The Reliability Information Analysis Center (RIAC) is a DoD Information Analysis Center sponsored by the Defense Technical Information Center.
November 14th marked the ribbon-cutting and luncheon at the State University of New York Institute of Technology (SUNYIT) to celebrate the “Grand Reopening” of the Department of Defense (DoD) Reliability Information Analysis Center (RIAC) at the Institute. Mr. Terry Heston, Program Manager for the 10 DoD Centers of Excellence called “Information Analysis Centers (IACs)”, officiated at the ceremony (Figure 1), accompanied by Contracting Officer Ms. Sarah Davis and Contracting Officer’s Representative Mr. Richard Hyle. The “re-opening” triples the size of the facility at SUNYIT that is the core operation of the government contract. The event also recognized the 40th anniversary of this important IAC, previously called the Reliability Analysis Center (RAC). Joining the RIAC management and staff members at the celebration was New York State Assemblywoman RoAnn Destito and key government managers from AFRL in Rome. Figure 2 shows the IAC exhibit at the luncheon that followed the ribbon-cutting.

The RIAC (http://theRIAC.org) is operated by a team led by Wyle Laboratories that includes the Center’s primary day-to-day operator Quanterion Solutions, the University of Maryland Center for Risk and Reliability, the Penn State University Applied Research Laboratory, and SUNYIT. The Center is the DoD’s Center of Excellence in reliability, maintainability, quality, supportability, and interoperability providing consulting services, guidance publications, and training to government and industry nation wide under an Air Force Contract administered by the Defense Technical Information Center (DTIC). The RIAC operation at SUNYIT serves as a model of successful government-industry-academia cooperation in addressing the technical needs of both the defense community and commercial industry. More than 40 SUNYIT faculty members, student interns, and support staff have been involved in the Center’s operation, contributing critical state-of-the-art information technology and knowledge management expertise.

Prior to 2005, the RIAC was known as the RAC, but the name was changed to emphasize that the Center is part of the IAC family of DTIC sponsored centers. Since its start in 1968, the Center has evolved from limiting its activities to the reliability of emerging microelectronics devices to addressing full system reliability, maintainability, quality, supportability,
and interoperability (RMQSI). In the course of doing so, the Center’s products have expanded from raw failure data compilations to a variety of state-of-the-art reports, “toolkit” guidance publications, and software tools. 1976 marked the beginning of RAC’s training program now consisting of more than 40 off-the-shelf courses. To date RIAC/RAC has trained thousands in the techniques and methodologies of reliability-related disciplines. Table 1 indicates some of the milestones in RIAC/RAC history and Tables 2 and 3 list the Government Program Managers (called Contracting Officer’s Representatives, or CORs) and Contractor RIAC Directors over the years.

Table 1: Milestones in RIAC/RAC History

<table>
<thead>
<tr>
<th>Years</th>
<th>Focus</th>
<th>Highlights</th>
</tr>
</thead>
</table>
| 1965-70 | Component Reliability | › 1968 RAC Started  
› 1971 RAC becomes DoD IAC                                                             |
| 1971-75 | Failure Rate/Mode Databases for Components |                                                                                             |
| 1976-80 | EOS/ESD                | › 1976 Reliability Design Handbook Published  
› 1976 First Training Course Presented                                                   |
| 1981-85 | System Reliability     | › VZAP (Electrostatic Discharge Susceptibility) Databook Published                          |
| 1986-90 | Quality/TQM            | › 1987 Technical Advisory Group Established (Currently Called Steering Committee)           |
| 1996-00 | Acquisition Reform     | › 1996 “RAC Blueprints for Product Reliability” Published                                   
› 1999 PRISM System Reliability Assessment Software Tool Released                         |
| 2001-05 | RAC-to-RIAC            | › RAC renamed RIAC to Emphasize IAC  
› Wyle Laboratories Team of Quanterion Solutions, University of Maryland Center for Risk and Reliability, Penn State Applied Research Lab and SUNY Institute of Technology Brings Broadened Capabilities to RIAC |
| 2006-  | Total System RMQSI     | › “System Reliability Toolkit” Published in Collaboration with the Data and Analysis Center for Software (DACS) IAC  
› 217Plus™ System Reliability Assessment Methodology and Software Tool Released as DoD Replacement for PRISM  
› 217Plus™ Methodology Published for First Time as “Handbook of 217Plus™ Reliability Prediction Models” |

Table 2: Forty Years of RIAC/RAC Program Managers

<table>
<thead>
<tr>
<th>Program Manager</th>
<th>RIAC/RAC Government Program Managers</th>
</tr>
</thead>
</table>
| John Fuchs      | The RIAC/RAC has been technically managed by AFRL/RI since its inception. The organization's name has  
                  | changed, but it's essentially the same management:                                                   |
| Joseph Schramp  | › 1968 to 1991 - Rome Air Development Center (RADC)                                                |
| Anthony Feduccia| › 1992 to 1995 - Rome Laboratory (RL)                                                               |
| Charles Bough   | › 1996 to 2007 - AFRL/IF                                                                           |
| Preston MacDiarmid| › 2008 going forward - AFRL/RI                                                                    |
| Duane Gilmour   | The Government refers to an IAC Program Manager as the Contracting Officer’s Representative (COR)  |
| Richard Hyle    |                                                                                                     |
Like the other IACs (see Table 4), when the RAC started, it was strictly a “core” operation collecting, processing, analyzing, and disseminating data and information under DoD regulation. Again in the 1970s, it became apparent that the DoD could make more effective use of the knowledge embodied in the IACs if DoD customers could get their technical help on a customer-funded basis. Now referred to as “Technical Area Tasks (TATs)” and their limited scope partner “Subscription Accounts (SAs),” funding for these activities now dwarfs DTIC’s core funding for most IACs.

