Chair’s Note

Marc Banghart, Chair
Reliability Division of ASQ
marc@asqrd.org
Q1, 2017 Newsletter

Chair’s Message

2017 is off to a great and busy start! The Reliability and Maintainability Symposium (RAMS) held in Orlando, Florida was very successful with high attendance numbers and excellent technical papers. We are proud to sponsor this premier event and urge our members to submit their work to the 2018 conference.

Our next Division leadership team meeting will be held in conjunction with the ASQ World Conference on Quality and Improvement (WCQI) in Charlotte, NC. Our meeting will be on Saturday 29 April from 8am to 5pm. We welcome any member to attend. Please send me an email if you would like more information. If you are attending the conference please stop by our booth and let us know how we are doing!

We continue to expand globally. I am excited to announce a reliability and maintainability course that will be held in conjunction with the ASQ Regional Quality Conference in Dubai. More information can be found at http://asqmeaconference.com/.

I would also like to thank all our members for their continued membership.
The division continued to have a strong balance sheet (Statement of Financial Position) with over $51,600 in its checking and ASQ Investment Program accounts. Investments in ASQ's reserve fund program were over $94,600. There are also advances in the amount of $3,500 each for RAMS 17 and ASTR 17.

* Membership revenue for the twelve months ended December 31, 2016 was $20,016.

* Investment Income for the twelve months ended December 31, 2016 was $7,289.

* Total division revenue from all sources for the twelve months ended December 31, 2016 was $57,488.

* Expenses for the twelve months ended December 31, 2016 were $60,040.

* The net deficit (net loss) for the twelve months ended December 31, 2016 was $3,051

Other Notes:

1. The income from “Education/Courses” was down from 2015. (RAMS and March courses were cancelled due to low enrollment)

2. Spending on on-line education increased from 2015.

3. Travel is our largest expense.

4. Income from advertising continues to be the bright spot in Income this year.

5. Dues reimbursement was down in 2016 by $2,000. This is being questioned in conversations with ASQ Finance. Dues reimbursement for years 2011-2015 were all ~$22,000, while dues reimbursement for 2016 was $20,000. Paid membership has not significantly changed over that same time period.
Building on today’s technology innovations to meet the needs of the modern workplace, Relyence offers an all-new approach to quality and reliability analysis.

Check out our tools to see the Relyence difference. Our complete cloud solutions offer the unparalleled ease and security of the Microsoft Cloud. You simply log in with your web browser and get to work! Our on-premise solutions provide the same high-powered features and functions, with the ability to install locally if you choose.

With Relyence, you have any time, any place, any device flexibility. Built with the needs of today’s collaborative workplace in mind, Relyence allows you the freedom to work however you choose, with the workflow you see fit. PC, laptop, tablet, smartphone – Relyence is designed for today’s fast-paced, virtual workplace.

Take us for a free trial test run today! We’re convinced you’ll see the power awaiting you when you choose to join the Relyence revolution.

Check out our online trial today at www.relyence.com
There’s nothing to install. Just sign up and you’re in!
Prenscia Access

Flexible access to engineering software for durability, reliability and maintenance

Prenscia Access is a unified, token-based licensing model that provides annual leased access to any combination of nCode and ReliaSoft desktop applications.

**Upgrade your organization’s toolkit**
Prenscia Access allows any number of users to run any configuration of applications — limited only by available tokens.

**Unite your engineering processes**
nCode software streamlines test and CAE durability processes, and ReliaSoft’s Synthesis Platform leverages data from all reliability activities.

**Save money across the enterprise**
Every engineer can utilize any or all nCode or ReliaSoft desktop applications at a fraction of the cost of individual licenses.

**Keep every user’s software up-to-date**
All version upgrades and new desktop application releases are included with the Prenscia Access license.
Synthesis Platform Version 11 in now available

Acclaimed for their ease of use, analytical power and unparalleled technical support, ReliaSoft’s reliability software tools facilitate a comprehensive set of reliability engineering modeling and analysis techniques.

