REPORT ON A LONG-RANGE FORECASTING STUDY

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SUMMARY

Prediction-making is a fundamental part of technological, military, commercial, social, and political planning in the modern world. Relatively short-term forecasts of events of, say, the next twenty-four hours, next year, or even trends of the next decade are often accurate enough to be of demonstrably practical use. But as the period of concern is moved further and further into the future, uncertainties multiply, confidence in prediction is degraded, and the scientific theories and techniques of forecasting increasingly give way to intuitive judgment. The fact remains, however, that for better or for worse, trend predictions—implicit or explicit, "scientific" or intuitive—about periods as far as twenty or even fifty years in the future do affect current planning decisions (or lack of same) in such areas as national defense, urban renewal, resource development, etc. Thus, almost anything further we can learn about the basis, the accuracy, and the means for improving such long-term forecasts will be of value.

This report describes an experimental trend-predicting exercise covering a period extending as far as fifty years into the future. The experiment used a sequence of questionnaires to elicit predictions from individual experts in six broad areas: scientific breakthroughs, population growth, automation, space progress, probability and prevention of war, and future weapon systems. A summary of responses from each round of questionnaires was fed back to the respondents before they replied to each succeeding round of questionnaires.

Results of the experiment illuminate a number of points: the contents of the predictions themselves, the bases on which respondents claimed their predictions were made, the spread of expert views, the convergence of views

following data feedback, the experts' critiques of each other's views, and not least of all, the weaknesses of the method and the possible means for improving it.

The report also discusses potential objections that may be leveled at this approach: its inherently insufficient reliability; its tendency to produce self-fulfilling or self-defeating prophecies which would make it both undesirable and unreliable; the sensitivity of results to ambiguity of questions; the difficulty of assessing and utilizing the degree of expertise; and the impossibility of taking into account the unexpected. One must judge the merits or promise of an approach such as this in terms of the alternatives available. These same objections generally apply with even greater force to less systematic means of using any intuitive judgment. Moreover, it does appear that some of the observed or suspected defects in the method can be eliminated on the basis of what has been learned from this experiment.

No claims are made, or can be made, for the reliability of the predictions obtained here. However, inasmuch as they reflect explicit, reasoned, self-aware opinions, expressed in light of the opinions of associate experts, such predictions should lessen the chance of surprise and provide a sounder basis for long-range decision-making than do purely implicit, unarticulated, intuitive judgments.

A few thought-provoking examples of the predictions that were elicited are the following:

> The implication that the water-covered portions of the earth may become important enough to warrant national territorial claims.
>
> The values assigned for the probability of another major war. (E.g., medians: 10% in 10 years; 25% in 25 years. Most likely cause: escalation.)

The absence, on the one hand, of significantly new ideas for the prevention of war, and the confidence, on the other, that the application of what may be called traditional proposals could reduce the probability of war significantly.

The possibility that continued developments in automation will result in serious social upheavals; the almost complete acceptance of the necessity of regulative legislation.

The strong likelihood of the emergence of weapons of a nonkilling, nonproperty-destroying nature, covert perhaps, attacking on the psychological or biological level.

The eventual abundance of resources of energy, food, and raw materials, but also the possibility that a continuing inequitable world distribution of these assets to the increasing world population may furnish a persisting stimulant to warfare.

ACKNOWLEDGMENTS

Among the many persons who contributed to this study, the greatest share of the credit must go to our questionnaire respondents, both within and outside of RAND, for their wisdom, patience, and constructive criticism. Numerous colleagues and RAND consultants offered helpful advice; among them we would like to mention especially Norman Dalkey, James DeHaven, Oskar Morgenstern, Ed Quade, and Milton Weiner. Two of our overseas respondents, whom one of the authors had the pleasure of contacting personally, were particularly helpful and encouraging—namely, Professor Dennis Gabor and Monsieur Bertrand de Jouvenel. To Arthur L. Shef we express our thanks for helping us pre-test the first set of questionnaires. Much of the burden of recording and analyzing the responses was carried by Bernice Brown, to whom we would like to express our very special gratitude. Jan Kurtz and Margaret Ryan contributed help by abstracting material and preparing graphical displays. Ann Rierson deserves our particular thanks for handling with admirable patience and reliability the inordinate volume of correspondence in connection with this project.

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REPORT ON A LONG-RANGE FORECASTING STUDY

1. INTENT

This is a report on an experiment in forecasting which has been conducted during the past twelve months. ("Forecasting" is used here in the sense of mapping out possible futures, as distinguished from "predicting" a single future.) The intended purpose of this undertaking was both substantive and methodological.

Substantively, our interests lay in assessing the direction of long-range trends, with special emphasis on science and technology, and their probable effects on our society and our world. Here, by "long-range" we had in mind something of the order of ten to fifty years. Our natural curiosity in this regard was enhanced by an awareness of the fact that our work at RAND is in many instances closely related to plans and policies affecting the rather distant future, and that consequently the direction of our studies and the substance of whatever recommendations may result from them are inevitably influenced by our concept of the shape of things to come.

Methodologically, we found ourselves confronted by a near-vacuum as far as tested techniques of long-range forecasting are concerned. Here our hope was to sharpen the few systematic methods that are available and, through practical experience, to gain some insight into specific needs for further methodological research.

Depending on one's point of view, a project such as this may be considered predestined to failure because of its over-ambitious scope, or predestined to success because even very little progress in so important and neglected an area is bound to be of value in the design of long-range plans. Actually, the outcome of this experiment has in no way been spectacular. Yet we hope that the reader of this report will agree with us that our undertaking has indeed been mildly successful, in the sense that our findings

represent a beginning in the process of sifting the likely from the unlikely among the contingencies of the future, and that we have obtained some hints as to how such efforts can be conducted more effectively hereafter.

Future events can be considered as roughly belonging to one of two sets: the expected and the unexpected. A study such as this cannot hope to uncover the unexpected, spectacular, unanticipated breakthroughs, but must concentrate on narrowing down the dates and circumstances of occurrences which can be extrapolated from the present. We recognize this as a shortcoming of our present study. Nevertheless, some of the substantive predictive material was, to the experimenters at least, unexpected. In that sense, the future may now hold fewer surprises for some of us.

2. SUBJECT MATTER

Among the many features of the world of the future that are competing for exploration, we had, for the sake of sheer manageability, to select only a few. Our choice, while somewhat arbitrary, was guided by the desire to have a collection of areas which in combination would provide broad (though not exhaustive) coverage of the most important determinants of the society of the future. We finally decided upon the following six topics:

(1) Scientific breakthroughs.
(2) Population control.
(3) Automation.
(4) Space progress.
(5) War prevention.
(6) Weapon systems.

In seeking out the future trends in these areas, we were of course well aware that we would not through some miracle be able to remove the veil of uncertainty

from the future. This did not seem to us to imply, though, that it is altogether impossible to make meaningful assertions of substantive content about the future.

The reliability with which the future can be predicted is a matter of degree. In planning our daily lives, we are accustomed to predicting the immediate 24-hour future with a reasonable degree of certainty. Plans as far as a year ahead—say, concerning the budget of a family, or of a firm, or of the federal government—although afflicted with a noticeable degree of uncertainty, still are recognized and accepted as a highly reliable means of regulating our lives. Even if the planning horizon is five to ten years away, as it is with many major governmental decisions, standard trend projections, obtained by extrapolation from the recent past and from knowledge of current activities, usually provide fairly reliable results. Nevertheless, in employing past and present trends as indicators of the future, we begin to be strongly aware of the need for judicious intuitive assessment.

