Research areas included standby redundancy policies, redundancy allocations in series and parallel systems, goodness-of-fit tests for censored data, autopsy models, nonparametric methods for imperfect repair, inference for systems operating in different environments, and dynamic reliability models. Twenty-nine technical reports were written in the period and twenty-six papers were published in the period.
# FINAL SUMMARY REPORT

for AFOSR Grant 91-0048

October 1, 1990 through September 30, 1994

Research in the Statistical Aspects of Reliability, Availability, and Maintainability

Approved:

[Signature]
Myles Hollander
Professor and Principal Investigator

[Signature]
Duane Meeter
Chairman, Department of Statistics

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1. **Summary.** During the four-year period (October 1, 1990 - September 30, 1994) of Grant AFOSR 91-0048 Statistical Aspects of Reliability, Availability, and Maintainability, Co-Principal Investigators Myles Hollander and Frank Proschan and other researchers partially supported under the Grant, produced 29 technical reports, 26 published papers, and one published book. Myles Hollander and Frank Proschan were Co-Principal Investigators from October 1, 1990 - December 31, 1992. In December, 1992, Frank Proschan retired and Myles Hollander was Principal Investigator from January 1, 1993 - September 30, 1994.

Research topics covered included standby redundancy policies for series systems, redundancy allocations in series and parallel systems, goodness-of-fit tests for censored data, testing the minimal repair assumption in an imperfect repair model, multiple dependent competing risk models, reliability models involving mutual censorship of component lifelengths, convex ordering with applications to reliability, autopsy models in reliability, redundancy, importance and allocation of spares in coherent systems, nonparametric methods for imperfect repair models, wavelet methods for curve estimation, models and inference for systems operating in different environments, stochastic inequalities in system reliability, dynamic models for reliability, nonparametric techniques for analyzing survey data arising in Air Force Quality Management surveys, and dependence properties of order statistics. Consulting was done with Air Force personnel at Eglin Air Force Base, Ft. Walton Beach, Florida and Maxwell Air Force Base, Montgomery, Alabama.

The Reliability Center was active during the period with visitors including Edsel Peña, Bowling Green State University, Ramesh Korwar, University of Massachusetts, Philip Boland, University College, Belfield Dublin, Ireland, Emad El-Neweihi, University of Illinois at Chicago, Kumar Joag-Dev, University of Illinois at Urbana, Ghagik Tsaturgan, Terevan Polytechnic Institute, Teryan, Armenia (former Soviet Union), T.E.S. Raghaven, University of Illinois, Chicago, Frank Samaniego, University of California, Davis, and Yung Tong, Georgia Institute of Technology. Many of the visitors, including P. Boland, E. Peña, E. El-Neweihi, and K. Joag-Dev made multiple visits.

2. **Technical Reports Produced Under Grant AFOSR 91-0048 (October 1, 1990 - September 30, 1994)**

   **A Mixed Limit Theorem for Stable Random Fields**
   by T. V. Kurien and Jayaram Sethuraman
   AFOSR Technical Report No. 91-251, January 1991

   **Singularities in Gaussian Random Fields**
   by T. V. Kurien and Jayaram Sethuraman
   AFOSR Technical Report No. 91-256, January 1991

   **Max-Infinite Divisibility and Multivariate Total Positivity**
   by Abdulhamid A. Alzaid and Frank Proschan

   **Standby Redundancy Policies for Series Systems**
   by Philip J. Boland, Frank Proschan, and Y. L. Tong
   AFOSR Technical Report No. 91-253, January 1991

   **Estimating and Modeling Gene Flow for a Spatially Distributed Species**
   by T. Burr and T. V. Kurien
Stochastic Order for Redundancy Allocations in Series and Parallel Systems by Philip J. Boland, Emad El-Neweihi and Frank Proschan
AFOSR Technical Report No. 91-254, January 1991

Some Classes of Nonparametric Goodness-of-Fit Tests for Censored Data, Part I: Simple Null Hypothesis Case
by Myles Hollander and Edsel Peña