The latest Version 11 offers new features in individual applications and significant platform enhancements, such as:

- Greater capabilities for navigating and managing large scale system models
- P-Diagrams, which are integrated with the analysis plan, design FMEA and control plan
- DOE++ functionality included as a part of Weibull++ and ALTA
- Integration with nCode GlyphWorks for utilizing actual stress profiles from data acquisition systems
- Siemens SN 29500 reliability prediction standard now available
- Complete redesign of SEP with enhanced workflows and user experience
- Increased flexibility to import/export FMEA and FRACAS data from Excel® and XML
- More configuration options to fit your organization’s needs with improved reporting capabilities

For more information, visit our website at http://www.reliasoft.com or email us at sales@reliasoft.com
RAMS Throughout the Product Lifecycle

RAMS Orlando 2017

64th Annual Reliability and Maintainability Symposium

The Annual Reliability and Maintainability Symposium (RAMS®) is a yearly gathering of the product assurance disciplines where training, tutorials, and the latest technical practices, procedures, and results are presented in easy-to-utilize forums and proceedings.

RAMS® consistently pushes the leading edge of our discipline and profession through published papers, informative tutorials, excellent networking and product demonstrations.

Coupled with our RAMS® Vendor trade show, RAMS® continues to be one of the most comprehensive gatherings of Product Assurance professionals available in today's competitive business environment.

We focus on providing real-world value for commercial and government applications through succinct delivery of the latest techniques and business practices.

We understand what it takes to succeed in today's market place, as our Symposium is organized and staffed by over 50 individuals, most volunteers, who are currently supporting these disciplines in some form or fashion.

RAMS 2018 General Chair

David Fernald

Keynote Speaker — Coming Soon

Banquet Speaker — Coming Soon

Important Dates

RAMS 2018 Abstract Due: April 15, 2017

Click here for RAMS 2018 Call For Papers

Click here for the RAMS 2017 Program Matrix

Latest Tweets

Tweets by @RAMS_Symposium

RAMS SYMPOSIUM

RAMS 2018 Call for Papers! rams.org/wp-content/uploads/2016/11/ramssympo...rabilityengineer #Engineering

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Embed View on Twitter

RAMS 2018 Announcement Poster

RAMS 2018 Program Matrix
RAMS 2017 was held in Orlando, FL. It was its usual success, drawing over 500 attendees. RAMS (www.rams.org) is sponsored by 9 professional societies, including the ASQ Reliability Division and this year we had a higher percentage representation at the conference than any of the other sponsors. This is not abnormal as the Reliability Division is one of the two most represented at RAMS every year. Suprasad Amari, one of RD’s own members, served as General Chair of the conference.

We offered two courses again this year at RAMS – a CRE Prep course and a course on Communicating Risk and Reliability to Decision Makers. Both were well attended. We also held our annual dinner banquet in conjunction with the EC Division. In addition to a wonderful meal and making announcements about the accomplishments and plans of the division, honorees were on hand to accept our annual awards for the Quality Engineering best paper and RAMS best paper.

The success of RAMS is not only because of its great program and attendees and networking opportunities, but because of the volunteer Management Committee that puts the conference together each year. You get the opportunity to work with a great team of leaders from the reliability community. If you’re interested in joining the management team for a great experience, please contact Trevor Craney (trevor@asqrd.org) for more information. RAMS 2018 will be held in Reno, NV and we look forward to seeing you all there.

Some Photos of the conference are included.

Typical RAMS Speaker session on opening day
Elaheh Rabiei and friend manning the ASQRD booth at RAMS

Education Chair Trevor Craney presenting Dr. Michael Hamada the 2015-2016 ASQ RD QE Best Reliability Paper Award at RAMS 2017.

RAMS Best Paper award Chair Mingxiao Jiang presenting Amirkiaarah Kiani, on the behalf of Professor Sharareh Taghipour, the 2016 ASQ RD RAMS Best Paper Award at RAMS 2017.
I am pleased to announce the paper entitled “Bayesian Analysis of Step-Stress Accelerated Life Tests and Its Use in Planning”, authored by Dr. Michael Hamada and published on Quality Engineering, 27:276–282, 2015, has won the 2015-2016 ASQ RD Best Reliability Paper Award. Congratulations to Dr. Hamada!

In this paper, Dr. Hamada illustrated the use of a modern Bayesian computational method called Markov chain Monte Carlo (MCMC) on analyzing step-stress accelerated life testing (SSALT) data and discussed some aspects of test planning. The paper provided practical advices on how to build the SSALT model and how to develop Bayesian inference on model parameter. One of the ASQ Reliability Division’s missions is to encourage the publication of reliability papers that are both technically sound and easy to be understood by reliability professionals. In this paper, Dr. Hamada introduced the advanced Bayesian inference method to readers by using a concrete engineering example and the clean and accessible writing style.

