CUSTOMER-FACING RELIABILITY GROWTH MODELING TO IMPROVE CUSTOMER SATISFACTION (PART 2 OF 2)

Bill Lycette, Agilent Technologies

In Part 1 of this article (published in the 4th Quarter 2008 RIAC Journal), limitations of design ruggedization and Design for Reliability were discussed. Reliability growth analysis (RGA) was introduced as a solution for the early prediction of fielded reliability. Elements of Agilent's customer-facing reliability growth modeling process were described, including collecting on-time data, defining what failures should count, and rigorously calculating BD mode effectiveness factors.

Part 2 of the article is presented here where the reliability growth (RG) process is applied to three new product introductions. Results of the reliability growth models are discussed and methods for transforming Projected MTBF's into accurate customer-experienced reliability metrics are presented.

Application and Results: Initial Experience with RG Modeling

As RGA methods were an unfamiliar concept for some managers, finding a New Product Introduction (NPI) project manager to commit precious time and resources to the new tool proved challenging. Eventually two project managers took a leap of faith and agreed to test the concept on an "experimental" basis. A microwave spectrum analyzer prototype build (NPI A) and a microwave network analyzer prototype build (NPI B) were studied. Failure details and on-time hours were collected over a period of several months and RG calculations were made on these two NPI's.

Two graphs were used to communicate RG progress and status to the NPI team as shown in Figures 1 and 2. In Figure 1 monthly snapshots were taken to show cumulative number of failures and cumulative on-time hours. The graph is useful in showing trends in failure occurrences. If reliability growth is occurring, one would expect the slope of the cumulative failures curve to decrease with calendar time.

In the second status update graph, snapshots of Demonstrated MTBF and Projected MTBF were plotted as shown in Figure 2. In this graph we see steady growth in Demonstrated MTBF, and more importantly, growth in the Projected MTBF using the Crow Extended model.

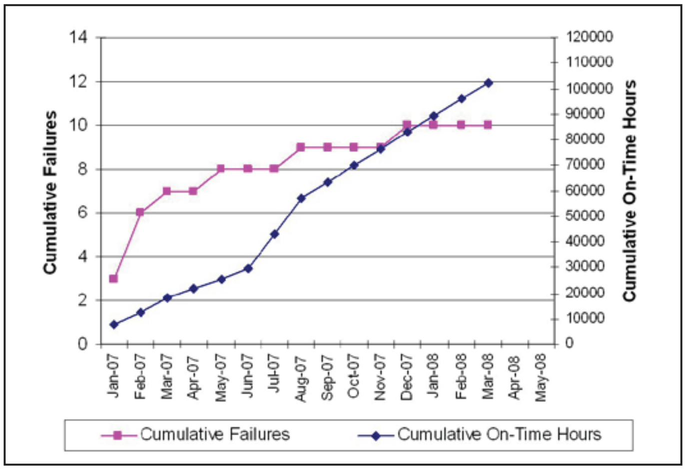

Figure 1. Tool for communicating reliability growth process status.

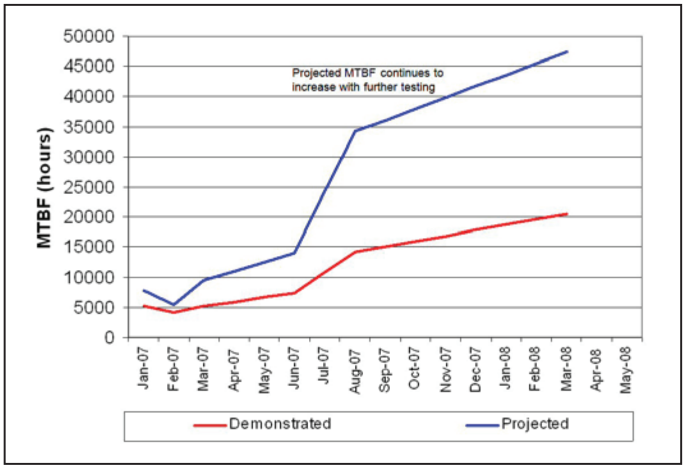

Figure 2. Tool for communicating reliability growth progress.

