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The final report briefly describes the accomplishments in research during the grant. It gives a list of the technical reports produced, followed by a list of published papers. In a later section it gives a brief summary of the research findings. Most of this research work was also reported at professional meetings.



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# Final Report

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# 1 ACCOMPLISHMENTS DURING THE GRANT

## 1.1 Introduction

In this chapter, In this Section, we briefly describe the accomplishments in research during the grant. We give a list of the technical reports produced, followed by a list of published papers. In a later section we give a brief summary of the research findings. Most of this research work was also reported at professional meetings. Other sections list our professional activities and Ph D. degrees awarded during the grant.

## 1.2 Publications and Technical Reports under the Grant

### 1.2.1 List of Technical Reports Prepared under the Grant.

A Study of the Role of a Module in the Failure of a System, by E. El-Neweihi and J. Sethuraman.
USARO Technical Report Number **D-112** July 1990.

The asymptotic distribution of the Rènyi Maximal Correlation, by J. Sethuraman.
USARO Technical Report Number **D-113** October 1990.

A mixed limit theorem for stable random fields, by T. V. Kurien and Jayaram Sethuraman
USARO Technical Report Number **D-114** September 1990.

Singularities in Gaussian random fields, by T. V. Kurien and Jayaram Sethuraman
USARO Technical Report Number **D-115** November 1990.

Estimating and modeling gene flow for a spatially distributed species, by Tom Burr and T. V. Kurien
USARO Technical Report Number **D-116** January 1991.

On the analysis of grouped survival data using cumulative occurrence/exposure rates, by Ian W. McKeague and Mei-Jie Zhang
USARO Technical Report Number **D-117** March 1991.

A constructive definition of Dirichlet priors, by Jayaram Sethuraman
USARO Technical Report Number **D-118** May 1991.

The role of a module in the failure of a system, by Emad El-Neweihi and Jayaram Sethuraman

USARO Technical Report Number **D-119** July 1991.

Order statistics and optimal allocation problems, by Emad El-Neweihi and Jayaram Sethuraman
USARO Technical Report Number **D-120** July 1991.

Identification of nonlinear times series from first order cumulative characteristics, by Ian W. McKeague and Mei-Jie Zhang
USARO Technical Report Number **D-121** August 1991.

The role of a group of modules in the failure of systems, by A. M. Abouammoh, Emad El-Neweihi and Jayaram Sethuraman
USARO Technical Report Number **D-122** August 1991.

Testing the minimal repair assumption in an imperfect repair model, by Brett Presnell, Myles Hollander and Jayaram Sethuraman
USARO Technical Report Number **D-123** September 1991.

Discussion of papers of P. Sasieni, E. Slud and J. Wellner, by Ian McKeague.
To appear in the *Proceedings of the NATO Advanced Studies Workshop on Survival Analysis and Related Topics*, Ohio State University, June 1991. Edited by J. P. Klein and P. K. Goel.

Markov chain simulations of binary matrices, by William B. Krebs
USARO Technical Report No. **D-124** January 1992.

A proof of the convergence of the Markov chain simulation algorithm, by Krishna B. Athreya, Hani Doss and Jayaram Sethuraman
USARO Technical Report Number **D-125** July 1992.

Wavelet methods for curve estimation, by A. Antoniadis, G. Gregorie and I. W. McKeague
USARO Technical Report Number **D-126** July 1992.

Some tests for comparing cause-specific hazard rates, by Emad-Eldin A. A. Aly, Subash C. Kochar and Ian W. McKeague
USARO Technical Report Number **D-127** July 1992.

Optimal allocation under partial ordering of lifetimes of components, by Emad El-Neweihi and Jayaram Sethuraman
USARO Technical Report Number **D-128** August 1992.

Multidimensional Strong Large Deviation Theorems, by Narasinga R. Chaganty and Jayaram Sethuraman
USARO Technical Report No. **D-129** 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.
USARO Technical Report Number **D-130** November 1992.

A partly additive risk model, by Ian W. Mckeague and Peter Sasieni.
USARO Technical Report No. **D-131** December 1992.

### 1.2.2 List of Publications under the Grant.

Nonparametric Inference Under Minimal Repair, by M. Hollander, B. Presnell and J. Sethuraman *Proceedings of the Thirty-Fifth Conference on the Design of Experiments in Army Research and Testing* (1990) **35** 103-111.

Families of Life Distributions Characterized by Two Moments, by M. C. Bhattacharjee and J. Sethuraman *Journal of Applied Probability* (1990) **27** 720-725.