Quality Engineering is a technical journal of ASQ published by Taylor & Francis. It is directed to professionals in all engineering and management fields interested in quality improvement and reliability. For additional information of ASQ RD Best Paper Award, please contact Dr. Rong Pan at rong.pan@asu.edu.

The Eyring equation (occasionally also known as Eyring–Polanyi equation) is an equation used in chemical kinetics to describe the variance of the rate of a chemical reaction with temperature. It was developed almost simultaneously in 1935 by Henry Eyring, Meredith Gwynne Evans and Michael Polanyi. And is often the bane of Reliability engineers on the CRE exam.

Henry Eyring was born on February 20, 1901 in Colonia JuBrez, a Mormon colony, in the state of Chihuahua, Mexico. He was the third child and first son of Edward Christian Eyring and Caroline Romney Eyring who were of German and English parentage, respectively. Henry’s grandparents had moved from the United States to Mexico in the 1880’s. The Eyrings and Romneys were large families. Henry claimed to have over 200 cousins. The Eyrings had acquired Mexican citizenship and so Henry was born a Mexican citizen. At the time they thought that they had also retained their United States citizenship. It was not until the 1930’s that Henry learned that he was not a US. citizen. It has always been something of a puzzle to me that the Mexican scientific community was largely unaware that Henry was one of them, especially as he was proud of his Mexican origins and frequently told stories of his youth as a Mexican ranchero, complete with Mexican songs learned in his youth.

Eyring was elected president of the American Chemical Society in 1963 and the Association for the Advancement of Science in 1965.
2017 Accelerated Stress Testing and Reliability (ASTR) Conference
Sponsored by IEEE Reliability Society and ASQ Reliability Division

CALL FOR PAPERS AND PRESENTATIONS

Exceeding Customer Expectations Through Accelerated Life Testing

September 27 – 29, 2017

Hilton Garden Inn Downtown, Austin, Texas
www.ieee-astr.org

The 2017 Accelerated Stress Testing and Reliability (ASTR) Conference is focused on highlighting cutting-edge methods to deliver maximum cost-benefits from accelerated reliability testing. ASTR 2017 is relevant to product development, test and manufacturers involved in the aerospace, automotive, consumer electronics, defense, biomedical, telecommunications, software and other leading industries where reliability is a key driver of operational and business success. ASTR 2017 will present detailed case studies, best practices, lessons learned, and clear insight on how to best apply and integrate accelerated testing tools and methods.

Abstracts are invited now with a 150 words summary due by March 15!

The 2017 focus will include (but not limited to):
- The science of test acceleration; integration of design modeling, analysis and accelerated testing
- New Accelerated Test Standards in progress
- Effects of corrosion and high energy radiation on reliability
- Highly Accelerated Life Testing (HALT) and Highly Accelerated Stress Screening (HASS)

OR send proposed papers to JMREL2@Aol.com James McLinn or weibullman@gmail.com Jim Breneman

Become part of this active, growing conference sponsored by both the ASQ-Reliability Division and the IEEE-Reliability Society. The hotel has special rates for this conference.

Accelerated Life Test (ALT) —— details

Day: Tuesday, September 26, 8:00am–5:00 pm

Objective

The successful student will understand how to use accelerated test principles that can improve hardware reliability for systems. Practical design techniques are encouraged with useful examples and case histories that supplement the theory. Design engineers and their managers who are responsible for design and development of long-lived systems. ALT can be a costly and time consuming activity, it is best to get it right the first time.
**Frequently Asked Questions for CBT CRE**

**What kind of calculator can I bring?**

**Calculator Policy:** With the introduction of palmtop computers and the increasing sophistication of scientific calculators, ASQ has become increasingly aware of the need to limit the types of calculators permitted for use during the examinations. Any silent, hand-held, battery-operated calculator **WITHOUT** an alphabetic keyboard will be permitted; however, **all programmable memory MUST be cleared before they enter the exam room. Calculators such as the Texas Instruments TI-83, TI-89 or similar are ABSOLUTELY NOT allowed because they contain alphabetic keyboards.** The examination is written so that a simple calculator will be sufficient to perform all calculations. Calculators that are approved for use during ASQ exams are: 1) Casio fx 115; 2) HP 33 s; 3) HP 35s; 4) TI 30X; 5) TI 36X. However, you may bring your own approved calculator. Examinees are allowed to have a backup calculator if necessary.

