Q&P SPES News

Joint Newsletter for the Section on Physical and Engineering Sciences and the Quality and Productivity Section of the American Statistical Association

Volume 19—Number 1 Established 1995 July 2011

Message from the Q&P Chair

J.D. Williams, 2011 Q&P Chair, JP Morgan Chase

As we approach mid-year, here is an update of the activities of Q&P:

Investing in the Future

The future of our profession lies in the hands of the rising generation of statisticians, many of whom are in undergraduate and graduate statistics programs across the country. These students can benefit enormously from participating in statistical conferences and other professional activities. In order to aid these students in participating in conferences, the Q&P Executive Committee has decided to initiate a student scholarship program to attend the JSM. This year we are funding five scholarships of $400 each to students to attend JSM in Miami Beach, FL. We received numerous applications for this scholarship, and we congratulate the following students for receiving the Q&P Student Scholarship: **Fadel Megahed** (Virginia Tech), **Matthias Tan** (Georgia Tech), **Ye Tian** (Iowa State), **Amanda McCracken** (University of Alabama), and **Gary Mercado** (University of Alabama). Congratulations to our winners and we look forward to recognizing these students at the joint Q&P/SPES mixer at the JSM!

Q&P in conjunction with Stefan Steiner of the University of Waterloo, co-sponsored a student competition, with the winning team receiving a $500 award, plus a travel stipend of $1000 per student for up to three students to attend JSM and present their process improvement implementation. Details of the student competition can be found in the October 2010 *Amstat News* *http://magazine.amstat.org/blog/2010/10/01/qandpoct10/*. We would like to congratulate the following team for their winning entry: **Long Luo** (Southern Methodist University), **Yalan Hu** (Southern Methodist University), and **He Yang** (Mississippi State University), with faculty mentor Hon Keung Tony Ng (Southern Methodist University). These students will present their work at the JSM and we will also recognize them at the joint Q&P/SPES mixer at the JSM.

For many years the Mary G. and Joseph Natrella Scholarhip has been awarded to deserving students to attend the annual Quality & Productivity Research Conference (QPRC) You can read about them in Will Guthrie's article in the subsequent page. In addition, other student travel awards are given to encourage student participation at the QPRC. The winners will also be recognized at the upcoming QPRC in Roanoke, Virginia.

Education

The Q&P webinar series is going very well. On April 21, Dr. Veronica Czitrom hosted the webinar "Graphical Analysis of Designed Experiments." In her webinar, real life examples of design of experiments were shared with the audience as well as a demonstration of graphing data using JMP software. Fifteen members participated in the webinar. Thanks to our Q&P webinar coordinator, Ananda Jayawardhana of Pitt State University, Kansas, for doing such a great job organizing our webinar series. Stay tuned for the next Q&P webinar are details become finalized.

Conferences/Networking

The 2011 Quality & Productivity Research Conference (QPRC) was held on June 7-10 in Roanoke, Virginia. The conference website is *http://www.cpe.vt.edu/qprc/*. Blan Godfrey, Dean of Textiles, North Carolina State University, was the conference honoree. A pre-conference short course entitled "Using Statistical Engineering to Solve Large, Unstructured Problems" was presented by Roger Hoerl and Ron Snee on June 7.

What's Inside . . .

SPES

Q&P

Both

Q&P will have a strong presence at the JSM this year in Miami Beach, FL. In addition to the invited and contributed session, probably the most anticipated event is the joint Q&P/SPES mixer to be held the evening of Tuesday, August 2. There will be ample food, drinks, and of course, DOOR PRIZES. Honestly, the Q&P and SPES sections spend a significant amount of the annual section budget to fund this joint mixer, because of the positive benefits it provides for the section members. We highly encourage you to attend (and to bring your friends and colleagues as well) to meet and greet with other like-minded professionals.

Finally, the 55th Annual Fall Technical Conference will be held on October 13-14, 2011 in Kansas City, Missouri. The Q&P invited plenary speaker for the FTC will be Dr. Christopher Nachtsheim from the University of Minnesota. Congratulations to Chris for this significant achievement. ■

Message from the SPES Chair

Philip R. Scinto, 2011 SPES Chair, The Lubrizol Corporation

I am extremely honored to be sending you my first newsletter message as SPES Chair. I would like to thank all of our members for enabling our section and interests and for making it special. I would like to especially thank our past and present officers for their dedication and service. Without their time and effort, our section could not function. I encourage you to peruse the SPES website and ASA Community to keep up with our list of current officers, as well as view past newsletters and news, and have easy access to conference websites, our industrial speaker program and our LinkedIn forum (*http://www.amstat.org/sections/spes/*).

In our last newsletter, I mentioned that the desire and willingness of SPES members to coach and mentor is one of the great strengths of the section. My vision continues to be for us to be the section that shares. So, how do we share? We share by taking the time to pass along useful visions, philosophies, ideas, techniques and experiences to other statisticians AND non-statisticians in our communities and networks. While the art of speaking directly to people is being somewhat lost due to electronic communications, I would suggest increasing our in-person communication. Make the time to stop by and visit a co-worker, colleague or student, and take advantage of opportunities to present at conferences, seminars and schools. In-person communication not only lets people know that you believe they are important, but it also allows for direct connections. They can better see and feel your passion and commitment, and you can better understand their problems, wants and needs.

As SPES members, we have many in-person opportunities to teach, communicate and learn. We have our JSM sessions (don't forget about Miami Beach this year), the Fall Technical Conference (Kansas City in October this year) and the Spring Research Conference (check the website for 2012 announcements). We also have the Marquardt Memorial Industrial Speaker Program. This program offers a tremendous opportunity to share our experiences with students and our future statisticians. We must keep in mind, however, that the opportunities are only part of successful sharing. Successful sharing, even when drawing on your own accomplishments and experiences, must focus less on 'What I did', which does not actively address the needs of the listener or customer, and focus more on 'Here is what can work for you and why'. The ASA Conference on Statistical Practice (*http://www.amstat.org/meetings/csp/2012/index.cfm*) is a new forum that SPES members may find useful in sharing and learning. While SPES does not sponsor this conference, almost half of the conference organizers are SPES officers. Given the SPES participation in the conference, it is of no surprise that the talks of the conference will focus on 'Here is what can work for you and why'.