Nonparametric Estimation of Trends in Linear Stochastic Systems, by I. W. McKeague and T. Tofoni *Statistical Inference in Stochastic Processes* eds. N.U. Prabhu and I.V. Basawa (1990) **1** 143–166.

Inference for a Nonlinear Counting Process Regression Model, by I. W. McKeague and K. Utikal *Annals of Statistics* (1990) **18** 1172–1187.

Stochastic Calculus as a Tool in Survival Analysis: a Review, by I. W. McKeague and K. Utikal *Applied Mathematics and Computation* (1990) **38** 23–49.

Identifying Nonlinear Covariate Effects in Semimartingale Regression Models, by I. W. McKeague and K. Utikal *Probability Theory and Related Fields* (1990) **87** 1–25.

A Study of the role of a module in the failure of a system, by E. El-Neweihi and J. Sethuraman (1991) *Probability in the Engineering and Informational Sciences* **5** 215–227.

The asymptotic distribution of the Rényi maximal correlation coefficient, by J. Sethuraman (1990) *Communications in Statistics* **19** 4291-4298.

Weighted least squares estimation for Aalen's additive risk model, by Fred W. Huffer and Ian W. McKeague (1991) *Journal of the American Statistical Association* **86** 114–129.

Convex-ordering among functions, with applications to reliability and mathematical statistics, by Wai Chan, Frank Proschan and Jayaram Sethuraman (1991) *Topics in Statistical Independence* Ed. by H.R. Block, A. R. Sampson and T.H. Savits, *IMS Lecture Notes* Monograph **16** 121-134.

Goodness-of-fit tests for additive hazards and proportional hazards models, by Ian McKeague and Klaus Utikal (1991) *Scandinavian Journal of Statistics* **18** 177–195.

A Diffusion Defined on a Fractal State Space, by William B. Krebs (1991) *Stochastic Processes and their Applications* **37** 199–212.

Discussions of papers of P. Sasieni and E. Slud, by I. W. McKeague (1992) *Survival Analysis: State of the Art*, Proceedings of the NATO Advanced Studies Workshop on Survival Analysis and Related Topics, Ohio State University, June 1991, pp. 263–265 and pp. 367–368. Edited by J. P. Klein and P. K. Goel.

Nonparametric methods for imperfect models, by Brett Presnell, Myles Hollander and Jayaram Sethuraman (1992) *Annals of Statistics* **20** 879-896.

Nonlinear time series analysis via cumulative regressograms, by Ian W. McKeague and Mei-Jie Zhang (1992) *Proceedings of the Thirty-seventh Conference on the Design of Experiments in Army Research, Development and Testing* 217-224.

Order statistics and optimal allocation problems, by Emad El-Neweihi and Jayaram Sethuraman (1992) *Order Statistics and Nonparametrics: Theory and Applications, Proceedings of the Symposium on Order Statistics and Nomparametrics, Ed. I. Salama and P. K. Sen.* 93–100.

Two basic partial orderings for distributions derived from Schur functions and majorization, by Kumar Joag-Dev and Jayaram Sethuraman (1992) *Current Issues in Statistical Inference in Honor of D. Basu*, Ed. M. Ghosh and P. K. Pathak, IMS Lecture Notes-Monograph Series, **17** 196–207.

Singularity of Gaussian random fields, by T. V. Kurien and Jayaram Sethuraman (1993) *Journal of Theoretical Probability*, **6** 89–99.

The role of a module in the failure of a system, by Emad El-Neweihi and Jayaram Sethuraman **(1992)** *Stochastic Inequalities*, Ed. M. Shaked and Y. L. Tong, IMS Lecture Notes-Monograph Series, **22** 91–99.

## 1.3 Nontechnical summary of research carried out under the grant

### 1.3.1 Reliability Theory.

**Optimal Allocation and Repair Models:**

Birnbaum, Barlow and Proschan, and others have given various definitions to capture a notion of importance of a component in a system. In Technical Report Number D-112, an alternative concept of the "role" of a module, that is a part of a system, is introduced. The role of a module is defined to be the probability that the module has failed at the time of the failure of the system. The role of a module is studied under various system structures. Applications of these results to optimal allocations of modules are presented.