The DTIC sponsored IACs are each a little different in the way they approach the classic IAC data collection, processing, analysis, and dissemination activities in their chartered subject areas. RIAC has always been very strong in publishing databooks, handbooks, and guides. Figure 3 is a collage of early significant publications over the early years that became “standards,” some updated several times.

The 1976 “Reliability Design Handbook” was so popular that in the 1980s the DoD patterned its MIL-HDBK-338 “Electronic Reliability Design Handbook” after it. As another example, the RIAC’s “Nonelectronic Parts Reliability Data” publication first edition appeared in 1978 and current edition is dated 1995, but its 2008 edition will soon be available as a complement to popular reliability prediction techniques for electronics.

In recent years, the “look” of the RIAC/RAC documents has changed from the “plain label” logo of the seventies, to the bold Eurostyle logo of the 1980s, to the italicized striped 1990s version showing RAC moving ahead, and now to the solidified system-RMQSI approach of the current RIAC team operation as indicated in Figure 4.

More important is the evolution of RIAC capabilities over the years. It’s grown from a few technical staff and a few technicians forming the “core operation” to literally hundreds of staff members working on core and funded projects solving DoD RMQSI problems. The Center now collaborates with other IACs when appropriate to solve a customer’s problem and to enhance the breadth of IAC publications. The very popular “System Reliability Toolkit” is an example of collaboration of RIAC with the Data and Analysis Center for Software (DACS), a sister IAC dealing with software engineering and software technology.
In summary, the RIAC has grown tremendously over the years now offering more than 85 products, more than 25 training courses, and greatly expanding its technical coverage into all areas of RMQSI. We think we’re doing pretty well, but it’s more important what you think. As RIAC Journal readers, you can help RIAC continue to improve by providing us your feedback. Let us know what new RMQSI data, guidance publications, analysis tools, training courses, Journal articles, and other works will help you be more productive in your job—that’s what we’re here for! Send your inputs to Inquiry@theRIAC.org.

Figure 3: Evolution of the RIAC Logo

Figure 3: Early RAC Publications Helped to Define the Reliability Discipline

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RCM AND RISK MANAGEMENT
(PART 2 OF 3)

Lynnwood Yates, RIAC (Wyle Laboratories)

As introduced in Part 1 of this three-part series, published in the Third Quarter 2007 Journal of the Reliability Information Analysis Center (available for download from the RIAC website - http://theRIAC.org), management is imminently concerned with minimizing the risks associated with their enterprises, while maximizing their profits or asset availability. Reliability-Centered Maintenance (RCM) is a proactive means of protecting their assets through a reasoned and practical maintenance management strategy; however these efforts may frequently fail to realize their potential. The answers may not readily translate into real management decisions or there may be so many recommendations that prioritizing them is very difficult. Part 1 of the article addressed the basic concept of risk, the management of unacceptable risks, and qualitative risk management. Part 2 introduces RCM analysis basics and how to apply RCM results in the decision-making process. The article concludes with an example from the USAF F-15 RCM program.

RCM Analysis

The ultimate goal of RCM is to maximize the inherent reliability of any asset or process by developing optimal maintenance strategies. In other words, RCM is doing the, “right maintenance, at the right time, by the right people, in the right way”. The outcomes of these analyses are usually in the form of recommendations such as, but not limited to, the following:

- **Scheduled monitoring** of equipment or process at intervals that insure detection of potential failures before they become a reactive maintenance problem. Monitoring forms may vary from simple visual zonal inspections up to complex automated monitoring systems (CBM or PDM technology), if justified.
- **Failure finding** tasks are typically designed to find hidden failures before an item is used or needed. This recommendation is mainly associated with redundancy, backup systems or safety actions that reduce risk.
- **Scheduled Replacement/Restoration** tasks to replace an asset just short of its remaining functional life. This task is generally associated with assets that are critical or result in costly unscheduled downtime.

- **Scheduled Lubrication/Replenishment** tasks should be optimized to insure that the maximum benefit of the lubricant or consumable (e.g. nitrogen, oil, grease, etc.) is accomplished. The most beneficial intervals are determined and matched to the equipment’s operating demands or capacity limitations.

- **Age Exploration** tasks investigate the root causes of failures to better understand the optimum maintenance management strategy needed. As this can be an expensive process it is usually relegated to critical assets.

- **No Preventative Maintenance (NOPM) or Run-To-Failure (RTF)** recommendations, where the results of actual failures have little or no impact on the overall function or health of the operation. Maintaining or inspecting RTF/NOPM items frequently contribute to higher failure rates due to maintenance-induced failures.