Before I leave you to read the rest of this fabulous newsletter, I want to remind you that our JSM Joint SPES/Q&P mixer will be on Tuesday night, August 2 (see program for details). Since I am not LeBron James, I cannot state that I will be taking my talents to the mixer in South Beach. However, I will be there, and I encourage you to attend and say hello to me and the other SPES officers. We will have food, drink, and terrific door prizes. Speaking of door prizes, if you would like to make a door prize donation to the mixer, please speak with Angela Dean (SPES Chair-Elect: *amd@stat.osu.edu*) as soon as possible. I also encourage you to check out the JSM on-line program (*http://www.amstat.org/meetings/jsm/2011/onlineprogram/index.cfm*) to find you favorite SPES sessions. Keep in mind that SPES is involved in sessions starting at 2:00pm and 4:00pm on Sunday, July 31 so don't delay. Get YOUR talents to South Beach as early as you can. ■

Remember: You can always find the most recent issue of this newsletter, along with archives back to 1996, on the SPES and Q&P home pages:

SPES: *www.amstat.org/sections/spes*

Q&P: *www.amstat-online.org/sections/qp*

Message from the SPES Newsletter Associate Editor

Jorge Luis Romeu, Associate Editor, Syracuse University

With this issue of the SPES/Q&P Sections Newsletter, I begin working as Associate Editor. I have big shoes to fill! But I will try my best.

I bring to the job thirty years of Academic and Quality/Reliability consulting experience. I taught applied and industrial statistics at SUNY and Syracuse University, as well as at several universities abroad. And I have helped solve practical statistical problems at the Reliability Analysis Center (formerly RAC, today RIAC), working through several of its contracting organizations.

The Associate Editor's most challenging responsibility is to come up with an interesting applied statistics paper, in every issue. Due to the short deadline, I had to write one for this issue. However, it is the general Newsletter readership who will provide the best input for this assignment, in two key aspects.

First, with your letters and commentary regarding the Newsletter content, and about your interests, you can provide guidance as to what topics in applied statistics you would like to read about. Then, some of you may be inclined to contribute such applied stats papers and tutorials. Contributions are welcome! The guidelines are simple.

An article should be about an applied statistics issue, balancing its applications with the more technical parts. The methods should have been originally developed elsewhere. A numerical and illustrative example should accompany the theoretical support.

Length should be about 10 thousand characters (six or seven pages, single spaced, in Word, Times Roman, Pica 12). There may be tables and figures, to help better understand the application. See previous Newsletter issues, for topic ideas and formatting examples.

Parameters given above are for guidance; they may be negotiable.

I look forward to working with all of you in the Newsletter, and welcome and encourage your correspondence. Feel free to write to *jlromeu@verizon.net* with your comments and your proposals for statistics tutorials. ■

Q&P Program at JSM 2011

Theresa L. Utlaut, Q&P Program Chair, Intel Corporation

It is amazing how quickly the time passes! It seems like not too long ago we were planning for JSM 2010 in Vancouver and now it is already time to make plans for JSM 2011 in Miami Beach. The Quality & Productivity Section is offering a strong program with one invited paper ses¬sion, four topic-contributed sessions, and five contributed sessions. In addition, the section is co-sponsoring a number of sessions that may be of interest to our members that have been coordinated by other sections of ASA. You can find all the Q&P sponsored and co-sponsored sessions by searching the online JSM program by spon¬sor at *http://www.amstat.org/meetings/jsm/2011/onlineprogram/index.cfm*. Please plan which sessions may be most beneficial for you to attend.

Invited Session

On Tuesday, August 2, at 8:30 a.m., an invited paper session organized and chaired by Connie Borror will have presentations on the hot topic "Quality Issues in Healthcare" (Session 282). The speakers are Benjamin Kemper, Jason Gillikin, Victoria Jordan, and James Benneyan.

Quality Issues in Healthcare

Tuesday, 8/2/11, 8:30am

- **Process Improvement in Healthcare: Overall Resource Efficiency**
  Jeroen de Mast, IBIS UvA; ***Benjamin Kemper***, IBIS UvA
- **Quality Issues in Healthcare**
  Jason Gillikin, Spectrum Health
- **Advancing Systems Engineering in Healthcare**
  Victoria Jordan, MD Anderson Cancer Center
- **Healthcare Quality Engineering: Current Practices and Needs**
  James Benneyan, Northeastern University, Center for Health Organization Transformation

Topic Contributed Sessions

Q&P will sponsor four topic-contributed sessions this year at JSM. On Sunday, July 31, at 4:00 p.m., the results from our student competition will be presented by the winning team, "Q&P Student Competition Winning Results - An Application of Statistical Engineering Using WatFactory for Quality Improvement." This contest and session were organized by Stefan Steiner who will also serve as a panelist. The session is chaired by J.D. Williams of JP Morgan Chase.

Q&P Student Competition Winning Results — An Application of Statistical Engineering Using WatFactory for Quality Improvement

Panelists:
He Yang, Southern Methodist University
Long Luo, Southern Methodist University
Yalan Hu, Southern Methodist University
Stefan Steiner, University of Waterloo

On Monday, August 1, at 10:30 a.m., a panel session organized by Theresa Utlaut and chaired by Stu Hunter entitled "Optimal Design of Experiments for Multiple Objectives" will include four panelists and time for floor discussion. The purpose of the panel is to illustrate that it is often possible to find a design that is near optimal for the primary objective but has superior performance across the suite of all objectives.

Optimal Design of Experiments for Multiple Objectives

Panelists:
Timothy Robinson, University of Wyoming
Bradley Jones, SAS
Roselinde Kessels, University of Antwerp
Chris Nachtsheim, University of Minnesota

On Tuesday, August 2, at 2:00 p.m., a session organized by Theresa Utlaut and chaired by Roger Hoerl entitled "In Over Our Heads? Demystifying Complex Problems with Statistical Engineering" will include three panelists and Ron Snee as a discussant. The panel will focus on how to best utilize statistical theory for practical benefit in solving complex challenges.

In Over Our Heads? Demystifying Complex Problems with Statistical Engineering

Panelists:
Martha Gardner, General Electric
Erin Tanenbaum, The Nielsen Company
Will Guthrie, NIST

Discussant:
Ron Snee, Snee Associates

On Wednesday, August 3, at 8:30 a.m., a session organized by Ejaz Syed Ahmed and chaired by Theresa Utlaut entitled "Monitoring and Change Detection in Industrial/Health Quality Control and Related Topics." The session will feature papers on:

- **Sensitivity Analysis Of Predictive Modeling For Responses From The Three-Parameter Weibull Model With A Follow-Up Doubly Censored Sample Of Cancer Patients**
  Saeed Alshahrani, Florida International University
- **Monitoring Process Capability Indices**
  Ejaz Syed Ahmed, University of Windsor
- **Nonparametric Sequential Monitoring Of Longitudinal Trials**
  Edit Gombay, University of Alberta
- **Effect Of Correlations On Risk-Adjusted Cusum Charts For Monitoring Binary Outcomes**
  Abdul K. Hussein, University of Windsor
- **New Cusum Charts For Monitoring Binomial Outcomes**
  Severien Nkurunziza, University of Windsor

Miami Beach, Florida, site of JSM 2011.