The tools of arrangement increasing and Schur functions play a central role in establishing stochastic inequalities in several areas of statistics and reliability. The role of a module in the failure of a system measures the importance of the module. In Technical Report No D-119, we define the role of a module to be the probability that this module is among the modules that failed before the failure of the system. A system is called a second order $r$-out-of-$k$ system if it is a $r$-out-of-$k$ system based on $k$ modules, without common components, and where each module is an $a_i$-out-of-$n_i$ system. For such systems, we show that the role of a module is an arrangement increasing or Schur function of parameters that describe the system. These results allow us to compare the role of a module under different values of the parameters of the system.

Order statistics play an important role in reliability. The life time of any coherent system is the first order statistic of the, generally dependent, lives of its cut sets. For the important class of $k$–out-of–$n$ systems, the lifetime of the system is the $n - k + 1$th order statistic of the lives of its components, which are often assumed to be independent. Therefore the reliability of many systems can be easily stated as a probability concerning an order statistic. A system is called a second order $r$-out-of-$k$ system if it is a $r$-out-of-$k$ system based on $k$ modules, without common components, and where each module is an $a_i$-out-of-$n_i$ system. Two features of such systems are of interest, namely the probability that a particular module is among the modules that failed before the failure of the system and the number of failed components at the time of the failure of the system. In Technical Report No. D-120, we review results regarding these features for some special cases of second order $r$-out-of-$k$ systems, emphasizing their applications to optimal allocation problems.

The importance of a module in a system has been a useful concept in Reliability Theory. Several definitions of this concept are available. One such has been called the role of a module in the failure of a system. It is measured by the probability that the module has failed at the time of the failure of the system. In an earlier paper we studied interesting properties of this measure for a class of second order $c$-out-of-$d$ systems. In Technical Report No. D-122 this paper we consider the role of a group of modules. As before this is measured by the probability that at least $s$ modules from this group of modules have failed at the time of the failure of the system, for $s = 1, 2, \ldots$. We use the tools of arrangement increasing functions and majorization to study monotonicity properties of this measure in terms of the parameters of the system.

We consider the competing risks problem with the available data in the form of times and causes of failure. In many practical situations (e.g. in deciding the most appropriate course of treatment for a patient) it is important to know whether the forces of two given risks are equal or whether one is "more serious" than the other. In Technical Report No. D-127, we propose some distribution-free tests for comparing their cause-specific hazard rates and cumulative incidence functions against ordered alternatives without making any assumptions on the nature of dependence between the risks. Both the censored and the uncensored cases are studied. The performance of the proposed tests is assessed in a simulation study. As an illustration we compare the risks of two types of cancer mortality (thymic lymphoma and reticulum cell carcinoma) in a strain of laboratory mice.

Assembly of systems to maximize reliability when certain components of the systems can be bolstered in different ways is an important theme in reliability theory. In Technical Report No. D-128 we consider the problem of optimal assembly under assumptions of various stochastic orderings among the lifetimes of the components and the spares used to bolster them. The powerful techniques of Schur and AI functions are used to pinpoint optimal allocation results in different settings involving active and standby redundancy allocation, minimal repair and shock-threshold models.

### Minimal repair:

Models assuming minimal repair specify that upon repair, a failed system is returned to the working state, which implies that the effective age of the system is held constant; that is, the distribution of the time until the next failure of the repaired system is the same as for a system of the same age which has not yet failed. These models are common in the literature of operations research and reliability, and probabilistic results and the recently proposed inferential procedures of Whittaker and Samaneigao (1989) and Hollander, Presnell, and Sethuraman (1989) depend on the minimal repair assumption. Though tests have been proposed for goodness of fit of the model when a particular form of the distribution is assumed, there are no tests to test the assumption of minimal repair. Technical Report No. D-123 proposes two nonparametric tests of the assumption that imperfectly repaired systems are minimally repaired in the models of Brown and Proschan (1983) and Block, Borges, and Savits (1985). The large sample theory for these tests is derived from the asymptotic joint distribution of the survival function estimator of Whittaker and Samaneigao (1989) and the ordinary empirical survival function based on the initial failure times of new, or perfectly repaired systems. Simulation results are also provided for the null hypothesis case, and under the alternatives proposed by Kijima (1989).

### 1.3.2 Statistics.

**Decision Theory and Inference:**

Rényi gave a definition of a maximal correlation coefficient of bi-variate distribution in 1959. In Technical Report Number D-113, we obtain the asymptotic distribution of the sample maximal correlation coefficient based on a sample from a discrete bi-variate distribution when the marginals are independent. This result can also gives the asymptotic distribution of the Fisher maximal linear correlation between two sets of random vectors which are independent.