For the more distant future, as the uncertainties grow, increased reliance on intuitive (as opposed to theory-supported) contingency forecasts becomes inevitable. Yet this does not deter us from planning ten to fifty years ahead, as evidenced by our public policies regarding such matters as educational institutions, urban renewal, aid to developing countries, procurement of military weapon systems, space exploration, and so on.

In view of such common practice of long-range planning, which both affects the ten- to fifty-year future and is itself influenced by our expectations regarding the world

at that time, it seems reasonable to adopt a pragmatic attitude: Since the use of intuitive forecasting as a basis for long-range planning is unavoidable, we should at least make an effort to obtain this intuitive judgment as systematically as possible from persons who are recognized experts in the area of concern. Until a satisfactory predictive theory of the phenomena in question becomes available, it would seem that any improvement in reliability, however slight, that could be achieved by replacing casual guess with the controlled use of intuitive expertise would be desirable because of the benefits that long-range public policies might derive from it.

These potential benefits are likely to grow with each decade; for, because of the ever more explosive rapidity with which new technological developments are apt to take hold, it becomes increasingly important to foresee the advent of such impacts in order to prepare for their social consequences and to avert possible calamities.

It is this potentially large payoff from even minor advances in the reliability of trend forecasting—not to mention man's natural fascination with the idea of exploring the future regardless of any tangible returns (just like exploring the Moon)—which we offer as justification for the present effort.

Our procedure, if we are fortunate, might even succeed incidentally in crystallizing the nucleus of a predictive theory of the subject matter under inquiry, by goading the experts from whom we solicit opinions

into formulating some of their perhaps hitherto unarticulated reasons for these opinions. Thus we hope that an effort such as ours may go beyond merely filling a temporary gap and set into motion analytical thought processes which eventually might lead to the formulation of a scientific theory regarding the phenomena in question.

3. METHOD

The method which we have employed for the systematic solicitation of expert opinions is the so-called Delphi Technique.* Instead of using the traditional approach toward achieving a consensus through open discussion, this technique "eliminates committee activity altogether, thus ... reducing the influence of certain psychological factors, such as specious persuasion, the unwillingness to abandon publicly expressed opinions, and the bandwagon effect of majority opinion. This technique replaces direct debate by a carefully designed program of sequential individual interrogations (best conducted by questionnaires) interspersed with information and opinion feedback derived by computed consensus from the earlier parts of the program. Some of the questions directed to the respondents may, for instance, inquire into the 'reasons' for previously expressed opinions, and a collection of such reasons may then be presented to each respondent in the group, together with an invitation to reconsider and possibly revise his earlier estimates. Both the inquiry into the reasons and subsequent feedback of the reasons adduced by others may serve to stimulate the experts into

*N. Dalkey and O. Helmer, "An Experimental Application of the Delphi Method to the Use of Experts," Management Science 9, 1963.

taking into due account considerations they might through inadvertence have neglected, and to give due weight to factors they were inclined to dismiss as unimportant on first thought."*

In line with this program, we selected 6 groups of experts, one each for the 6 areas to be surveyed (see Section 2 above). Of the approximately 150 persons approached, 82 responded to one or more questionnaires. Of these, 35 were members of RAND, 7 others were RAND consultants, and the remaining 40 were not connected with RAND; 6 of these 40 were European respondents. Some of the participants responded voluntarily also to questionnaires submitted to other panels. (It was our practice, in order to keep the participants informed of all phases of the experiment, to send copies of the questionnaires for all 6 panels to each respondent, distinguishing that addressed to his own panel by a special color of paper.)

Each panel of experts answered 4 sequential questionnaires, spaced approximately 2 months apart. The average number of filled-in questionnaires received from each panel per round was 14.5 (making a total of $6 \times 4 \times 14.5$, or 348).

Details about the respondents and reproductions of the relevant parts of the 24 questionnaires are given in the appendix to this paper.

4. ILLUSTRATION OF PROCEDURE

To illustrate our procedure, we will give the details of a small segment of the inquiry conducted with the help of Panel 1 on Scientific Breakthroughs.

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*See "On the Epistemology of the Inexact Sciences," by O. Helmer and N. Rescher, Management Science 6 (1959), p. 47.

In the opening round we addressed the following question to the panel:

> Questionnaire 1.1.
>
> One of the major problems of conducting a predictive study which poses its questions on the basis of extrapolations of current technology is the almost unavoidable exclusion of discontinuous state-of-the-art advances.
>
> In this current study a period of 50 years is being considered. It is possible that inventions and discoveries not yet visualized could have a major impact on our society during this interval. It is easy to observe that the pace of scientific and technological innovation has been steadily increasing and that the time between origination and application has been decreasing. Therefore we believe that many generations of inventions can find application during the period under study.
>
> Some insight even into discontinuous state-of-the-art advances might perhaps be gained by examining the world's need for such advances, in view of the old truism that necessity is the mother of invention. Therefore, you are asked to list below major inventions and scientific breakthroughs in areas of special concern to you which you regard as both urgently needed and feasible within the next 50 years.

Collation and paring of the responses led to a list of 49 items, which were presented to the panel in the next round (Questionnaire 1.2) with a request to indicate, for each item, the probability of actual implementation in each of the following time intervals:

1963–65	1972–78	1997–2013
1965–68	1978–86	Later than 2013
1968–72	1986–97	Never

Three examples of the 49 items were these:

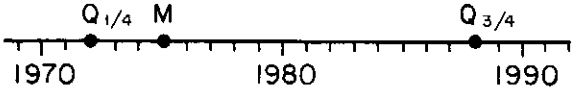
B1. Chemical control over heredity – molecular biology.
S8. Popular use of personality control drugs.
P10. Reliable weather forecasts.

For each item, each respondent's probability distribution over time obtained from Questionnaire 1.2 was used to determine approximately the year by which the item, in his opinion, had a probability of 50% of being implemented.

For the three illustrative items, these "50%-years" had the following medians and quartiles:

	Median	Quartiles
B1	1993	1982–2033
S8	2050	1984–2050
P10	1975	1972–1988

In the case of P10, for instance, this means that one quarter of the respondents thought that the date by which P10 had an even chance of occurring would be prior to 1972



(the lower quartile), and similarly that one half thought it would be prior to 1975 (the median), and one quarter that it would be later than 1988 (the upper quartile).

On the basis of findings such as these, it was judged that for 10 of the 49 items (Item P10 among them) there existed a reasonable consensus among the respondents. This consensus was announced to the respondents in Questionnaire 1.3, together with an invitation to take exception if they differed strongly from this majority consensus:

> P10 (Reliable weather forecasts): Not within 5 but within 35 years.
>
> Do you, by and large, agree with the opinion represented by the consensus...? If you disagree ..., briefly state your reason for your differing opinion.