- **Other actions** or improvement opportunities are recommendations that relate to design or process deficiencies. This can range from redesign to publications changes. New technology may be considered as an option (e.g. oil purification, vibration analysis).

An integral aspect within the RCM process is the categorization of failure modes through analysis by risk impact on the function of the end item. The secondary benefit of undertaking risk assessment (usually qualitative) is that it allows the analyst to focus on items that are unacceptable risks. The level at which risk failure modes do not require analysis is determined between the RCM analysts and the customer, and can result in reduced work loads. Some items can also be identified as requiring a QRA. The depth of the analysis is determined by the customer’s needs and acceptable level of risk, however, all reasonably likely failure modes should at a minimum be subjected to the qualitative risk assessment.

Some RCM practitioners do not use failure rates or a quantitative approach in their analysis [Reference 5]. Regrettably, Smith’s perceptions are credible assertions, predominantly derived from the lack of relevant failure data available within the commercial industry. However, risk assessment and mitigation should be based on the
best information available. If one cannot demonstrate probability in a meaningful way determination of acceptable risk assessment levels becomes a mere assumption. A non-quantitative approach, in many cases, is adequate to develop an RCM based maintenance program, yet it is imperative that items with potential hazards or possible critical consequences be assessed quantitatively to insure a robust analysis. If the risks are indeed unacceptable, the effort to generate the data should be undertaken (Age Exploration) and a cost benefit study completed to justify effort.

**Decision Making**

Clear and accurate information is essential within any decision process. The degree of clarity and accuracy required relates directly to the importance of the decision. The decision to go to war requires a far higher degree of information fidelity than deciding to go to the movies. In the same way management decisions that have high risk associated with them require tenable information. RCM has the ability to provide much of the information needed to make proficient decisions.

One aspect of RCM that may be problematic is communication of results. Results must be presented in a manner that assists managers to make the decisions needed in order to realize the benefits of RCM analysis. Over the past 30 years, as RCM has evolved, one of the methods to facilitate this has been through the team concept where key people from the company or organization are directly involved in the RCM process, promoting confidence in the results and a buy-in factor. Anthony M. Smith, the author of RCM Gateway to World Class Maintenance, states that the buy-in factor is critical: “...must be a clear and visible endorsement from top management” [Reference 5]. Even with team interaction sections of the analyses fail to be implemented, often due to key member’s inability to adequately characterize the benefits to upper management. This has resulted in RCM developing a reputation as another “flavor-of-the-month” maintenance concept in some arenas.

This paper addresses the development of better decision-making tools to help mitigate communication gaps that exist in many maintenance management organizations. The following section gives an example of an actual RCM problem encountered by the author.

**Example from U. S. Air Force**

After 3 years of analysis on the F-15 RCM program the following question was posed by the customer. What is the overall hazard risk to the aircraft if we implement the RCM recommendations? The customer wanted an answer with a quantitative approach in order to “sell” it to his bosses. After exhaustive research and consultation with experts both in the Air Force and the commercial market, it was concluded that there was no clear means of doing this within the existing framework of Air Force safety programs.

While trying to identify the impediments to making decisions within the framework of management priorities, it was revealed that managers were constrained by upper management’s enforcement of maintaining the safety and risks allowed within certain limits. Additionally, there were no clear means for managers to furnish convincing arguments for initiation of the actions recommended through the RCM analysis. A further investigation into how various engineering staff assessed these risks or hazards revealed no clear method for making the risk assessment. One engineering staff surveyed approached the problems by a fairly robust means. The approach was a comprehensive Hazard Risk Assessment (HRA) that quantified all the relevant aspects of a critical failure. The business practices guidance provided by management of this organization was general in nature, however the assigned engineers developed a comprehensive approach to the problem. This approach was adopted and modified for application to the current F-15 risk management questions.

This HRA approach to, “What is the risk to our aircraft if we extend the interval of the phase inspections from 200 Flight hours (FH) to 300 FH?” was divided into the following sequence. All failure modes (FM) associated with the 200 plus inspections were compared to the HRI matrix in accordance with MIL-STD-882D once MTBF was determined. Secondary and sometimes tertiary factors required for the risk of failure to be realized, were then included to calculate the overall risk.

continued on next page »»»
probability. These results were then compared to the HRI once more to determine if risk was reduced to acceptable levels. If the criterion was not met, various mitigation techniques were considered with an estimate of the proposed solution’s impact upon risk. This final failure probability was the basis for a new HRA iteration.

In this instance management wanted to know the impact an inspection interval change would have on risk. After all failure modes had been placed on the HRI, the most critical (drivers) were analyzed by HRA. This necessitated that failure characteristics be calculated and then used to estimate the change in failure rate (or MTBF) that would result from the interval change. Once completed, the HRA was recalculated for each high risk failure mode using the new MTBF figures. If the interval change had acceptable HRA results on these failure modes, the remaining (non-critical) failure modes were assumed to be representative of impact on the less critical failure modes.

A spreadsheet was developed to facilitate this effort into four sections; RCM, HRA, Interval factors and final HRA. Table 1 below is the RCM section from the initial analysis of the critical failure modes identified.