Mixed limit theorems in the area of Image Analysis provide approximations for the a random field when both the size of the lattice on which it is defined and the gray scale gradations of the colors at its sites grow together. Such mixed limit theorems have been proved earlier when the acceptor function defining the Markov random field was Gaussian. In Technical Report No. D-114 we obtain a mixed limit theorem for a linear graph when the acceptor function is a stable distribution of index $\alpha$ with $0 < \alpha < 2$.

Many authors have established phase transitions for Markov random fields in various contexts. In Technical Report No. D-115 we establish phase transitions in a simple situation of a Gaussian Markov random field. This result shows that one should exercise caution when using Gaussian Markov random fields as priors in Bayesian image analysis.

Technical Report No. D-116 illustrates the use of Markov random fileds in estimating and modeling gene flow for a spatially distributed species under various assumptions on mating. The relative frequencies of an allele $A1$ at the various sites of the colonies of a species distributed spatially are modeled by a Markov random field in which information about the mating patterns across the colonies can be incorporated as parameters. This parameter is also known as the migration rate. The fitting of a Gaussian Markov random field and the estimation of its parameters are illustrated on simulated data.

The "parameter" in a Bayesian nonparametric problem is the unknown distribution $P$ of the observation $X$. For Bayesian nonparametrics to be successful one needs a large class of priors for which the corresponding posterior distributions can be easily calculated. Unless $X$ takes values in a finite space, the unknown distribution $P$ varies in an infinite dimensional space. Thus one has to talk about measures in a complicated space like the space of all probability measures on a large space. This has always required a more careful attention to the attendant measure theoretic problems. A class of priors known as Dirichlet measures have been used for the distribution of a random variable $X$ when it takes values in $\mathcal{R}_k$ and can be found in the work of Ferguson. This family forms a conjugate family and possesses many pleasant properties. In Technical Report No. D-118 a simple and new constructive definition of Dirichlet measures not requiring the restriction that the basic space should be $\mathcal{R}_k$. is given. This construction is very helpful in carrying out the sometimes difficult computations involving Dirichlet measures.

### Markov chain simulation methods

Markov chain simulation methods include the popular Gibbs sampler. These methods have become very important in the computational analysis of Bayesian posterior distributions, when they become intractable. The Markov chain simulation method is successful only when it can be proved that it converges. When the distributions are discrete and give positive mass to each point it is easy to establish convergence. Many authors have claimed, without proofs, that convergence occurs even when the distributions are not discrete. In Technical report No. D-125 we provide a complete and rigorous proof of the convergence of the Markov chain simulation method under easily verifiable conditions.

### Inference from Stochastic Processes:

A conditional hazard function can be estimated from grouped (and possibly censored) survival data by using the classical occurrence/exposure rate over cells that partition the time and covariate state space. In Technical Report No. D-117, we obtain asymptotic results for cumulative versions of this estimator using counting process methods. Various constraints on the asymptotic behavior of the widths of the calendar periods and covariate strata employed in grouping the data are needed to prove the results. The results are used to give a grouped data based goodness-of-fit test for Cox's proportional hazard model.

In Technical Report No. D-121 we consider the problem of identifying the class of time series model to which a series belongs based on observation of part of the series. Techniques of nonparametric estimation have been applied to this problem by various authors using kernel estimates of the one-step lagged conditional mean and variance functions. We study cumulative versions of Tukey regressogram estimators of such functions. These are more stable than estimates of the mean and variance functions themselves and can be used to construct confidence bands as well as goodness-of-fit tests for specific parametric models.

The theory of wavelets is a developing branch of mathematics with a wide range of potential applications. Compactly supported wavelets are particularly interesting because of their natural ability to represent data with intrinsically local properties. They are useful for the detection of edges and singularities in image and sound analysis, and for data compression. However, most of the wavelet based procedures currently available do not explicitly account for the presence of noise in the data. A discussion of how this can be done in the setting of some simple nonparametric curve estimation problems is given in Technical Report No. D-126. Wavelet analogues of some familiar kernel and orthogonal series estimators are introduced and their finite sample and asymptotic properties are studied. We discover that there is a fundamental instability in the asymptotic variance of wavelet estimators caused by the lack of translation invariance of the wavelet transform. This is related to the properties of certain lacunary sequences. The practical consequences of this instability are assessed.