No beepers, radios/CD players/iPods/MP3 players, or headphones, Kindles, Nooks, Smart Watches, etc. are allowed. If brought into exam room they MUST be turned off and stored away. **NO CELL PHONES ARE ALLOWED IN THE EXAM ROOM.**

**Is the exam open-book?**

The CRE is open book, with the following rules:

All reference materials (i.e. including all forms of notes) must be bound and remain bound during the exam. Bound refers to material permanently bound by stitching or glue and materials fastened securely in its cover by fasteners, which penetrate all papers (i.e. ring binders, spiral binders, plastic snap binders, brads, or screw posts). Manually or hand stapled documents that are not securely fastened in their covers are not allowed. The size of workspace area at Prometric test centers is limited. The approximate desk dimensions are 48" in length and 24" in width.

Before you enter the exam room, the Test Center Administrator (TCA) will inspect all references. "Post-Its" will be permitted as book tabs only (must be attached prior to entering the test center). Items strictly prohibited in the exam area: hand stapled materials, blank writing tablets or tablets containing blank pages, unbound tablets, unbound notes, slide charts and/or wheel charts (hand-held cardboard or plastic calculating devices with rotating or sliding pieces).

Absolutely no collections of questions and answers or weekly refresher-course quizzes are permitted. Reference sources that contain such copy are not allowed **unless** the questions are removed or obscured.

**Are there any tips to help me prepare for test day?**

Yes, please visit the following webpage for tips to help you prepare for your appointment at a Prometric test center.

Call for Instructors

The Division is looking to expand its cadre of Reliability and Maintainability instructors! If you are interested in teaching and reside in the USA or Europe please send your resume and course abstract to our education chair, Trevor Craney at trevor.craney@shell.com. Instructors may be required to provide a short sample course via WebEx.

ASQ RD invites the interested professional to submit the proposed courses to ASQRD for RAMS 2017. Send the course Description to the ASQ RD education chair, Trevor Craney at trevor.craney@shell.com.

Certified Reliability Engineer (CRE) Handbook

The Certified Reliability Engineer (CRE) Handbook is being updated by a team of volunteers from the Reliability Division to reflect the updated Body of Knowledge (BoK). The BoK is periodically updated based upon the results of a survey administered to current CREs. The survey results are then confirmed by a twelve-member committee which makes the update to the BoK. The new BOK is comprised of five parts including:

Part I  Reliability Fundamentals
Part II  Risk Management
Part III  Probability and Statistics for Reliability
Part IV  Reliability Planning, Testing, and Modeling
Part V  Lifecycle Reliability

The Handbook will have 13 chapters and include acronyms, definitions, and comprehensive...
English webinars:

1. **Planning a Winning Safety Case- ISO 26262 Relevant**
   March 9, 2017, 12:00 PM EDT, Chad Kymal

2. **Reliability Calculation for Dormant k-out-of-n Systems with Periodic Maintenance**
   April 13, 2017, James Li

3. **Design and Analysis of Experiments in MINITAB**
   May 11, 2017, Mohammad Sadegh Mobin

* All English Webinars at 12:00 PM EST

Spanish webinars:

1. **Sobre La Determinación Del Tamaño De Muestra Optima**
   February 28, 2017, Time: 5:00 PM EST, Jorge Romeu

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**ASQ- Reliability Division Webinar Series**

Reliability division offers free Webinars in English, Spanish, and Chinese featuring leading international practitioners, academicians, and consultants. Enhance your reliability knowledge. For more information, click here: [http://asqrd.org/webinars/](http://asqrd.org/webinars/)

The ASQ Reliability Division Webinar Series remains popular. Since the Webinar and Short Course programs were first offered in November 2010, the Reliability Division has provided 168 webinars providing nearly 15,142 hours of professional development to its members at no cost (See page 14 for Detail Statistics). The most recent topics included webinars on:

* ASQ RD Webinar Series - Software FMEA
* ASQ RD Webinar Series - Weibull Analysis II
* ASQ RD Webinar Series - Thermodynamic Degradation Science Physics of Failure, Accelerated Testing, Fatigue

In addition, to date we have provided Recertification Units

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**Webinar Outreach**

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For previously recorded webinars on topics relevant to reliability engineers delivered by subject matter experts. Visit: [http://www.asqrd.org/past-webinars](http://www.asqrd.org/past-webinars)
ASQ Learning Institute™ Training

The ASQ Learning Institute™ provides you with career enhancing training to help you make an impact in your professional path and your organization. Take advantage of member pricing, and register for one of these upcoming courses. To register, click here or call 800-248-1946 and provide promo code MFGEM.