Contributed Sessions

Q&P also had some very good contributed submissions that were organized into five sessions. The titles of the presentations and the authors' names and affiliations are as below:

Methods in Experimental Design

Sun, 7/31/2011, 2:00 PM - 3:50 PM

- **The Point Estimation Method Practical Applications In Engineering Design**
  Allan T. Mense, Raytheon Company; Jerry L Alderman, St. Johns Engineering
- **A Comparison Of Location Effect Identification Methods For Unreplicated Fractional Factorials In The Presence Of Dispersion Effects**
  Tom Loughin, Simon Fraser University Surrey; Yan Zhang, Simon Fraser University
- **Supersaturated Designs For Robust Products And Processes**
  Chris Marley, University of Southampton; David Woods, Southampton Statistical Sciences Research Institute (S3RI); Dennis Lin, Pennsylvania State University
- **A Statistical Model Based Quantile Normalization Method For Hit Detection In High Through-Put Screening Experiment (Hts)**
  Xin Wei, Roche Pharmaceutical
- **Another Look At Dorian Shainin's Variable Search Technique**
  Tirthankar Dasgupta, Harvard University, Department of Statistics; Nagesh Adiga, Georgia Institute of Technology; C. F. Jeff Wu, School of Industrial and Systems Engineering, Georgia Institute of Technology
- **Construction Of Balanced Estimation-Equivalent Second-Order Split-Split-Plot Designs**
  Fang Yuan, The University of Alabama; Marcus Perry, The University of Alabama
- **The Lattice Designs By Use Of Pseudo Factors**
  Ateq A. Alghamedi, King Abdulaziz University

Advances in Process Control

Mon, 8/1/2011, 2:00 PM - 3:50 PM

- **The Statistical-Economic Design Of The Xbar Chart Used For Monitoring A Wandering Process Mean**
  Marcela Machado, UNESP; Bruno Franco, UNESP; Antonio Costa, UNESP
- **Sampling Strategies To Reduce The Effect Of The Autocorrelation On The Xbar Chart's Performance**
  Antonio Costa, UNESP; Marcela Machado, UNESP
- **Monitoring The Covariance Matrix In High Dimension**
  Edgard Maboudou, University of Central Florida
- **Evaluation Of The Performance Of A Random Coefficient Regression Model Cusum Control Chart Under Varying Model Conditions: With Human Services Applications**
  Christopher John McKinney, University of Northern Colorado; Jay Schaffer, University of Northern Colorado
- **Monitoring Variability Of Multivariate Processes**
  Amit Mitra, Auburn University
- **Phase I Control Chart Based On A Kernel Estimator Of The Quantile Function**
  Gary R Mercado, The University of Alabama; Michael D. Conerly, The University of Alabama; Marcus Perry, The University of Alabama
- **Stability Analysis In The Exponential Families And Generalized Linear Model**
  Ying Lu, University of Minnesota

Data Streams, Web Pages & Image Analysis

Tue, 8/2/2011, 10:30 AM - 12:20 PM

- **Non-Stationary Network Traffic Diagnosis Under Correlation Context**
  Yingzhuo Fu, University of California, Riverside; Daniel R. Jeske, University of California, Riverside
- **Nonparametric Sequential Change-Point Procedure For Network Surveillance Data**
  Tatev Ambartsoumian, Department of Statistics, University of California, Riverside
- **Website Monitoring And Improvement**
  Roger Longbotham, Microsoft; Ji Chen, Microsoft Corporation; Dave DeBarr, Microsoft Corporation; Shaojie Deng, Microsoft; Justin Wang, Microsoft Corporation
- **Data Quality For Online Experimentation**
  Ji Chen, Microsoft Corporation; Roger Longbotham, Microsoft; Justin Wang, Microsoft Corporation; Shaojie Deng, Microsoft; Dave DeBarr, Microsoft Corporation
- **Framework For Measurement And Prevention Of Human Error In Service Delivery**
  Larisa Shwartz, T.J.Watson Research, IBM; Genady Grabarnik, St. John's University
- **A Spatiotemporal Method For The Monitoring Of Image Data**
  Fadel M. Megahed, Virginia Tech; Lee J. Wells, Virginia Tech; Jaime A. Camelio, Virginia Tech; William H. Woodall, Virginia Tech
- **Use Of Image Analysis Methods In Nondestructive Evaluation**
  Ye Tian, Iowa State University; William Q. Meeker, Iowa State University; Ranjan Maitra, Iowa State University

Reliability Methods: Censoring, Estimation and Control
Wed, 8/3/2011, 2:00 PM - 3:50 PM

- **Two Robust Estimation Techniques For Monitoring Reliability**
  Derya Karagoz (Caliskan), Hacettepe University
- **A Special Nonhomogeneous Poisson Process Estimation For Window-Observation Repairable System**
  Ming Li, Applied Statistics Lab, GE Global Research; Brock Osborn, Applied Statistics Lab, GE Global Research; Yili Hong, Department of Statistics, Virginia Tech
- **Statistical Inference Of Adaptive Progressively Censored Data With Lognormal Lifetimes**
  Fang Duan, Southern Methodist University; Hon Keung Tony Ng, Southern Methodist University
- **Service Life Prediction Using Accelerated Degradation Data From Laboratory Testing And Outdoor Weathering Data**
  Yili Hong, Department of Statistics, Virginia Tech; William Q. Meeker, Iowa State University
- **The Cost Of Reliability: Demonstrating The Financial Benefit Of Reliability Testing**
  Robert O'Donnell, Hewlett-Packard
- **A New Exponential Goodness-Of-Fit Test For Data Subject To Ordinary And Multiply Type Ii Censoring**
  Scott Lesch, Riverside Public Utilities; Daniel R. Jeske, University of California, Riverside
- **Generalized Linear Modeling For Assessment Of A Performance Based Logistics Strategy (Pbl) On Demand/Cost Reductions In An Aging Complex System**
  Mark Carpenter, Auburn University; Wesley Randall, Auburn University