As for the remaining 39 items, on which an insufficient consensus had been observed, the experimenters at this point used their discretion in singling out a subset of 17 items which they thought to be deserving of further exploration. These were presented once more to the panel, together with an indication of the consensus status to date and a request for a statement of reasons for opinions differing from those of the majority. In some cases the item was reworded, because it was felt that the ambiguity of the original phrasing, rather than any factual disagreement among the participants, might have been partly responsible for the

observed divergence of responses. (This contention was supported, in various instances, by explicit comments to this effect from the respondents.) In the case of our examples, B1 and S8, Questionnaire 1.3 followed up thus:

	Description of potential breakthrough	Consensus or dissensus to date	In your opinion, by what year does the probability of occurrence reach 50%	90%	If your 50% estimate falls within either the earlier or the later period indicated, briefly state your reason for this opinion
B1	Feasibility of chemical control over hereditary defects through molecular engineering	Consensus that it will occur; disagreement as to when			Why before 1987 or after 2013?
S8	Widespread socially accepted use of non-narcotic personality control drugs producing specific psychological reactions	Divergent opinions, possibly due to differing interpretations of the original question			Why before 1987 or after 2013 (or never)?

The responses now had the following medians and quartile ranges:

	Median	Quartiles
B1	2000	1989–2015
S8	2000	1980–2033

We notice that in both cases the quartile range narrowed, while the median shifted to a somewhat later year for B1 and to a considerably earlier year for S8. Our sample was too small and unstable to permit us to trace such changes to specific causes. (The instability of the sample had two causes: the long interval between questionnaires, and changes in the composition of the panel.) We may merely conjecture that the sharpening in wording of the questions contributed to the narrowing of the quartile ranges; whether this also produced the shift in medians is even more uncertain.

The procedure for composing the last questionnaire in the series, 1.4, was similar to that used in the preceding cycle: Elimination of a few additional items, announcement

of a satisfactory consensus on some, and restatement (possibly again involving actual rewording) of the remainder. Both of our illustrative items were judged to need such reconsideration. In this case, the information given to the panel comprised both a statement of the majority opinion and an indication of the reasons for a deviating opinion on the part of a minority. As far as B1 and S8 were concerned, the questionnaire appeared as follows:

	Description of potential breakthrough	Majority consensus to date	Minority opinion	50%-year	90%-year
B1	Feasibility (not necessarily acceptance) of chemical control over some hereditary defects by modification of genes through molecular engineering	By 2000	Will take longer or occur never, because it would necessitate intervention during embryonic development, when the foetus is inaccessible, hence would require prior development of techniques of gestation in vitro		
S8	Widespread and socially widely accepted use of nonnarcotic drugs (other than alcohol) for the purpose of producing specific changes in personality characteristics	By 2000	Will take 50 years or more, because research on psychopharmaceuticals has barely begun, and negative social reaction will cause delays		

This time the outcome was as follows:

	Median	Quartiles
B1	2000	1990–2010
S8	1983	1980–2000

Thus, for B1 the median remained unchanged and the quartile range shrank a little further; in the case of S8, the median was now even earlier than before and the quartile range shrank considerably. In both cases we now had what may be considered a reasonably narrow consensus.

5. THE SUBSTANTIVE OUTCOME: INTRODUCTORY REMARKS

Having illustrated our procedure through the cases of these three representative items, we now present the prima-facie predictions by our panels, and then return later

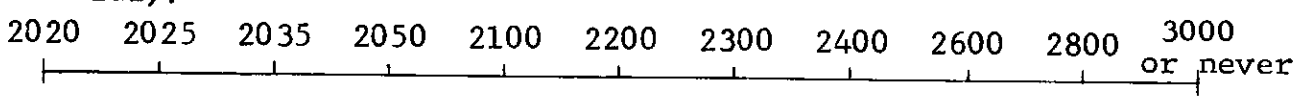
to a discussion and critique of the method. The reader is cautioned, however, to regard the data about to be listed with some reservation. It consists of summaries of considered opinions about the future by a small group of people, each an expert on some, but not necessarily all, of the subjects under inquiry. There is no question but that more reliable predictions could have been obtained with a greater effort and a wiser group of experimenters. We shall try to indicate later, through retrospective wisdom, how we believe that an effort such as this can be improved to the point where it might become a more reliable and valuable planning tool.

6. PREDICTED SCIENTIFIC BREAKTHROUGHS

Panel 1's predictions of scientific breakthroughs are summarized in graphical form on the following page. This is done here and throughout in terms of the "break-even" date, that is, the date for which there is an equal expectation that the event in question will materialize before or after it.

Each bar on the graph extends from the lower to the upper quartile of responses, the peak indicating the position of the median. The events are ordered according to the median date.

The time scale beyond 2020 has been foreshortened. The reader may wish to interpret the interval to the right of 2020, as we have done, as follows (although precise dates that far in the future are clearly not very meaningful):



In addition to specific substantive breakthroughs, the panel was interrogated regarding potential developments in the organizational and operational methods of scientific investigation. There was a strong consensus that the

following four, among eight taken into consideration, represent desirable trends which are likely to occur:

Reform of present modes of scientific communication through the use of automated information retrieval systems.

Reorientation of scientific methodology toward greater interdisciplinary cooperation.

Increased emphasis on basic research in government-supported R and D.

Reformation of educational processes toward an increased interdisciplinary understanding of science.

7. PREDICTED POPULATION TRENDS

The questions addressed to Panel 2, on Population Control, were concerned with world population growth between now and the year 2050. The following four graphs (Figs. 7.1–7.4) exhibit the median and quartile curves derived from the panel's predictions for the birth rate, the death rate, the net-growth rate (= birth rate minus death rate), and the population size.

The population curves in Fig. 7.4 were derived as follows: From the responses of each individual we determined approximately what, according to him, the population would be as a function of time; for each year t between the present and 2050, we then selected the median and quartiles of these predictions.

An obvious alternative method is to use the three net-growth rate curves shown in Fig. 7.3 and to compute the corresponding population curves; the result is shown in Fig. 7.5, and is seen not to differ significantly from that in Fig. 7.4.

We note that the population trend forecast by our panel is considerably more conservative than estimates obtained by straightforward extrapolation from past population growth, as shown by Fig. 7.6, where the shaded area, lying entirely below the projected curve, represents the quartile range of the panel's forecast over the next 87 years.

