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EYE EFFECTS MATHEMATICAL MODELS

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EYE EFFECTS MATHEMATICAL MODELS*

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FOREWORD

This report was prepared at the Life Sciences Division of Technology Incorporated by--

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Publication of this report does not constitute Air Force approval of the findings or conclusions. It is published only for the exchange and stimulation of ideas.

ABSTRACT

This report describes the results of research to develop mathematical models of eye effects produced by nuclear flashes. The model for prediction of retinal burns gives temperature values by using a numerical method to approximate the solution of a differential equation governing the conduction of heat in the ocular fundus. Consideration is given to the validity of the solution by discussing the convergence, stability, and accuracy of the numerical method. Comments are given on a statistical model for the prediction of flashblindness recovery times.

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EYE EFFECTS MATHEMATICAL MODELS

1. INTRODUCTION

Technology Incorporated has undertaken this study in an effort to develop safe separation distance charts for eye hazards from nuclear flashes and to establish design criteria for eye protective devices. This report outlines the work development to date and sets forth the status of the problem.

In order to establish design criteria and develop safe separation distance charts which take into account the full variation of the many parameters involved, mathematical models are needed. A statistical model of flash-blindness, which was developed by Czeh, Casper and Segraves (1), was selected for possible refinement by inclusion of new data. A mathematical model for retinal burns, utilizing temperature rise (2), was used to generate safe separation distances (3), but the need for improvement in the model, particularly the fireball representation (4), resulted in a new effort. During the subsequent effort which included analysis, evaluation, and comparison of available data on both nuclear weapons detonation and ocular response to thermal radiation, it was determined that the numerical method used to solve the heat conduction equation was sufficiently accurate only when smaller finite difference approximations were used. The use of smaller differences have led to computational problems on a Philco 2000 computer both in running time and core storage.

2. DISCUSSION

The objective of the research during the contractual period was to improve existing eye effects models or to develop new models, if required. One of the presently available models for prediction of retinal burn, which has received considerable attention in the past, is the retinal temperature model. The temperature model has been retained, even though difficulties have been encountered, because it appears to be a very realistic description of the physical situation. In anticipation of new data, the flashblindness model of Czeh et al. was reviewed with the intention of possible refinement.

2.1 Model of retinal burn

Presently, the major problem area in the temperature model is that of heat conduction in the eye. Temperature as a function of position and time is needed for the geometry encountered in the eye and a given heat source that is a function of position and time.

2.1.1 Analytical method

An analytic solution of the differential equation of heat conduction was attempted. Several approaches were attempted and in each case the cylindrical coordinate system was used. In one approach, a solution was attempted in the volume occupied by a very thin section of the cylinder, having the shape of a disc, and within which it was assumed that the temperature did not vary with the axial coordinate, z. Each disc would have appropriate

boundary conditions and the solutions for all the discs were to be combined for the complete solution. This approach was unsuccessful. Another approach was to transform the heat conduction equation, which contains derivatives with respect to position and time, into an equation containing derivatives with respect to position only by the use of the Laplace transform. After solving the equation without the explicit time variable, the inverse transformation was to be performed, and the resulting solution would contain the position and the time. This approach met with only very limited success, solutions being obtained only for a simple geometry and a square pulse source.

The analytical solution was attempted after encountering several difficulties with the numerical solution. Most of these difficulties have been cleared up. Of those that have not been solved, it is known how to proceed to solve them.

2.1.2 Numerical method

The numerical method consists of replacing the partial differential equation of heat conduction

$$\nabla^2 T + \frac{A}{k} = \frac{\rho c}{k} \frac{\partial T}{\partial t}$$

with a difference equation at each of many discrete points arranged in a rectangular grid and solving the difference equation which is algebraic. The two dimensions of the rectangle are taken to be in the r and z directions.

The difference equation at a point of interest is obtained by expanding the temperatures at points adjacent to the point of interest in Taylor series, ignoring the fourth or fifth and higher terms of the series, and combining the truncated series into approximate expressions for the partial derivatives with respect to position at the point of interest. For example, the second partial derivative with respect to r at the point (r_o, z), in terms of the temperatures at points which are a distance Δr from r_o, is obtained as follows:

$$T_1 = T_o + T_o'(\Delta r) + \frac{T_o''(\Delta r)^2}{2!} + \cdots$$

$$T_{-1} = T_o - T_o'(\Delta r) + \frac{T_o''(\Delta r)^2}{2!} - \cdots$$

$$T_1 + T_{-1} = 2T_o + T_o''(\Delta r)^2 + \cdots$$

$$T_o'' = \frac{T_1 - 2T_o + T_{-1}}{(\Delta r)^2} + \cdots$$

and the second derivative is written

$$\left(\frac{\partial^2 T}{\partial r^2}\right)_o = \frac{T_1 - 2T_o + T_{-1}}{(\Delta r)^2} .$$

The time derivative is written in the difference form

$$\left(\frac{\partial T}{\partial t}\right)_{r=r_o,\, t=\tau} = \frac{T_{o,\tau} - T_{o,\tau-\Delta t}}{\Delta t}$$

The solution proceeds step-by-step in time increments Δt. An elliptic boundary-value problem is solved at each step. The difference equation takes the form

$$\left[(\Delta r)^{-2} - 1/2(r\,\Delta r)^{-1}\right] T(r + \Delta r, z, t)$$

$$+ \left[(\Delta r)^{-2} - 1/2(r\,\Delta r)^{-1}\right] T(r - \Delta r, z, t) + \left[(\Delta z)^{-2}\right] T(r, z + \Delta z, t)$$

$$+ \left[(\Delta z)^{-2}\right] T(r, z - \Delta z, t) - \left[2(\Delta r)^{-2} + 2(\Delta z)^{-2} + \rho c(k\Delta t)^{-1}\right] T(r, z, t)$$

$$= - \left[\frac{A(r, z, t)}{k} + \rho c(k\Delta t)^{-1}\, T(r, z, t - \Delta t)\right] \qquad (1)$$

One of the problems in using the difference equation approximation was that of whether the difference equation has a unique solution. It was found that the solution of the equation used is, indeed, unique (5, 6).

The question of convergence of the exact solution of the difference equation to the solution of the differential equation as the differences Δr, Δz, and Δt are made smaller indefinitely has been answered and this convergence was found to hold (7). However, very little is known about the accuracy for given values of Δr, Δz, and Δt. A procedure which can be used is to solve the difference equation using difference sizes Δr, Δz, and Δt and then again using difference sizes $\frac{\Delta r}{2}$, $\frac{\Delta z}{2}$, and $\frac{\Delta t}{2}$ and taking the difference between the two solutions as a measure of the error. Experimentation has shown that the difference can be made small.

The total error in the numerical solution of the heat conduction equation is viewed as being the sum of two errors. One error is the approximation error which depends on the size of Δs and Δt, apparently mainly on Δs, with

which the problem of convergence of the difference equation is related. The second error is the numerical error, with which the problem of stability of the difference equation is related. The practical solution of the difference equation usually differs from the exact solution and this difference is due to round-off error and the inherent limitations of the iterative method used to solve the difference equation. The stability of the difference equation refers to whether round-off errors accumulate in successive steps of calculation. If these errors accumulate during such a large number of calculations as are made in solving the present problem, the resulting solution will have nothing in common with the desired solution. An effort was made to determine the mathematical conditions under which the equation is stable. It was found that the equation is absolutely stable, i.e. is stable for all values of the parameters involved that are of interest (8).

The property of the equation that gives it absolute stability is its implicit character. The implicitness is seen in the fact that at the point (r, z) the temperature for the time t is given in terms of the known temperature at time $t-\Delta t$ and the unknown temperatures surrounding it at time t. Obviously, the equation cannot be solved one point at a time in a step-by-step manner as can its explicit counterpart which, however, has such a stringent stability requirement that its use is impractical. The implicit equation requires the solution, simultaneously, of as many difference equations as there are points in the grid covering the region of interest. Formally, this algebra problem of the

simultaneous solution of linear equations is simple enough. However, the smallest problem requires the calculation of the temperature at over one thousand points and for the largest problem foreseen, over ten thousand points would be needed with the model in its present form. An iterative method is used to solve the system of simultaneous equations. An approximate solution is modified at each iteration until, if the method converges, a built-in measure of the error becomes smaller than a preassigned value. The method is known as the Gauss-Seidel method or the method of successive displacements.

That part of the numerical error due to the inherent limitations of the iterative method arises from the fact that a characteristic of the method is that the exact solution cannot be obtained with a finite number of iterations. The value of the error is not known, but it is small. Using a given accuracy criterion the error seems to vary directly with the value of the parameter Δs. For the accuracy criterion that the maximum temperature over the entire grid, from one iteration to the next, be less than .04% of the temperature at the center of the image, and using $\Delta s = .0005$ cm., the change at the edge of the region is about one third of one percent. If $\Delta s = .001$ cm. is used the change at the edge is about three percent, and for $\Delta s = .002$ cm. the change at the edge is about thirteen percent. A procedure has been found, recently, which would increase the accuracy considerably. The approximate solutions for each point are substituted into the difference equations. Because the numbers have errors,

ie equations will not balance. The discrepancies or residuals are then iade part of a second system of linear equations in which the coefficients f the unknowns are the same and the constant terms are the residuals. The ew set of equations is then solved simultaneously, using the same iterative method. The resulting solution is then subtracted from the first, which subtracts the aforementioned residuals, leaving a more accurate result.

Another question to be answered was that of whether the iterative method converged, i.e., whether the numbers obtained, supposedly a solution of the system of difference equations, using the Gauss-Seidel method, constituted the desired solution. Even though, after several iterations, the numbers were being modified by from just a few percent to less than one tenth of one percent, it was thought possible that the solution obtained could differ greatly from the solution desired. Saulyev (9) showed that the Gauss-Seidel method does converge if the equations are of a form taken by equation (1). Also, since the residual at a point after completion of a given iteration is approximately equal to the change in the value of the solution at the point from the given iteration to the next, then if the change is small the convergence of the iterative method can be deduced from the uniqueness of the solution. Hamming (10) gives sufficient conditions for convergence of the Gauss-Seidel method in the case of the general system of linear algebraic equations, and these conditions are satisfied in the model.

Although the method is one of the most convenient for programming and converges for a wide class of problems, it also has one of the slowest convergence rates. A method of speeding up the convergence, called the method of successive over-relaxation (11), shows promise. In this method the Gauss-Seidel method is modified by the introduction of an optimized "relaxation factor." This method which has only recently been introduced into the program and it needs more work, but it can cause the iterations to converge many times faster. It has, at this time, multiplied the convergence rate for the present problem by four. The computer time per problem, however, is still excessive. Young (12) considers the use of the alternating-direction method of Peaceman, Rachford, and Douglas for problems of which the present one is a type, namely the solution of a parabolic partial differential equation. It may be unnecessary to solve an elliptic boundary value problem at each time step, as has been done.

Another source of excessive computer time is the necessity of computing temperatures in a region larger than the region of interest. The boundary conditions which are used include the condition that the normal derivative at the edge of the region be zero. This condition can be satisfied accurately only by using a large grid of points. Besides necessitating the solution of a larger problem, the condition increases the computer storage requirement. In many practical cases, the storage capability of the Philco 2000, 16,000 locations, would be exceeded. A formulation of the difference equation (1)

has been found (13) whereby the size of the parameters Δr and Δz may be varied with position so that at points distant from the center of the retinal image the points at which the temperature is calculated may be relatively far apart and so the number of points, and computer storage requirements, may be drastically reduced. At the present time, only small problems can be solved accurately.

2.1.3 Model refinements

Refinements to the temperature model were of a limited nature since they are considered to be of secondary importance while there are problems persisting in the numerical approximations to the heat-conduction equation. Provisions have been made for a "curved-earth" atmosphere. The computer subroutines which calculate the air and water masses along a line of sight path through variable atmospheric density were obtained from Dr. Oskar K. Ritter at the School of Aerospace Medicine. The feasibility of checking the predicted temperature against a scaled-up physical model was considered. However, no attempt was made to develop a physical model because of the problems in the present temperature model.