On the Analysis of Grouped Survival Data Using Cumulative Occurrence/Exposure Rates
by Ian W. McKeague and Mei-Jie Zhang

A Stochastic Ordering of Partial Sums of Independent Random Variables and Some Random Processes
by Philip J. Boland, Frank Proschan, and Y. L. Tong

Choosing The Resampling Scheme When Bootstrapping: A Case Study in Reliability
by Yuang-Chin Chiang and Hani Doss

Inequalities for the Parameters λ(F), µ(F) with Applications in Nonparametric Statistics
by C. Dorado and Myles Hollander

Identification of Nonlinear Times Series From First Order Cumulative Characteristics
by Ian W. McKeague and Mei-Jie Zhang

An Elementary Approach To Weak Convergence For Quantile Processes, With Applications To Censored Survival Data
by Hani Doss and Richard D. Gill

Testing the Minimal Repair Assumption in an Imperfect Repair Model
by Myles Hollander, B. Presnell, and Jayaram Sethuraman

A Comparison of Various Estimators in Reliability Models Involving Mutual Censorship of Component Lifelengths
by Robin Antoine, Hani Doss, and Myles Hollander

Stochastic Order in System Reliability Theory
by Philip J. Boland and Frank Proschan
Applications of the Hazard Rate Ordering in Reliability and Order Statistics
by Philip J. Boland, Emad El-Neweihi and Frank Proshcan
AFOSR Technical Report No. 91-269, September 1991

On Identifiability in the Autopsy Model of Reliability Theory
by Robin Antoine, Hani Doss and Myles Hollander
AFOSR Technical Report No. 91-267, October 1991

A General Composition Theorem and its Applications to Certain Partial Orderings of Distributions
by Kumar Joag-Dev, Subhash Kochar and Frank Proshcan

Wavelet Methods for Curve Estimation
by A. Antoniadis, G. Gregoire, and I. W. McKeague

Some Tests for Comparing Cause-Specific Hazard Rates
by E.A.A. Aly, S. C. Kochar, and I. W. McKeague
AFOSR Technical Report No. 91-272, July 1992

Schur Properties of Convolutions of Exponential and Geometric Random Variables
by P. J. Boland, E. El-Neweihi, and F. Proshcan

Some Recent Applications of Stochastic Inequalities in System Reliability
by P. J. Boland, F. Proshcan, and Y. L. Tong
AFOSR Technical Report No. 91-274, September 1992

Transformations of Gaussian Random Fields and a Test for Independence of a Survival Time from a Covariate
by I. W. McKeague, A. M. Nikabadze, and Y. Sun
AFOSR Technical Report No. 91-275, November, 1992

Models and Inference for Series Systems Operating Under Different Environments
by Edsel Peña and Myles Hollander
AFOSR Technical Report No. 91-276, December, 1992

A Partly Parametric Additive Risk Model
by I. W. McKeague and P. Sasieni
AFOSR Technical Report No. 91-277, January, 1993

Bivariate Dependence Properties of Order Statistics
by P. J. Boland, M. Hollander, K. Joag-Dev, and S. Kochar
AFOSR Technical Report No. 91-278, January, 1994

Dynamic Reliability Models Using Conditional Proportional Hazards
by Myles Hollander and Edsel Peña
AFOSR Technical Report No. 91-279, August, 1994
Dynamic Reliability Models
by Myles Hollander and Edsel Peña
AFOSR Technical Report No. 91-280, September, 1994

3. Papers Published Under Grant AFOSR 91-0048 (October 1, 1990 - September 30, 1994).

Inference for a Nonlinear Counting Process Regression Model

Identifying Nonlinear Covariate Effects in Semimartingales
Regression Models by Ian W. McKeague and Klaus J. Utikal

Independence of the Time and Cause of Failure in the Multiple
Dependent Competing Risks Model by Subhash C. Kochar and Frank

Laplace Ordering and its Applications by Abdulhamid Alzaid, Jee Soo Kim,

Stochastic Order for Inspection and Repair Policies by Philip J. Boland,
No. 2, pp. 207-218, (1991)

Some Majorization Inequalities for Functions of Exchangeable
Random Variables by Philip J. Boland, Frank Proschan, and Y. L. Tong.
*Topics in Statistical Dependence*, Ed. by H. W. Block, A. R. Sampson, and T. H.