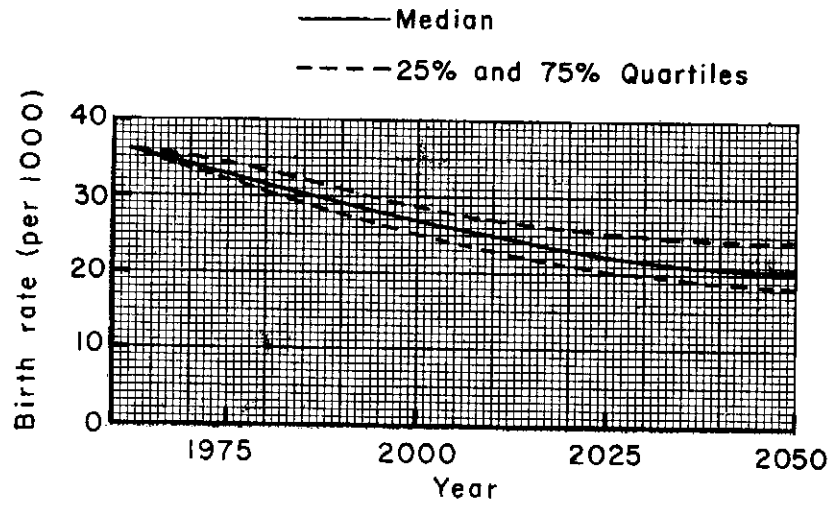


Fig. 7.1 — Birth rate per thousand

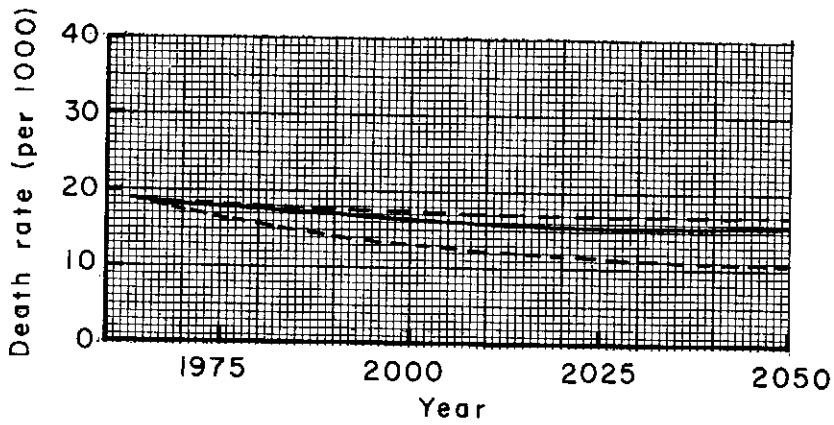


Fig. 7.2 — Death rate per thousand

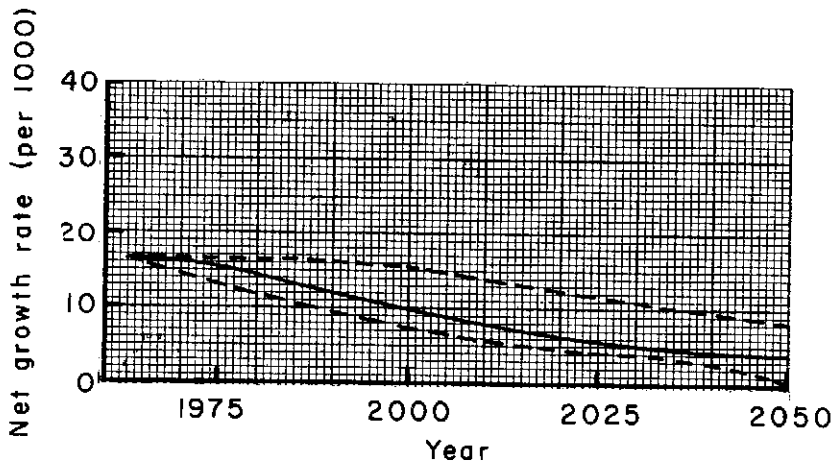


Fig. 7.3 — Net growth rate per thousand

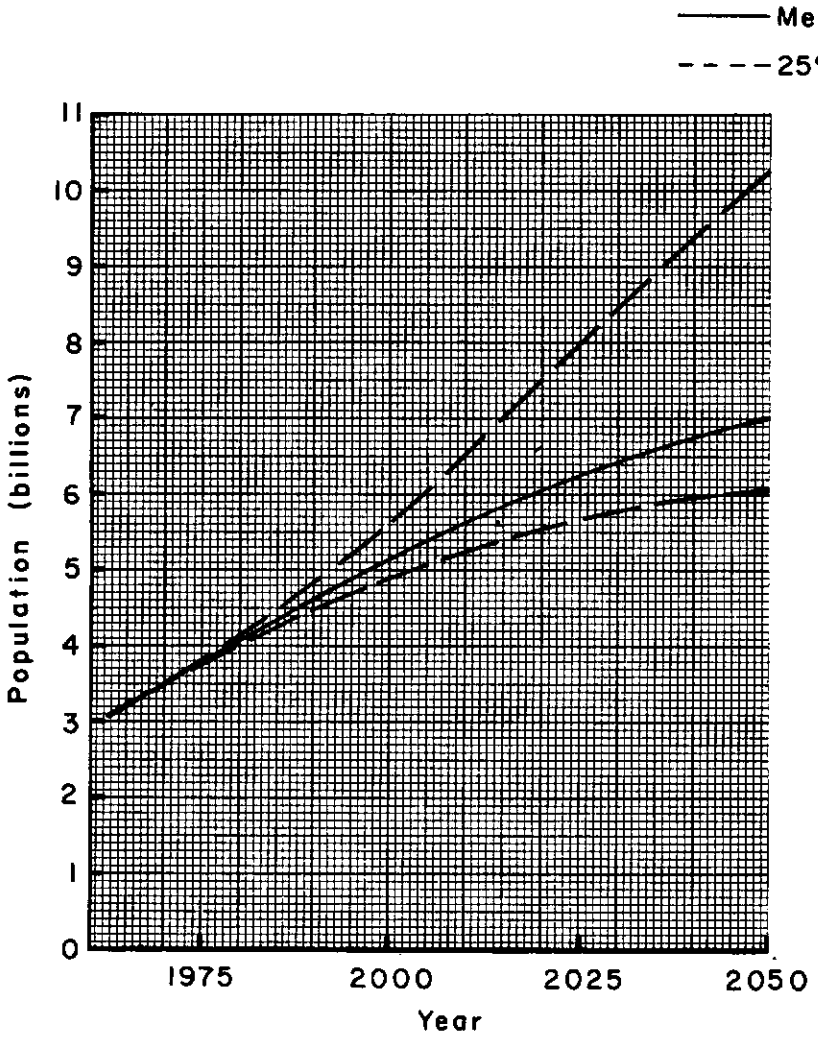


Fig. 7.4 — Population estimate (first method)

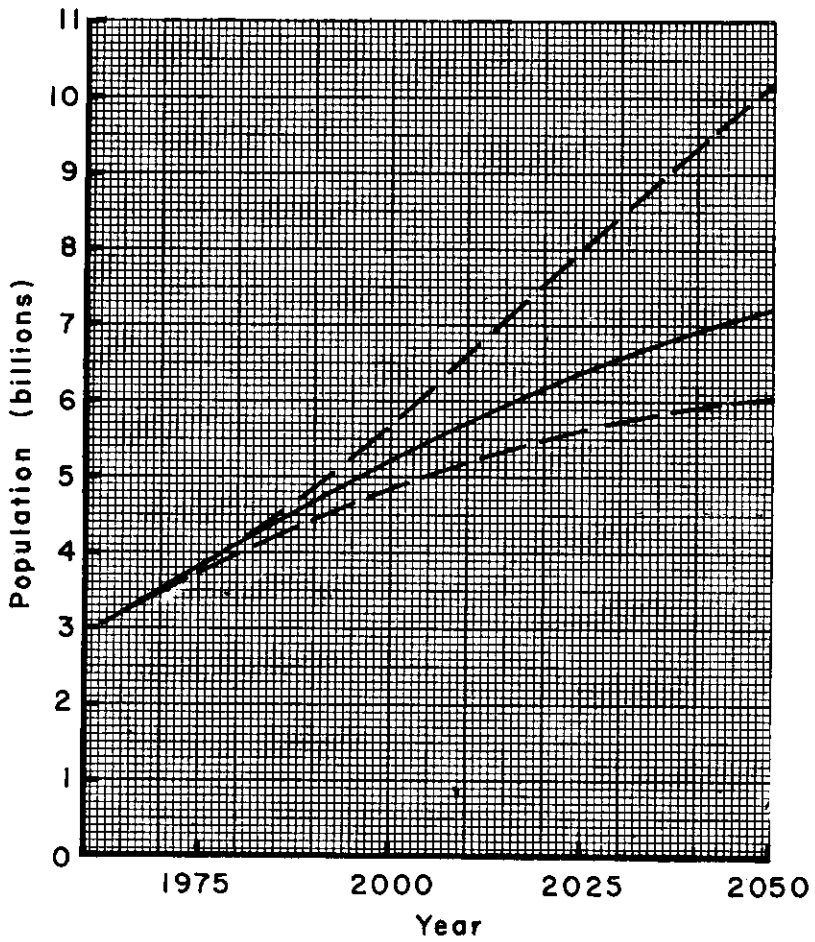


Fig. 7.5 — Population estimate (second method)