Bayesian Approaches in Quality Control
Thu, 8/4/2011, 8:30 AM - 10:20 AM

- **Experience Of Redesign Of A Bayesian Medical Device Trial**
  Cathy Zeng, Medtronic inc.
- **A Recursive Bayesian Approach In Biosurveillance**
  Gideon Zamba, Department of Biostatistics
- **Bayesian Inference in Multivariate T Linear Mixed Models Using the IBF-Gibbs Sampler**
  Wan-Lun Wang, Feng Chia University; Tsai-Hung Fan, National Central University
- **Bayesian Inference in Joint Modelling of Location and Scale Parameters of the T Distribution for Longitudinal Data**
  Tsung-I Lin, National Chung Hsing University; Wan-Lun Wang, Feng Chia University
- **A Bayesian Acceptance Sampling Model For Combining Judgmental And Randomly Selected Samples**
  Landon H. Sego, Pacific Northwest National Laboratory
- **A Bayesian Approach To Control Attributes**
  Panagiotis Tsiamyrtzis, Athens University of Economics & Business
- **A Bayesian Approach For Interpreting Mean Shifts In Multivariate Quality Control**
  Matthias Hwai Yong Tan, Georgia Institute of Technology; Jianjun Shi, Georgia Institute of Technology ■

2011 Mary G. and Joseph Natrella Scholarship Awards

Will Guthrie, Natrella Scholarship Selection Committee Chair

Ambartsoumian

Szarka

The Quality and Productivity Section will award two Mary G. and Joseph Natrella Scholarships at the 2011 Quality and Productivity Research Conference, which will be held June 8-10 in Roanoke, VA. The scholarships are funded from the ASA Natrella Scholarship Fund and by the Quality and Productivity Research Conference. Each winner will give a research presentation at the conference and will receive a $3500 scholarship, plus $500 for travel expenses and complimentary registration for the conference and the pre-conference short course.

The recipients for 2011 are: **Tatevik Ambartsoumian**, a PhD candidate in the Department of Statistics at the University of California - Riverside, and **John Szarka**, a PhD candidate in the Department of Statistics at Virginia Tech. Ms. Ambartsoumian was recommended for the award by Professors Daniel Jeske and Linda Penas. Her presentation at the conference will be entitled "Generalized Likelihood Ratio Cusum Based on a Nonparametric Kernel Density Estimation." Mr. Szarka was recommended for the award by Professors William Woodall and Jeffrey Birch. The title of his presentation will be "Comparisons to the Early Aberration Reporting System's W2count Method."

The winners were chosen for their outstanding teaching, com¬munity service, mentoring, leadership, scholarship and commit¬ment to the pursuit of quality improvement through the use of statistical methods.

Current members of the Scholarship Selection Committee include Scott Kowalski (Minitab), Christina Mastrangelo (Univ. of Washington), Sharad Prabhu (SAS), and Jolene Splett (NIST). ■

SPES Program of Invited and Topic-Contributed Sessions at JSM 2011

Kary Myers, 2011 JSM Program Chair, Los Alamos National Laboratory

People who know something about Florida promise that Miami Beach in August will be a lot of fun (despite my Midwesterner misgivings). And if our SPES slate of invited and topic-contributed sessions is any indication, it really will be a fun time. As program chair, the fun started early when I found myself with more strong session proposals than available slots for invited sessions. When three of the organizers converted their proposals into topic-contributed sessions, we doubled the number of organized sessions sponsored by SPES and rounded out a really terrific program. The topics range from experimental design and reliability to applications in astronomy, chemical biology, and statistical engineering, plus a panel discussion on forensic science. See below for an overview of these seven sessions.

Miami Beach Convention Center

Efficient Data Collection Techniques for Cutting-Edge Applications (Invited)

Organizer: Xinwei Deng, Department of Statistics, University of Wisconsin-Madison

Efficient data collection through design is one of the fundamental contributions of statistics to society. This session will showcase the importance of efficient data collection techniques in several nontraditional applications. The speakers are Robert Nowak, University of Wisconsin-Madison; Brian Williams, Los Alamos National Laboratory; and Peter Z. G. Qian, University of Wisconsin-Madison.

A Universe of Challenges: Development, Application, and Testing of Statistical Methods in Astronomy and Beyond (Invited)

Organizer: Elizabeth Martinez-Gomez, Center for Astrostatistics, Penn State University

This session addresses the increasing interest of astronomers in applying more sophisticated statistical techniques as well as statisticians' interest in developing and applying new methodologies to complex problems. The speakers are Eric Feigelson, Penn State University; Eric B. Ford, University of Florida; Brandon Kelly, Harvard-Smithsonian Center for Astrophysics; and Chad Schafer, Carnegie Mellon University.

Cheminformatics and Chemical Biology (Invited)

Organizer: Kerby Shedden, Department of Statistics, University of Michigan

During alternating years, SPES sponsors an invited session on chemometrics. This year's session focuses on image analysis, chemical biology, and computational chemistry. The speakers are Kerby Shedden, University of Michigan; Rajarshi Guha, National Institutes of Health Chemical Genomics Center; and Kjell Johnson, Pfizer, Inc.

Statistical Engineering: Creating Sustainable Business Solutions by Integrating Statistics with Science (Topic-Contributed)

Organizer: Stephanie Pickle DeHart, DuPont

During this session, statistical engineering practitioners will discuss their experiences solving large, complex problems that involve the integration of multiple organizations and tools to create beneficial and sustainable solutions. Speakers are Jennifer Van Mullekom, DuPont; Philip Scinto, The Lubrizol Corporation; James Wendelberger, Urban Science Applications, Inc.; and Jennifer Lynn Golek, Barclays. Peter Parker of the NASA Langley Research Center will serve as the discussant.

Reliability and Quantification of Margins and Uncertainties with Application to National Security (Topic-Contributed)

Organizer: Aparna Huzurbazar, Los Alamos National Laboratory

Reliability and industrial statistics methods are extremely important in the physical and engineering sciences. One new emerging area in engineering involves the quantification of margins and uncertainties. This session brings together experts in these areas that work primarily in our nation's national laboratories and armed forces where all of these concepts are used. Speakers are Richard Warr, Air Force Institute of Technology; David Collins, Los Alamos National Laboratory; Alix Robertson, Lawrence Livermore National Laboratory; John Lorio, Sandia National Labs; and Roger Zoh, Iowa State University.

Modern Reliability Data: Opportunities and Challenges (Topic-Contributed)

Organizer: Yili Hong, Department of Statistics, Virginia Tech

The next generation of reliability field data, such as data from smart chips, will contain richer, dynamically recorded information. This session will explore the tremendous opportunities and challenges in using this dynamic information to obtain more accurate predictions of system reliability and to do real-time system health monitoring. Speakers are Bill Meeker, Iowa State University; Necip Doganaksoy, General Electric; I-Li Lu, The Boeing Company; Aparna Huzurbazar, Los Alamos National Laboratory; and Shuen-Lin Jeng, National Cheng Kung University.