The HRA, Step Two, was evaluated on the risk drivers as shown in Table 2 below. This is a continuation of the above spreadsheet, separated for ease of viewing.

The failure characteristics of the failure modes were then calculated using Weibull shape (β) and scale (η) parameters to describe the failure curve in the ‘Internal Change Factors’ section of the spreadsheet. The ‘Y’ intercept was calculated to the new point on the PDF curve to estimate the η Factor based on the time interval change (new interval, or NI). An increase or decrease in MTBF was then estimated for determining the new failure rates based on the slope characteristic β. This is Step Three of the analysis, as shown in Table 3. Step 4 is the final HRA for comparison with the original HRA using the new projected MTBF.

The final recommendation to move the inspection interval to 400 hours was optimal, verses the 300 requested. A separate phase interval at 400 hours, already in place, could include...
the 200 hour inspections within the 400 flight hour inspection package. The spreadsheet had the further benefit of easily communicating the results in an interactive “what-if” presentation that allowed instant calculation of the impact of different intervals placed in the ‘Proposed Interval’ section above.

### Acknowledgments

Thanks to Jeremy Trotter, Reliability Engineer, BSE, MSEE, Mercer University, for his assistance in derivation of the formulae associated with this analysis and research obtained in support of this paper. The Wyle Laboratories RCM analysts are also thanked for their gathering and population of the spreadsheets containing inspection and failure mode data from the RCM analysis.

Additional thanks goes to Melanie Moore Yates, BA, MAT for her research assistance and citation recommendations. In addition to being a very talented researcher, she is recognized by Who’s Who of American Woman and Who’s Who in Finance and Industry, a winner of a National Science Foundation fellowship as an undergraduate, and a co-author of published papers on cancer research.

Final thanks to Michele Dunlap, BA, Bath Spa University, Bath England, for her exhaustive editing to convert this author’s ‘Americanized language’ into true English. She is an accomplished editor and historian.

### Table 3: Interval Factors and HRA Results

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<th>β</th>
<th>η Factor</th>
<th>Current Interval</th>
<th>Proposed Interval</th>
<th>MTBF for NI with Factors</th>
<th>λ NI</th>
<th>λ Total</th>
<th>HRA Matrix Equivalent</th>
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### References


### Bibliography

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Reliability Information Analysis Center Continues Efforts to Reduce the Costs of Corrosion

In 2002, the results from a federal study on the cost of corrosion were publicly released. The study concluded that corrosion costs the U.S. economy $276 billion per year, or 3.2 percent of the gross domestic product (GDP). This study examined 26 economic sectors, including the Department of Defense (DoD), with its estimated costs coming in at $20 billion per year. Upon learning the magnitude of this problem, the U.S. Congress quickly enacted a law directing the DoD to implement a department wide corrosion prevention and control program. Soon afterward, the Office of the Secretary of Defense (OSD) established the Office of Corrosion Policy and Oversight. Over the past 4 years, this office has put in place a number of plans and programs specifically designed to reduce overall corrosion costs.

Since 2003, the Defense Technical Information Center’s (DTIC) Information Analysis Center (IAC) program has actively supported DoD’s corrosion mitigation efforts. Mr. David Rose, a senior technical staff member at the Reliability Information Analysis Center (RIAC) and past Director of the Advanced Materials, Manufacturing, and Testing Information Analysis Center (AMMTIAC) and its predecessor, Advanced Materials and Processes Technology Information Analysis Center (AMPTIAC), has written extensively and made numerous presentations on corrosion.

In March 2004, Mr. Rose appeared before the Defense Science Board’s Corrosion Task Force and presented the results of an ad-hoc study which investigated corrosion education in the curricula at 20 top engineering schools. This study provided anecdotal evidence supporting his assertion that schools inadequately cover corrosion education, and thus were significantly responsible for the enormous cost of corrosion. Afterward, he wrote a white paper that identified his concerns about corrosion education and, furthermore, recommended the National Academies be tasked to conduct a formal study to determine whether the results from his ad-hoc study were accurate. If the National Academies found the results accurate, the white paper tasked them to make recommendations on improvements to curricula that engineering schools could adopt. He submitted this white paper to OSD, and it was ultimately forwarded to the Senate. The white paper directly led to the DoD’s corrosion prevention and control as well as the IAC program’s associated support.

RIAC has been actively supporting the National Research Council (NRC), the investigative arm of the National Academies, in its effort to prepare for the DoD-sponsored formal study on corrosion education. Mr. Rose first began working with professional staffers at the NRC in November 2006 and subsequently became a member of the NRC’s Corrosion Education Workshop Organizing Panel (CEWOP). As a result of his advocacy, the participants at the Corrosion Education Workshop came from diverse engineering backgrounds.

Members of the CEWOP asked Mr. Rose to make a presentation to participants and other invited guests at the Corrosion Education Workshop, which was held in March 2007. He briefed the participants on corrosion education as well as the results from the ad-hoc study he commissioned. He further went on to recommend mechanisms for improving corrosion education by implementing an approach that would insert modular corrosion content into relevant science, materials, and design engineering courses of instruction.