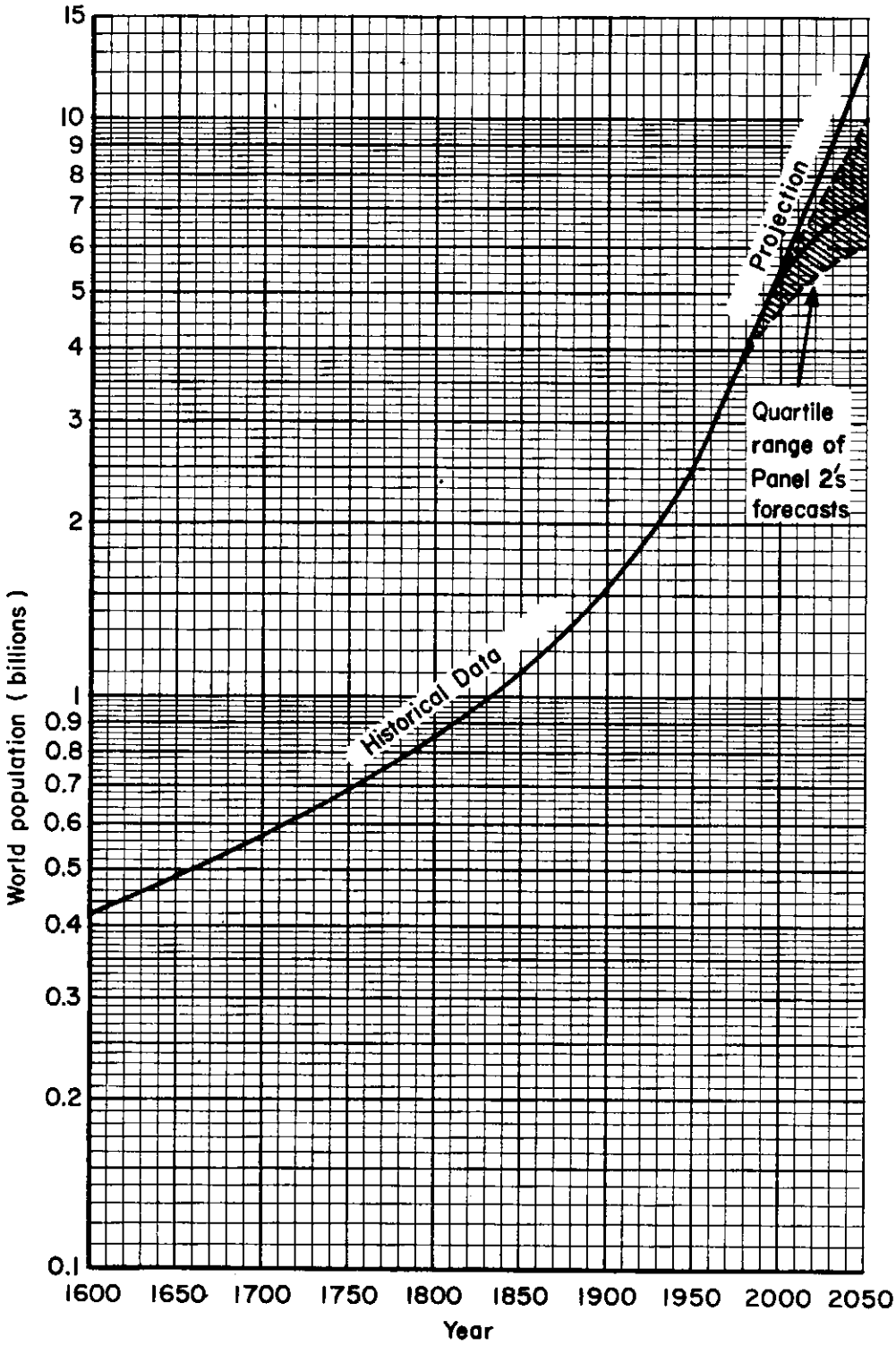


Fig. 7.6 — World population from 1600 A. D.

We did inquire into the reasons for the opinions reflected in these relatively low population estimates.

Not surprisingly, the following three factors emerged as the principal ones affecting birth and death rates, and consequently population:

(i) the degree of acceptance of birth control measures;

(ii) the rate of further medical progress;

(iii) advances in the production and distribution of food.

Of these, judging by the variance of responses, the first seems to be the least predictable. There was much more of a consensus regarding predictions of the availability (as opposed to the acceptance) of birth-control measures. This, incidentally, was confirmed by the Science panel (Panel 1), which predicted the general availability prior to 1980 of simple and inexpensive means of fertility control.

Further medical advances (Item (ii) above) were seemingly generally accepted as a matter of course. The consequent drop in the death rate will be attenuated, in the opinion of most respondents, by insufficient advances in the production and distribution of food (Item (iii)). A minority even predicted famine conditions and a consequent eventual sharp rise in the death rate.

These misgivings regarding food production and distribution should perhaps be examined in the light of relevant forecasts made by the Science and Automation panels (1 and 3). According to Panel 1, commercially efficient production of synthetic food may be expected within 40 years, to be augmented in the early part of the next century by large-scale ocean farming. In spite of this forecast of food abundance for even a much enlarged world population, there may still be an ominous gap between potential and effective availability of food for all, because, according to the view expressed by Panel 3, an effective world-wide system of food distribution may not be implemented until later in the twenty-first century.

In view of such facts as the uncertainty regarding large-scale acceptance of birth control measures, the comparative certainty of further medical progress, and the doubts about equitable food distribution, one cannot help but wonder whether the panel's forecasts (which in the median suggest a nonfamine-induced levelling off of the population curve) would have remained quite so optimistic, had the Delphi process of examining the reasons for proffered opinions been carried through another round or two.

8. AUTOMATION PREDICTIONS

The predictions by Panel 3 regarding major developments in the field of automation are summarized on the following page, in the same graphical form we used for Panel 1. Each bar again extends from the lower to the upper quartile of the responses and peaks at the median. The foreshortened scale beyond 2020 was explained in Section 6.

In addition to technological progress in automation, the panel was asked to give some thought to the problem of unemployment resulting from automation. Almost all respondents agreed that the problem is a very serious one. While one third of the panel felt that social upheavals will accompany automation, the majority opinion indicated that suitable counter-measures, taken either preventively or at least therapeutically, will forestall severe social disruptions.

