases there may be factors such as regulatory requirements that require past failure data to be maintained. In our case study this exercise was taken up to take advantage of the extensive product deployment history. In order to take credit for the units deployed (cumulative service hours), a review of the failures was also necessary. There are, however, some challenges in achieving this. In the years leading up to this classification system, failure reports became more and more detailed, allowing easier reclassification for recent failures. However, the further back the failure was, the harder it was to get a clear understanding of what had happened. This problem was made worse by the fact that often the original engineer who performed the failure analysis was no longer working at the company. Some of the historical failures had failure descriptions vaguely written, or sometimes entirely missing. Although a missing analysis could not be replaced, the vaguely written ones were sometimes possible to use. Those responsible for reclassifying old failures started with the newest failures, and worked in reverse chronological order. This allowed for learning typical failures on returns with the best failure analysis, and then for the use of this knowledge to be extrapolated to the older failures. Although this was not a foolproof method of classifying all the old failures, it did work in many instances. In the end a comprehensive and complete failure database was developed.

6. Data Analysis

Once the data is collected and entered into a database, reliability data analysis is a relatively standard process. With all the right classifications in place any information required to improve the design or process can be easily obtained. The quantitative data analysis primarily includes estimation of metrics such as MTBF and FIT. It is important to emphasize the importance of Weibull analysis at this point. Weibull analysis helps us to compute the "true" metrics accounting for the non-constant failure rate of a product. It can also be used identify the shape parameter, which provides insights on the failure mechanisms [1]. For instance a shape parameter less than one may indicate a predominant infant mortality situation. The corrective actions may need to be focused on manufacturing processes to address such failure mechanisms. A larger shape parameter indicates a "wear out" mechanism and may require a design fix. Other conditional probability calculations may also be useful. For example a customer with a deployed unit with several years of accumulated life may want to know the probability of survival for the next year. Such information can help the customer with decisions on preventive maintenance and refurbishments. This data analysis was relatively simple compared to the collection of the data, and took a small fraction of the time. However, this is an incredibly important step, as a miscalculation can skew the final results far more than a mis-classification of a failure. Commercial software packages such as Minitab®, Reliasoft®, etc can be used to aid this process.

7. Reporting Analysis Results

Once the data has been collected and analyzed, it is necessary to present it both internally within the organization and externally to the customers. This had to be done with great care, especially while dealing with a customer. It is necessary to show the customer as much information as possible that is relevant to the reliability of the product being sold to them, while not giving out too much information, especially of that involving other customer's confidential data. Therefore, standard formats were developed for external reports, external presentations, and internal presentations. The internal presentation contains the most information of the three, and can include breakdowns such as failures by customer and percent returned by customer. This is very useful internally, but obviously cannot be reported to a customer. This may also point to the use/misuse patterns of the customers with low or high failure rates and aid with training and in developing more robust designs. The external presentations and reports primarily served as reliability assurance tools. They provided information on the demonstrated field reliability of the product. In addition to providing the metrics on reliability and maintainability the report also provided results on test data, Failure Modes Effects and Criticality Analysis (FMECA), and also provides information on key corrective actions taken to address the known failures and to improve the product. In order to ensure the integrity of the reliability metrics, the customers typically require an overview of the reliability data from which the metrics are computed. With the increased scrutiny in the reliability sensitive industries such as the offshore industry, the information required also includes an overview of the established process of data collection and validation of the data collection method. In addition to these standard reports, many customers may require information in a specific custom format, and with a well designed FRACAS any such requests may be addressed in a timely manner.

8. Reliability Analysis Applications

One of the applications of good field data is its use in several of the reliability analysis tools. Some of the key tools are presented here.

For instance, the field data can be very useful in performing a FMECA. These real world failures allowed the FMECA to be continually updated both with new failure modes, and better estimates on how often a current failure mode occurred and how critical it was. With good field data, the FMECA process is more effective and efficient.

Reliability Block Diagram Analysis is used to identify any design weaknesses and also in the quantitative prediction of the expected reliability. Field performance of the key components in prior designs can be extremely useful in estimating failure rates of the components in a new design. The known failure mechanisms are also useful in addressing design deficiencies in a new design. Without a good FRACAS, component failure rates necessary to perform a block diagram analysis will not be available. It must be noted that an organizations product failure rate may be a customer's component failure rate.

Another new application of field data is in accelerated life testing, with the "time to market" being a key factor in today's market. The data from the field can be used to augment the accelerated life test data to obtain better estimate in a shorter time period using fewer test units. This is accomplished using Bayesian Analysis [2].

9. Conclusion

This project was an extremely intriguing exercise in the setting up and implementing of a FRACAS, with the associated struggles and pitfalls along the way. While this can often be a long and tedious process, the rewards of having such a system set up provides the ability to both prove the field reliability of an organizations products, and to improve the quality and reliability of the design and associated manufacturing processes. The case study shown in this paper shows some of the practical challenges and solutions in setting up a FRACAS system.

10. References

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[2] Accelerated Testing, Wayne Nelson, 1990