REPORT OF THE WAR PREPAREDNESS COMMITTEE OF THE INSTITUTE OF MATHEMATICAL STATISTICS

The generally recognized functions of a *statistician* are the calculation of averages, percentages, and index numbers; the construction of bar graphs and pie diagrams; and the compilation of data in general. His other activities are less widely known. In particular, the recent advances in *mathematical statistics* are known to a relatively small proportion of the persons occupying responsible positions in academic life, in industry, and in government. The *mathematical statistician*, in fact, is concerned chiefly with the interpretation of data through the use of probability theory; his is the science of reasoning from a part to the whole, and of prediction; and to him falls the task of stating the conditions under which such inferences are possible, of devising means of testing whether these conditions are satisfied, and of evaluating the probability that such 'uncertain inferences' are correct in specific instances. Furthermore, it is his responsibility to so plan the lay-out of experiments and the conduct of surveys that the data they yield will contain the maximum information on the points at issue and be amenable to unambiguous statistical interpretation.

Because of the functions which the *mathematical statistician* can perform his services should be of value to the National Defense Program in the following fields:

I. **Quality Control and Specification.** The functions of a mathematical statistical nature connected with quality control and specification of articles produced by mass production are:

(1) *Tests of randomness.* These are important because statistical methods of inference are strictly valid only for random samples.

(2) *The use of probability theory in predicting the outcome of future repetitions of an operation which is in a state of statistical control.*[1] The evaluation of the probability that the quality of a piece of product will lie within any previously specified tolerance limits as long as a state of statistical control is maintained, and the development of sampling inspection techniques are examples of this function.

[1] A repetitive operation, such as a production process, is said to be in a *state of statistical control* when it produces a sequence of observations which exhibit the property *randomness*. An important aspect of quality control is the improvement of quality which comes as the result of an effort to reduce a manufacturing process to a state of statistical control. Furthermore, when this state of control is attained it is possible to gain a reduction in cost of inspection, a reduction in cost of rejections, a reduction in tolerance limits where quality measurement is indirect, and the attainment of uniform quality even though the inspection test is destructive.

(3) *Representative sampling.* When a repetitive operation such as a production process is not in a state of statistical control, it is not possible to make valid inferences about the quality of a lot from an examination of a sample from the lot unless the sampling process is one of random selection within "strata" in accordance with the principles of representative sampling.

(4) *Analysis of variance.* Reference is made here to the technique whereby the total variability of a product of an operation which is in a state of statistical control can be decomposed into components associated with the various sub-operations involved.

(5) *Correlation methods.* When a direct measurement of quality is extremely costly, it is sometimes advisable to use as an indirect measurement of quality the value of some character less costly to measure which is highly correlated with quality.

(6) *Specification of quality as a variable.* Statistical theory, including tests for randomness, must be taken into account in writing quality specifications if the consumer is to be protected against the vagaries of sampling and the producer safeguarded from the incurring of penalties of an unjust chance.

II. **Sampling Surveys.** The importance of conducting sampling surveys in accordance with the principles of *representative sampling* is well established. It is quite possible that such surveys and partial censuses will be needed in connection with the National Defense Program in order to determine the frequency and location of individuals possessing special traits, e.g. persons capable of withstanding the rigours of dive bombing, or persons possessing types of color blindness which render them valuable as observers who can detect camouflage, etc. The "problem of sizes" connected with Stores and Supplies—see below—may require careful preliminary surveys. Also, surveys may be needed to evaluate the effects of various types of propaganda.

III. **Experimentation of Various Kinds.** The mathematical statistician can be of service in connection with experimentation of various kinds undertaken as a part of the National Defense Program since the following aspects of experimentation are of a mathematical statistical nature:

(1) *Randomization.* Since statistical tests for the existence of differences between samples, of correlation, etc. are strictly valid only for random samples, the operation of randomization is of paramount importance in "the comparison of new designs, new materials or alloys, study of contact phenomena under different conditions, corrosion of materials under different atmospheric conditions, and field trial of equipment, to mention only a few." If randomization is not undertaken, observed differences between designs, for instance, may have arisen from non-random assignable differences in the material presented. Furthermore, the validity of tests for significant differences between the effects of various designs rests upon the condition that the variability observed in the effects of each design be of *random* character and free from trends and non-random shifts in magnitude—i.e. the operation of determining the effects

of each design must be in a state of statistical control, to use a phrase employed in quality control.

(2) *Experimental design.* Without careful attention to the lay-out of an experiment, the data it yields may be difficult and even impossible to interpret. Therefore, the principles of experimental design set forth by R. A. Fisher and his followers are of great importance, as are also the special experimental arrangements which have been devised to cope with many of the more usual difficulties met in practice.

IV. **Personnel Selection.** The allocation of individuals to places where they can be of greatest value in the National Defense Program will undoubtedly require tests for mental and physical traits. Although the development and analysis of such tests is largely in the hands of psychometric groups, the use of methods of multivariate statistical analysis in such work renders this field one in which mathematical statistics ought to play an important role.

It is in the above four fields that there is special need for the training and endowments of the *mathematical statistician.* He can also render valuable assistance in the following fields:

V. **Stores and Supplies.**

(1) *Problem of sizes.* Preliminary surveys are likely to prove useful in ascertaining the relative frequencies of demand for the respective sizes of clothing, etc. in different parts of the country.

(2) *Development of procedures for charting the day to day location and movement of stores and supplies.*

(3) *Problem of replacement of parts and equipment.* In many it is more economical to make replacement at statistically determined times, than to wait for complete failure.