2.2 Model of flashblindness

In anticipation of new data described in the contractual statement of work, the work of Czeh et al. was reviewed with the intention of updating the flashblindness model given in the report. This effort was suspended because

of a lack of appropriate new recovery time data.

The report searches for a model of recovery time in terms of surrounding parameters. The authors decided to use source energy, target luminance and visual acuity in their predictor. Three models are discussed. The model suggested by Brown as well as the Gompertz function were rejected by the authors in favor of a multiple regression in terms of log luminance, visual acuity and log energy as independent variables (up to the 3rd degree) and log recovery time as the dependent variable.

The authors do not comment on the hypotheses that must be assumed before such a model is appropriate. In order to justify probability statements concerning time, it is necessary to assume that log recovery time is normally distributed. Perhaps a test of normality would be appropriate to gain full insight to the problem.

The technique employed in solving the normal equation as suggested by Efroymson is one which provides valuable intermediate results in obtaining the proper model. The Efroymson algorithm selects the best sub-model of the original model. It is up to the experimentor however to recognize this choice. The results are quite interesting.

The Miller and Brown data (1306 points) were used and when a multiple R^2 value of .89 was achieved only log energy and log luminance (both to the first

power) appeared in the model. By continuing the computation to the end with all ten terms, a multiple R^2 of .926 was obtained. A similar phenomena occurred when source energy was measured in lamberts.

3. CONCLUSIONS

The presently available digital computer program for solving the heat conduction equation is beset by three difficulties. The first difficulty, which gives rise to the other two, is inaccuracy of results. The second and third difficulties are excessive running time and computer core storage when operating on a Philco 2000 type computer. There are possibilities of alleviating these difficulties which appear very promising at this time. A method for improving the accuracy of the results is that of iterating on the solution of the difference equations to further reduce the final residuals. This method has proved successful on problems of a similar nature. Computer running time may be reduced by a factor of about five by a proper choice of successive over-relaxation factors. Computer core storage and running time can both be reduced by using unequal spacing in the computational grid, i.e. a fine mesh within and immediately surrounding the image and a coarse mesh beyond.

A very important facet of the flashblindness experiment is not reckoned with in the linear regression model. Subject differences are not included as a source of variation. The study did include separate regression analyses for

each of five subjects (Miller data) and the observation was made that there are significant subject differences. It is suggested that a covariance model be introduced in further studies so that subject differences may be statistically evaluated on the same basis as regression coefficients with valid significance levels.

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Subject: Progress Report
Contract AF 41(609)-3079

Enclosed are three (3) copies of the Progress Report for the subject contract. This report covers the period from 1 December 1966 through 28 February 1967.

Arthur F. Muller
Project Engineer

AFM/df

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Enclosure

TECHNOLOGY INCORPORATED

LIFE SCIENCES DIVISION

SAN ANTONIO, TEXAS

Progress Report No. 3
Period 1 December 1966 to 28 February 1967

Contract: AF 41(609)-3079

EYE EFFECTS MATHEMATICAL MODELS

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Director of Research

1. INTRODUCTION

This Quarterly Progress Report is submitted in compliance with Contractual Agreement AF 41(609)-3079 and covers the period 1 December 1966 through 28 February 1967.

2. WORK ACCOMPLISHED

During the last work period the temperature model was run on a faster computer in an attempt to obtain an accurate solution for the chorioretinal temperature in spite of a slow rate of convergence for the iterative method used to solve the heat conduction equation in difference form. The running time turned out to be excessive even on the faster computer. Another difficulty encountered was computer storage capacity. Work was begun on developing an analytical solution to the heat conduction equation.

2.1 Difficulties

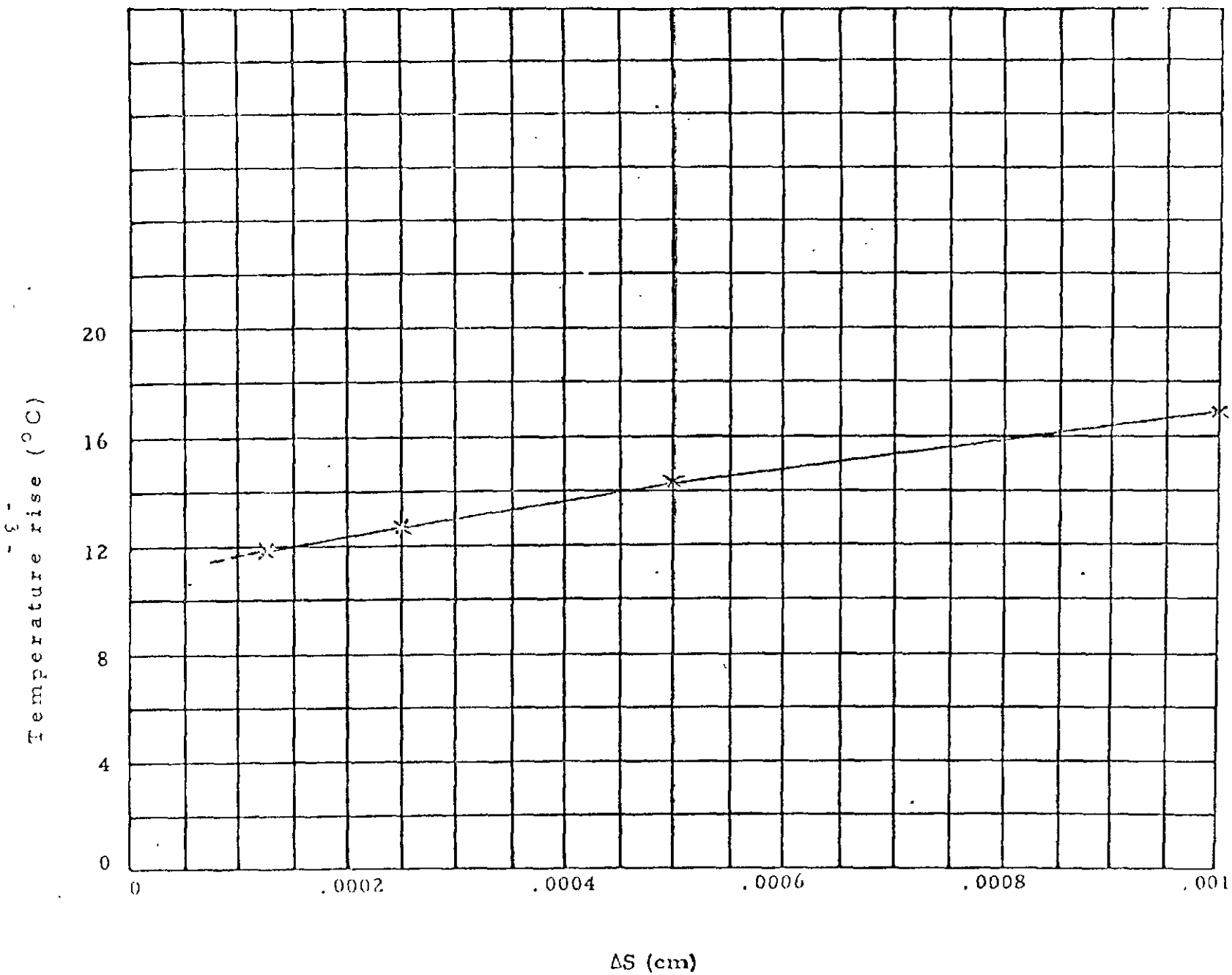
A difficulty has been experienced with a slow rate of convergence of the iterative method, the method of successive approximations, for solving the system of equations governing the conduction of heat in the chorioretinal region of the eye. The model program was run on a CDC 6600 computer to determine the feasibility of using the time consuming model with the faster computer. Runs on the 6600 showed that the difference equations were not approximating the differential equation accurately enough. In

order to improve the accuracy, the finite differences in the time and position variables were decreased just as has been done on the Philco 2000. Unfortunately, this procedure led to excessive running time even on the CDC 6600 which is almost two orders of magnitude faster than the Philco 2000. The table below shows the very rapid increase in computer time required to solve a very small portion of a simple problem, as the parameter values are changed. ΔS is the fundamental increment in the position variable, and Δt is the increment in the time variable.

ΔS (cm)	Δt (sec)	Computer time (sec)
.0010000	.001	2.89
.0005000	.001	5.46
.000250	.001	39.5
.000125	.001	388.

The following Figure shows the model temperature prediction for several choices of the parameter ΔS. It can be seen that there is approximately a 7.5 percent change in the temperature rise predicted when the grid spacing is changed from .00025 centimeters to .000125 centimeters, the two smallest spacings used. In view of the strong dependence on the size of the parameters, it is felt that the solution is not sufficiently accurate.

Another difficulty experienced was with insufficient computer


Temperature rise (°C)
0
4
8
12
16
20
0
.0002
.0004
.0006
.0008
.001
ΔS (cm)

storage capacity. Due to the boundary condition being used, that the normal first derivative on the boundary is zero, a large grid must be used and the temperature must be calculated at a large number of points. For practical problems, the required computer storage surpasses the available capacity of 64,000 locations.

2.2 Analytical Solution

An alternative is to solve the differential equation of heat conduction analytically for the boundary conditions used in the present model. The analytical solution, incorporated into the model, would replace the difference equations and iterative solution. Several approaches are being used to obtain an analytical solution. In each case, the cylindrical coordinate system has been used. In one approach, a solution was attempted in the volume occupied by a very thin section of the cylinder, having the shape of a disc, and within which it was assumed that the temperature did not vary with the axial coordinate, z. Each disc would have appropriate boundary conditions and the solutions for all the discs were to be combined for the total solution. This approach was unsuccessful. The latest approach is to transform the heat conduction equation, which contains derivatives with respect to position and time, into an equation containing derivatives with respect to position

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TECHNOLOGY INCORPORATED

LIFE SCIENCES DIVISION

SAN ANTONIO, TEXAS

Progress Report No. 2
Period 1 September 1966 to 30 November 1966

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EYE EFFECTS MATHEMATICAL MODELS

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1. INTRODUCTION

This Quarterly Progress Report is submitted in compliance with Contractual Agreement AF 41(609)-3079 and covers the period 1 September 1966 through 30 November 1966.

2. WORK ACCOMPLISHED

During the last work period the validity of the retinal temperature calculation portion of the mathematical model was investigated. Attention was directed toward the stability, convergence, and accuracy of the numerical method being used to solve the heat conduction equation. Work has continued on a spectral radiant exposure model to calculate eye-safe-separation envelopes. Attention was directed toward decreasing computer running time for the model.

2.1 Stability

The stability of the numerical method refers to whether round-off errors accumulate in successive steps of calculation. If these errors are allowed to accumulate during a large number of calculations the resulting solution will have nothing in common with the desired solution. An effort was made to determine the mathematical conditions under which the numerical method being used is stable. It was found that the method is absolutely stable, i.e., is stable for all values of the parameters involved that are of interest.[1]

2.2 Convergence

The numerical method being used involves the approximation of a differential equation at a number of discrete points within a region by a difference equation in which infinitesimals of the calculus are replaced by finite differences. The problem of convergence of the numerical method consists in finding the conditions under which the solution of the difference equation approaches the solution of the differential equation as the finite differences are made smaller. It was found that the conditions for convergence of the numerical method being used are the same as those for stability with the additional requirement that the absolute value of the second derivative of the solution with respect to time be bounded in the region of interest.[1] This condition is satisfied in the present model.

2.3 Accuracy

The accuracy and therefore the error of the solution depends on the size of two major errors. The first error depends on how close the practical solution of the difference equation is to an exact solution of the difference equation. The second error depends on how close the exact solution of the difference equation is to the exact solution of the differential equation. The first error is well under control and can be made to be less than a preassigned value. The second

error is reduced by decreasing the size of the finite differences of the variables until the solutions using two successive sizes differ only negligibly. The drawback to this procedure is that reducing the size of the time and space differences results in a finer grid or mesh of points, while the size of the region of interest remains the same. This situation causes an increase in the time required to solve the problem. Efforts to increase the efficiency of the program have resulted in a twenty percent decrease in running time. An approximate 500 percent decrease is needed. At the present time, the model is unable to solve the problem with the required accuracy in a sufficiently short period of time on the Philco 2000.