Later, the two new products were released into the marketplace and warranty annualized failure rate (AFR) data was collected. It generally takes six to nine months of warranty data for the AFR to reflect stable, accurate reliability metrics. Once this data became available, a plot of Projected MTBF from the RG model versus actual customer-experienced MTBF (calculated using Weibull methods) was created as shown in Figure 3. The heights of the ellipses reflect confidence limits of the customer-experienced reliability and normal fluctuations typically seen with reliability over time. The widths of the ellipses are meant

to reflect uncertainty in the Projected MTBF from the RG model. The intent of this initial foray into RGA was not to immediately achieve accurate reliability predictions, but rather to develop a baseline of data and process understanding that could be applied to future projects for accurate predictions.

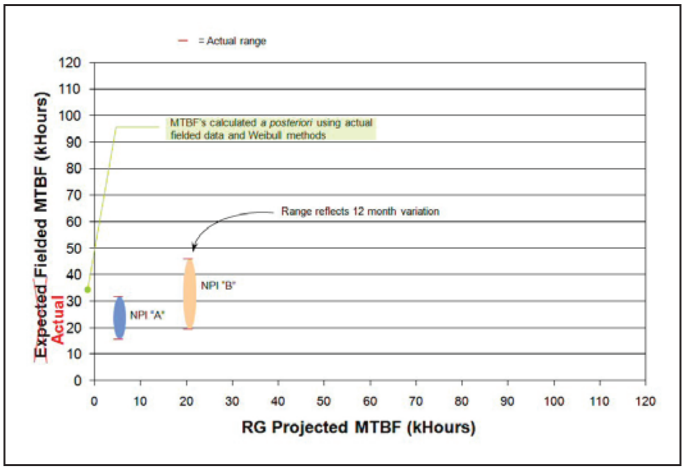

Figure 3. Baseline data for estimation of fielded MTBF on future NPI's.

From these two RG modeling experiments we:

- Developed technical and logistical experience for collecting failure and on-time data;
- Gained experience in calculating RG metrics using a commercially-available RGA software package;
- Built a baseline of RG data and experience;
- Established credibility within the project management community that RGA had merit and might be useful for predicting customer-experienced reliability early in the product life cycle;
- Witnessed firsthand that Projected MTBF tended to increase with additional test time (reliability growth!); and
- Discovered that the Projected MTBF from the RG model was *lower* than the eventual customer-experienced fielded MTBF.

This last point came as a surprise to the team and was problematic in terms of being able to simply use the final modeled Projected MTBF as the expected fielded MTBF. Still, the experience gained from the two NPI projects provided sufficient evidence of merit and a third NPI project was enlisted to continue the RGA journey.

Using Modeled Baseline RG Data to Predict Fielded Reliability

A complex RF Comms Tester product (NPI C) participated in the third RG model. The plan was to construct separate RG models of three prototype builds from NPI C, and to use the baseline data garnered from NPI's A and B to predict the fielded reliability of NPI C.

RG data was collected from the first two prototype builds (designated NPI's C1 and C2) and upon completion of prototype testing, Projected MTBF figures were calculated. It was hypothesized that a useful relationship existed between the Projected MTBF and eventual fielded MTBF, and that this hypothesized relationship could be graphically represented using results from the experiments with NPI A and NPI B. This hypothesis is depicted in Figure 4.

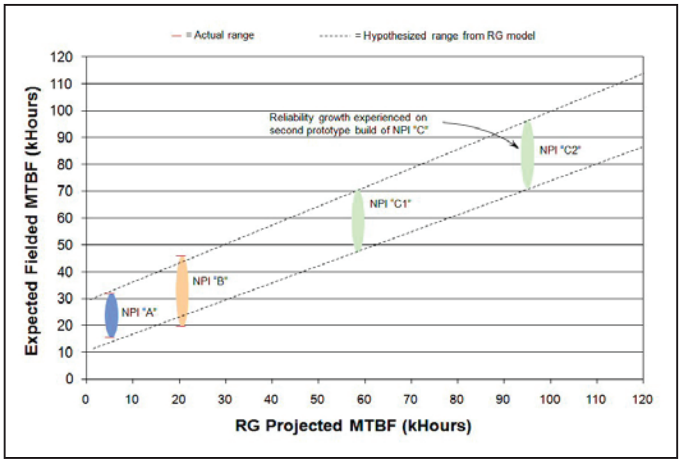

Figure 4. Hypothesized relationship between modeled Projected MTBF and eventual customer-experienced MTBF.