Onsite Training

Customize ASQ learning to meet your organization's unique needs and eliminate travel expenses with on-site training.

Courses

- Certified Quality Engineer Certification Preparation
- Failure Modes and Effects Analysis -- Design
- Failure Modes and Effects Analysis -- Process
- Lean Six Sigma Black Belt Training
- Lean Six Sigma Green Belt Training
- International Courses

See ASQ courses offered outside of the United States and Canada.

CRE Exam Information and Facts

Current CRE statistics:

The total number of CREs as of the March 2015 exam was 5,961. Local ASQ Sections and international organizations host exams all over the world. You will be asked to designate a preferred examination site on your application. If you are not a member of ASQ, please find the Section that is closest to your location. If you live in a country other than the United States, Canada or Mexico, international certification affiliates administer certification exams. Find an international certification exam location. ASQ will make every effort to accommodate your request. ASQ offers some translated certification exams.

The ASQ certification exam dates (by type of certification) is at:

http://prdweb.asq.org/certification/control/dates
ASQ RD Member numbers = 2356 Members
LinkedIn = 3796 members
Twitter = 498 followers

**Webinar statistics:**

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<td>Average attendees</td>
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RD vs ASQ Trend
ASQ Reliability Division Regional Councilor 2016 Annual Report

By: Dan Burrows

Team
At the end of 2016, we have 27 Regional Councilors.

During 2016, we deactivated 17 Regional Councilors who had become unable to fulfill their duties or became ineligible to serve (no longer member of ASQ Reliability Division). We will continue to deactivate Regional Councilors who do not maintain their membership in ASQ Reliability Division or do not perform at least one engagement per year.

During 2016, we recruited 3 new Regional Councilors:
- Rabia Muammar in Jordan
- Riyadh Al-Harbi in Saudi Arabia
- Deven Subramoney in New Zealand

Recruitment
We continue to recruit for Regional Councilors in regions that are not represented:
- Region 2 - Western/Upstate New York & Northern Pennsylvania
- Region 3 - New York City/New Jersey Metro
- Region 7 - Southern California, Arizona, Southern Nevada
- Region 14B - Arkansas, Oklahoma, North Central Texas
- Region 15B - Alabama, Mississippi, eastern Louisiana
- Global - Countries outside of the USA

We are also open to having multiple Regional Councilors for regions since the geographic areas are so large.

Will use social media and our newsletter for recruitment. Engagements

In 2016, we had 23 engagements with local ASQ sections and other organizations to introduce them to the ASQ Reliability Division and educate them on reliability topics. This is a reduction from 30 engagements in 2015.

Future Plans
In 2017, we will provide additional material for Regional Councilors to use for engagements beyond our current introductory presentation:
- Provide materials on the core topics of Reliability Planning, Design for Reliability, FMEA, and Reliability Testing.
- Encourage that Regional Councilors take advantage of our webinar content whereby they can present a recorded webinar that is of interest to their audience and then lead a discussion about the webinar.

In 2017, I will explore conducting a reliability networking event in my area to include ASQ Reliability Division members, CREs, IEEE Reliability Society members, and Society of Reliability Engineer members. The goal of the event is to generate interest in and awareness of what each society offers but recently ASQ RD has been the more involved and active so I believe this could add to ASQ RD ranks.