Current Issues in Forensic Science (Topic-Contributed Panel)

Organizer: Clifford Spiegelman, Texas A&M University
Chair: Karen Kafadar, Indiana University

This panel will discuss several recent developments in forensic science. First, former National Resource Council panelists will discuss two recent NRC reports: one on the 2001 anthrax attacks (2011), one on strengthening forensic science in the U.S. (2009). Then, members of the Innocence Project will discuss proposed legislation responding to 2009 NRC recommendations. Finally, a member of the statistical community will discuss the state of firearm toolmark evidence in courts post the 2009 NRC report. Panelists are Constantine Gatsonis, Brown University; Sarah Chu, Innocence Project; and Cliff Spiegelman, Texas A&M University.

Look for more details about all of these sessions, as well as the nine contributed sessions sponsored by SPES, in the JSM 2011 online program: *http://www.amstat.org/meetings/jsm/2011/onlineprogram*. ■

SPES Roundtables at 2011 JSM

Paul Kvam, JSM Program Chair-Elect, Georgia Tech

This year, SPES is sponsoring three morning roundtable discussions at the 2011 Joint Statistical Meetings in Miami. Roundtables provide an open environment for speakers to join with the audience in sharing opinions and experiences related to the roundtable subject. SPES roundtable sessions are well attended, and it is advised to sign up early to ensure your place in the session.

On Monday, August 1 (7:00 - 8:15 AM), William H. Woodall of Virginia Tech will present New Directions and Methods in Process Monitoring". He will discuss some of the latest developments in process monitoring and statistical process control. The topics will depend largely on the interests of the participants, but can include the monitoring of image data, profile monitoring, risk-adjusted monitoring in healthcare, and the monitoring of "high quality" attribute processes.

On Tuesday, August 2 (7:00 - 8:15 AM), Alexander Kolovos of SAS Institute, Inc. will share his experiences on "Engaging Stochastic Spatiotemporal Methodologies in Renewable Energy Research". This discussion builds on last year's JSM panel session which explored the interest in connecting statistical methodologies with research in the fields of renewable energy and sustainability. In particular, stochastic spatiotemporal analysis can provide a plethora of tools for fundamental aspects in the modeling of attributes related to renewable energy resources such as solar radiation, wind fields, tidal waves. This session will take a further step forward and engage energy-related disciplines in the industry and the academia to benefit their research from the availability of advanced methodologies in space-time analysis. Ideally, the session looks into enabling a communication core between statisticians and specialists in renewable energy and sustainability to bring forward the potential and benefits of shared research in these disciplines.

On Wednesday, August 3 (7:00 - 8:15 AM), Dorin Drignei of Oakland University leads a discussion on "Statistical Aspects of Complex Computer Models". Computer models are ubiquitous in science and engineering. In industry, they are often used to supplement expensive physical testing. There are inherent uncertainties associated with computer models, and statistics has already made significant contributions in this area. During this roundtable we shall explore some of these complexities and how far can statistics go to address them. We hope to create a bridge between the academia and industry that will enhance further communication in this area. ■

SPES Short Course at the Fall Technical Conference 2011 on Saturday October 15, 2011

Tena Katsaounis, SPES Education Chair, Ohio State University

This year the Section on Physical and Engineering Sciences is sponsoring a one day short course at the 55th Annual Fall Technical Conference "Statistics and Quality: Getting up to Date" (October 13-14, 2011, Kansas City, Missouri) on Reliability growth.

Reliability growth is the improvement in the reliability of a product (component, subsystem or system) over a period of time due to changes in the product's design and/or the manufacturing process. Generally, early prototypes produced during the development of a new complex system will contain design, manufacturing and/or engineering deficiencies leading to reliability below goals or requirements. In order to identify and correct these deficiencies, the prototypes are often subjected to a rigorous testing program that may be specifically dedicated to reliability or integrated into existing engineering and development tests. To properly manage this reliability improvement process a variety of factors must be considered such as the management strategy toward taking corrective actions, effectiveness of the fixes, reliability requirements, the initial reliability level, reliability funding and competitive factors. The reliability currently achieved and the projected reliability impact of proposed future corrective actions must be appropriately measured and analyzed. This tutorial presents reliability growth analysis - the process of collecting, modeling, analyzing and interpreting data from the reliability growth test program. Depending on the metric(s) of interest, the data collection method, and the corrective action strategy, different models can be utilized (or developed) to analyze the growth processes. The models and methods presented in this tutorial are designed for real world applications and are useful to reliability engineering and program management. This hands-on workshop will feature software demonstrations and exercises to illustrate basic reliability concepts in addition to reliability growth methods.

Dr. James Wisnowski is cofounder and principal consultant at Adsurgo. He currently teaches short courses for the Department of Defense in reliability engineering, reliability growth, design of experiments, and data mining methods. Additionally, he provides analytical consulting across various commercial industries to include biotech/pharma, medical, entertainment, and manufacturing. He received his PhD in Industrial Engineering from Arizona State University and retired as a career officer in the US Air Force working on quality and reliability engineering issues.

Participants should bring a personal laptop to load some relevant trial software.

For more information visit *http://www.asqstatdiv.org/ftc.htm*. ■

2011 Statistics in Chemistry Awards

Rick Lewis, Chemometrics Comm. Chair, GlaxoSmithKline

The winners of the 2011 Statistics in Chemistry Award are **Thomas Brendan Murphy**, **Nema Dean**, and **Adrian E. Raftery** for their paper "Variable Selection and Updating In Model-Based Discriminant Analysis for High Dimensional Data with Food Authenticity Applications" published in *Annals of Applied Statistics*, 4(1):396-421.

ASA will be issuing a press release with this, and other award information, in a couple of weeks.The President of the ASA will be presenting this award at JSM. Funding for this year's award was graciously provided by DuPont. One of my goals at this year's JSM is to obtain funding for the 2012 award, and beyond. ■

SPES Awards for Outstanding Presentations and Poster Presentations

Allison Rajakumar, SPES Awards Chair, The Lubrizol Corporation

The Section on Physical and Engineering Sciences is pleased to announce the results of its annual competition for contributed papers presented at the 2010 Joint Statistical Meetings in Vancouver, British Columbia. The outstanding presentation awards encourage

excellence in presentation and have helped to raise the SPES contributed sessions to a higher level of quality. All awards are based on audience evaluations of each speaker. Each year, SPES recognizes the outstanding presentation among all papers contributed to SPES sponsored sessions; the runner-up and honorable mentions are also recognized. Winners receive a certificate recognizing their accomplishment as well as a cash award. The awards for the 2010 JSM best presentations will be presented at the SPES mixer during the 2011 meetings in Miami Beach, FL. The 2010 awards go to:

Outstanding Presentation Award to **William Meeker**, Iowa State University, for the SPES contributed paper "An Automatic Crack Detection Algorithm for Vibrothermography Sequence-of-Images Data." The paper presented is joint work with **Ming Li** and **Steve Holland**, Iowa State University.