2.4 Spectral Radiant Exposure Model

Programming has continued in order to incorporate the mathematical model into a computer program for the Philco 2000. A progressive method of programming is being used so that variations of the radiant exposure model can be developed concurrently, e.g., a radiant exposure model utilizing atmospheric transmission based on a "round-earth model". A large portion of the time during this period was expended in order to reduce the running time of the computer program. This effort was quite successful since a reduction in running time of a factor of approximately ten was achieved with a

sacrifice in accuracy of the final result of less than two percent. The time reduction was effected by relaxing an integration accuracy requirement in "round-earth" subroutine and by improving the efficiency of the method of convergence to a safe separation distance. The necessity of this refinement resides in the present ability of producing approximately ten safe separation envelopes whereas previously the limit was one envelope for each computer run submitted.

3. ANTICIPATED WORK

In the next period, the temperature model will be put on a CDC 6600 computer. The much faster machine should give the accurate solution in a short time. It should then be possible to decide whether the model can be shortened to run sufficiently fast on the Philco 2000 or if the CDC 6600 will have to be used exclusively. Because of exigent problem areas, no significant progress can be reported in determining the feasibility of using a scaled up physical model in order to verify the present temperature model. Programming of the spectral radiant exposure model and its variations for the Philco 2000 will continue with a completion date expected during the next period.

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TECHNOLOGY INCORPORATED

LIFE SCIENCES DIVISION

SAN ANTONIO, TEXAS

Progress Report No. 1
Period 1 June 1966 to 31 August 1966

Contract: AF 41(609)-3079

EYE EFFECTS MATHEMATICAL MODELS

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1. INTRODUCTION

This quarterly progress report is submitted in compliance with Contractual Agreement AF 41(609)-3079 and covers the period 1 June 1966 through 31 August 1966.

2. WORK ACCOMPLISHED

During the last work period effort was expanded in three areas. The first area involved an investigation of stability and convergence of the numerical method presently being used in the temperature model. The second area included a review of the General Electric report of October 1965 by R. S. Czeh, A. W. Casper and E. C. Segraves, Jr. entitled "A Mathematical Model of Flashblindness". The third area was the initiation of programming a simplified model to calculate eye-safe-separation-distances.

2.1 Stability and Convergence

Particular consideration is being given to the retinal temperature calculation portion of the mathematical model for prediction of retinal burns. The differential equation of heat conduction is replaced by a difference equation which is solved by the method of relaxation. A continued attempt is being made to define a criterion which will insure the convergence of the relaxation

process to the solution of the difference equation. A characteristic of the relaxation method of solution is that an exact solution cannot be obtained in a finite number of steps. A method is being sought which will determine at any stage of the relaxation how close the problem is to the solution. Previously, an intuitive determination of precision has been used.

Requisites for stability of the difference equation are being studied, i.e., it is desired to know under what mathematical conditions the inevitable round-off error in computer calculation does not accumulate in successive steps. Because of the large number of calculations involved in the retinal temperature calculation, the round-off error can become quite serious, even with the available twelve-place accuracy of the Philco 2000.

Another consideration under investigation during the last three months and at present is the question of convergence of the solution of the difference equation to the solution of the differential equation as the finite increments of the independent variables, namely time and space, are made smaller and

smaller. A question related to this consideration is that of how the initial conditions and boundary conditions of the problem affect the solution.

Answers to all these questions must be found before there can be any confidence in the numbers the model obtains for retinal temperature as a function of time and position. Progress is being made in these areas and it is felt the answers will soon be forthcoming.

2.2 Model of Flashblindness

In anticipation of new data described in the contractual statement of work, the work of Czeh et al. was reviewed with the intention of updating the flashblindness model given in the report. To date, no new appropriate recovery time data has been made available.

The report searches for a model for recovery time in terms of surrounding parameters. The authors decided to use source energy, target luminance and visual acuity in their predictor. Three models are discussed. The model suggested by Brown as well as the Gompertz function were rejected by the authors in favor of a multiple regression in terms of

log luminance, visual acuity and log energy as independent variables (up to the 3rd degree) and log recovery time as the dependent variable.

The authors do not comment on the hypotheses that must be assumed before such a model is appropriate. In order to justify probability statements concerning time, it is necessary to assume that log recovery time is normally distributed. Perhaps a test of normality would be appropriate to gain full insight to the problem.

The technique employed in solving the normal equation as suggested by Efroymson is one which provides valuable intermediate results in obtaining the proper model. The Efroymson algorithm selects the best sub-model of the original model. It is up to the experimentor however to recognize this choice. The results are quite interesting.

The Miller and Brown data (1306 points) were used and when a multiple R^2 value of .89 was achieved only log energy and log luminance (both to the first power) appeared in the model. By continuing the computation to the end with all ten terms, a multiple R^2 of .926 was obtained. A similar

phenomena occurred when source energy was measured in lamberts.

A very important facet of this experiment is not reckoned with in the linear regression model. Subject differences are not included as a source of variation. The study did include separate regression analyses for each of five subjects (Miller data) and the observation was made that these are significant subject differences. It is suggested that a covariance model be introduced in further studies so that subject differences may be statistically evaluated on the same basis as regression coefficients with valid significance levels.

2.3 Simplified Model

Programming has begun on a mathematical model to calculate eye-safe-separation envelopes. This model will be similar to the one described in Progress Report Number 3 under Contract AF 41(609)-2900; the difference arising from time dependent fireball size and temperature and atmospheric transmission based on a "round-earth model". Because of the time dependence, this model will produce separation envelopes at each selected time interval after

detonation.

3. ANTICIPATED WORK

The investigation of stability and convergence for the numerical method used in the temperature model will be completed and reported on in detail during the next period. There will be no further effort expended on updating the General Electric flashblindness model until new data becomes available. Work will continue on the simplified mathematical model and an investigation started to determine the feasibility of using a scaled up physical model in order to verify the present temperature model.

AF 41(609)-3079

RESEARCH and

TECHNOLOGY

INCORPORATED

DEVELOPMENT

A TECHNICAL PROPOSAL FOR

DEVELOPMENT OF EYE EFFECTS

MATHEMATICAL MODELS

PROPOSAL NUMBER 66-518-A

Headquarters
ce Medical Division
ir Force Base, Texas

Lt Col Dan Brown
HQ AFMDA/SGPT
202-767-5078
70A-655-B04
Floor Lindsey
Suitland Records Ctr

e Request Number
AM-6-10390

TEXAS DIVISION

8531 N. NEW BRAUNFELS AVE. • SAN ANTONIO, TEXAS 78217

COST AND PRICE ANALYSIS - RESEARCH AND DEVELOPMENT CONTRACTS

(This form is to be used in lieu of DD Form 633, as provided under ASPR 16-206. It will be executed and submitted with proposals in response to "Requests for Proposals," for the procurement of research and development services. If your cost accounting system does not permit analysis of costs as required, contact the purchasing office for further instructions.)

FORM APPROVED
BUDGET BUREAU NO. 22 - R208

PURCHASE REQUEST NUMBER
AM-6-10390

NAME AND ADDRESS OF OFFEROR
Technology Incorporated, 7400 Colonel Glenn Highway, Dayton, Ohio 45431

TITLE OF PROJECT
Development of Eye Effects Mathematical Models

DETAIL DESCRIPTION

1. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE/HOUR	TOTAL ESTIMATED COST (Dollars)
Mathematician - Programmer	1500	5.75	$ 8,625.00
Senior Research Engineer	800	6.35	5,080.00
Junior Research Engineer	1500	[illegible]	5,250.00
Programming and Data Processing	1200	[illegible]	4,800.00
Technical Support	400	2.25	900.00
Technical Editing	100	6.05	605.00
TOTAL DIRECT LABOR			[illegible]

2. BURDEN (Overhead - specify) DEPARTMENT OR COST CENTER	BURDEN RATE	X BASE	BURDEN
Overhead	70%	25,260.00	17,682.00
TOTAL BURDEN			$17,682.00

3. DIRECT MATERIAL	EST COST
Cards, Tape, Special Forms, etc.	200.00
TOTAL MATERIAL	$ 200.00
4. SPECIAL TESTING (Including field work at Government installations)	
TOTAL SPECIAL TESTING	
5. SPECIAL EQUIPMENT (If direct charge - specify in Exhibit B, reverse)	
6. TRAVEL (If direct charge)	
a. TRANSPORTATION	1,475.00
b. PER DIEM OR SUBSISTENCE	240.00
TOTAL TRAVEL	$ 1,715.00
7. CONSULTANTS (Identity - purpose - rate)	
TOTAL CONSULTANTS	
8. SUBCONTRACTS (Specify in Exhibit A on reverse)	
9. OTHER DIRECT COSTS (Specify in Exhibit B on reverse - explain royalty costs, if any)	$ 640.00
10. TOTAL DIRECT COST AND BURDEN	$45,497.00
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of item nos.	
12. TOTAL ESTIMATED COST	$45,497.00
13. FIXED FEE OR PROFIT (State basis for amount in proposal) ASPR 3-808	$ 4,818.00
14. TOTAL ESTIMATED COST AND FIXED FEE OR PROFIT	$50,315.00

DD FORM 1 SEP 60 633-4

☆ GPO : 1963 O - 643985

25 February 1966

Technology Incorporated

San Antonio, Texas

TECHNICAL PROPOSAL

Purchase Request Number AM-6-10390

PREPARED FOR:

School of Aerospace Medicine

Brooks Air Force Base, Texas

APPROVED BY:

George R. Boone
Director
Texas Division

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1. INTRODUCTION AND SUMMARY

Technology Incorporated is proposing to continue the research being conducted under Contract AF 41(609)-2437 to formulate eye protection criteria by preparing appropriate mathematical models of eye effects and develop nuclear flash eye safe separation distance charts and graphs. The proposed research team which has a number of years experience in nuclear flash eye effects, is currently working in this area and includes personnel with experience in mathematical analysis, computer programming, nuclear weapons effects and other closely related areas.

Supporting capabilities in these areas have been gained by Technology Incorporated as shown by the following:

1.1 Mathematical Analysis

Capabilities in mathematics and physics are currently available through Technology Incorporated. The company's efforts in this area are being utilized on Contracts AF 41(609)-2437, AF 41(609)-2267, AF 33(657)-9537, AF 33(615)-1894, AF 41(609)-2906, AF 41(609)-2900 and AF 33(615)-1851 for the Aerospace Medical Division and Contracts AF 33(615)-1600, AF 33(615)-3282, AF 33(657)-10686, and AF 33(657)-11676 for the

Aeronautical Systems Division. Technology Incorporated's Analysis Section of the Texas Division is continually growing due to the demand for this type of capability in the San Antonio, Texas, area.

1.2 Computer Programming

Programmers are available with backgrounds in mathematics, statistics, physics and engineering. Programming is currently being done on the Philco S-2000 Computer. In addition to experience on the S-2000 Computer, Company personnel at the Texas Division have experience on the IBM 7094, 7090 and 709, Burroughs 205 and 220, and NCR 304 Computers.

1.3 Nuclear Weapons Effects

Two key personnel on the staff of the Texas Division participated in the latest Pacific nuclear testing effort. These people were concerned with such problems as the placement of data collecting instruments, aircraft, and personnel. Preliminary support by means of analysis was furnished by the Company's personnel before the testing effort began. A considerable amount of valuable experience was acquired through participation in these tests. In addition, other experience includes

past and present work involving safe separation distances for aircraft, based on thermal, ionizing, and blast effects from nuclear detonations.

Other advantages of Technology Incorporated are its location, size, and operation. The offices and laboratories of the Texas Division are located within the city of San Antonio, Texas. This location permits close liaison between interested Ophthalmology Department personnel and Technology Incorporated's project team.

To supply the Staff of Technology Incorporated with up-to-date information on technical literature, techniques, and products, a Company library is maintained.

The facilities of Technology Incorporated and the personnel assigned to this task are cleared to handle classified information up to and including Secret.