We will aim to grow the Regional Councilor effort organically and opportunistically to serve ASQ and ASQ RD and make valued contributions to PAR.
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<td>James McLeish <a href="mailto:jmcleish@dfrsolutions.com">jmcleish@dfrsolutions.com</a> Rochester Hills (Detroit), MI</td>
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<td>Dan Burrows <a href="mailto:dan@asqrd.org">dan@asqrd.org</a> Tinley Park (Chicago), IL</td>
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<td>Tim Adams <a href="mailto:tim.adams@nasa.gov">tim.adams@nasa.gov</a> Melbourne (Kennedy Space Center), FL</td>
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<td>David Jennings <a href="mailto:david.jennings@orpaconsulting.com">david.jennings@orpaconsulting.com</a> Atlanta, GA</td>
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<td>Argentina</td>
<td>Leandro Daniel Torres</td>
<td><a href="mailto:infotorresconsulting@gmail.com">infotorresconsulting@gmail.com</a></td>
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<td>China</td>
<td>Mingbin Chen</td>
<td><a href="mailto:mingbin.a.chen@invista.com">mingbin.a.chen@invista.com</a></td>
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<td>Greece</td>
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<td><a href="mailto:rharbi@gmail.com">rharbi@gmail.com</a></td>
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<td>Honduras</td>
<td>Carlos Beza</td>
<td><a href="mailto:carlosbeza@hotmail.com">carlosbeza@hotmail.com</a></td>
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<td>Italy</td>
<td>Alessio Griffoni</td>
<td><a href="mailto:alessio.griffoni@gmail.com">alessio.griffoni@gmail.com</a></td>
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<td>Jordan</td>
<td>Rabia R. Muammar</td>
<td><a href="mailto:r.muammar@outlook.com">r.muammar@outlook.com</a></td>
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</table>
The mission of the Reliability Division is:

* Provide a global forum for networking among practitioners of reliability engineering, management and related topics,
* Facilitate growth and development of division members,
* Promote reliability engineering principles and serve as a technical resource on reliability engineering for ASQ, standards agencies, industry, government, academia and related disciplines.
* Sponsor, present and promote reliability, maintainability, and related training materials for courses, symposia, and conferences.
# 2016-2017 ASQ-RD Leadership Positions

## Elected Positions
- **Chair**
  - Marc Banghart
  - Marc@asqrd.org
- **Chair-elect**
  - Dan Burrows
  - dan@asqrd.org
- **Secretary**
  - Tim Gaens
  - tim.gaens@gmail.com
- **Treasurer**
  - Jim Breneman
  - weibullman@gmail.com
- **Past Chair**
  - Trevor Craney
  - tacraney@yahoo.com

## Appointed Positions (continued)
- **Education & Arrangements Chair**
  - Trevor Craney
  - tacraney@yahoo.com
- **Regional Councilors Coordinator**
  - Dan Burrows (N. America)
  - dan@asqrd.org
- **RAMS**
  - **RAMS Board of Directors**
    - Trevor Craney
    - tacraney@yahoo.com
  - **RAMS Best Paper Award Chair**
    - Mingxiao Jiang
    - Mingxiao.jiang@medtronic.com
- **ASTR**
  - **ASTR General Chair**
    - Charles Recchia
    - charles.recchia@ieee.org
  - **ASTR program Co-Chairs**
    - Jim McLinn/Jim Breneman
    - jmrel2@aol.com/
    - weibullman@gmail.com
  - **ASTR Treasurer**
    - John Bowles
    - bowles@cse.sc.edu
- **QE Best Paper Award Chair**
  - Rong Pan
  - rong.pan@asu.edu
- **CRE Liaison**
  - Mark Durivage
  - mdurivage@hotmail.com

## Outreach
- **Newsletter Editors:**
  - Jim Breneman
  - weibullman@gmail.com
  - Mohammad Pourgol-Mohammad
  - mpourgol@gmail.com
- **Social Media Moderator**
  - Tim Gaens
  - tim.gaens@gmail.com
- **ASQRD.ORG:**
  - **Project Manager**
    - (Vacant)
  - **Webmaster Backup**
    - Marc Banghart
    - Marc@asqrd.org
  - **IT lead**
    - Vacant
  - **Marketing-Constant Contact**
    - Angleat Shelikoff
    - adshelikoff@gmail.com
  - **Subscription Manager**
    - Suprasad Amari
    - suprasad.amari@gmail.com
Using Weibull Analysis in Probabilistic Risk Assessment

Probabilistic risk assessment is used to predict future risk, both number of future events and the event rate. Probabilistic risk assessment is a decision making tool that helps management determine appropriate risk management actions. However, in order to be of value Probabilistic Risk assessment requires the definition of acceptable risk thresholds.