Ten counter-measures, proposed by the panel members themselves, were appraised by the panel with regard to: (1) potential effectiveness in reducing unemployment, (2) overall desirability, and (3) the probability of actual implementation. The averages of the appraisals concerning these three aspects turned out to be highly correlated, as shown by the following tabulation of results, in which the measures at the top of the list are considered effective, desirable, and probable, while those at the bottom are

considered ineffective, undesirable, and improbable:

Proposed Measure	Average Effectiveness	Average Desirability	Average Probability
Creation of new types of employment	mod/high*	high	mod/high
Retraining of persons unemployed through automation	mod	mod/high	high
All-out vocational training program	min/mod	mod/high	mod/high
Education for better leisure-time enjoyment	min/mod	mod/high	mod/high
Massive aid to underdeveloped regions (including parts of the United States)	mod	mod	mod
Two years of compulsory post-high school education	mod	mod	mod
Legislation shortening the work week by 20%	min/mod	neut/mod	mod/high
Massive WPA-type programs	min/mod	neut	mod
Legislation lowering the retirement age by 5 years	min/mod	neut	mod
Legislation protecting household and service jobs from automation	nil/min	neg	min

*mod = moderate
min = minor
neut = neutral
neg = negative

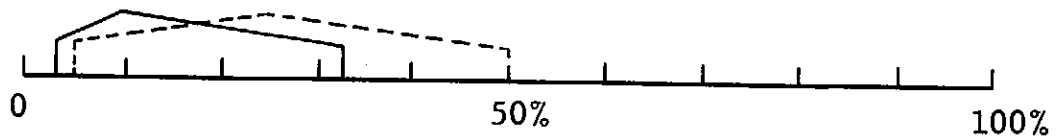
9. PREDICTED PROGRESS IN SPACE

A graphical summary of predicted progress in space is given on the next page. We note that for events whose median break-even dates are within the next 15 years, the quartile ranges are remarkably narrow, reflecting no doubt the rather firm timetable of near-future space achievements to which our space specialists expect to adhere.

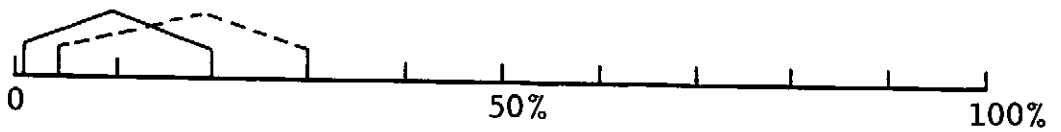
10. PREDICTIONS CONCERNING WAR AND ITS PREVENTION

The members of Panel 5, on War Prevention, were asked both in the first questionnaire (June 1963) and the last questionnaire (January 1964) to give us their personal probability estimates of the occurrence of another major war within 10 and within 25 years. The responses, in terms of medians and quartiles, were these:

June 1963 responses



January 1964 responses



Here, the solid bars refer to the probability of war within 10 years, the dotted bars to the probability of war within 25 years.

A significant decrease in the probabilities between the June and January responses is evident. Even in the case of the 10-year estimates, where the median remained at 10%, the shift of the quartile bar as a whole is quite pronounced. While the identity of the panel membership was not stable enough to draw the conclusion directly from this summary evidence that events of the intervening seven months had caused most of the respondents to take a rosier view of the future, examination of the responses of those individuals who participated in both the first and fourth questionnaires did tend to confirm this hypothesis. For example, none of them raised the value given to the probability of war within 10 years, and the median reduction of probability was 20% of the value originally given.

The panel's views as to the manner in which a major war might break out, if at all, did not change significantly between June 1963 and January 1964. When we average the minor differences in responses between these dates, the

panel's opinions as to the relative probabilities of the modes of outbreak may be summarized as follows:

Inadvertence	11%
Escalation of a political crisis	45%
Escalation in the level of violence in an on-going minor war	37%
Surprise attack at a time when there is no ostensible acute crisis	7%

We considered the main assignments of Panel 5 to be the proposal and appraisal of realistic and effective measures that might be undertaken in the future in order to reduce the overall probability of the occurrence of another major war. Members of the panel submitted a total of 42 distinct proposals for consideration. These were then resubmitted to the panel for appraisal.

Much of the response was in verbal rather than numerical form. Even numerical responses, such as effectiveness and probability-of-implementation ratings and desirability rankings, were subject to interpretation and relative weighting. Taking all these caveats into account, it appears that the picture which emerges can be described roughly by the following tabulation of proposed measures, arranged in the approximate order of decreasing overall desirability, with "effectiveness" to be understood as referring specifically to the lowering of the probability of war. A framed entry indicates a considerable consensus among the panel members:

Proposed Measure	Overall desirability	Effectiveness if implemented	Probability of implementation
Build-up of Western-bloc conventional forces	high	high	high
Increased security of command-and-control and retaliatory capability	high	high	high
Development on both sides of invulnerable delayed-response weapons that are incapable of surprise attack	high	high	high

Proposed Measure	Desira-bility	Effect-iveness	Proba-bility
Greater political and economic unity among free advanced democracies	high	high	medium
US–SU political agreement to seek peace and restrain other nations from developing nuclear weapons	high	high	medium
Establishment of a standing world-wide U.N. police force, not subject to veto	high	high	low
Improved defensive warfare techniques to reduce probability of escalation in limited wars	high	medium	medium
U.N. economic and military aid to areas threatened by political upheaval	high	medium	low
Development of a code of international law and establishment of effective world courts of justice and a world supreme court	high	medium	low
US–promoted rapid technological and economic advancement of under-developed nations	high	low	high
Strengthening of the U.N. with the objective of forming a world government	medium*	high	low
Bilateral US–SU arms control agreements	medium	medium	high
Studies by sociology, group psychology, etc., seeking clues to war prevention	medium	medium	high
US–SU political association against China or other third party	medium	medium	high
Holding the status quo against even minor aggressions	medium	medium	medium
Central–European disengagement to reduce military activity, induced by an improving SU–US atmosphere	medium	medium	medium
Instituting population control in all nations according to U.N. decisions	medium	medium	low

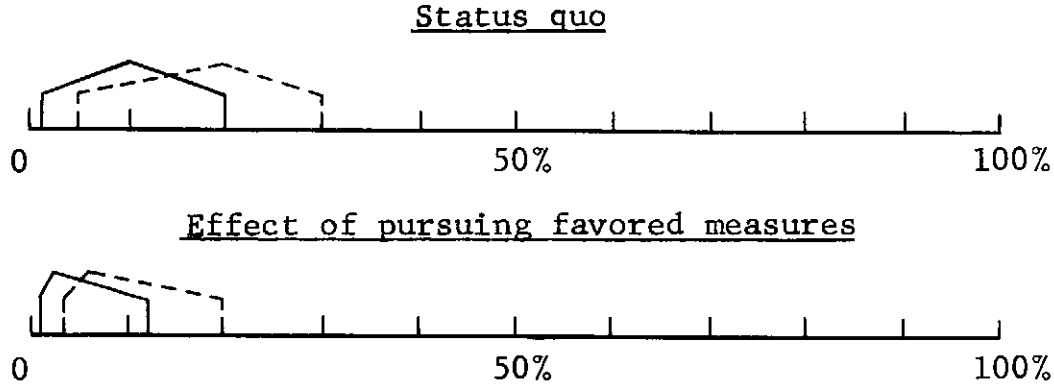
*The doubt, implied by this entry, on the part of some respondents regarding the unconditional desirability of this item appears to be unrelated to their opinion of the U.N. as such but reflecting their fear that a single world government might be subject to subversion of its original purpose.