2. STATEMENT OF THE PROBLEM

Since normal visual acuity is a requisite to the successful completion of an air combat mission, eye protection from nuclear flashes is an established requirement for combat aircrews. Probably the most critical situation is that of a pilot flying a high performance aircraft at low level where loss of visual function for more than a few seconds could be disastrous. Eye protection is also an important factor in planning for nuclear weapons tests since the safety of participating and observing personnel must be insured.

The basic purpose of this work is to develop predictions that can assist in the planning and analysis of combat operations. A secondary need also arises. Quite often with minimal notice, the Ophthalmology Branch, SAM, is called upon to provide estimates of distances at which personnel will not suffer detrimental ocular effects. Since even the relatively simple computational methods for predicting safe distances are fairly time consuming and sacrifice a certain amount of accuracy, it is quite important to have available reliable safe separation distances which can be acquired from graphs. In order to be most useful, these curves must be accurate and available in sufficient quantity to cover the more frequently encountered situations with the possibility of interpolation for intermediate values.

3. APPROACH TO THE PROBLEM

Technology Incorporated proposes to continue the effort to develop nuclear flash eye safe separation distance charts and eye protection criteria by preparing appropriate mathematical models of eye effects. Further, currently available information on both nuclear weapons detonation and ocular response to thermal radiation will be analyzed, evaluated, and compared in order to further explore the relationship between the two. The best available data concerning the thermal radiation of nuclear detonations, atmospheric transmission, and the effects of this radiation on the eyes will then be utilized in mathematical models.

3.1 Investigation

Technology Incorporated proposes to continue an investigation to uncover the best available data concerning the thermal radiation of nuclear detonations. A continued effort is necessary because theoretical fireball data generated by radiation-transport hydrodynamics computer codes are being made available. A limited amount of theoretical data have been generated at the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico

and at Lockheed Missiles and Space Division, Sunnyvale, California. Also, all pertinent test data from Operation Dominic has not, as yet, been made available in final form. The missing test data includes fireball size data primarily and thermal data to a lesser degree.

A continuing investigation to uncover any new relevant effects of thermal radiation on the eyes is also proposed. Cognizance will be maintained in order to keep abreast of any recent findings concerning recovery times, the response of the tissues to various levels of flash energy, and absorption of ocular media, retinal pigment and choroid. Particular vigilance will be directed toward such places as Ohio State University, Medical College of Virginia, University of Michigan, the School of Aerospace Medicine, and the Naval Air Development Center.

All eye effects information acquired by Technology Incorporated under Contract AF 41(609)-2906 for the School of Aerospace Medicine will be fully exploited wherever applicable to the eye effects problem in general and the mathematical models specifically.

Technology Incorporated proposes to conduct this investigation by all means at its disposal, e.g., telephone calls, personal visits, literature search, information available through the monitoring agency, etc.

3.2 Analysis

In order to facilitate the preparation of eye safe separation distance charts and the development of eye protection criteria, it is prudent to define mathematical representations of the nuclear detonations, the intervening atmosphere and the interaction of the energy with the eye of the observer. In order to produce reliable mathematical representations, it will be necessary to analyze, evaluate and compare currently available data on both nuclear weapons detonation and ocular response to thermal radiation in order to further explore the relationship between the two. To aid in the investigation and calculation associated with eye effects, the Philco 2000 Computer System and other computational facilities located in Building 150, Brooks Air Force Base, Texas, will be utilized whenever feasible.

3.2.1 - Fireball. Although a fireball source equation for low altitude air bursts was developed under Contract AF 41(609)-2437 using Dominic test data, there are limitations to this model. The most serious limitation is a lack of early time data which is a region of prime interest. If no other better fireball data becomes available, Technology Incorporated proposes to extend the scope of this source model to include other burst heights of interest, and to generally upgrade the model by incorporating applicable fireball data as it becomes available.

Several organizations have developed, or are developing, theoretical fireball models. It is possible that the results of these theoretical studies can be incorporated in the source model for use in the retinal burn-flashblindness programs. Presently, limited data is available from the Air Force Weapons Laboratory and Lockheed Missiles and Space Division. The most promising of the two, at this time, is the Lockheed data which is in the form of color temperature, ultra violet cut-off wavelength, and uniformly radiating fireball size all as a function of time. This data might be used to supplement the empirical

model or, if it becomes available in sufficient quantity, it could be used in its present form since it has compared favorably with test data.

Whenever reliable experimental data is available in proper form and quantity, it will be used in defining the fireball source, however, the available theoretical data will be compared with test data where possible and used to extend the source in those regions where test data does not exist, is inconsistent, or is not available.

3.2.2 - Atmosphere. In choosing a model atmosphere in which to calculate atmospheric transmission as a function of wavelength, it is recommended that a general type atmosphere be utilized, i.e., continental, industrial, or perhaps, maritime. This recommendation is fostered by the Air Force Standard Day method of classification and because the largest number of nuclear detonations will probably occur over inland areas during combat conditions. Once the transmission path is above the haze level, the type of atmosphere is unimportant and molecular scattering corrected for density may be used. In past

calculations the atmospheric density between two points at coaltitude was assumed to be constant. This approximation serves quite nicely and introduces little error when the path length is relatively short. However, for certain conditions of yield and position the path length may well exceed a hundred miles. Under these conditions it may be advisable to use a better estimate of the variation in density which will reflect the actual optical path length. Any change in method will be dictated by the amount of error introduced by using the approximation.

When dealing with the flashblindness problem, the transport of energy through the atmosphere must be handled differently. In addition to the energy focused by the eye, the scattered and reflected energy will make a background contribution. For low altitude detonations the surface albedo for for the Air Force Standard Days might well be used to account for reflected energy. The amount of scattered energy will depend upon the composition of the model atmosphere used.

3.2.3 - Eye. For the simplified human eye, the most probable dimensions for pupil size and focal length are three and seven millimeters for diurnal and nocturnal pupillary diameter and seventeen millimeters for the equivalent focal length of the eye. In the past, the three ocular transmission tables which are presented in DASA Report 1282 entitled "Model for Prediction of Retinal Burns" and which are reportedly based on research at the Medical College of Virginia have been used for computational purposes. Because of the manner in which these values were collected, i.e., a sensor at a relatively large opening cut in the sclera, scattered energy may have been included in the results. If this is so, it maybe necessary to use data collected at the University of Michigan using a different method.

The temperature rise necessary to cause retinal damage will be based on values previously determined by the mathematical model by utilizing minimal burn data. The earlier minimal temperatures will be updated using laboratory data currently being generated at the School of Aerospace Medicine under contract AF 41(609)-2906.

It may be advantagous to check the predicted temperature given by the mathematical model against a scaled-up physical model.

This might be done by a gridwork of thermocouples submerged in a water bath on which a known quantity of thermal energy is focused.

In developing a flashblindness prediction model, the same spectral energy source as used for retinal burn can be utilized. After the energy has been properly transported through the atmosphere, it can be adjusted for the luminous efficiency curve of the eye. (It will probably not be necessary to distinguish between scotopic and photopic luminous efficiency curves at this time because of other inaccuracies.) The resulting energy can then be used as input to the flashblindness equations developed at General Electric to give an estimate of recovery time. Presently, these equations have a fairly large percent standard error which can be decreased by inclusion of better data which should be available from research at Ohio State University. Safe separation distances for flashblindness would involve choosing an acceptable recovery time compatible with the mission being performed.

It is recommended that close liaison be maintained between interested Ophthalmology Department personnel and Technology Incorporated's

project team so that any extensive modifications to the models or generation of any significant amount of data may be judiciously initiated by the Contract Monitor.

4. RELATED EXPERIENCE

Technology Incorporated will utilize the experience which has been gained in related research efforts to successfully complete the proposed program. This related experience not only includes complete awareness of present state-of-the-art, but also, certain insight into those procedures and mathematical treatments which are especially applicable to the present problem.

Company background and experience may be emphasized through a review of past and present related research efforts.

Utilizing a computer program in FORTRAN, Technology Incorporated computed the retinal safe-separation distances from the burning effects of nuclear detonations. Curves based on sea-level positions of the nuclear blast and the observer with and without protective eye devices were prepared for normal and abnormal standard days under day and night conditions. The Radiation Shielding Branch of the 6570th Aerospace Medical Research Laboratories sponsored this study under Contract AF 33(657)-8334.

The research conducted under Contract AF 33(657)-11557, a continuation of the study under Contract AF 33(657)8334, refined

previously prepared curves indicating under various conditions the retinal safe-seapration distances between observer and nuclear blast, both positioned at sea level, and extended the scope of these curves to different observer and nuclear blast evaluations. Upon completion of these curves, Technology Incorporated investigated the temperature associated with minimal retinal burns produced under laboratory conditions.

Supplementing the research initiated under Contract AF 33(657)-8334 and continued under Contract AF 33(657)-11557, Contract AF 41(609)-2437, also sponsored by the Aerospace Medical Division, involved refinement of a mathematical model of retinal burns from nuclear flashes. Another task required preparation of nuclear fireball source tables which showed for various yields and altitudes the spectral irradiance and dimensions versus time. Related to this requirement was the writing, for the Philco S-2000, of a program to handle spectral data as a direct input to a mathematical model for retinal burn. Also retinal burn data from laboratory tests were analyzed in the light of similar data from weapons tests.

Working in support of the Air Force Special Weapons Center, Kirtland Air Force Base, Technology Incorporated is performing various statistical tests on nuclear test data to develop a statistical design

procedure for shock isolation systems to be incorporated in underground protective structures. Tasks include dividing air-blast induced ground shock records into sets of different wavelength patterns, statistically analyzing the records in each set for population grouping, estimating the significant parameters defining each set distribution function, deriving from these functions the response distribution function of a mechanical system, finding the probability of the mechanical system failure due to each input set, and finally giving a detailed statistical design procedure for the shock isolation systems.

Nuclear blast effects upon in-flight aircraft were investigated in the research effort under Contract AF 33(657)-8373. Nuclear phenomena were examined to determine the heat, overpressure, and radiation inputs to specific weapon systems as functions of the atmosphere, weapon yield, and aircraft location. After these levels were computed and the aircraft areas most susceptible to damage were ascertained, the tolerance levels of each parameter and the structural limits for particular types of aircraft were established.

Under Contract AF 33(657)-10686, Technology Incorporated is analyzing existing nuclear effects prediction formulae to verify the safe-escape calculations used in ADC Nuclear Weapon Delivery

Handbooks. This analysis will lead to the writing of a nuclear weapons effects IBM 7090 program for the ASD Offensive Systems Office. In addition, voids in existing knowledge of systems capability are being determined to recommend future test efforts to the Air Force.

Contract AF 41(609)-2464 for the USAF School of Aerospace Medicine involved research on the ocular effects of thermal radiation. Included was the design, fabrication, and calibration of a high-intensity thermal source for experimental use. Program objectives included the defining of criteria for the production of flashblindness and chorioretinal burns, developing and testing techniques to predict flashblindness and chorioretinal burns suffered under various exposure conditions, and developing and evaluating devices as well as techniques to protect against visual impairment from thermal radiation exposure. Particular aims sought development of a mathematical model capable of predicting flashblindness severity and duration, wavelength response, and post-exposure illumination level; expansion of flashblindness threshold data; and methods to identify minimal burns and to relate them to pertinent parameters, such as image size, irradiance, and retinal location.

Under Contract N 140(131)-75271B (X), Technology Incorporated aided the Naval Material Laboratory in installing, calibrating, and operating the instrumentation to record the thermal and visible radiation effects of nuclear detonations. Such data, recorded on magnetic tape, oscillogram, camera film, and strip chart, was processed.

Initiated under Contract N 140(131)-75231 B(X), research on the thermal and visible radiation effects of nuclear detonations continues under Contract N 140(62462)-7680 4B for the Navy's Applied Science Laboratory. The processing of Operation Dominic data is a major phase of this effort. In the development of a testing capability, instrumentation systems to record data on oscillograms and magnetic tape are being designed, fabricated, and tested. These systems will incorporate specially designed transducer packages. Various light sources are being employed in the development of calibration systems for laboratory and field use.

Under Contract N 62269-2264, sponsored by the U. S. Naval Air Development Center, Technology Incorporated is expanding the capability of a multivisual optical device designed for nuclear flash blindness experimentation. Phenomena related to flash blindness are being studied to evolve additional types of test parameters.