First, the steps in a Probabilistic Risk Assessment:

- Understand cause of failure/type of failure mode
- Define population at risk
- Define historical data
- Using the event prediction method: Weibull/lognormal distribution(s), usually in conjunction with Monte Carlo simulation—especially in complex system problems.
- Determine severity factor (probability of basic event leading to a safety event)
- Compare calculated risk to accepted threshold values
- Determine appropriate risk mitigation actions

Understanding the Physics of Failure is Important for Successful Risk Predictions:

Risk Assessment Example:

Component in automobile system has fracture failure mode with potential safety hazard

LCF Crack initiation Weibull: $\beta = 1.8, h = 300,000$ miles
Crack propagation Weibull: $\beta = 3.3, h = 10,000$ miles
Fracture Time = Crack Initiation Time + Crack Propagation Time
Historically, there have been 3 fractures, the last one nearly caused a catastrophic failure
Inspection Probability of Detection: 0.98
New fleet of 1000 automobiles, average 25,000 miles/year used for 10 years
Acceptable risk threshold: No more than 0.7 catastrophic failures in fleet usage
Is risk acceptable? Are additional risk mitigation actions needed?
Risk Calculation Steps:

1. **Understand the failure mode:**
   - Fatigue failure mode represented by wear-out Weibull distribution.

2. **Population at risk:**
   - 1000 new automobiles
   - Utilized for 10 years at 25,000 miles/year
   - Per automobile: 1 unit x 10 years x 25,000 miles/year = 250,000 miles
   - Fleet: 1000 units x 10 years x 25,000 miles/year = 250,000,000 miles

3. **Historical data:**
   - Three (3) previous fracture events:
     - 2 found during shop maintenance,
     - 1 found by the operator seeing smoke.
   - Historical events/lab findings used to generate crack initiation and crack propagation Weibull distributions.

4. **Prediction method:**
   - Time to fracture = Time to crack initiation + Time to crack propagation

\[
\begin{align*}
\text{Weibull} & \quad \beta = 1.8 \quad \eta = 300,000 \\
& = \\
\text{Weibull} & \quad \beta = 3.3 \quad \eta = 10,000
\end{align*}
\]

NOTE: Using Monte Carlo simulation is a quick method to combine the two distributions

Monte Carlo Simulation to Obtain Fracture Time Distribution (using EXCEL™):
5. **Severity Factor:** 3 Historical events, 1 nearly catastrophic… SF = 1/3 = 0.333

6. **Calculate Risk, Compare to Threshold**
Each automobile accrues 250,000 miles over 10 years

![Fracture Distribution](image)

0.499 probability of failure at 250,000

Fleet events over 10 years:

1000 x 0.499 = 499 fractures

6. **Calculate Risk, Compare to Threshold (continued)**

499 fractures predicted in fleet of 1000 automobiles over 10 years

499 fractures x 0.333 catastrophic events/fracture = 166 catastrophic events

Acceptable Threshold = 0.7 catastrophic events in fleet

**Risk is unacceptable… Corrective actions required.**

7. **Appropriate Corrective Actions:**

Several options can be considered to reduce risk:

a.) Replace component at a defined limit

b.) Inspect component at defined frequency

c.) Retire automobile fleet early

d.) Redesign component to eliminate failure mode

Continuing,

Acceptable threshold criteria = 0.7 catastrophic events in fleet

0.333 is severity factor, or probability of a fracture leading to catastrophic event

This translates to 0.7 catastrophic events / 0.333 = 2.1 fractures acceptable

Each automobile cannot exceed 2.1 / 1000 = 0.0021 fractures

![Fracture Distribution](image)

Indicates life limits will be restrictive and costly… evaluate other options
Next possible step: Recurring Inspections are a common risk mitigation action

Inspection effectiveness is a function of Probability of Detection (POD) and the number of inspection opportunities
Crack propagation time and inspection interval establish number of opportunities
POD based on ease and reliability of inspection technique
Effectiveness = 1 - (1 - POD)^opportunities
POD is known = 0.98 (previous field experience)
Effectiveness must be 1 - (2.1/166) = 0.987 for acceptable risk level
Need to determine number of opportunities...

Monte Carlo Simulation can be used to define the number of opportunities
(again, using EXCEL™)

Summary
Ultimate Fleet Actions Based on Least “Level of Pain” to Achieve Acceptable Risk
In this example an inspection interval of 8000 (miles) would achieve keeping the risk under threshold.
In general, this combination of using available data (or expert opinion if data is not available) along with the well-known Weibull distribution that describes ~95% of failure modes and Monte Carlo simulation illustrates how to achieve a threshold risk in environmental areas, safety risk, financial risk, Maintenance of refineries, and can be ex-