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CAMERON STATION ALEXANDRIA. VIRGINIA

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Contract Nonr 266/04·

Task 047-005

Department of Industrial and Management Engineering
Columbia University
New York, N.Y. 10027

F I N A L   R E P O R T
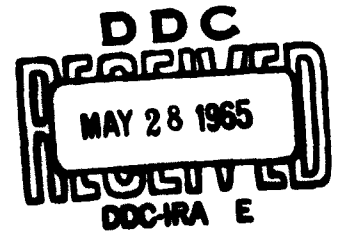
Sebastian B. Littauer

Project Director

15 May, 1965

The following is a final summary report on Contract
Nonr 266(04), Task No. 047-005, as of the date of termination
of this contract June 30, 1964.   This report covers some
eleven years during the incumbency of the present project
director.   It includes in the first part a statement of the
scientific accomplishment, in the second part a review of the
various honors accorded scientists associated with this con-
tract.   Reference is made to a number of the scientific
contributors.

Scientific Accomplishments

Some 30 scientists were associated with this contract,
a number of them quite distinguished.   Principal among these
were Professors J. Wolfowitz, A Dvoretsky and J. Kiefer.
Among other well known scientists who worked on the contract
for longer and shorter periods were

L. Hurwicz	B. Mandelbrot
S. Kakutani	J. Marschak
G. Kallianpur	J. Tiago de Oliveira
T. Koopmans	L. Weiss

A number of graduate students had the opportunity to
develop while working on this contract.   Some of them did

excellent work and produced fine dissertations. Outstanding
among these is Lawrence D. Brown.

Many directions were pursued contributing to the main
aims of the contract. Specific directions receiving con-
siderable attention are: 1) inventory policy, 2) information
theory, 3) optimal design of experiments, and 4) statistical
control principles. We are summarizing essential highlights
of the scienfitic achievements during the life of the contract.

One of the principal and most effective contributions
to the contract was the work done by A. Dvoretsky, J. Kiefer
and J. Wolfowitz in 1952 and 1953 on optimal inventory policy.
This work was publihsed in two parts in Econometrica Vol. 20,
1952 pages 187-222 and 450-466. The impact of these papers was
so great that they are quoted in almost all texts on operations
research, management science, and inventory policy. These papers
also listed in some works on economics. Besides that, they are
referred to extensively in the literature on inventory policy
and mathematical statistics. The importance of these two
papers was so great that the scientific officer asked the
project director to have a paper more accessible to practitioners
and users of inventory policy, prepared so that it could be
published for wide circulation. This paper was to have a
more applied perspective, simplification of expositions, and
numerical examples. Towards this end Dr. Laderman and
Professor Weiss joined with the project director in preparing
a paper entitled, "The Inventory Problem" which was published

in the Journal of the American Statistical Association,
December 1953, pages 717 to 732. This paper was reprinted
and has very wide circulation; it is also referred in texts
and periodical literature to a considerable extent. Another
very important paper was published by Dvoretsky, Kiefer and
Wolfowitz, namely, "On the Optimal Character of the (s,S)
Policy in Inventory Theory," in Econometrics Vol. 21, 1953,
pages 586-596. One may without exageration, say that the foregoing
represents a very important and stimulating phase of the
scientific work which has great potential application.

An outstanding achievement was made by Professor
Wolfowitz in the publication of his book entitled, Coding
Theorms of Information Theory. This book contains mostly
original contributions by Professor Wolfowitz, some of them
solutions of outstanding problems, one of which is represented
in his paper, "Strong Converse of the Coding Theorm for
Finite Memory Channels." This work represents a marked ad-
vance in information theory.

Kiefer and Wolfowitz did some very interesting and
original work culminating in two papers: "Optimum Extrapplation
and Interpolation Designs." This work appeared in the Annals
of Mathematical Statistics following the termination of this
contract. It does, however, represent important original
scientific work done during the tenure of this contract.

Professor Kiefer did fundamental work in optimum
experimental designs. He comprehensively investigated the field

and obtained results which more or less exhausted the pos-
sibilities. Two of the important papers among others are,
"Optimum Experimental Designs," Journal Royal Statistical
Society, Vol. 21, No. 2, 1959 vp. 272-319 and "Optimum Design
in Regression Problems, 2," Annals of Mathematical Statistics,
Vol. 31, March 1961. The optimality properties of experi-
mental designs are very important contributions to statistical
experimentation.