At the workshop, Mr. Rose also recommended that the cost of corrosion could be further reduced by examining the stakeholder community responsible for designing systems, equipment, structures, and other items to determine which engineering specialties could take on a broader role in corrosion, and was subsequently invited to present the origins of the study at the inaugural meeting of the NRC’s Committee on Assessing Corrosion Education. This meeting was held in June 2007, and Mr. Rose’s presentation contained both the history of DoD’s involvement in corrosion prevention and control as well as the IAC program’s associated support.

In the summer of 2007, a new RIAC initiative began to investigate existing corrosion engineering practices and analysis methods and transform them into techniques that can be employed in current reliability engineering practices. Reliability engineering, as a participant in the systems engineering process, is a horizontally integrated function with a charter that extends from product design until retirement. Reliability engineers have broad insight concerning product design as well as system operation, and the discipline by its very nature cuts through the stovepipes because it works with many different engineering specialties. As a result, reliability engineering practices could evolve into a critical and effective element in the process of corrosion prevention and control. RIAC will develop an initial suite of corrosion-related reliability methodologies and present them to the community using appropriate venues, including conferences and articles published in the RIAC Journal. Its long-term strategy is to continue advocacy using the aforementioned promotional mechanisms to encourage others in the reliability community to evolve the nascent tools developed by RIAC so they eventually become mature processes thoroughly ingrained in the reliability discipline.
In a previous edition of the RIAC Journal [Reference 1], we provided a high-level introduction to the 217Plus™ component failure rate prediction models, and in the last two editions we presented the 217Plus™ capacitor and diode failure rate models [Reference 2] and the integrated circuit and inductor failure rate models [Reference 3].

In this edition of the Journal, we present the Transformer and Optoelectronic Device component models in their entirety. A brief example will be provided at the end of the article.

### 217Plus™ Transformer Failure Rate Model

The failure rate equation for transformers [Reference 4] is:

\[
\lambda_T = \pi_G (\lambda_{\text{EB}} \pi_{\text{DCO}} \pi_{\text{TO}} + \lambda_{\text{EB}} \pi_{\text{DCN}} \pi_{\text{TE}} + \lambda_{\text{TCB}} \pi_{\text{CR}} \pi_{\text{DT}}) + \lambda_{\text{IND}}
\]

where,

- \(\lambda_T\) = Predicted failure rate, failures per million calendar hours
- \(\pi_G\) = Reliability growth failure rate multiplier:
  \[
  \pi_G = e^{(-\beta Y - 1993)}
  \]
  - \(\beta\) = Growth constant. Function of transformer type (see Table 1)
- \(\lambda_{\text{EB}}\) = Base failure rate, environmental (see Table 1)
- \(\pi_{\text{DCO}}\) = Failure rate multiplier for duty cycle, operating:
  \[
  \pi_{\text{DCO}} = \frac{DC}{DC_{\text{op}}}
  \]
  - \(DC\) = Constant. Function of transformer type (see Table 1)
  - \(DC_{\text{op}}\) = Constant. Function of transformer type (see Table 1)
- \(\pi_{\text{TO}}\) = Failure rate multiplier for temperature, operating:
  \[
  \pi_{\text{TO}} = e^\left(\frac{-E_{\text{op}}}{0.01008617(T_{\text{AO}} + T_R + 273) - \frac{1}{298}}\right)
  \]
- \(\lambda_{\text{TCB}}\) = Base failure rate, temperature cycling (see Table 1)
- \(\pi_{\text{CR}}\) = Failure rate multiplier, cycling rate:
  \[
  \pi_{\text{CR}} = \frac{CR}{CR_1}
  \]
  - \(CR\) = Constant. Function of transformer type (see Table 1)
  - \(CR_1\) = Constant. Function of transformer type (see Table 1)
- \(\pi_{\text{DT}}\) = Failure rate multiplier, delta temperature:
  \[
  \pi_{\text{DT}} = \left(\frac{T_{\text{AO}} + T_R - T_{\text{AE}}}{DT_1}\right)^2
  \]

- \(E_{\text{op}}\) = Activation energy, operating. Function of transformer type (see Table 1).
- \(T_R\) = The junction temperature rise above the ambient operating temperature \(T_{\text{AO}}\). The junction temperature is, therefore, \(T_{\text{AO}} + T_R\). \(T_R\) can be determined in several ways:
  - \(T_{\text{Rdefault}}\) = Default temperature rise (see Table 1)
  - \(T_R\) = Actual (measured) temperature rise, if known

\(\pi_{\text{DCN}}\) = Failure rate multiplier, duty cycle – nonoperating:

\[
\pi_{\text{DCN}} = 1 - \frac{DC}{DC_{\text{nonop}}}
\]

- \(DC_{\text{nonop}}\) = Constant. Function of transformer type (see Table 1)

\(\pi_{\text{TE}}\) = Failure rate multiplier, temperature:

\[
\pi_{\text{TE}} = e^{\left(\frac{-E_{\text{nonop}}}{0.01008617(T_{\text{AO}} + 273) - \frac{1}{298}}\right)}
\]

- \(E_{\text{nonop}}\) = Activation energy, nonoperating. Function of transformer type (see Table 1)