It has been almost sixty years since Kolmogorov introduced a distribution-free omnibus test for the simple null hypothesis that a distribution function coincides with a given distribution function. Doob subsequently observed that Kolmogorov's approach could be simplified by transforming the empirical process to an empirical process based on uniform random variables. Recent use of more sophisticated transformations has led to the construction of asymptotically distribution-free omnibus tests when unknown parameters are present. In Technical Report No. D–130 we use the transformation approach to construct an asymptotically distribution-free omnibus test for independence of a survival time from a covariate. The test statistic is obtained from a certain test statistic *process* (indexed by time and covariate), which is shown to converge in distribution to a Brownian sheet.

Aalen's additive risk model allows the influence of covariates on a hazard function to vary over time, and to do so in a different fashion for each covariate. Although allowing greater flexibility than a Cox model, which has a more parsimonious temporal structure, Aalen's model is more limited in the number of covariates it can handle. One way around this difficulty is to impose some a priori structure on the form of the model, thereby reducing the number of functions to be estimated. In Technical Report No. 131, we introduce a partly parametric version of Aalen's model in which only a small number of the covariates are selected to have their influence vary nonparametrically over time, and the influence of the remaining covariates is restricted to be constant in time. Efficient procedures for fitting this new model are developed and studied. The approach is applied to data from the British Medical Research Council's myelomatosis trials.

### 1.3.3 Probability

In Technical Report No. D-124 we consider Markov chains to simulate graphs with a fixed degree sequence and binary matrices with fixed row and column sums. By means of a combinatorial construction, we bound the subdominant eigenvalues of the chains. Under certain additional conditions, we show that the bounds are polynomial functions of the degree sequences and the row and column sums, respectively.

**Large Deviations:**

In Technical Report No. D-129 we obtain a strong large deviation result for an arbitrary sequence of random vectors under simple and verifiable conditions on the moment generating functions. The key to this result is a local limit theorem for arbitrary sequences of random vectors which is also proved in this paper. The local limit theorem gives conditions on the characteristic functions of random vectors for their pseudo-density function to converge uniformly on bounded sets. We apply these results to the multivariate $F$-distribution.

### 1.3.4 Professional activities during the period covered by the grant

**J. Sethuraman:**

Attended the spring meeting of the Institute of Mathematical Statistics at E. Lansing, MI, May 1990.

Participated in a workshop to disseminate the David II report on the state of Mathematics, organized by the Board of Mathematical Sciences in Washington, DC, June 1990.

Attended the Joint Annual Meetings of the American Statistical Association (ASA) and the Biometric Society (ENAR/WNAR) and attended a meeting the Committee on Applied and Theoretical Statistics (CATS) in Anaheim, CA , August 1990.

Participated in the Army Design of Experiments Conference at Newark, DE, October 1990.

Participated in a panel discussion on the David II report and chaired the Statistics session at the Annual Mathematics Chairs Colloquium in Washington, DC, October 1990.

Participated in a review of center proposals for the U.S. Army Research Office, Research Triangle Park, NC, November 1990.

Attended the meeting of the Florida Chapter of the ASA in Gainesville, FL, January 25–26, 1991.

Participated in the meeting of the Committee for Applied and Theoretical Statistics at Irvine, CA, February 1, 1991.

Attended the Army statistical consulting group and planning meeting for the Army Workshop in Washington, DC, February 6, 1991.

Gave an invited talk at the International Conference on Nonparametrics and its Applications at Ottawa, Canada, May 4–8, 1991.

Gave an invited talk at the conference on Stochastic Inequalities, University of Washington, Seattle, WA, July 6–12, 1991.

Chaired the meeting of ASA Institutional Heads and Department Chairs, and participated in the meeting of the Committee on Applied and Theoretical Statistics during the annual meeting of the ASA in Atlanta, GA, August 18-14, 1991.

Participated in the 48th Session of the International Statistical Institute held at Cairo, Egypt, September 9-17, 1991

Gave an invited Talk at the satellite meeting on Order Statistics and its Applications held at Alexandria, Egypt, September 18-20, 1991.

Chaired a panel on Statistics and participated on a panel in the Annual Mathematics Chairs' Colloquium, sponsored by the Board on Mathematical Sciences, held at Washington, DC, October 18-19, 1991.

Panelist in a technical paper session at the 27th Conference on Design of Experiments in Army Research, Development and Testing, held at Vicksburg, MS October 23-25, 1991.

Gave a talk to the College of Arts and Sciences and a talk in the Statistics Colloquium at the University of Northern Illinois, Dekalb, IL, October 30 and November 1, 1991.