The Projected MTBF's calculated from modeling NPI C1 and NPI C2 were added to the hypothesized graph to provide an estimate of expected reliability of the two NPI C prototype builds. The project team was very encouraged to see that considerable progress was made in increasing the reliability

continued on next page ›››

continued from page 15

during the second prototype build. While the hypothesized fielded reliability of NPI C2 still fell short of the project's final reliability goal, the team felt confident the goal would be accomplished with the planned third prototype run given past reliability growth improvement rates.

The third prototype build (NPI C3) was constructed and upon completion of RG testing, the Projected MTBF was calculated and plotted as shown in Figure 5. To the disappointment of the project team, the hypothesized fielded MTBF not only did not hit the project's goal, it actually degraded from the earlier two prototype builds. This calculated result was not totally surprising to the team because a number of new technical problems emerged in NPI C3, but what the RG model did provide for the first time was the capability to quantify the magnitude of the reliability setback. Furthermore, the RGA tool enabled the team to confidently say 1) how much more testing would be required, and 2) what failure mode corrective action strategy would be needed to hit the goal. The model also enabled the team to back up these statements with facts and figures. The "additional test time" prediction is represented by the cross-hatched ellipse in Figure 5.

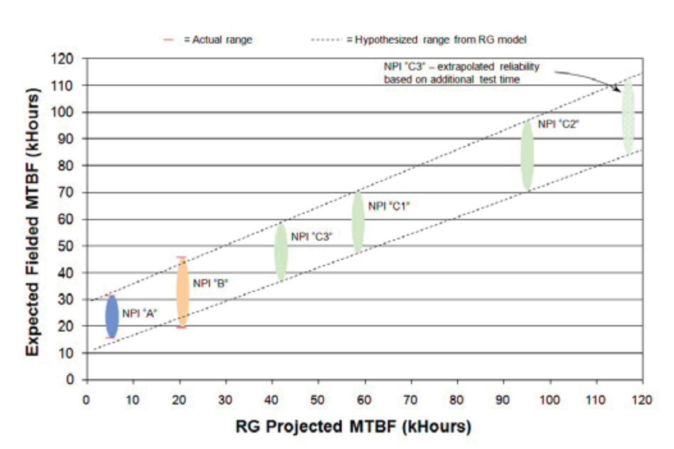

Figure 5. Expected customer-experienced MTBF of NPI C3 and extrapolated prediction based on additional test time.

The project team set out on an aggressive campaign to eliminate failure modes on NPI C3 and the RG testing continued. At the conclusion of the additional testing, the Projected MTBF was calculated using the RG model and to the delight of the team, the Projected MTBF came in at close to 110,000 hours as hoped.

Interpreting and Communicating RG Results

Creating an accurate RG model is an important step in the process, but the reliability engineer's job does not end there. The results must be interpreted for meaning and communicated effectively to the broader organization and management chain.

A key step here is communicating the results in language and metrics that are recognizable by the organization. For instance, Agilent's primary customer-facing reliability metrics are annualized warranty failure rates. The direct output from the RG model is Demonstrated MTBF and Projected MTBF, terms that may be recognized by reliability experts but unrecognizable to many team members. It certainly would be difficult for most project managers to easily decipher these metrics and judge them as good, bad or neutral. In any case, it would be prudent to convert the modeled MTBF figures into Demonstrated AFR and Projected AFR, and to provide definitions of what is meant by "Demonstrated" and "Projected." It should not be overlooked the importance of communicating RG results in terms that are easily understood by engineers, technicians, project managers and management.

One very important question still remained. What is the transformation process for converting the modeled Projected MTBF into the expected customer-experienced AFR? From a practical standpoint, the transformation process must be simple, transparent and easy to explain.

Complicating matters, the customer use model for NPI A and NPI B is 2000 hours/year whereas the customer use model for NPI C is 7000 hours/year. Because of this difference, the graphical process of transforming modeled Projected MTBF to expected fielded AFR necessitated two sets of curves. Figure 6 shows a view of the graphical transformation process.

