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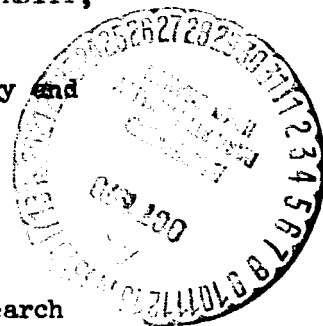
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FINAL REPORT: NASA GRANT NGR-10-004-029 to FLORIDA STATE UNIVERSITY,
September 1, 1965 to September 1, 1970

PROJECT TITLE: Biostatistics of Space Exploration: Microbiology and
Sterilization

PRINCIPAL INVESTIGATOR: Richard G. Cornell
September 15, 1970



The purpose of this grant has been to provide continuing research support on statistical problems arising in investigations on the decontamination of spacecraft and related studies of microbial life. This has been done through statistical studies described in the Technical Reports, Other Reports and Journal Publications listed at the end of this report and through consultation to the Planetary Quarantine Officer, Mr. Lawrence B. Hall, to the Spacecraft Sterilization Advisory Committee and to other scientists working with NASA on space quarantine.

Consultation on research problems was enhanced by attendance of the Principal Investigator, Richard G. Cornell, at meetings of the Spacecraft Sterilization Advisory Committee during the period from 1965 through early 1968 and by his membership on this Committee during 1967. He prepared Technical Report Number 2 for presentation to this committee. He also visited the jet propulsion Laboratory during March, 1966 to work with scientists there and during that same year prepared a standard nomenclature of mathematical terms for Mr. Hall which is listed at the end of this as Technical Report Number 5 and which formed the basis for the preparation of a COSPAR document. On February 8 and 9, 1967, Professor Cornell chaired a meeting of the subcommittee on Mathematical Models of the Spacecraft Sterilization Advisory Committee. He prepared

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the minutes of that meeting which are listed below under Other Reports.

He also worked closely with Norman J. Petersen of the Applied Microbiology and Planetary Quarantine Section of the Phoenix Laboratories of the National Communicable Disease Center and that work led to Technical Report 17 and Journal Publications 8 and 12. This latter publication is scheduled to appear in the December, 1970 issue of Biometrics. Reprints will be sent to NASA as soon as they are available.

Research initiated at Florida State University under this grant is of three main types: spacecraft sterilization probability models, statistical procedure for microbial assays and related nonlinear regression problems, and statistical procedures of general usage. Technical Reports 1, 14, 15 are on the first of these topics. The latter two describe a way of incorporating several types of biological losses, including a loss of information through inaction, into space quarantine decisions while the former is a critique of the work of Sagan and Coleman.

The second topic is the subject of Technical Reports 3,4,6,7,8,9,10,11 17,20,21,22 and 23 and Publications 1,4,5,9 and 12. Technical Report 3 and Publication 4 contain a review of literature and illustrations of the estimation of the exponential die-off parameter in a quantal assay model. Technical Reports 6,17,20,21 and 23 and Publication 12 contain the development of new procedures, including Bayesian procedures, for the same model which is often used in the analysis of microbial decontamination data. The Bayes procedures give an explicit mechanism for combining past experimental evidence with new results. Other exponential die-off

models for count data are developed in Technical Reports 8 and 22. Technical Reports 20, 21, and 22 accompany this report. Preparation of Technical Report 23 is still underway and it will be sent later. Articles based on Technical Reports 6 and 8 and 20 through 23 are concurrently being submitted for journal publication. It is anticipated that publication will result in a little over one year, at which time reprints will be sent to NASA. Technical Reports 4, 7, 9, 10, and 11 and Publications 1, 5 and 9 develop estimation procedures for more general nonlinear models.

The last of the three areas of research, statistical methodology in general, is the classification of Technical Reports 12, 13, 16, 18 and 19, the dissertation of William E. Lever listed under Other Reports, and Publications 2, 3, 6, 10, and 11. Reprints of Publications 10 and 11 accompany this report. The work of Dr. Myles Hollander, which constitutes most of this research, is concerned with nonparametric statistic and is applicable to experimental data in a wide variety of situations.