In Table 1, the values of the failure rate multipliers, \(\lambda_{\text{EB}}, \lambda_{\text{TCB}}, \pi_{\text{DCO}}, \pi_{\text{TE}}, \pi_{\text{CR}}, \pi_{\text{DT}}\), and the activation energies \(E_{\text{op}}\), \(E_{\text{nonop}}\) will be provided for different transformer types.
DT \_1 = \text{Constant. Function of transformer type (see Table 1)}

\lambda \_\text{IND} = \text{Failure rate, electrical overstress (see Table 1)}

NOTE: Environment-type and equipment-dependent default values for DC, T \_\text{AO}, T \_\text{AE}, \text{CR} and \text{CR} were previously presented in Reference 1, where,

DC = Duty cycle (the percent of calendar time that the system in which the component is operating is in an operational state)

T \_\text{AO} = \text{Ambient temperature, operating (in degrees C)}

T \_\text{AE} = \text{Ambient temperature, nonoperating (in degrees C)}

CR = Cycling rate (the number of power cycles per year to which the system is exposed). In this case, it is assumed that the system transitions from a nonoperating environment to an operating environment at the same time that the power is applied.

### 217Plus™ Optoelectronic Device Failure Rate Model

The failure rate equation for optoelectronic devices [Reference 4] is:

\[
\lambda \_p = \pi \_G \left( \lambda \_\text{OB} \pi \_\text{DCO} \pi \_\text{TD} + \lambda \_\text{EB} \pi \_\text{DCN} \pi \_\text{TE} + \lambda \_\text{TCB} \pi \_\text{CR} \pi \_\text{CR} \right) + \lambda \_\text{IND}
\]

where,

\[
\lambda \_p = \text{Predicted failure rate, failures per million calendar hours}
\]

\[
\pi \_G = e^{\beta(Y - 1993)}
\]

\[\beta = \text{Growth constant. Function of optoelectronic device type (see Table 2)}\]

\[
\lambda \_\text{OB} = \text{Base failure rate, operating (see Table 2)}
\]

\[
\pi \_\text{DCO} = \text{Failure rate multiplier for duty cycle, operating:}
\]

\[
\pi \_\text{DCO} = \frac{DC}{DC\_\text{op}}
\]

\[
DC\_\text{op} = \text{Constant. Function of optoelectronic device type (see Table 2)}
\]

### Table 1: Transformer Parameters

<table>
<thead>
<tr>
<th>Part Type</th>
<th>( \lambda _\text{OB} )</th>
<th>( \lambda _\text{EB} )</th>
<th>( \lambda _\text{TCB} )</th>
<th>( \lambda _\text{IND} )</th>
<th>( \beta )</th>
<th>DC_\text{op}</th>
<th>E_\text{op}</th>
<th>T_\text{default}</th>
<th>DC_\text{nonop}</th>
<th>E_\text{nonop}</th>
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<td>10</td>
<td>0.62</td>
<td>0.240</td>
<td>312</td>
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<tr>
<td>Flyback</td>
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<td>0.0007388</td>
<td>0.0005737</td>
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<td>0.24</td>
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<td>0.240</td>
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<td>29.66</td>
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<td>Isolation</td>
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<td>0.0085063</td>
<td>0.0087950</td>
<td>0.0008498</td>
<td>0.38</td>
<td>0.24</td>
<td>10</td>
<td>0.62</td>
<td>0.240</td>
<td>312</td>
<td>29.66</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>0.0001214</td>
<td>0.0001499</td>
<td>0.0000518</td>
<td>0.0000386</td>
<td>0.38</td>
<td>0.24</td>
<td>10</td>
<td>0.62</td>
<td>0.240</td>
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<td>0.0009463</td>
<td>0.0001335</td>
<td>0.0000510</td>
<td>0.38</td>
<td>0.24</td>
<td>10</td>
<td>0.62</td>
<td>0.240</td>
<td>312</td>
<td>29.66</td>
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</tr>
<tr>
<td>RF</td>
<td>0.0000913</td>
<td>0.0004160</td>
<td>0.0001022</td>
<td>0.0000182</td>
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<td>0.24</td>
<td>10</td>
<td>0.62</td>
<td>0.240</td>
<td>312</td>
<td>29.66</td>
<td></td>
</tr>
</tbody>
</table>

continued on next page"
\( \pi_{TO} = \) Failure rate multiplier for temperature, operating:

\[
\pi_{TO} = e^{\frac{-E_{A_{op}}}{100000000000} \left( \frac{1}{T_{AO}} + \frac{1}{T_R} \right)}
\]

\( E_{A_{op}} = \) Activation energy, operating. Function of optoelectronic device type (see Table 2).