This does not exhaust the work done by either Professors
Wolfowitz or Kiefer individually or jointly. For example,
Professor Wolfowitz contributed some very interesting analytical
methods called the "minimum distance method." Professors
Kiefer and Wolfowitz worked on certain sequential decision
procedures. Professor Kiefer joined with Professor Bechhofer
or Cornell and Sobel of Minnesota in preparating of a book
entited, Sequential Multiple-Decisions Identification and
Ranking Procedures prepared for the Chicago University Press.

The preceeding resumee indicates adequately the qualit: and
the quantity of scientific research performed by Professors
Kiefer and Wolfowitz.

Professor Lionel Weiss in addition to the joint work
he has done has contributed to a number of directions of
research, namely, among others, limiting distributions of
homogenous sample spaces and minumum tests of goodness of fit.

Among the variety of other work that has been performed
on the contract, one might single out the work of J. Marschack

and H.D. Block on random ordering of choice among alternatives, of L. Hurwicz and H.D. Block on stability of competitive equilibrium and of Mandelbrot on stable probability distributions with applications to Pareto type laws of distribution, because of their bearing on economics.

Another direction of application has been to statistical control and acceptance sampling in life testing. Professors de Oliveira and Littauer have established a rigorous determination of double control limits which give a whole range of flexibility to the user in the choice of statistical control limits. In addition they have applied these results to determining sample size and the intersample spacing interval, based on certain cost considerations in industrial production. They have also developed a run criterion which includes an outer limit c and a parameter R representing the run length above or below the mean value of the sample's selected. The double control limit has been tabulated and the run criterion is still in the process of tabulation. Two reports have been submitted, the first one of which has been reformulated and translated into French for forthcoming publication in __Revue de Statsique Applique__ A second paper, "The Economic Choice of Control Chart Parameters," together with tables and graphs is being prepared for the same journal at the invitation of the editor. Under the sponsorship of Professors de Oliveira and Littauer a doctoral dissertation was completed by I. Gibra in pursuit of work deriving from these researches.

Professor de Oliveira has also presented papers on checking statistical assumptions and on fundamentals of inductive inference.

Professor J.H.K. Kao completed a paper on "Variables Inspection for the Weibull Distribution," a basis for acceptance sampling in life testing where the items are distributed according to Weibull type distributions.

The preceeding material does not completely represent all the work done on this contract. It does, however, give a reasonable sampling of both the quantity of the work and its quality in basic aspects of research as well as in certain applications. It can be said that the research on this contract is quite alive and is being continued not only in the work of the successor contract but in the work of many others who have followed the publications which have resulted from this research. These researches have been widely referred to in the literature.

Honors and Other Recognitions

Many of the scientists associated with this contract have received various forms of recognition and honors. These have been specified in the various periodic progress reports. Herein we will list the more recent ones with respect to the scientists most closely associated with the contract.

Professor J. Wolfowitz:

Has been president of the Institute of Mathematical Statistics;

Addressed by invitation) the International Statistical Institute Conference held inTokyo, June 1960, on decision functions;

Addressed (by invitation) the April meeting of the American Mathematical Society, 1961;

Invited to address the academies of science of Czechoslovakia and Hungary, 1961;

Invited to lecture on information theory before the conference on brain functions held at the University of California Medical School in Low Angeles;

Invited to address the seventh all Soviet Congress on Probability and Mathematical Statistics in Georgia, USSR, October 1963;

Invited to address the Conference on Information Theory to be held in France 1965;

Professor J. Kiefer

Chairman Joint Statistical Societies Committee of Visiting Lecturers;

Invited to give the Wald Memorial Lectures at the Institute of Mathematical Statistics Annual Meeting in Minneapolis, 1962;

Invited to address the Econometrics Society at its Annual Meeting in 1961;

Invited by the Royal Statistical Society of England to give lectures on comprehensive summarization and critical evaluation of the field of Design of Experiment at its May 1959 meeting.

Professor S.B. Littauer

Invited by the European Society for Quality Control to present the lead off paper on Scientific Aspects of Integrated Quality Control at their Fifth International Meeting held in Torino September 1961;

Elected Fellow of the American Statistical Association;

Invited to present a paper at the International Meeting of the Institute of Management Sciences held in Brussels, September 1960;

Member of the staff of the NATO Seminar on Theory and Applications of Extreme Values, held in Rolighed, Denmark June 1964;

Appointed Editor-in-Chief of MANAGEMENT SCIENCE, Series B a new periodical published jointly with the MANAGEMENT SCIENCE, Series A, by the Institute of Management Science.

Invited to address the Italian Quality Control Society in Torino, October 1965.