Predetermined by digital computation, data for test parameters, such as target-surround luminance, flicker rates, and target positioning, will be fed through tape or cards as simulated input to the optical device and the resulting signal output will be supplied to an analog-to-digital converter to generate a data format compatible with a standard electronic computer.

Contract AF 33(616)-7887, sponsored by the Bionics and Neurophysiology Section of the Aerospace Medical Research Laboratories, entailed the design and construction of experimental equipment and simulation systems for research on living information handling systems. Included among the developmental equipment was an electronic analog, based on the functioning of biological systems, to simulate neurosensory networks for the conversion of sensory information, such as a light or sound pattern, to a form compatible with neuron network analogs or adaptive computers.

5. REPORTS

Technology Incorporated will submit informal progress reports, in triplicate, at the end of three, six and nine months and a final technical documentary report at the end of thirteen months. The informal progress reports will cover work status, difficulties encountered during the reporting period and the remedial action taken, and a statement of anticipated activity during the subsequent reporting period. The final report will be submitted as follows:

A. Instructions for Preparation:

The report will be prepared in accordance with the provisions of USAF Aerospace Medical Division publication, "Specifications and Standards for Technical Reports", (or respective supplementing or superseding documents.)

B. Preliminary Draft:

1. Technology Incorporated will submit a typed, double-spaced preliminary draft manuscript of the Technical Documentary Report to the USAF School of Aerospace Medicine for technical and format review. The preliminary draft shall be complete, including (as applicable) all test results, conclusions, tables, illustrations, and appendices.

2. Technology Incorporated will be responsible for insuring that the report is editorially correct and that it conforms to accepted common usage and good practices in scientific and technical writing for a generally broad audience.

3. When the preliminary draft is returned, Technology Incorporated will make the changes, additions, or corrections designated by the USAF School of Aerospace Medicine. The corrected copy will be called the approved draft.

4. Technology Incorporated will make every effort to insure that the preliminary draft manuscript is complete and accurate, thus eliminating the need for submitting a second preliminary draft. However, if the USAF School of Aerospace Medicine determines that the first preliminary draft require extensive rewriting or additions requiring further technical review by the USAF School of Aerospace Medicine, the first preliminary draft will be returned for appropriate revision. The Contractor will prepare a second preliminary draft. The Contractor will return the revised draft for approval of the USAF School of Aerospace Medicine.

5. Final Drafts: Reproduction Copies for Photo-offset Printing: After receipt of the approved draft, Technology Incorporated will prepare an original typed bound copy in accordance with the requirements of Paragraph A and submit this copy to the USAF School of Aerospace Medicine for final format review, approval, printing, and distribution. In addition, Technology Incorporated will prepare and forward 51 Xerox quality bound copies of the final draft fifteen months after the starting date of the contract.

6. CHRONOLOGY

Technology Incorporated is prepared to perform the proposed work as a continuation of Contract AF 41(609)-2437 and estimates that it will require a period of one year.

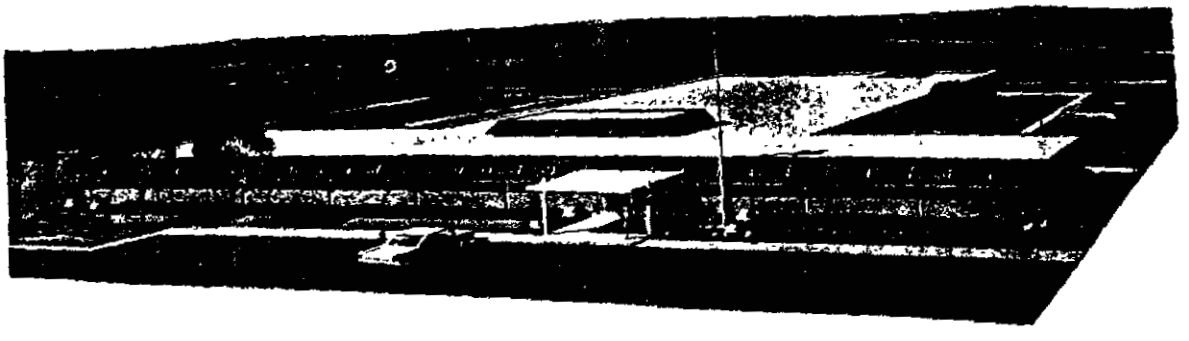
7. PERSONNEL

The work proposed by Technology Incorporated will be conducted under the general supervision of Dr. Ralph G. Allen, Director of Research, Texas Division.

It is anticipated that Mr. Arthur F. Muller will be assigned to this project as principal investigator. He has had considerable experience in this scientific area and has been principal investigator on the preceding effort.

In addition, other scientific members of the staff will be available to contribute their special skills to the solutions of the various problems associated with this research effort. Their resumes are presented on the following pages.

PERSONNEL



RALPH G. ALLEN, JR., Ph. D., Principal Research Scientist

Education: B. S., University of Texas, 1947
M. A., University of Texas, 1948
Ph. D., University of Texas, 1953

Publications:

(1) Allen, Ralph G., Jr., "Slow Neutron Cross Sections of Au, Ag, In, Ni and NiO," Physical Review, January 1954.

(2) Pickering, John E., W. T. Culver, Ralph G. Allen, Jr., R. E. Benson, F. N. Morris, D. B. Williams, R. W. Zellmer, and E. O. Richey, Effects on Eyes from Exposure to Very-High Altitude Bursts, Operation Hardtack ITR-1633. Project 4. 1., 1958.

(3) Allen, Ralph G., Jr., The Shadow and Substance of Space, Command Staff School, Maxwell AFB, Alabama, April 1960.

(4) Allen, Ralph G., Jr., Frank A. Brown, Loren C. Logie, David R. Rovner, Stephen G. Wilson, Jr., Robert W. Zellmer, Acute Effects of Gamma Radiation in Primates; SAM Reports 59-41, April 1959; Radiation Research, Vol. 12, No. 5, pp. 532-539, Academic Press Inc., May 1960.

(5) Zellmer, Robert W., and Ralph G. Allen, Jr. "Cosmic Radiation - Laboratory Observations," presented at symposium on Aerospace Radiobiology, October 1961; published in Aerospace Medicine, Vol. 32, No. 10, pp. 942-946.

(6) Brown, Frank A., Ralph G. Allen, Jr., and Bruce E. Jacobson, Determination of the Dissociation Constants of Chlorophenal Red, Paranitrophenol and Phenol Red, SAM Report 61-69, October 1961; Radiobiology 7757-67016.

(7) Pickering, John E., Ralph G. Allen, Jr., and Oskar L. Ritter, Problems in Shielding. Medical and Biological Aspects of the Energies of Space, Columbia University Press, New York and London, 1961.

RALPH G. ALLEN, JR., Ph. D., Principal Research Scientist (continued)

(8) Allen, Ralph G., Jr., Everett O. Richey, James F. Culver, et al., "Production of Chorioretinal Burns by Nuclear Detonations and Tests of Protective Devices and Phototropic Materials," Operation Dominic, Project 4.1, POIR, August 1962. FCDASA 2014 SECRET RD.

(9) Allen, Ralph G., Jr., Everett O. Richey, James F. Culver, et al., "Production of Chorioretinal Burns by Nuclear Detonations and Tests of Protective Devices and Phototropic Materials," Operation Dominic, Project 4.1, POIR (Addendum)," November 1962, FCDASA 2014-1.

(10) Zellmer, Robert W., Granville J. Womack, Richard C. McNee, and Ralph G. Allen, Jr., "Significance of Combined Stresses of G-Forces and Irradiation," presented at the Aerospace Medical Association Meeting in Atlantic City, New Jersey, April 1962; published in Aerospace Medicine, Vol. 34, No. 7, July 1963.

(11) Allen, Ralph G., Jr., Everett O. Richey, James F. Culver, et al., "Production of Chorioretinal Burns by Nuclear Detonations and Tests of Protective Devices and Phototropic Materials," Operation Dominic, Project 4.1, POIR, October 1963, in publication by FCDASA SECRET RD.

(12) Allen, Ralph G., Jr., James F. Culver, and Everett O. Richey, "Chorioretinal Burns and Protective Devices," presented at DASA Fish Bowl Symposium, Chicago, Illinois, November 1963.

(13) Allen, Ralph G., Jr., and Everett O. Richey, "Chorioretinal Burns (Chapter Seven)," Thermal Effects Handbook, AF Weapons Laboratory, 1963.

Experience: As chief, Nuclear Physics Division, Air Force Office of Scientific Research, Dr. Allen planned, initiated, and managed the primary Air Force program of contract research in basic nuclear physics, including research in elementary

particles, nuclear structure, cosmic rays, relativity and gravitation. He also represented the AFOSR and the Air Force on various scientific committees, including committees of the National Science Foundation, the National Academy of Sciences, and the Federal Council for Science and Technology.

As chief, Plans and Analysis Division, Aerospace Medical Division, he interpreted Air Force plans and objectives in terms of the Aerospace Medical Division, particularly in the rapidly developing field of space technology.

With the Department of Radiobiology, Air Force School of Aviation Medicine, Dr. Allen planned and conducted research dealing with the effects of radiation on biological systems. Part of this work was concerned with the biological effects of radiations from nuclear weapons and was conducted during weapon tests at the Nevada and Pacific test areas.

As chief, Air Force Special Projects Office, AEC Oak Ridge Operations Office, Dr. Allen performed Air Force liaison with the AEC and the Oak Ridge National Laboratory in connection with technical projects of mutual interest to the Air Force and the Atomic Energy Commission, particularly the Aircraft Nuclear Propulsion Program. This work involved a familiarity with reactor principles and reactor development problems, metallurgy, shielding, radiation effects, nuclear instrumentation, etc. In addition, he gained experience in various aspects of radiobiology, health physics, and dosimetry associated with Air Force radiobiology projects conducted at the Oak Ridge National Laboratory and the Air Force School of Aviation Medicine.

While employed by the Optical Research Laboratory, University of Texas, he planned, directed, and performed research in physical optics with primary emphasis on investigations dealing with interference phenomena and the optical properties of thin metallic films and interference filters.

ARTHUR F. MULLER, Senior Research Mathematician

Education: A. B. Mathematics, St. Benedicts College
M. S. Mathematics-Statistics, Kansas State University
Completed additional course work in Mathematics at the University of Wichita and the University of Dayton

Professional Affiliations: Society for Industrial and Applied Mathematics
American Statistical Association

Publications: Minimum Distances for Retinal Burn, AMRL-TDR-63-56
Co-author - A Study Covering Utilization of Statistical Data in Relation to Design Criteria Analysis Techniques

Experience: Serving as an applied mathematician, Mr. Muller is now engaged principally in the mathematical analysis of data utilizing the Philco 2000 to reveal the thermonuclear effects on the chorioretinal region of the human eye. He had previously conducted an extensive study on the utilization of statistical data in relation to design criteria analysis and to the design of IBM 7090 programs for aeronautical loads programs.

During prior employment with the Boeing Company, Wichita, Kansas, Mr. Muller's main responsibility was the analysis of engine-to-wing configurations, using mission programs written specially for them. Mr. Muller also worked on the analysis of structures, the resolution of aerodynamic problems, and the design of IBM 709 programs with FORTRAN and machine language. His various efforts included the performance of cross-correlations, auto-correlations, mission program design, regression analysis, and the writing of several FORTRAN programs.

Before the Boeing Company employment, Mr. Muller taught mathematics at St. Benedicts College, Atchison, Kansas.

ROBERT A. SCHMALL, P. E., Associate Principal Research Engineer

Education: M. S. in Aeronautical Engineering, University of Cincinnati
Bachelor of Mechanical Engineering, University of Dayton

Professional Affiliations: American Society of Mechanical Engineers
Dayton Society of Professional Engineers

Publications: "The Transfer of Thermal Radiation from a Point Source to a Plane Receiver, Both Source and Receiver Located Between Two Lambert Planes," ASD Technical Report 61-282, June 1961.