Presented an invited talk at the First Triennial International Calcutta Symposium on Probability and Statistics, University of Calcutta, WB, India, December 27, 1991 - January 1, 1992.

Gave a talk at the Indian Statistical Institute, Calcutta on December 31, 1991.

Gave a talk at Madras University, Madras, India on January 7, 1992.

Attended the meeting of the Florida Chapter of the American Statistical Association at the University of Central Florida, Orlando, FL, February 7-8, 1992.

Participated and arranged for a panel on Statistical Quality Issues at the Workshop in Intelligence at the Army Research Office, Research Triangle Park, NC, March 7,8, 1992.

Attended the workshop on Statistical Hydrodynamics and large Deviations at MSRI, Cornell University, Ithaca, NY, April 5-7, 1992.

Presented a paper at the Joint Annual Meetings of the American Statistical Association, the Biometric Society, and IMS; Boston, MA, August 9–13, 1992.

Presented an invited paper at the Workshop on Changepoint Analysis and Empirical Probability at Carleton University, Ottawa, Canada, September 1–6, 1992.

Gave a talk at the departmental colloquium in the Department of Statistics, University of California, Davis, CA, October 27, 1992.

Gave a talk at the Neyman seminar in the Department of Statistics, University of California, Berkeley, CA, October 28, 1992.

Presented a paper and participated in a panel session at the Thirty-eighth Conference on Design of Experiments in Army Research, Development and Testing, held at Santa Monica, CA, October 28–30, 1992.

Gave a talk at the Indian Statistical Institute, Bangalore, India, December 11, 1992.

Gave a talk at the Indian Statistical Institute, Calcutta, India, December 14, 1992.

Presented an invited paper at the International Symposium on Multivariate Analysis held in Delhi, India, December 18–December 22, 1992.

**I. W. McKeague:**

Invited talk, Joint Annual Meetings of the American Statistical Association (ASA) and the Biometric Society (ENAR/WNAR), Anaheim, California, August 1990.

Contributed talk, 2nd World Congress of the Bernoulli Society and the 53rd Annual Meeting of the Institute of Mathematical Statistics, Uppsala, Sweden, August 1990.

Attended Annals of Statistics Editorial Board and IMS Council Meetings at the 53rd Annual Meeting of the Institute of Mathematical Statistics, Uppsala, Sweden, August 1990.

Invited discussant, Nato Advanced Studies Workshop on Survival Analysis and Related Topics, Ohio State University, Columbus, June 23–28, 1991.

Invited discussant, Nato Advanced Studies Workshop on Survival Analysis and Related Topics, Ohio State University, Columbus, June 23–28, 1991.

Invited speaker, The Thirty-Seventh Conference on Design of Experiments in Army Research, Development and Testing. U.S. Army Engineering Waterways Experiment Station, Vicksburg, Mississippi, October, 1991.

Two contributed papers, Joint Annual Meetings of the American Statistical Association (ASA), the Biometric Society (ENAR/WNAR) and IMS, Atlanta, Georgia, August, 1991.

Invited visitor and participant, *Program on Non and Semiparametric Models and Survival Analysis*, December 1991–January 1992, Mathematical Sciences Research Institute, University of California, Berkeley.

Invited visitor, Department of Statistics, Université Joseph Fourier, Grenoble, France, February–May 1992. Gave two seminar talks.

Invited talks at University of Padua, University of Cologne, University of London, University College Dublin, and University College Cork, June 1992.

Invited speaker at a conference to celebrate the tenth anniversary of the Institute of Statistics, Academia Sinica, Taiwan, July 1992.

Attended the Joint Annual Meetings of the American Statistical Association, the Biometric Society, and IMS; Boston, MA, August 9–13, 1992.

**W. B. Krebs:**

Presented a paper at the 21st annual conference on Stochastic Processes and Applications, held at York University in Toronto, June 1992.

### 1.3.5 Ph. D. Degrees Awarded

**Mei-Jie Zhang** Cumulative Regression Function Methods in Survival Analysis and Time Series, (1991) (dissertation directed by Ian McKeague).

**T. V. Kurien** Limit Theorems for Markov Random Fields, (1991) (dissertation directed by Jayaram Sethuraman).

**Yanqing Sun** Transformations of certain Gaussian random fields, with applications in survival analysis, (1992) (dissertation directed by Ian McKeague).

**Donna Carol Herge** Effects on inspection error on optimal inspection policies and software fault detection models (1992) (dissertation directed by Frank Proschan and Jayaram Sethuraman).