Proposed measure	Desira-bility	Effect-iveness	Proba-bility
Establishment of national assessment centers which would evaluate crisis situations and transmit policy statements to the potential enemy to clarify U.S. intent	medium	medium	low
US or SU demonstration of the intent to use force of increasing levels (in identifiable steps) in response to specific provocations	medium	medium	low
Removal of trade barriers with Communist countries	medium	medium	low
Development of realistic understanding among western Allies of dynamics of nuclear warfare, by techniques including joint US/Allied crisis- and war-gaming and systems analyses	medium	medium	low
Settlement of the division of Germany on terms acceptable to West Germany and compatible with German membership in NATO	medium	medium	low
Development of a cadre of international U.N. civil servants dedicated to world values	medium	low	high
Military alliance between US and SU (plus possibly India)	medium	low	low
Support and promotion of a United States of Africa, Latin America, Europe, Asia	medium	low	low
Invitation to other nations to become member states of the U.S.A.	medium	low	low
Simulated US-SU war games, played by professional military planners of both sides (possibly with sides interchanged)	medium	low	low
Increased cooperative economic, political, and military ventures by the US with the SU and China to promote interdependency	?*	high	low
Bilateral reduction of armaments enforced by U.N. police force	?	high	low

*A question mark indicates that with respect to this item the respondents had not been asked to assess the desirability as such.

Proposed Measure	Desira-bility	Effect-iveness	Proba-bility
Strengthening of NATO alliance to insure a guaranteed response to prestated provocations	?	high	low
SU-initiated gradual improvement of political atmosphere	?	high	medium
Strategic arms control (halting production but not R-and-D)	?	low	medium
Clear US statement as to which national interests are to be protected by nuclear deterrents, and orientation of our policies to that end	?	low	low
Development of a new system of international political cue "signals" which would indicate real intent to go to war unless political situation changes, such as general mobilization in the past	?	low	medium
Fostering educational and propaganda measures designed to amend or establish values of mutual toleration of various ideologies and the right to self-determination	?	low	high
Sharing of technological innovations between US and SU	?	low	medium
Support of NATO, SEATO, and OAS to increase number of world forums where political differences can be resolved with minimum "loss of face"	?	low	high
Offer of nuclear weapons to countries which agree to support our stated national policies	?	low	medium
Organized encouragement of conscientious objection on the part of scientists to cooperation in the improvement of weapon systems	low	low	low
Creation of buffer zones to avoid direct confrontation of major powers	?	low	high
Recognition of Communist China and East Germany - creation of a realistic policy	?	low	medium
US-initiated unilateral steps toward disarmament	?	low	low

In order to obtain some idea of the potential impact that the above measures might have, we concluded our inquiry by asking each respondent his opinion of how much the probability of a major war in the next 10 and the next 25 years would be reduced if the measures which he favored were pursued vigorously. The result is shown below. The status-quo graph, shown for comparison purposes, repeats the January, 1964, estimates of the probability of war. The solid bars again refer to the 10-, the dotted bars to the 25-year period.



We note that the reduction in the median probability is 75% (for 10 years) and 70% (for 25 years). We also examined the record to find each individual's reduction in these probabilities; the medians of these reductions turned out to be 25% and 33% respectively, which—while not nearly so large—may still be considered strong evidence of the respondents' optimism regarding the possibility of reducing their own dire forecasts by taking appropriate preventive measures.

11. PREDICTED WEAPON SYSTEMS OF THE FUTURE

Panel 6, whose subject matter was future weapon systems, had to work under a slight handicap in that the details of such systems are generally not in the public domain because of military secrecy. This had the dual effect of putting a restraint on respondents who did have access to such information, and of keeping respondents without such access in the dark with regard to some of the current work being

done in this area. A classified inquiry on the same subject would presumably have yielded additional items and also more reliably dated forecasts.

The panel members suggested a total of 58 distinct weapon-system developments. Of these, all but 32 were eventually dropped from further consideration, because a majority consensus indicated either that their feasibility was so low as to make development in the foreseeable future very unlikely, or else that their effectiveness, even if developed, would be too low, or both.

The following page gives a graphical picture of the outcome. Again—as in the case of Panels 1, 3, and 4 (Science, Automation, and Space)—we used quartile bars peaked at the median. Figure 11.1 shows predicted dates in grey under the assumptions of the status quo prevailing (dark bars), and of a crash program (light bars). The green bars show the "absolute" predictions solicited in Questionnaire 4, in which the respondents had been required to estimate operational readiness dates on the basis of their own expectations as to the likelihood of a crash program being instituted. The items were arranged in the order of the median dates of the "absolute" predictions (green bars). (The three gaps appearing among the grey bars correspond to items representing afterthoughts that were not submitted to the panel until the final round.)

It should be noted that in a few cases the median of the operational-readiness estimates lies toward the right not only of the bar of crash-program estimates but even of that of the status-quo estimates. This may mean that the respondents had a change of mind between Questionnaires 3 and 4. More probably, though, in the last round the concept of actual operational readiness prevailed, while in the earlier rounds the contingency estimates may have been made subject to the additional, tacit assumption: "Suppose there is a decision to go ahead with the weapon system in question."

Figure 11.1 also carries, in the left-hand margin, a tabulation of the medians of effectiveness and feasibility, each measured on a scale from 0 to 10.

We have made an effort below to abstract from the responses of the other five panels such material as might be relevant for future weapon systems. No implication is intended that these are forecasts of military instrumentalities in the offing; we simply leave it to the reader to consider them for what they are worth as regards possible relevance to potential weapon systems of the future. The statement in the last column of this tabulation merely represents the authors' extrapolation of the item described in the first column into the field of weapons application.

Item	Panel	Predicted time of availability		Possible implication for weapon systems
		Median	Quartiles	
Establishment of a global satellite communication system	4	1968	1967–1970	Improvement in the security of command-and-control
Unmanned inspection and capability for destruction of satellites	4	1967	1967–1970	Potentially important defense against unauthorized reconnaissance or against satellites suspected of carrying bomb loads
Manned co-orbital inspection of satellites	4	1970	1970–1974	
Effective fertility control by oral contraceptive or other simple and inexpensive means	1	1970	1970–1983	Possibility of long-term manipulation of enemy's population size through covert seeding of his water supply with oral contraceptives (alternative non-aggressive version: contraceptive aid to underdeveloped nations in an effort to upgrade their economies and to remove a future cause for war through relieving population pressure)

Item	Panel	Predicted time of availability Median	Quartiles	Possible implication for weapon systems
Development of new synthetic materials for ultra-light construction	1	1971	1970–1978	New light-weight military equipment, including construction items such as bridges
Air traffic control – positive and predictive track on all aircraft	3	1974	1970–1977	Complete tracking of all aircraft by the Air Defense Command
Widespread use of automatic decision-making at management level for industrial and national planning	3	1979	1977–1997	More efficient military procurement planning; aid in strategic and tactical combat direction
Controlled thermonuclear power	1	1986	1980–2000	Mobile power plants for tactical use; possibly rocket propulsion
Limited weather control, in the sense of substantially affecting regional weather	1	1990	1987–2000	Destruction of crops; flooding of enemy territory
Biochemical general immunization	1	1994	1983–2000	Defense against biological-warfare attacks
Global ballistic transport (including boost-glide techniques)	4	2000	1985–never	Rapid mobility of men and arms to any point on earth
Man-machine symbiosis, enabling man to extend his intelligence by direct electromechanical interaction between his brain and a computing machine	1 3	2020 2010	1990–never 1985–2600	Greater adaptability to hostile environments, especially in space combat; more effective use of computing aids in tactical decision-making
Breeding of intelligent animals (apes, cetaceans, etc.) for low-grade labor	1	2020	2020–never	Use of animals for reconnaissance and other ground-combat tasks
International agreements which guarantee certain economic minima to the world's population as a result of high production from automation	3	2024	2018–2100	Removal of potential pressures toward war (i.e., a means for eliminating the need for weapon systems)
Control of gravity through some form of modification of the gravitational field	1	2063	2030-never	Weightless combat vehicles; raising the enemy forces off the ground