Design and Operation of a Space Rendezvous Simulator, AF APL TR-64-130, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, October 1964. (coauthor)

Experience: As a staff member of the company's Astronautics Division, Mr. Schmall applies the theories of mass and energy transport, dynamics, and kinematics to pertinent research. Included among his activities have been the investigation of the thermal and pressure effects of nuclear detonations on manned and unmanned aeronautical systems; the computer programming of thermal and over-pressure inputs resulting from nuclear detonations in multiple combinations of yield, burst height, and atmospheric conditions: the design, development, and test of an advanced wind shear probe; the design of a hydraulically actuated acceleration system; and the design and evaluation of various space maintenance concepts and equipment. Mr. Schmall has a broad programming experience including use of the Donner Analog computer, machine language and ALGOL on the Burroughs 205 and 220, and FORTRAN on the IBM 1620 and 7094.

Before joining Technology Incorporated, Mr. Schmall was a research engineer for the University of Dayton Research Institute where he worked on heat transfer in aircraft structures, the transport of energy through the atmosphere, the determination of aircraft response in the delivery of nuclear weapons, and the measurement of laser outputs. He was also an instructor in the Mechanical Engineering Department of the University.

ROBERT A. SCHMALL, P. E., Associate Principal Research Engineer (Cont'd)

As a Project Engineer for the Duriron Company, Inc., he was responsible for the design, development, and test of heat exchangers, pumps, valves, and filters for the chemical process industry.

ROGER L. BESSEY, Research Physicist

Education: B.S. in Physics, Yale University
M.S. in Physics, Purdue University

Professional Affiliations: Sigma Pi Sigma

Experience: Mr. Bessey has been applying various statistical and computational techniques to nuclear detonation data to determine the threshold positions and distances for permanent visual damage and temporary flash blindness. Various types of atmospheres, which govern the degree of nuclear effects transmission, the relative altitudes of the nuclear burst and the participating personnel, and the types of protective eye devices are among the vital parameters of his research. He is currently programming a *Philco* S-2000 Computer for a more stable solution to a heat conduction problem.

On the faculty of Purdue University, he served in the Physics Department. While engaged as a research physicist for the Army Quartermaster Corps, he conducted flash blindness experiments with laser models; by using 1 Mev Van der Graaf generator and resistivity measurements, he studied energy for production of vacancies and intersitials in thin metel foils; and he constructed a shock tube.

PATRICK W. WILSON, JR., Junior Research Physicist

Education: B. S. in Physics, St. Mary's University
Graduate courses in Physics, St. Mary's University
Studies in Electronics in U. S. Navy

Experience: Mr. Wilson is doing work in the analysis of nuclear weapon fireball data with respect to use as input to a mathematical model for the prediction of retinal burns. He has conducted investigations of the merit of various eyeball parameters in connection with this work. Assigned to basic research on the human eye, he has been active in the design, fabrication, calibration, and operation of instrumentation systems to facilitate this research.

While serving the U. S. Navy, Mr. Wilson maintained and operated various electronic mechanisms, including airborne communication, navigation, countermeasures, and anti-submarine warfare equipment.

BRIAN E. ARMENT, Scientific Programmer

Education: B. A. in Mathematics, Wilmington College

Experience: Mr. Arment is currently involved in processing irradiance data from nuclear detonations to determine resulting temperature rise in the eye for prediction of retinal burns. He also wrote several computer programs for determination of total irradiance and radiant exposure at a source.

Engaged in the processing of physiological data, Mr. Arment has been evaluating and improving a system for the signal correction and diagnostic analysis of orthogonalized electrocardiographic data by means of pattern recognition techniques. He has written several computer programs to perform the following operations: correlation of respiration and heart rates of human subjects experiencing various events before undergoing free-fall impact tests, analysis of five physiological parameters from dogs subjected to vibration tests to determine respiratory and hemodynamic responses, and analysis of parameters associated with human subjects subjected to impact tests for center-of-mass shift studies.

In the performance of his assignments he has been involved in nearly all phases of electronic data processing. He has written programs in ALTAC III for the PHILCO 2000 computer, and FORTRAN II and IV for the IBM 7090 and 7094 computer, and has operated the D.E.C. PDP-1 computer.

P. E. KIELPINSKI, Research Statistician

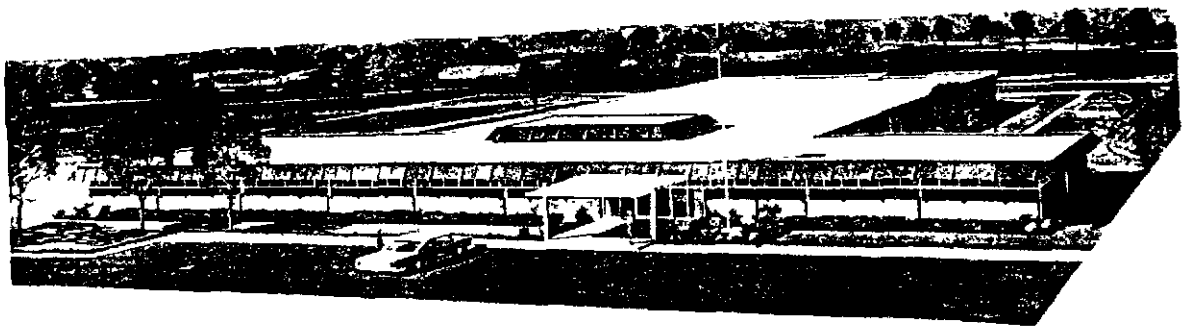
Education: B. S. in Mathematics, University of Dayton
M. S. in Mathematics, Purdue University
Doctoral Studies in Mathematical Statistics, Purdue University

Experience: Mr. Kielpinski is a Research Statistician with Technology Incorporated and Assistant Professor of Mathematics at St. Mary's University of San Antonio, Texas. He is currently involved in research pertaining to statistical analysis of physiological data and experimental statistical design.

Mr. Kielpinski was a recipient of a National Institutes of Health fellowship for the study of public health statistics of the School of Public Health of the University of Michigan.

During his two years of doctoral studies, Mr. Kielpinski served as a statistical consultant of the Computing Center of Purdue University. He collaborated in research in Economics and Agricultural Economics.

FACILITIES



In early July 1965 Technology Incorporated moved into its newly constructed 30,000-square-foot plant facing Colonel Glenn Highway. Located on a 12-acre site, the plant is within a half mile of the center of both the Wright-Patterson Air Force Base complex and the Dayton campus of Ohio State University-Miami University.

Completely air-conditioned and soundproofed throughout, the plant contains administrative, engineering, and research sections. Among the support facilities are a data processing section, developmental and environmental test laboratories, an engineering model shop, an engineering design and technical art department, and a publications department. Data processing equipment includes semiautomatic chart readers and an 80-inch-bed stereo viewer with a complete line of auxiliary equipment to reduce analog data to digital form for immediate printout as well as for computer processing. The model shop has the capability of fabricating with any type of material from plastics to stainless steel. Supported by technical art and editorial personnel, the publications department is equipped with a complete line of equipment to print all types of final reports and manuals.

To serve customers in the Southwest more effectively, the Texas Division is staffed and equipped for research, design, development, and manufacturing functions. The Texas facility is housed in a modern, air-conditioned 10,000-square-foot plant in San Antonio, Texas.

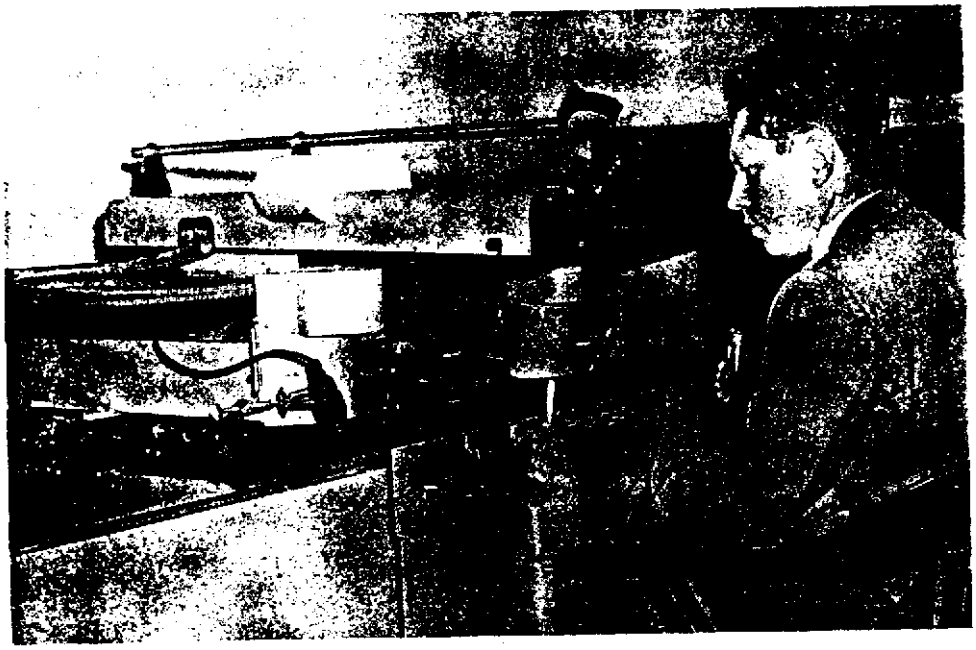
Engineering liaison offices to serve our customers in the East, Midwest, Southwest, and West are located, respectively, as follows: 6461 Edsall Road, Alexandria, Virginia 22312 (Tel. 703, 354-6311; TWX 703, 354-0301); 7400 Colonel Glenn Highway, Dayton, Ohio 45431 (Tel. 513, 426-2405; TWX 513, 426-6991); 8531 N. New Braunfels Avenue, San Antonio, Texas 78217 (Tel. 512, TA-4-7373; TWX 512, 571-0939); and 6305 Woodman Avenue, Suite 106, Van Nuys, California 91401 (Tel. 213, 781-2720).

Technology Incorporated holds a Department of Defense Secret facility clearance. The accounting, purchasing, and property control procedures now in effect have been approved for Government contracting.

ENGINEERING
MODEL SHOP

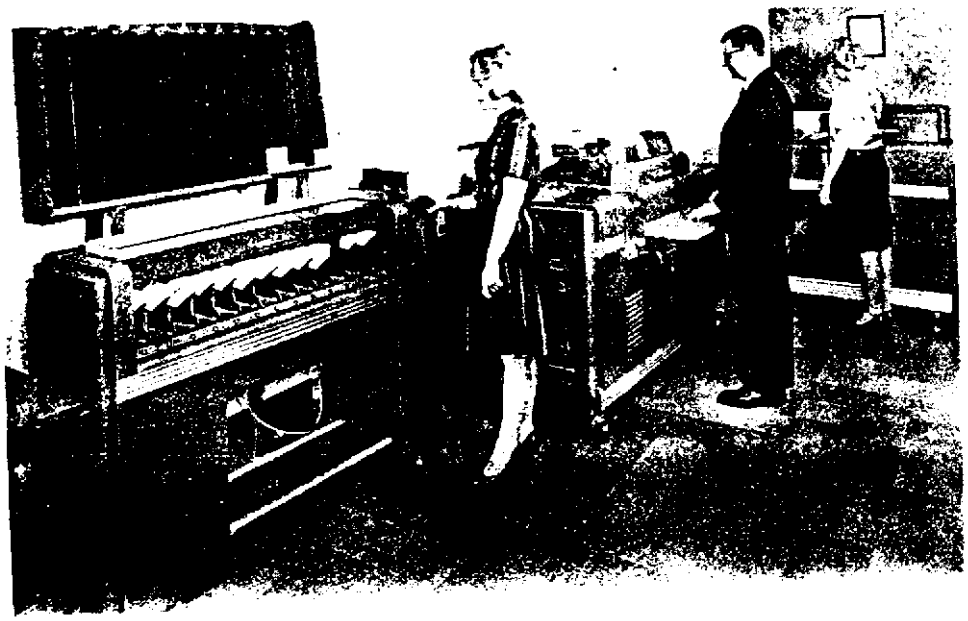
This complete 5800-square-foot model shop has the capability of fabricating with any type of material from plastics to stainless steel. Included among the operations performed are drilling, milling, turning, gas and arc welding, and high- and low-temperature soldering. Facilities include provision for complete sheet metal construction and precision measuring and inspection. Experience of seven of the senior model makers averages 20 years.