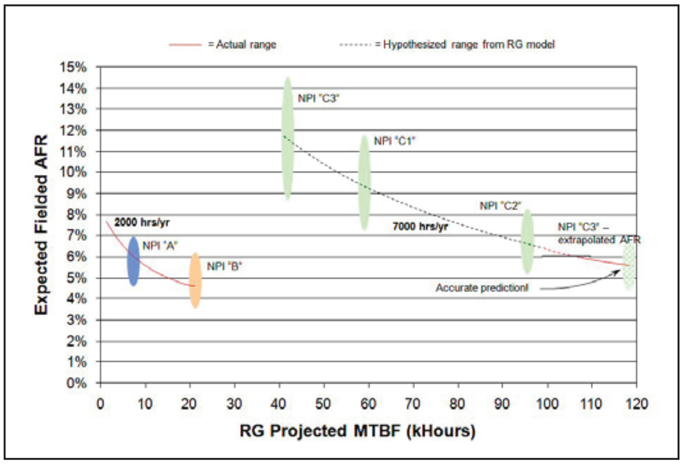

Figure 6. Expected customer-experienced reliability based on RG modeled results.

As with the MTBF view in Figure 5, we see the accurate AFR prediction from NPI C after the completion of further RG testing and corrective actions. The concept here is to be able to take the modeled Projected MTBF number from a prototype RG test and use that figure to accurately predict the eventual fielded AFR. NPI C represented the first occasion where this was successful. A subsequent NPI (not discussed here) also resulted in successfully predicting the customer-experienced AFR on the 2000 hour/year customer use model curve.

Key Learnings for Successful Application of RGA

This work highlighted the importance of putting as much run-time on the prototype units as possible, and doing it as quickly as possible. All available units should be secured for RG testing, and they should be run 24x7 if at all possible.

Reliability growth modeling applies focus and process rigor on correcting all failure modes. The impact on expected customer-experienced reliability can be quantified when decisions are made to not take correction action. Thus, it reduces the tendency to rationalize some modes as "random one-off flukes." By utilizing a structured method for assigning EF's, it becomes possible to quantify the reliability impact when different failure mode corrective action strategies are employed.

Additional Benefits of RG Modeling

Reliability growth modeling provides capability to track and report progress made toward achieving the project's reliability goals. It provides insights into what strategies may be employed for making mid-course changes in project management so that reliability goals can be achieved. Objective feedback can be provided to management by measuring demonstrated reliability and projected reliability against reliability goals.

Mitigation strategies can be developed earlier should it become apparent that reliability goals will be missed. For example, the project manager may decide to re-direct resources to convert A modes to BC/BD modes. Alternatively, investments may be made to change the corrective action strategy such that EF's are increased. Test time may be increased to reduce the number of unseen modes, i.e. convert more latent defects to observable patent defects. Creative service and support strategies may be deployed which could involve replacement parts, loaner units, service notes or repair depot capability. In short, RGA modeling enables project managers to make earlier, more informed decisions.

Selling RG to Project Managers

NPI project managers face a myriad of business demands and requirements during the development and launching of a new product. Assuring high reliability is just one of many requirements that is on the list of tasks to complete. It is no wonder that adding "yet another project task" such as RG modeling might send the project manager running from the reliability engineer. The job of selling RGA as a good business decision should not be overlooked. It is the role of the reliability engineer to be equally successful in selling the idea and successfully performing the RG modeling.

Some ideas for helping to sell the RGA process and enlisting the full support of NPI project managers include:

- Look for project managers who have demonstrated a passion for achieving high quality and reliability;
- Show how you can help make the project more successful at little or no cost;
- Quantify the benefit of RGA in dollars;
- Do the heavy lifting for the team and take on as much responsibility for the process as possible;
- Minimize the burden on the project team – utilize existing data collection tools and corrective action processes; and
- Keep RG modeling off of the project's critical path.

Future Work

During the course of this study, it was discovered that the modeled MTBF was less than the fielded MTBF. It would be instructive to understand the causes of this phenomena so that steps can be taken to reduce the delta. Some plausible explanations might include accelerated life during RG testing, wrong assumptions concerning customer use models, and unaccounted reliability growth occurring between RG modeling and the product launch. Further work is planned to explore these potential causes.

Conclusions

Most design ruggedization and DfR processes utilized during the product development phase are not intended to predict system-level fielded reliability. Traditional quality and reliability metrics are lagging indicators and are slow to respond to changes in reliability. Consequently, customers can become unintentional participants in the process of verifying the effectiveness of the NPI's reliability program.

Reliability growth analysis on prototype and pilot units was shown to be successful in predicting customer-experienced reli-

continued on next page ›››