Runner-up Outstanding Presentation Award to **Michael Frey**, Bucknell University, for the SPES contributed paper "Robust Probe for the Quantum Pauli Channel." The paper presented is joint work with **Jeffrey Graham**, Susquehanna University, **Lucas Mentch**, Bucknell University, and **Amy Miller**, Muskingum University.

Honorable Mention to **Joel Vaughan**, University of Michigan, for the SPES contributed paper "Network--Specific Computer Traffic Modeling and Prediction." The paper presented is joint work with **Stilian Stoev** and **George Michailidis**, University of Michigan.

Honorable Mention to **Martin Luke Hazelton**, Massey University, for the SPES contributed paper "Inference for Day-to-Day Dynamic Traffic Models." The paper presented is joint work with **Katharina Parry**, Massey University.

Honorable Mention to **Byran Jay Smucker**, Penn State, for the SPES contributed paper "Maximin Model-Robust Designs for Split Plot Experiments." The paper presented is joint work with **Enrique Del Castillo** and **James Rosenberger**, Penn State.

In an effort to encourage excellence in the JSM poster program, SPES began the outstanding poster presentation awards program at JSM 2007. The Section on Physical and Engineering Sciences is pleased to announce the results of its fourth competition for contributed posters presented at the 2010 Joint Statistical Meetings in Vancouver, BC. As with the paper presentation awards, all awards are based on audience evaluations. The awards will be presented to the winners at the SPES mixer during the 2011 meetings. The 2010 awards go to:

Outstanding Poster Presentation Award to **Jin Xia**, Purdue University, for the SPES contributed poster "Characterizing Packet Delay and Jitter Through a Semiempirical Model for VoIP Traffic." The poster presented is joint work with **Mark Daniel Ward** and **William Cleveland**, both from Purdue University.

Runner-up Outstanding Poster Presentation Award to P**eter William Hovey**, University of Dayton/Air Force Academy, for the SPES contributed poster "Are Some Vehicle Colors Safer Than Others?" The poster presented is joint work with **Deogratias Eustace** and **Stephen Owusu-Ansah**, both from University of Dayton.

Congratulations to all the winners!

Start preparing now for JSM 2011 in Miami Beach, FL and you may see your name listed among the SPES Outstanding Presentation Awards or SPES Outstanding Poster Awards winners next year. Good luck to all the 2011 SPES contributed papers and posters presenters. ■

Estimating the Sample Size in Reliability Experiments

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Introduction

The most frequent question posed by our customers, during our fifteen years working as statistical advisors for the *Reliability Analysis Center* **(RAC/RIAC)**, deals with the calculation of the sample size **n** required in experimentation. For, having an adequate sample size saves time and dollars dedicated to the experimentation effort.

Experimental sample size **n** depends, first, on the statistical distribution of the random variable (r.v.) device life, which may be symmetric or skewed. Secondly, it depends on the variability of the distribution, which induces higher levels of uncertainty in the estimations. These have to be compensated by drawing larger sample sizes. Finally, the desired *confidence level* in estimation, or the *Types I and II error probabilities*, in testing problems, constitute yet another factor.

In this paper we present three cases of sample size derivations for location parameters in reliability experiments. We first obtain sample sizes for Exponential distributions. Then, we obtain the sample size for testing the mean of the Weibull distribution. Finally, we present examples of sample size derivation in the non parametric (distribution free) case.

Sample Size for Estimating the Exponential Mean

We know (3), that if **n** device lives X_i, i = 1, … , n, are independent and identically distributed (iid) as Exponential, with mean time to failure (MTTF) μ, then the statistic $2\times T/\mu$ (where $T = \Sigma\, X_i$ is the Total Test Time) is distributed as Chi Square (X^2) with Degrees of Freedom (DF) equal to $2\times n$. Using this statistic, we can derive a $100(1-\alpha)\%$ Confidence Interval (CI) for MTTF μ:

$$\left(\frac{2T}{X^2_{2n,1-\alpha/2}} ; \frac{2T}{X^2_{2n;\alpha/2}} \right)$$

Assume that we want a **precision** τ, for such CI to cover the real (but unknown) MTTF (μ). We can express precision τ as the ratio of the distance of such CI limits, to MTTF μ:

$$\tau = \frac{\mu - \frac{2T}{X^2_{\alpha/2;2n}}}{\mu}; or; \tau = \frac{\frac{2T}{X^2_{1-\alpha/2;2n}} - \mu}{\mu}$$

Following (1), and denoting by $C = X^2_{\alpha/2;2n}$ and $D = X^2_{(1-\alpha)/2;2n}$, we can solve the above system of two equations, for variables C, D and τ, obtaining:

$$\tau = \frac{C-D}{C+D} \Rightarrow \frac{C}{D} = \frac{X^2_{\alpha/2;2n}}{X^2_{1-\alpha/2;2n}} = \frac{1+\tau}{1-\tau}$$

Therefore, we can use the above equation to obtain adequate DF for the desired *precision* and *confidence*. We only need to inspect the Chi Square Tables and find the ratio C/D closest to the ratio $(1+\tau/1-\tau)$, that fulfills the above conditions of confidence $(1-\alpha)$ and precision τ. The DF obtained from such ratio C/D, constitutes the 2n that we are looking for. Hence, the sample size required is given by **n**.

For example, assume we seek the sample size requirement for a 90% CI for MTTF (μ), with a precision τ = 45%. Therefore, for a confidence $(1 - \alpha) = 0.9$, we have: $\alpha = 0.1$, $\alpha/2 = 0.05$, $\tau = 0.45$, and the ratio C/D of the Chi Square coefficients, that yield:

$$\frac{C}{D} = \frac{X^2_{0.95;24}}{X^2_{0.05;24}} = \frac{36.415}{13.848} = 2.629 \cong$$

$$\frac{1+\tau}{1-\tau} = \frac{1+0.45}{1-0.45} = \frac{1.45}{0.55} = 2.636;$$

$$Hence: D.F. = 2 \times n = 24 \Rightarrow n = 12$$

When the sample size **n** required is large, we can use the Normal approximation to the Chi Square distribution: $z = \sqrt{(2X^2_n)} - \sqrt{(2n-1)}$. After some algebra, we obtain from substituting said approximation in the above ratio, the equation for sample size **n**:

$$\frac{1+\tau}{1-\tau} = \frac{(\sqrt{4n-1} + z_{\alpha/2})^2}{(\sqrt{4n-1} - z_{\alpha-2})^2} \Rightarrow n =$$

$$\frac{1}{4} + \left(\frac{1}{2}\right) z^2_{\alpha/2} \left[\frac{1}{\tau}\left(\frac{1}{\tau} + \sqrt{\frac{1}{\tau^2} - 1}\right) - \frac{1}{2}\right]$$