Information, Censoring, and Dependence by Myles Hollander, Frank
Proschan, and James Scoming. *Topics in Statistical Dependence*, Ed. by H. W.
257-268, (1991)

Convex-Ordering Among Functions, with Applications to Reliability and
Mathematical Statistics by Wai Chan, Frank Proschan, and Jayaram Sethuraman.
*Topics in Statistical Dependence*. Ed. by H. W. Block, A. R. Sampson, and T. H.

Redundancy Importance and Allocation of Spares in Coherent Systems
by Philip J. Boland, Emad El-Neweilihi and Frank Proschan

Dispersivity and Stochastic Majorization
by Abdulhamid A. Alzaid

Birthday Problem with Unlike Probabilities
by Kumar Joag-Dev and Frank Proschan
Stochastic Order for Redundancy Allocations in Series and Parallel Systems
by Philip J. Boland, Emad El-Neweihi and Frank Proschan

Classes of Nonparametric Goodness-of-Fit Tests for Censored Data:
Simple Null Hypothesis Case
by Myles Hollander and Edsel A. Peña

A Chi-Squared Goodness-of-Fit Test for Randomly Censored Data
by Myles Hollander and Edsel Peña

Nonparametric Models for Imperfect Repair Models
by Myles Hollander, Brett Presnell and Jayaram Sethuraman

Nonlinear Time Series Analysis via Cumulative Regressograms
by I. W. McKeague and Mei-Jie Zhang

A Stochastic Ordering of Partial Sums of Independent Random Variables
and Some Random Processes
by P. J. Boland, F. Proschan, and Y. L. Tong

Inequalities for the Parameters $\lambda(F), \mu(F)$ with Applications in
Nonparametrics Statistics
by C. Dorado and M. Hollander

A Comparison of Various Estimators in Reliability Models Involving
Mutual Censorship of Component Lifetimes
by R. Antoine, H. Doss, and M. Hollander
In: *Advances in Reliability* (edited by A. P. Basu) 1-20, North Holland

Some Recent Applications of Stochastic Inequalities in System Reliability Theory
by P. J. Boland, F. Proschan, and Y. L. Tong
In: *Advances in Reliability* (edited by A. P. Basu) 19-41, North Holland

Discussion of T. Hastie and R. Tibshirani's paper "Varying-Coefficient
Models"
by I. W. McKeague and P. Sasieni

On Identifiability in the Autopsy Model of Reliability Theory
by R. Antoine, H. Doss, and M. Hollander
Testing the Minimal Repair Assumption in an Imperfect Repair Model
by B. Presnell, M. Hollander, and J. Sethuraman

Applications of the Hazard Rate Ordering in Reliability and Order Statistics
by P. J. Boland, E. El-Neweihi, and F. Proschan

A Partly Parametric Additive Risk Model
by I. W. McKeague and P. D. Sasiene
*Biometrika* 81, 501-514, (1994)

Identification of Nonlinear Time Series from First Order Cumulative Characteristics
by I. W. McKeague and M. Zhang

4. **Book Published Under AFOSR 91-0048** (October 1, 1990 - September 30, 1994)


5. **Awards and Honors under AFOSR 91-0048** (October 1, 1990 - September 30, 1994)

Frank Proschan and colleague Richard E. Barlow, University of California at Berkeley, jointly received the 1991 von Neumann Award for their fundamental research in reliability theory and practice. The award was presented by the Operations Research Society of America and The Institute of Management Sciences at their Annual Joint Meeting in Nashville, Tennessee, May, 1991.