TECHNICAL REPORTS

1. Spacecraft Sterilization Requirements, Richard G. Cornell, February, 1966.
2. Variation in Measurements of Microbial Loads, Richard G. Cornell, February, 1966.
3. Estimation for a Simple Exponential Model, Richard G. Cornell and Janace A. Speckman, February, 1966.
4. Simultaneous Nonlinear Estimation, John J. Beauchamp and Richard G. Cornell, February, 1966.
5. A Nomenclature of Symbols Relevant to the Probability of Contaminating Mars, Richard G. Cornell, August 1966.
6. Dilution Model: A Bayesian Approach, Andreś Petrášovits, August, 1966.
7. A Newton-Gradient Method for Non-linear Problems in Hilbert Space, Duane A. Meeter, August, 1966.
8. Estimation of the Parameters in Exponential Decontamination Models, Richard G. Cornell, February, 1967.
9. Spearman Simultaneous Estimation for a Compartmental Model, John J. Beauchamp and Richard G. Cornell, February, 1967.
10. Simultaneous Estimation by Partial Totals for Compartmental Models, John J. Beauchamp and Richard G. Cornell, February, 1967.
11. Simultaneous Nonlinear Estimation, John J. Beauchamp, February, 1967.
12. Asymptotic Efficiency of Two Nonparametric Competitors of Wilcoxon's Two Sample Test, Myles Hollander, February, 1967.
13. Certain Uncorrelated Nonparametric Test Statistics, Myles Hollander, September, 1967.
14. Biological Losses and the Quarantine Policy for Mars, S. Eric Steg and Richard G. Cornell, February, 1968.
15. A Martian Quarantine Risk Model, S. Eric Steg and Richard G. Cornell, March, 1968.
16. A Comparison of Two Model-Discrimination Criteria, Duane Meeter, Walter Pirie and William Blot, October, 1968.
17. Evaluation of a Quantal Response Model with Variable Concentrations, Richard G. Cornell, March, 1969.

18. Contingency Table Analysis by Means of a Linearizing Transformation of Poisson Variates, Gerald van Belle, September, 1969.
19. Population Estimation with Plot Removal Sampling, Duane A. Meeter, Richard G. Cornell and Douglas S. Robson, September, 1969.
20. Bayesian Analysis for an Exponential Surveillance Model, Andrés Petrásovits and Richard G. Cornell, August, 1970.
21. Approximations to the Bayes Estimate for a Quantal Assay with Simple Exponential Tolerance Distribution, Andrés Petrásovits and Richard G. Cornell, September, 1970.
22. Exponential Decontamination Models for Count Data, Richard G. Cornell and Ashok K. Bansal, September, 1970.
23. A Spearman-Based Bayes Estimation Procedure for a Serial Dilution Assay, Andrés Petrásovits and Richard G. Cornell, 1970.

OTHER REPORTS

- Minutes of the Mathematical Models Subcommittee of the Spacecraft Sterilization Advisory Committee of the American Institute of Biological Sciences, Richard G. Cornell, February, 1967.
- Part 1 - The Limiting Distribution of the Likelihood Ratio Statistic $-2 \ln \lambda_n$ Under a Class of Local Alternatives: Part 2 - Minimum Average Risk Decision Procedures for the Noncentral Chi-Square Distribution, William E. Lever, Dissertation, Florida State University, January, 1968.

JOURNAL PUBLICATIONS

1. Beauchamp, J. J. and Cornell, R. G., "Simultaneous nonlinear estimation," Technometrics 8 (1966), 319-326.
2. Hollander, M., "Rank tests for randomized blocks when the alternatives have an a priori ordering," Annals of Mathematical Statistics 38 (1967), 867-877.
3. Hollander, M., "Asymptotic efficiency of two nonparametric competitors of Wilcoxon's two-sample test," Journal of the American Statistical Association 62 (1967), 939-949.
4. Cornell, R. G. and Speckman, J. A., "Estimation for a simple exponential model," Biometrics 23 (1967), 717-737.
5. Beauchamp, J. J. and Cornell, R. G., "Simultaneous estimation by partial totals for compartmental models," Journal of the American Statistical Association 63 (1968), 573-583.
6. Hollander, M., "Certain uncorrelated nonparametric test statistics," Journal of the American Statistical Association 63 (1968), 707-714.
7. Steg, S. E. and Cornell, R. G., "Biological losses and the quarantine policy for Mars," Space Life Sciences 1 (1969), 514-519.
8. Petersen, N. J., Puleo, J. R. and Cornell, R. G., "Release of microbial contamination from fractured solids," Space Life Sciences 1 (1969), 531-537.
9. Beauchamp, J. J. and Cornell, R. G., "Spearman simultaneous estimation for a compartmental model," Technometrics 11 (1969), 551-560.
10. Hollander, M., "A distribution-free test for parallelism," Journal of the American Statistical Association 65 (1970), 387-394.
11. Meeter, D., Pirie, W. and Blot, W., "A comparison of two model-discrimination criteria," Technometrics 12 (1970), 457-470.
12. Cornell, R. G. and Petersen, N. J., "Evaluation of a quantal response model with estimated concentrations," Biometrics 26 (1970).