\( T_R = \) The junction temperature rise above the ambient operating temperature \( (T_{AO}) \). The junction temperature is, therefore, \( T_{AO} + T_R \). \( T_R \) can be calculated in several ways:

\( T_{R\text{default}} = \) Default temperature rise (see Table 2)

\( T_R = \) Actual temperature rise, if known

\[
T_R = \Theta_{JA} \times P
\]

where \( \Theta_{JA} \) is the junction-to-ambient thermal impedance and \( P \) is the power dissipated by the device

\[
T_R = \Theta_{JC} \times P
\]

where \( \Theta_{JC} \) is the junction-to-case thermal impedance and \( P \) is the power dissipated by the device

If this option is used, \( T_{AO} \) should be replaced by \( T_C \), the component case temperature, in the above equation for \( \pi_{TO} \)

\( T_R = \Delta T \times S \)

where \( \Delta T \) is the difference in junction temperature between no power dissipated and full rated power dissipated, and \( S \) is the stress ratio, which is equal to the actual forward current divided by the rated forward current.

\( \lambda_{EB} = \) Base failure rate, environmental (see Table 2)

\( \pi_{DCN} = \) Failure rate multiplier, duty cycle – nonoperating:

\[
\pi_{DCN} = \frac{1 - DC_{\text{nonop}}}{DC_{\text{op}}}
\]

\( DC_{\text{nonop}} = \) Constant. Function of optoelectronic device type (see Table 2)

\( \pi_{TE} = \) Failure rate multiplier, temperature:

\[
\pi_{TE} = e^{\frac{-E_{A_{nonop}}}{100000000000} \left( \frac{1}{T_{AO}} + \frac{1}{T_R} \right)}
\]

\( E_{A_{nonop}} = \) Activation energy, nonoperating. Function of optoelectronic device type (see Table 2)

\( \lambda_{TCB} = \) Base failure rate, temperature cycling (see Table 2)

\( \pi_{CR} = \) Failure rate multiplier, cycling rate:

\[
\pi_{CR} = \frac{CR_{\text{op}}}{CR}
\]

\( CR_{\text{op}} = \) Constant. Function of optoelectronic device type (see Table 2)

Table 2: Optoelectronic Device Parameters

<table>
<thead>
<tr>
<th>Part Type</th>
<th>( \lambda_{CB} )</th>
<th>( \lambda_{EB} )</th>
<th>( \lambda_{TCB} )</th>
<th>( \lambda_{IND} )</th>
<th>( \beta )</th>
<th>DC_{op}</th>
<th>E_{A_{op}}</th>
<th>T_{R\text{default}}</th>
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<td>0.32</td>
<td>0.6</td>
<td>7</td>
<td>0.68</td>
<td>0.4</td>
<td>388</td>
<td>14.61</td>
</tr>
<tr>
<td>Optoisolator</td>
<td>0.0032244</td>
<td>0.0095466</td>
<td>0.0009116</td>
<td>0.0024039</td>
<td>0.087</td>
<td>0.32</td>
<td>0.6</td>
<td>7</td>
<td>0.68</td>
<td>0.4</td>
<td>388</td>
<td>14.61</td>
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<td>Photodiode</td>
<td>0.0000269</td>
<td>0.0000761</td>
<td>0.0000076</td>
<td>0.0000195</td>
<td>0.087</td>
<td>0.32</td>
<td>0.6</td>
<td>7</td>
<td>0.68</td>
<td>0.4</td>
<td>388</td>
<td>14.61</td>
</tr>
<tr>
<td>Phototransistor</td>
<td>0.0012884</td>
<td>0.0037624</td>
<td>0.0003599</td>
<td>0.0009682</td>
<td>0.087</td>
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<td>7</td>
<td>0.68</td>
<td>0.4</td>
<td>388</td>
<td>14.61</td>
</tr>
</tbody>
</table>
As with the Transformer model, the environment-type and equipment-dependent default values for DC, $T_{AO}$, $T_{AE}$, and CR were previously presented in Reference 1.

**Example Calculation**

What is the predicted failure rate of a power transformer manufactured in 2006. The power transformer operates in a “Ground, Mobile, Heavy-wheeled” vehicle with an assumed operating temperature of 55°C, a dormant temperature of 14°C and a relative humidity of 40%. The actual temperature rise of the transformer is unknown. The operating profile of the equipment is typical of military ground equipment, with a duty cycle of 45% and a cycling rate of 263 cycles per year.

The failure rate equation for a transformer [Reference 4] is:

$$\pi_p = \pi_G (\lambda_{OB} \pi_{DCO} \pi_{IO} + \lambda_{EB} \pi_{DCN} \pi_{IE} + \lambda_{TCB} \pi_{CR} \pi_{DT}) + \lambda_{IND}$$

where,

$$\pi_G = e^{(-\beta(Y-1993))} = 1.0$$

$\beta = 0$ (from Table 1) and $Y = 2006$ (given)

$\lambda_{OB} = 0.0001214$ (from Table 1)

$$\pi_{DCO} = \frac{DC}{DC_{top}} = 1.184$$

DC = 0.45 (given as 45%)

$DC_{top} = 0.38$ (from Table 1)

$$\pi_{IO} = e^{\left(-\frac{E_{ap}}{0.00008641}(\frac{1}{T_{AO} + 273} - \frac{1}{298})\right)} = 2.351$$

$E_{ap} = 0.24$ (from Table 1)

$T_{AO} = 55$ (given)

$\lambda_{EB} = 0.0001499$ (from Table 1)

$$\pi_{DCN} = \frac{1 - DC}{DC_{nonop}} = 0.8871$$

DC = 0.45 (given as 45%)