For example, assume we now seek the sample size requirement for a 95% CI for MTTF (μ), with a precision τ = 20%. Then, for a confidence $1-\alpha = 0.95$, we obtain $\alpha = 0.05$, $\alpha / 2 = 0.025$, $\tau = 0.2$ and $z_{\alpha/2} = 1.95$. Substituting above, we obtain:

$$n = \frac{1}{4} + \left(\frac{1}{2}\right) z^2_{0.025} \left[\frac{1}{0.2}\left(\frac{1}{0.2} + \sqrt{\frac{1}{0.2^2} - 1}\right) - \frac{1}{2}\right]$$

$$= 0.25 + \frac{1.95^2}{2}\left(\frac{5 + \sqrt{25-1}}{0.2}\right) - 0.5 = 93.8 \approx 94$$

To verify the accuracy, we calculate the ratio of two Chi Squares, with DF = 2n ≈ 188:

$$\frac{X^2_{0.975;188}}{X^2_{0.025;188}} = \frac{227.863}{151.923} = 1.499 \approx$$

$$\frac{1+\tau}{1-\tau} = \frac{1+0.2}{1-0.2} = \frac{1.2}{0.8} = 1.5$$

Hence, a 95% CI for the Exponential MTTF (μ) of the device lives, with a precision of 20% (i.e. $\tau = 0.2$) of the true MTTF, would require drawing 94 observations.

Sample Size Requirements for Testing the Weibull Mean

Some times we need the sample size requirement **n** for testing, instead of for estimating parameters. In such case, we need both (Types I and II) error probabilities αβ*. We illustrate below this situation for the Weibull distribution. Assume we need the sample size **n** to test the Weibull Mean Life **m**, when Weibull shape parameter β is known, and Types I and II error probabilities, device reliability **R** and test time **T** are given. Weibull distribution also involves a scale or characteristic life parameter η (now a "nuisance" parameter), that we need to drive out of the equations.

We again follow the algorithm described in (1), using the Weibull density f(x), the cumulative distribution F(x), the mean life **m**, and the Reliability R(x):

$$f(x) = \frac{\beta}{\eta^\beta} x^{\beta-1} \exp\{-\left(\frac{x}{\eta}\right)^\beta\} \text{ and } F(x) =$$

$$1 - \exp\{-\left(\frac{x}{\eta}\right)^\beta\} \text{ and } m = \eta \times \Gamma\left(\frac{1}{\beta} + 1\right)$$

$$R(x) = P\{X \geq x\} = Exp\{-(x/\eta)^\beta\}$$

We construct a Test Plan (n, c) that yields a sample size **n**, and a critical number c (of failures to be observed), that meet the confidence and mission time requirements.

We assume that the r.v. *number of failures in test time T*, denoted **c**, can be approximated by a Binomial (n, p) distribution. The parameters are **n**, the number of devices on the life test, and **p**, the probability of device failure, at each independent trial:

$$p = F(T) = P\{X < T\} = 1 - R(T) = 1 - Exp\{-T/\eta)^\beta\}$$

We define a hypothesis test for device mean life **m**, that fulfills error probabilities α and β*, yielding Confidence $(1 - \alpha)$ and Power $(1 - \beta^*)$. The two hypotheses H_i: $m = m_i$ for i = 0,1 were originally based on the Weibull mean. However, they have now become the new hypotheses H'_i: $p = p_i$ for i = 0 or 1, based on the Binomial parameter **p**:

$$p_i = 1 - Exp\left\{-\left(\frac{T}{m_i}\right)^\beta \times \left(\Gamma\left(\frac{1}{\beta} + 1\right)\right)^\beta\right\}; i = 0,1$$

Since Weibull shape β is known, reliability R(T) = 1 – p is only a function of the known test time **T** and the hypothesized Weibull mean **m**. We can then establish a system of two Binomial equations, that fulfill the required α and β*error probabilities of the problem:

$$\sum_{x=0}^{c} C_x^n p_0^x \left(1-p_0\right)^{n-x} = 1-\alpha;$$

$$and: \sum_{x=0}^{c} C_x^n p_1^x \left(1-p_1\right)^{n-x} = \beta^*$$

Solving the above non-linear system, we obtain the appropriate values for **c** and **n**.

Graphical methods for obtaining such **n** and **c** values are the same as those used for obtaining an Acceptance plan from an OC curve (4). Calculate the two p_i, for i = 0, 1, from the equations above. Then, place these two p_i values on the left hand scale, and the (1 – α) and β* values on the right hand scale of an Acceptance Plan nomogram (1, 4, 7).

Finally, we draw the two connecting lines for these pairs of points and find values **n** and **c** in the chart margins, by projecting their intersection. We can check the resulting **n** and **c** values, by substituting them, jointly with values p_i for i = 0,1 and α and β*, in the above Binomial equations. Examples of such computations are given in References 1 and 4.

Again, approximations allow us to avoid graphical procedures. When sample size n is large, r.v. **c** approximates the Normal, with μ = np and σ^2 = np(1 – p). We can then, using the two hypothesized p_i, for i = 0,1, and the two errors probabilities μ and β*, analogously establish a system of two simultaneous equations:

$$\frac{c-np_0}{\sqrt{np_0\left(1-p_0\right)}} = z_\alpha; and; \frac{c-np_1}{\sqrt{np_1\left(1-p_1\right)}} = -z_{\beta^*}$$

Solving them, for the values **n** and **c** that fulfill the problem requirements, we obtain:

$$n = \left[\frac{z_\alpha\sqrt{p_0\left(1-p_0\right)} + z_{\beta^*}\sqrt{p_1\left(1-p_1\right)}}{p_1-p_0}\right]^2;$$

$$and; c = np_0 + z_\alpha\sqrt{np_0\left(1-p_0\right)}$$

For example, assume we seek the sample size **n** required to test that Weibull mean **m** of a device life is 5000 hours, versus that is 1000 hours. The time available for testing each device is only 500 hours, and both probabilities α and β* are 0.01. The Weibull shape parameter is assumed to be β = 2. We first calculate the two p_i, for i = 0 and 1, as above:

$$p_0 = 1-Exp\left\{-\left(\frac{T}{m_0}\right)^\beta \times \left(\Gamma\left(\frac{1}{\beta}+1\right)\right)^\beta\right\} =$$

$$1-Exp\left\{-\left(\frac{500}{5000}\right)^2 \times \left(\Gamma\left(\frac{1}{2}+1\right)\right)^2\right\} = 1-0.9922$$

$$p_1 = 1-Exp\left\{-\left(\frac{T}{m_1}\right)^\beta \times \left(\Gamma\left(\frac{1}{\beta}+1\right)\right)^\beta\right\} =$$

$$1-Exp\left\{-\left(\frac{500}{1000}\right)^2 \times \left(\Gamma\left(\frac{1}{2}+1\right)\right)^2\right\} = 1-0.8217$$