DATA MEASURING AND PROCESSING FACILITIES



One of only two existing models of the 80-inch-bed stereo viewer to enable accurate generation of a common coordinate system for numerous overlapping aerial photographs. After a pair of conjugate (common) points — one in a frame in the left bank and the other in a frame in the right bank — have been aligned, the operator actuates the automatic measuring of their coordinates and the subsequent transcribing of the measurements onto punch cards.

In this view of a section of the Data Reduction Department facilities may be seen parts of 12 Benson-Lehner Model K Oscar reader and IBM 026 key punch combinations. Here measured analog data are transcribed in digital form onto punch cards.



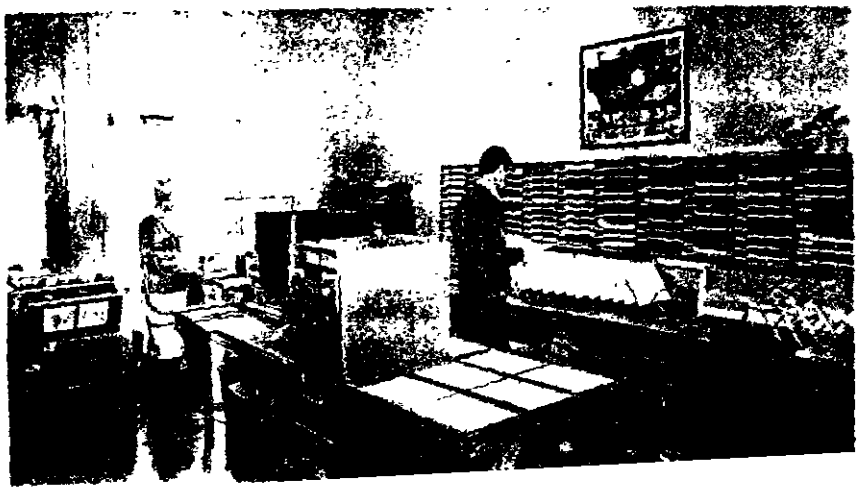
Among the items comprising the complete line of data processing equipment are the IBM 082 sorter, IBM 407 tabulator, and IBM 519 card punch seen here from left to right.

SUPPORT FACILITIES

Library contains current product catalogs, technical publications, DDC documents, military specifications, periodicals, and journals.

Engineering Design and Technica Art Department. Here are prepared all engineering drawings, schematics, flow charts, and technical illustrations presented in reports, specification sheets, and manuals.

Xerox Model 914 copier and Ditto Model L-16 offset duplicator for single and multiple copy reproduction.



Nu-Arc plate burner and Xerox N camera for offset reproducible c equipment for cutting, collating, binding.

LABORATORY TEST EQUIPMENT

Quantity	Description
1	Air Sampler, Sentry Model 25101
1	Amplifier (hi-fi), Model EE02254
1	Amplifier (high gain), Tektronix Type D
1	Amplifier (strain gage), Central Eng. Model #3AC
1	Balance (triple beam), Ohaus Scale Corp. - max C. 2600g
1	Barometer, Aloe Model #V9120
1	Barometer, Precision Instrument Model 9434
1	Bridge (general radio), Orthonull CRL
1	Bridge (impedance), Heath, 1B-2A, #009-07794
1	Camera, Graflex Model #CF905
1	Capacitester, Model CT-1
2	Clean Bench, Farr Model C-6
1	Counter, Hewlett-Packard Model #522B
1	Counter (frequency), Hewlett-Packard, #521C1909
1	Counter (frequency), Hewlett-Packard, #032-04585
1	Curve Tracer (transistor), Technology Incorporated
1	Curve Tracer (transistor), Tektronics, Type 575
20	Decade (capacitance)
4	Decade (capacitance), Heath
2	Decade (capacitance), Model CDA-5
2	Decade (capacitance), Model CDB-5
4	Decade (resistance), Heath
5	Decade (resistance), Eico Model 1171-W
8	Decade (resistance), Leeds and Northrup
21	Decade Resistors
1	Distortion Analyzer, Hewlett-Packard, HO 2330B
1	Drill Press (precision), Dumore Model 16-021
1	EPUT and Timer, Beckman Model 735OR
1	Fan (centrifugal), Clarage Model 309-G Type O
1	Flow Element (precision, laminar), Meriam Model 50MH10-1
1	Flow Element (precision, laminar), Meriam Model 50MJ10
1	Flowrator, Fischer and Porter Model 10A2735A-LK
1	Generator (R. F. signal)
1	Generator (R. F. signal), SG-8
1	Generator (signal), Washington Inst. Tech. Model #43-41
1	Generator (signal), Ferris Model #18FS
1	Generator (sine square), AG10
1	Grinder, Dumore Model 1-111
1	Heat Exchanger, Prefex Model RBS-640-132
1	Indicator (temperature)
1	Laminar Flow Element, Merriam Inst. Model 50MH10-1
2	Magnifying Lamps, Luxo
1	Magnifying Light (5 power), 8 in. diameter
2	Manometer (inclined tube), Merriam Model 40HE35WM
10	Manometer (water)
1	Manometer (mercury), multiscale
1	Meter (distortion), HD-1
1	Meter (grid dip), Millen Model F718
1	Meter (grid dip), Millen, w/coils
2	Meter (microamp), Simpson (Shell)
1	Meter (multipurpose), International Model M2548-2
1	Meter (meg. ohm), General Type 1862-C
1	Meter (volt), Ballantine Lab. Model #302B
1	Meter (volt), D. C., Fluke, Model 801
1	Meter (volt), Hewlett-Packard Model #400H

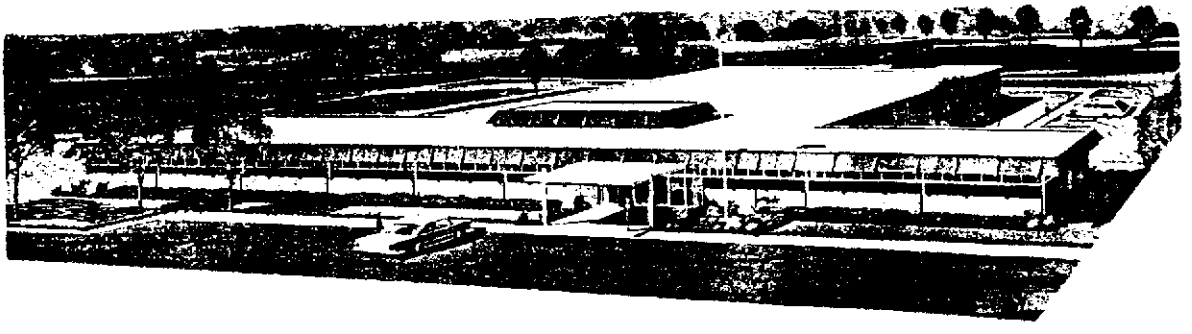
DATA PROCESSING AND REPRODUCTION FACILITIES

Quantity	Description
7	Calculator (desk), Marchant
1	Camera, Crown Graphic "45"
1	Diazo Machine, Brunning 42", "Revolute"
1	Nu-Arc Plate Burner
1	Offset Duplicator "Ditto", Model L-16
15	Oscillograph Reader, Benson-Lehner Model Oscar "K"
1	Photographic Stero Viewer with Key Punch and Type Readouts
1	Photograph Reader, Benson-Lehner Model Oscar N-2 with Key Punch and Type Readouts
1	Planimeter, A. Ott
15	Punch (key), IBM Model 026
1	Punch (reproducing), IBM Model 519
1	Scale (variable), Gerber
1	Sorter, IBM Model 082
1	Tabulator (accounting), IBM Model 407
1	Verifier, IBM Model 056
2	Xerox No. 4 Camera
1	Xerox 914 Copier

MODEL SHOP FACILITIES

Quantity	Description
1	Anvil (Swedish steel), 30 in.
1	Blocks (precision gage), Weber
1	Calipers (vernier), Lufkin - 6 in.
1	Calipers (adj. feel), Lufkin - 1 to 20 in. inclusive
1	Compressor (air), Milwaukee Model C202 - 2 in. by 3 in. stroke, 1 1/2 H. P.
1	Drill (flexible shaft), Craftsman - 1/2 H. P.
1	Drill (hand), Black and Decker - 1/2 in. capacity
1	Drill (hand), Shopmate - 1/2 in. capacity
1	Embossing Tool, Dymo
1	Engraving Tool, Speedway
1	Etcher and Demagnitizer (electrical), Daytrol Model 100
1	Filing Machine (table), Oliver
1	Gage, Height, Brown and Sharpe - 18 in.
1	Gage, Height, Starret Model 454 - 12 in.
1	Gage, Small Hole (1/2 ball), Lufkin Model 785 - 1/8 in. to 1/2 in.
1	Gage, Telescoping (rod type), Lufkin Model 79L - 1/2 in. to 6 in.
1	Gage, Wire (round), General Model 20 - No. 1 to No. 36
1	Gage, Lay-out (round-base, standard), Fairfield - 6 in.
1	Gage, Radius (flat, Brown and Sharpe) - 1/32 in. to 1/2 in.
2	Gages, Surface (flat base), Lufkin - 6 in. and 12 in.
1	Grinder (surface), Covell Model 7A - 11 3/4 in. Height, 6 in. x 12 in. chuck
1	Grinder (internal-external), Brown and Sharpe Model 3275 - #1, 18 in. between centers
2	Grinder (6 in. snag), Tool Line Model 2645551 - polishing and buffing wheels
1	Grinder (10 in. snag), Standard Model 622445 - polishing and buffing sheels
1	Grinder (hand), Dumore Model 8-021, #21900 - 0 to 1/8 in. Jacobs Chuck

EXPERIENCE



Ascertaining accurate levels of human tolerance to forces of abrupt deceleration through test and calibration was the prime objective of Contract AF 33(616)-6970. This effort, conducted for the Aerospace Medical Research Laboratories, involved the design of instrumentation and a "fail-safe" control system for the test equipment, the Vertical Deceleration Tower located at Wright-Patterson Air Force Base. A built-in analog computer for data optimizing before recording was designed, constructed, and incorporated into the recording system.

Under Contract N 62269-2264, sponsored by the U.S. Naval Air Development Center, Technology Incorporated is expanding the capability of a multivisual optical device designed for nuclear flash blindness experimentation. Phenomena related to flash blindness are being studied to evolve additional types of test parameters. Predetermined by digital computation, data for test parameters, such as target-surround luminance, flicker rates, and target positioning, will be fed through tape or cards as simulated input to the optical device and the resulting signal output will be supplied to an analog-to-digital converter to generate a data format compatible with a standard electronic computer.

To acquire flight loads data for Contract AF 33(616)-7593, Technology Incorporated installed and maintained recording systems in thirty F-101A and C and thirty RF-101 aircraft, assigned to air bases in England, France, and Libya. From the recordings selected data were extracted, processed, and analyzed to determine the load spectrum for fatigue life evaluation. Such findings may lead to the verification or revision of structural design criteria.

Under subcontract PO-4364 with IBM, Technology Incorporated has been applying various techniques to incomplete photogrammetric data to study methods for rectifying photographic images. Rectified by determining photogrammetric parameters obtained from ground control data, object plane coordinates are derived as functions of image plane coordinates. Projective geometry concepts are employed; and specific techniques include iterative solutions, least mean square fits, and solutions of over-determined systems of linear over-homogeneous equations. From estimates of image and object plane coordinate covariances used to derive transformational matrices, variances of object plane dimensions are derived. Photogrammetric parameters are solved through matrix manipulations involving inverse, transpose, and multiplicative operations. The IBM "Storm" Matrix Manipulation program is being used to solve over-determined systems of linear equations.

Research completed under Contract AF 33(616)-7440 included the design, fabrication, calibration, and test of a complete electronic instrumentation system involving three RF telemetry links for in-flight testing of B-58, RS-70, and Dyna Soar Emergency escape systems. Anthropomorphic dummies and two B-58 escape capsules were instrumented; a semiautomatic control system for the instrumentation and ejection sequencing was installed in the test vehicle; and a mobile van facility with test data receiving, recording, discrimination, playback, and display capabilities was provided.