$DC_{nonop} = 0.62$ (from Table 1)

$$\pi_{IE} = e^{\left(-\frac{E_{nonop}}{0.00008641}(\frac{1}{T_{AE} + 273} - \frac{1}{298})\right)} = 0.6989$$

$E_{nonop} = 0.24$ (from Table 1)

$T_{AE} = 14$ (given)

$\lambda_{TCB} = 0.0000518$ (from Table 1)

$$\pi_{CR} = \frac{CR}{CR_1} = 0.8429$$

CR = 263 (given)

$CR_1 = 312$ (from Table 1)

$$\pi_{DT} = \left(\frac{T_{AO} + T_{E} - T_{AE}}{DT_1}\right)^2 = 2.957$$

$T_{AO} = 55$ (given)

$T_{E_{default}} = 10$ (from Table 1)

$T_{AE} = 14$ (given)

$DT_1 = 21.94$ (from Table 1)

$\lambda_{IND} = 0.0000386$ (from Table 1)

$$\lambda_p = (1.0)[(0.0001214)(1.184)(2.351) + (0.0001499)(0.8871)(0.6989) + (0.0000518)(0.8429)(2.957)] + (0.0000386)$$

$\lambda_p = 0.0005986 f/10^6$ calendar hours

**Next Issue**

The next issue of the RIAC Journal (1st Quarter 2008) will present the 217Plus™ switch and relay failure rate models.

**References:**


References 1, 2, 3 and 5 available for free download from the RIAC website at http://theRIAC.org
David Nicholls, Operations Manager for the Reliability Information Analysis Center, has been invited to participate in the development of GEIA-STD-0009, “Reliability Program Standard for Systems Design, Development and Manufacturing”.

The dual-use standard is being developed by the Government Electronics and Information Technology Association (GEIA) and is supported by the Office of the Secretary of Defense (OSD), Office of the Director, Operational Test and Evaluation (DOT&E). It is intended to address specific needs within the DoD, where a large number of systems are failing to meet their reliability requirements in OT&E.

Two-day Workshops were held in October and December 2007 to define a framework for the standard, and establish teams to address specific areas of the standard that correlate to major phases of the system life cycle. Other organizations currently participating in this effort include the US Army Evaluation Center, (AEC), the US Army Materiel Systems Analysis Activity (AMSA), the Aviation and Missile Research, Development and Engineering Center (AMRDEC), Naval Sea Systems Command (NAVSEA), the Defense Information Systems Agency (DISA), the University of Alabama - Huntsville (UAH), Raytheon Missile Systems, General Dynamics Land Systems and Harris Corporation. A third two-day Workshop is scheduled for 15-16 January 2008 to finalize a draft of the standard.

In support of the GEIA-STD-0009 development process, the RIAC was asked to provide Workshop participants with the six-part “RIAC Blueprints for Product Reliability”. The Blueprints promote effective reliability tasks during each phase of the system/product life cycle.
RIAC JOURNAL SURVEY
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I need help with a reliability, maintainability, quality, supportability, or interoperability problem. ☐ Please contact me
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Total Life Cycle Cost Benefits Calculator for Root Cause Failure Analysis Decision-Making

by David Nicholls

The purpose of this Microsoft Excel® Workbook is to estimate the net total life cycle cost (TLCC) impact of performing root cause failure analysis and corrective action (CA) identification, implementation and verification to improve system, product, assembly, component, part or process reliability. It is intended to be an aid to the decision-making process that can be used to justify (or not) the upfront financial investment needed to perform root cause failure analysis and CA for specific failure incidents and compare them to the savings that may be achieved over the long term by virtue of the improved reliability of the system, product, assembly, component, part or process. It should be noted that net TLCC impact may be only one factor in determining whether root cause failure analysis and CA should be pursued. Other factors that should be considered may include, but not be limited to, (1) the criticality of the item function, (2) safety/liability impacts associated with a failure (regardless of net TLCC), (3) contractual requirements, (4) schedule constraints and/or (5) resource constraints. Where cost is the sole determining factor, however, the results generated by this tool can be used to convince the user, his/her management, a Program Manager and Senior Management of the long-term financial benefits to the company of determining the root cause of a failure, and implementing the corrective action necessary to improve reliability.

The contents of this Workbook cover three separate areas for which root cause failure analysis and CA activities can be implemented. These areas are (1) Hardware, (2) Process and (3) Software. When doing the net TLCC calculations, the user fills in the relevant information in each of these three areas, as necessary, to adequately describe all of the actions needed to implement the full root cause analysis and CA process. For example, a hardware failure may result in a root cause analysis and corrective action process that is traced back to a defective process, or a need to change software. Therefore, the net TLCC analysis should include the various cost elements associated with each of these areas. The Hardware, Process and Software areas are subdivided into the following tabs: (1) the costs associated with performing root cause analysis (RCA Yes), (2) the costs associated with not performing RCA (RCA No), and (3) the net TLCC impact associated with that area (RCA Net TLCC). There is a summary tab (NET TLCC - SUMMARY) that combines the results to present the composite net TLCC impact that should be used to support the decision to proceed with root cause failure analysis and CA (or not) for that specific failure incident.

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