VI. **Transportation and Communication.** Probability theory has shown its usefulness in peace time in handling "traffic" problems that arise in telephone and telegraph communication, electric power distribution, etc. No doubt it will find corresponding application to problems in these fields arising out of the National Defense Program.

VII. **Gunnery and Bombing.** Although there is a need in connection with artillery fire for further development of methods of estimating standard deviations from successive differences in order to minimize the biases arising from slowly changing conditions during the period of firing, the principles of artillery fire are quite firmly established and the relatively new science of bombing is likely to present greater opportunities for the application of the methods of mathematical statistics. For instance, in evaluating bombing techniques there is need of statistical methods in separating the constant biases from the random variability.

VIII. **Meteorology.** The extent to which statistical methods are being employed in meteorology can be seen from an examination of the Monthly Weather Review Supplement No. 39, issued April 1940, and entitled "Reports on Critical Studies of Methods of Long-Range Weather Forecasting." There seems to be excellent opportunity here for the application of methods of multivariate analysis and for the development and uses of methods applicable to serially correlated data. Such work would be of value in National Defense so far as it would enable the forecasting of conditions suitable for launching an attack.

IX. **Medicine.** The National Defense Program will probably require the preparation and storage of hormone substances, toxic compounds, drugs, and other medicinal supplies. Since many such are examined for potency, toxicity, etc. by means of animal assays, there will be considerable opportunity here for the sound application of mathematical statistics in planning and interpreting these bioassays.

In nearly all of the above activities the application of mathematical statistics is likely to encounter two major difficulties:

(1) Obtaining an adequate trial of the methods of mathematical statistics.

(2) Supplying persons to occupy key positions in the application of mathematical statistics in a given field—persons competent in mathematical statistics and who possess a sound background in the field of application.

In some of the above activities, e.g. Quality Control, there will be the further difficulty of

(3) Supplying the vast number of slightly trained workers who will gather the data and perform the analyses.

It is with these difficulties in mind that the Committee recommends that the Institute

(1) Prepare a register of Institute members, stating for each member his background, interests, and experience so far as these relate to mathematical statistics and its applications;[2]

(2) Appoint a committee to handle inquiries concerning personnel qualified to deal with particular projects;

(3) Cooperate to the fullest extent in matters pertaining to quality control and specification with the *Joint Committee for the Development of Statistical Applications in Engineering and Manufacturing*, of which the Institute is a sponsor [3]

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[2] The preparation of this register should be coordinated with any similar undertaking sponsored by the *National Roster of Scientific and Specialized Personnel*, National Resources Planning Board, Executive Office of the President, Washington, D. C.

[3] We suggest the following as possible undertakings in a cooperative program with the Joint Committee:

(1) Requesting statements regarding the potential contribution to National Defense

(4) Undertake such steps as are feasible which will lead to cooperation with other organizations having interests similar to those of the Institute, e.g. the American Statistical Association, the Psychometric Society, and the Econometric Society.

(5) Establish contact with the National Defense Research Committee headed by Dr. Vannemar Bush and coordinate the Institute's activities with those of this national Committee.

In conclusion, we feel that as an organized group the Institute's primary function in relation to the National Defense Program should be to serve as a reservoir of specialists, experienced in the use of the methods of mathematical statistics, who can direct the use of these methods and be of assistance in the development of new techniques as needed. As a secondary, but equally important function, the Institute is in a position to supervise, and perhaps to undertake through the activities of its individual members, the training in mathematical statistics of the individuals who will be needed in the application of whatever statistical programs of the type noted above are undertaken in connection with the National Defense Program. *It is recommended, therefore, that the Institute's interest in the above activities, and its willingness to be called upon, be adequately publicized,* possibly by sending copies of this report to various members of the Government, such as the Chief Signal Officer and the Coordina-

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of statistical methods in quality control and specification from men prominent in industry who are familiar with recent developments in quality control. Such individuals would be asked to give, where possible, concrete evidence of the value of such methods in their experience—evidence which would be helpful in securing authoritative acceptance of statistical methods in quality control and specification.

(2) The organization of a syllabus on statistical methods for use in evening courses at various industrial centers. (Captain Simon of our Committee is preparing "An Engineer's Manual of Statistical Methods" which will be issued shortly.)

(3) The preparation of a list of topics for inclusion in university courses.

(4) The preparation of a list of suggested reading on statistical methods in quality control and specification, arranged under such headings as "expository," "methodology," etc.

(5) The arrangement of local meetings and round table discussions at some of the universities in a few large industrial centers. Some well known leader of the locality might serve as chairman. To such a meeting would be invited those men in local industries who were interested in the possibility of applying statistical methods to their problems, and the meeting could be thrown open to discussion after a brief paper outlining the accomplishments of statistical methods of quality control in the speaker's experience and stating the advantages to be gained by employing such methods in the mass production of the War Preparedness Program.

(6) Sponsor the preparation of popular expository articles on quality control for industrial journals, Readers Digest, Scientific American, etc., and other activities designed to popularize the subject and gain authoritative acceptance of statistical methods of quality control.

tor of National Defense Purchases and also to the secretaries of appropriate organizations, such as the American Standards Association, with the request that they advise the Institute of any specific action they feel the Institute should take.

A. T. CRAIG
E. G. OLDS
L. E. SIMON
R. E. WAREHAM
C. EISENHART, *Chairman.*