Contract AF 33(616)-7887, sponsored by the Bionics and Neurophysiology Section of the Aerospace Medical Research Laboratories, entailed the design and construction of experimental equipment and simulation systems for research on living information handling systems. Included among the developmental equipment was an electronic analog, based on the functioning of biological systems, to simulate neurosensory networks for the conversion of sensory information, such as a light or sound pattern, to a form compatible with neuron network analogs or adaptive computers.

To assist Lloyd Brothers Inc. in gaining the Federal Drug Administration approval of Segontin, a drug for angina patients, Technology Incorporated used statistical techniques to determine the efficacy of the drug. Responses of angina patients, each given the drug and a placebo, make up the data acquired by doctor-conducted tests.

Under Contract AF 33(616)-7927 with the Aerospace Medical Research Laboratories, Technology Incorporated conducted drop tests from the Inclined Test Facility at Wright-Patterson Air Force Base to acquire impact data on various test subjects. The test results were processed and analyzed with the aid of the IBM 7090 computer and associated equipment.

As a subcontractor to AiResearch under the prime contract NAS 9-150 for the National Aeronautics and Space Administration, Technology Incorporated designed and manufactured nine Mass Flowmeters, each to measure linearly oxygen flow from 0.2 to 0.5 lb. per hr. in Apollo spacecraft. The company has developed a line of other compact, self-contained, linear Mass Flowmeters for various scientific applications requiring the measurement of gas flow.

Sponsored by the Ohio State Research Foundation under Contract AF 33(616)-6288, ML-201, Technology Incorporated completed the following tasks: a general synopsis of data processing methods and equipment, a summary of the general operation of a computer and its limitations when performing various functions, and a number of solutions to various data processing problems.

A long-range planning program to establish the structural loads measurement requirements for future aerospace vehicles was developed under Contract AF 33(616)-7406. Study of the vehicles, including an advanced boost-glide vehicle, a recoverable satellite, a manned satellite, and a lunar vehicle for a "soft" moon landing, was pursued from ground handling through landing or impact to determine the conditions of the critical loads. Instrumentation systems for two configurations of the Blue-Scout were designed. After a study of all available and planned instrumentation was completed, instruments needed for load measurements were specified and a transducer handbook was compiled.

To determine the performance characteristics of clustered parachutes under infinite mass conditions, Technology Incorporated conducted under Contract AF 33(657)-7985 a series of wind tunnel tests. Objectives were determination and presentation in report form of the effects of the type of parachute canopy, of the number of parachute canopies in a cluster, of the canopy reefing ratio, and of the riser length on the drag and static stability characteristics of clustered configurations. A sting balance capable of measuring the two component forces of the cluster configurations up to a 25-degree angle of attack was designed, fabricated, and instrumented.

With the sponsorship of the Protective Equipment Section, Aerospace Medical Research Laboratories, and under Contract AF 33(657)-9417, Technology Incorporated developed the structural design of a support system to evaluate the performance of personnel in a simulated environment with continuous acceleration and vibration forces. Other efforts included the integration of a system comprising a five-channel physiological monitor. Also the complete system was evaluated and calibrated during impact tests. An analog computer and the IBM 7090 digital computer were used to process the data.

The Physiological Monitor—a portable, self-contained, completely automatic electronic unit to measure the vital body functions of critical-care patients—has been designed and developed by Technology Incorporated personnel. Extensive tests have proved the accuracy and reliability of the Physiological Monitor in measuring continuously pulse rate, respiration rate, temperature, and both systolic and diastolic blood pressure. Units are commercially available through medical equipment distributors.

Contract AF 33(657)-9537 involves the design, fabrication, and test of a system to measure the mechanical impedance of the human body, the whole body and various portions of it. Other research on this contract includes continued research on the vibration effects on human subjects, determination of the tolerances for high- and low-frequency sinusoidal and random vibration, and investigation of the effects of low-frequency sinusoidal vibration on visual acuity, speech transmission, and hearing.

Under Contract AF 33(657)-10686, Technology Incorporated is analyzing existing nuclear effects prediction formulae to verify the safe-escape calculations used in ADC Nuclear Weapon Delivery Handbooks. This analysis will lead to the writing of a nuclear weapons effects IBM 7090 program for the ASD Offensive Systems Office. In addition, voids in existing knowledge of systems capability are being determined to recommend future test efforts to the Air Force.

Determination of the levels of human tolerance to forces of abrupt deceleration through test and calibration was initiated for the Aerospace Medical Research Laboratories under Contract AF 33(616)-6970. The effort, continued under Contract AF 33(657)-10010, includes related research for AMRL in conjunction with NASA, such as the current studies of abrupt deceleration tests conducted on components of the Mercury and Gemini space vhicles.

As purchased by the U.S. Navy under Contract N 62269-2122, Technology Incorporated supplied two units of the Mass Flowmeter, which were designed, fabricated, and tested by company engineers. Measuring linearly the mass flow of gas, the Mass Flowmeter is a compact, self-contained unit constructed for operation in space environments. Each of the units supplied to the Navy is 2 1/4 in. in diameter by 3 in. in length, weighs approximately 12 oz., and has a range of 0 to 0.4 lb. per min. and a linearity of $\pm 2.5\%$ of full scale referred to the best straight line.

Sponsored by the Aeronautical Systems Division under Contract AF 33(657)-9845, Technology Incorporated instrumented seventy C-130 aircraft to record three in-flight parameters: airspeed, altitude, and acceleration. Instrumented aircraft were assigned to six air bases: four in the states of Tennessee, Texas, and Hawaii; one in Okinawa; and one in France. Presentation of the processed and analyzed data in the form of a load spectrum for fatigue life evaluation of this aircraft type completed the program. The findings will be used in the review of design criteria.

Development of digital methods for the automatic and cyclical processing of biological signal information is the general requirement of Technology Incorporated's effort under Contract AF 41(609)-2267, sponsored by the Air Force School of Aerospace Medicine, Brooks Air Force Base. These methods will be used to determine the presence of significant information in biological data, supplied in analog or digital form on various media, such as magnetic tape and strip charts. The effects of variable rates of digitizing on biologic signals will be investigated. Novel as well as classical diagnostic methods will be utilized and their capabilities compared both to establish the most efficacious techniques and to lead to still other novel approaches. Techniques to be developed are intended to establish criteria for normality and specified abnormalities through the application of the methods to known populations.

Through the acquisition, processing, and analysis of Flight Technical Error data under Federal Aviation Agency Contract FA-WA-4542, Technology Incorporated is determining the random deviation of rotary- and fixed-wing civil aircraft from their intended cruising altitudes. This information will be reviewed for the possible revision of current altitude separation distances. Phenomena being studied include the design stability of the aircraft and its systems; effects of airspeed, turbulence, gusts, and altitude; inaccuracies of the automatic flight control systems; and pilot technique.

Engaged in the first phase of a four-year study for the Air Force Personnel Research Laboratory, Brooks Air Force Base, Technology Incorporated under Contract AF 41(609)-2294 processed data written on military questionnaires. The questions were designed to generate criteria, that is, a set of specific responses, which could be used to project early officer-career tenure. Original information was key punched and verified, and computer programs were written for the statistical analyses leading to the evolvement of the criteria.

As a subcontractor to Giannini Controls Corporation under P. O. E-24906, Technology Incorporated designed, fabricated, and successfully tested a digital translating system to extract and digitize in-flight data recorded on magnetic tape by the Giannini VGH Statistical Recorder. Data are fed directly to an IBM 7090 computer. Another requirement was the computer analysis of the data to determine the recorder capability; for this purpose, computer programs were written in FORTRAN IV and MAP.

Under Contract AF 41(609)-2328, sponsored by the Air Force Personnel Research Laboratory, Brooks Air Force Base, Technology Incorporated used two methods to determine the extent to which supervisory officers consistently give high or low ratings to officer personnel, regardless of their objective merits, on Officer Effectiveness Reports. Determination of characteristics distinguishing high and low raters from raters in general was a secondary objective. Data supplied on tape were sorted for appropriate information selection and modified for desired format presentation. Regression program routines were selected from the company library and other programs were specially written to analyze the data.

Under Federal Aviation Agency Contract FA-WA-4590, Technology Incorporated is conducting a pilot program to record structural loads on civil transport helicopters. These aircraft have been instrumented to record the structural flight loads parameters affecting their performance in normal operational environments. Such data are being processed and analyzed to determine the optimum parameters, data processing techniques, and data presentation arrangements for future full-scale helicopter structural loads recording programs.

To assist the Air Force School of Aerospace Medicine in determining an acceptable gaseous environment for men during prolonged spacecraft occupancy, Technology Incorporated is conducting research, under Contract AF 41(609)-2334, to evaluate the responses of men and animals subjected to the breathing of pure oxygen at decreased pressure. Specially designed double-wall test cells enabling high-accuracy control of the gaseous environment will be used to investigate the oxygen toxicity effects on the hematology, histology, and enzymology of the test subjects; also the surface activity of material lining the lungs of the subjects will be analyzed.

Collaborating with the Air Force Avionics Laboratory, Technology Incorporated has been directed under Contract AF 33(615)-1600 to apply statistical computer techniques to data for the evaluation of control systems and components involved in navigation and guidance systems. Included among the tasks are the fit of a Weibull distribution to component reliability data to reveal life characteristic information, particularly that generated by gyros, the comparative evaluation of several system reliability models developed for guidance and control systems; the introduction of various parameters into computer subroutines to simulate satellite or ICBM interception in order to determine the feasibility of acquiring reliable solutions to intercept guidance and control problems, and the evaluation of existing techniques of error analysis and synthesis used in studying guidance system performance, including determining the effect of ignoring nonlinear terms and the manner in which errors are propagated during the boost and coast portions of a trajectory.

Studies of the random deviations of aircraft from intended cruise altitudes continue under Contract FA 65WA-1163. Complementing the data acquired under Contract FA-WA-4542, results will be used by the Federal Aviation Agency to review standards established for the safe vertical separation between aircraft. As in the first program, the current effort involves acquiring and analyzing the data from general aviation aircraft whose cruise altitudes are normally below 20,000 feet. In the data analysis, the effects of pilot technique and experience, aircraft, and flight mode (VFR and IFR) are distinguished.

Under Contract No. FA-65WA-1329 sponsored by the Systems Research and Development Service of the Federal Aviation Service, Technology Incorporated is conducting a flight loads recording program for the Sikorsky S-61 helicopter. An instrumentation system will be designed and fabricated to record at least the following parameters: airspeed, altitude, normal acceleration at the aircraft's center of gravity, pitch rate, manifold pressure of the piston engine, rpm and fuel flow of the turbojet engine, rpm of the rotor, gross weight, and patch acceleration. Data will be processed and analyzed to derive the loads spectra applicable to service life studies of this type of helicopter.

Under Contract AF 33(615)-3127, Technology Incorporated will expand upon electromagnetic compatibility studies begun under Contract AF 33(657)-11119 and continued under AF 33(615)-2081 for the Air Force Avionics Laboratory. Current research seeks to evolve basic designs of instrumentation and techniques to measure the electromagnetic susceptibility of avionics solid-state circuitry at frequencies below 1000 megacycles. Instrumentation and techniques to measure avionic electromagnetic interference at frequencies from 3 cycles to 10 megacycles will be developed primarily to find new methods of measuring the E and H vectors close to the interference source with a minimum of disturbance. Studies will be conducted on RF banding evaluation measurements using radiators and sensors.

In support of the Air Force Cambridge Research Laboratories, Technology Incorporated is evolving under Contract AF 19(628)-5218 a system to record and process automatically data to yield the gravitational field encountered by an aircraft at any point above the earth's surface. Such information will permit determining the shape of the earth. An airborne magnetic tape recorder, developed under Contract AF 19(628)-2755, will be flight tested and progressively expanded to digitize and record in IBM format all basic parameters needed for gravitational field measurement. Initial data will be evaluated to define the smoothing interval most appropriate to the data and the requirements for short-interval gravity values. Final results will be presented as elevated gravity profiles.

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