Substituting proportions p_0 = 0.0078 and p_1 = 0.1783 in the equations below, we obtain:

$$n = \left[\frac{z_{0.01}\sqrt{p_0\left(1-p_0\right)} + z_{0.01}\sqrt{p_1\left(1-p_1\right)}}{p_1-p_0}\right]^2 = \frac{z_{0.01}^2\left(\sqrt{p_0\left(1-p_0\right)} + \sqrt{p_1\left(1-p_1\right)}\right)^2}{\left(p_1-p_0\right)^2}$$

$$= \frac{2.326^2\left(\sqrt{0.0078\left(1-0.0078\right)} + \sqrt{0.1783\left(1-0.1783\right)}\right)^2}{\left(0.1783-0.0078\right)^2} = 41.3 \approx 42$$

$$c = np_0 + z_{0.01}\sqrt{np_0\left(1-p_0\right)}$$

$$= 42\times 0.0078 + 2.326\sqrt{42\times 0.0078\times\left(1-0.0078\right)} = 1.66 \approx 2$$

To check the above approximation formulas we use OC nomograms (1, 4). We obtain the values **n = 43** and **c = 2** which are close, as expected.

Sample Size and Nonparametric estimation for at least one failure

Some times, we cannot (or don't want to) assume a specific distribution, but we do know the Reliability requirement. In addition, we need to observe, during the life test, at least one failure. In such cases, we can use a non parametric (distribution free) approach. The cost from not specifying a specific distribution is to define the test length T_0 equal to the Mission Time T. The sample size **n** derived for this case, will guarantee that we will observe at least one failure, with probability 1 – α.

Assume **n** random iid items are placed in a life test, for the prespecified (Mission) Time T = T_0. In addition, assume we will only observe each item the end of the test: that is, at time T_0. Therefore, each item has only two outcomes: to fail or pass such test, of length T_0. Hence, each item on test becomes an independent Bernoulli trial. And the r.v. *total number of failures* ***c****, out of* ***n*** *trials*, is distributed Binomial. The failure probability is **p** = 1 – R, where **R** is the reliability at mission time T_0.

Using the definition of the Binomial distribution, and the required reliability **R**, we state:

$$\Pr ob\left\{Obtaining.x \le c.Failures \middle| n, p\right\} =$$

$$\sum_{x=0}^{c} C_x^n p^x \left(1-p\right)^{n-x} = \sum_{x=0}^{c} C_x^n \left(1-R\right\}^x \left(1-\left(1-R\right)\right)^{n-x}$$

For our case, of *observing at least one failure* with probability 1 – α during the life test:

$$Prob\{Obtaining.AtLeastOne.Failure|n,p\} =$$
$$1 - Prob\{Obtaining.NoFailures|n;p\}$$
$$= 1 - \sum_{x-0}^{0} C_x^n p^x (1-p)^{n-x} = 1 - (1-R)^0 (1-(1-R))^n =$$
$$: 1 - (1-(1-R))^n = 1 - R^n = 1 - \alpha$$

For example, in a test to demonstrate a reliability R = 0.95, with a Confidence 1 – α = 0.9, for a Mission Time of T_0 hours, we place **n** devices in a life test of length T_0. Each device can fail the test with probability **p** = 1 – R = 0.05. Zero failures imply that all **n** devices survive. So we search the Binomial tables for a convenient **n**, that yields zero failures (c = 0) with probability α = 0.1. The Binomial (n, p) equation then reduces to:

$$P\{\text{Observing NO failures}\} = (1-p)^n = R^n = (0.95)^n = \alpha = 0.1$$
$$\Rightarrow (0.95)^{45} = 0.0994 \approx 0.1, \text{ for } \mathbf{n \approx 45}.$$

Therefore, sample size **n** = 45 provides *Confidence* (1 – α) = 0.9, required in the problem statement, of *finding at least one failure*, in a life test for Mission Time T_0, when the true reliability **R** for this mission time $\mathbf{T_0}$ is R = 0.95.

However, searching the Binomial (n, p) tables for a suitable **n** can be tedious and time consuming. We can also use an equivalent equation, derived from Binomial distribution, using failure probability **p** = 1 – R and Confidence 1 – α:

$$\sum_{x=0}^{0} C_x^n p^x (1-p)^{n-x} = (1-p)^n =$$
$$Exp\{nLog(1-p)\} = 1 - Confidence = \alpha$$

Taking Logarithms in both sides and solving for **n**, then substituting **p** = 1 – R:

$$n = \frac{Log(1-Confidence)}{Log(1-p)} = \frac{Log(\alpha)}{Log(R)}$$

For example, applying this formula to the same case given above, we obtain:

$$n = \frac{Log(0.1)}{Log(0.95)} = \frac{-1.0}{-0.02227} = 44.89 \approx 45$$

Both above results are equivalent. However, using the second formula is easier and faster.

We have only developed three cases in this paper. For additional information and further readings on this topic, the reader can consult:

1. Reliability and Life Testing Handbook. Kececioglu, D. Volume 2. Prentice Hall, NJ. 1993.
2. Empirical Assessment of the Weibull Distribution. Romeu, J. L. RAC START. Volume 10, Number3. *http://src.alionscience.com/pdf/WEIBULL.pdf*
3. Reliability Estimations for the Exponential Life. Romeu, J. L. RAC START. Volume 10, Number 7. *http://src.alionscience.com/pdf/R_EXP.pdf*
4. OC Functions and Acceptance Sampling Plans. Romeu, J. L. RAC START. Volume 12, Number 1. *http://src.alionscience.com/pdf/OC_Curves.pdf*
5. Quality Toolkit. Coppola, A. RAC, 2001.
6. Practical Statistical Tools for Reliability Engineers. Coppola, A. RAC, 2000.
7. Probability and Statistics for Engineers and Scientists. Walpole, R., R. Myers, S. Myers. Prentice Hall. NJ 1998.
8. An Introduction to Reliability and Maintainability Engineering. Ebeling, C. E. Waveland Press. IL. 1997. ■

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