Item	Panel	Predicted time of availability Median	Quartiles	Possible implication for weapon systems
Manned maneuverable geocentric bombardment fleet	4	2500	1990–never	Possible follow-on to the Polaris concept
Feasibility of education by direct information recording on the brain	1	2600	1997–never	Potentiality of permitting deductions from vast amounts of collected data; possible edge in scientific and technological innovation
Military force on the Moon	4	never	1999–never	Self-explanatory
Heliocentric strategic fleet	4	never	2500–never	Self-explanatory

12. THE WORLD OF 1984

If we abstract the most significant items from the forecasts of all six panels, the following picture emerges of the state of the world as of 1984:

The population of the world will have increased by about 40% from its present size to 4.3 billion—that is, provided no third world war will have taken place before then. There is an 80 to 85% probability that it will not, if present trends continue, but this probability can be raised to 95% by appropriate policy measures.

To provide the increased quantities of food needed, agriculture will be aided by automation and by the availability of desalinated sea water.

Effective fertility control will be practised, with the result that the birth rate will continue to drop.

In the field of medicine, transplantation of natural organs and implantation of artificial (plastic and electronic) organs will be common practice. The use of personality-control drugs will be widespread and widely accepted.

Sophisticated teaching machines will be in general use.

Automated libraries which look up and reproduce relevant material will greatly aid research. World-wide communication will be enhanced by a universal satellite relay system and by automatic translating machines. Automation will span the gamut from many service operations to some types of decision making at the management level.

In space, a permanent lunar base will have been established. Manned Mars and Venus fly-bys will have been accomplished. Deep-space laboratories will be in operation. Propulsion by solid-core nuclear-reactor and ionic engines will be becoming available.

In the military arena, ground warfare will be modified by rapid mobility and a highly automated tactical capability, aided by the availability of a large spectrum of weapons, ranging from non-lethal biological devices and light-weight rocket-type personnel armament to small tactical nuclear bombs and directed-energy weapons of various kinds. Ground-launched anti-ICBM missiles will have become quite effective. Anti-submarine warfare techniques will have advanced greatly, but improved, deep-diving, hard-to-detect submarines will present new problems.

13. THE WORLD OF 2000

When we continue our projection to the year 2000, the following major additional features emerge as descriptive of the world at that time, judging from the forecasts of the six panels:

The population size will be up to about 5.1 billion (65% more than 1963).

New food sources will have been opened up through large-scale ocean farming and the fabrication of synthetic protein.

Controlled thermonuclear power will be a source of new energy. New mineral raw materials will be derived from the oceans. Regional weather control will be past the

experimental stage.

General immunization against bacterial and viral diseases will be available. Primitive forms of artificial life will have been generated in the laboratory. The correction of hereditary defects through molecular engineering will be possible.

Automation will have advanced further, from many menial robot services to sophisticated, high-IQ machines. A universal language will have evolved through automated communication.

On the Moon, mining and manufacture of propellent materials will be in progress. Men will have landed on Mars, and permanent unmanned research stations will have been established there, while on Earth commercial global ballistic transport will have been instituted.

Weather manipulation for military purposes will be possible. Effective anti-ICBM defenses in the form of air-launched missiles and directed-energy beams will have been developed.

14. CONCEIVABLE FEATURES OF THE WORLD IN THE YEAR 2100

When we try to look as far ahead as to the year 2100, there can be no pretense regarding the existence of any consensus among our respondents. We record the following developments, for which there was a median forecast of no-later-than 2100, not as a prediction of the state of the world world at that time but as an indication of what a number of thoughtful people regard as conceivable during the next few generations to come:

By the year 2100 the world population may be of the order of 8 billion.

Chemical control of the aging process may have been achieved, raising a person's life expectancy to over 100 years. The growth of new limbs and organs through biochemical stimulation may be possible. Man-machine symbiosis,

enabling a person to raise his intelligence through direct electromechanical tie-in of his brain with a computing machine, is a distinct possibility. Automation, of course, will have taken further enormous strides, evidenced in all probability by such things as household robots, remote facsimile reproduction of newspapers and magazines in the home, completely automated highway transportation, etc.

The problem of adequately providing the necessities of life for all peoples of the earth will presumably have been solved by international agreements based on the abundance of new sources of energy and raw materials opened up in the twenty-first century. As for materials, it is even possible that elaborate differential mining processes will have been abandoned in favor of commercially efficient transmutation of elements.

Conceivably, revolutionary developments will have become feasible as a result of control of gravity through some form of modification of the gravitational field.

A permanent lunar colony may well have been established, with regularly scheduled commercial traffic between Earth and Moon. A permanent base on Mars, landings on Jupiter's moons, and manned fly-bys past Pluto are likely accomplishments. Possibly even a multi-generation mission to other solar systems may be on its way, aided conceivably by artificially induced long-duration coma. Two-way communication with extra-terrestrial intelligent beings is a definite possibility.

15. EDITORIAL COMMENTS ON THESE FORECASTS

Before leaving the substantive aspects of this report and proceeding to a discussion of method, we would like to interject a few remarks reflecting our own reaction to some of the panel forecasts.

First of all, we would like to register our surprise at some of the ideas that have been propounded. To other

persons, of course, a different set of items might be the unexpected ones. These are among the ones which we had failed to anticipate:

The implication that the water-covered portions of the earth may become important enough to warrant national territorial claims.

The possibility that continued developments in automation will result in serious social upheavals; the almost complete acceptance of the necessity of regulative legislation.

The probability, in the relatively near future, of very widespread use of personality-control drugs.

The notion of an actual symbiosis of man and machine.

The use of computers as "colleagues" rather than servants or slaves.

The fact that control of gravity was not rejected outright.

The relative confidence that the population curve would begin to level off during the next generation.

The strong likelihood of the emergence of weapons of a nonkilling, nonproperty-destroying nature, covert perhaps, attacking on the psychological or biological level.

The idea of perishable counter-insurgent arms.

The general disagreement with the concept of deep-space military applications, such as heliocentric strategic fleets.

The anticipated relatively high probability of another major war.

The absence, on the one hand, of significantly new ideas for the prevention of war, and the confidence, on the other, that the application of what may almost be called traditional proposals to this effect hold great promise for reducing the probability of war.

Secondly, we feel it incumbent upon us to point out certain warnings which seem to be implied in the opinions of our respondents. Our motivation in doing so is not to prophesy doom but to indicate the areas, however obvious, in which a major effort will have to be concentrated in order to avoid future disaster. They can be subsumed under four headings:

War prevention. While the odds are considered to be

against another major war within the next generation even a 20% chance of this (within 25 years), which is the War Prevention panel's median prediction, is clearly intolerable. The main danger appears to be in mutually undesired escalation and downright inadvertence, hence a major effort to seek improved ways of forestalling such disaster is mandatory.

Equitable distribution of resources. While there is a consensus that eventually there will be an abundance of resources in energy, food, and raw materials, it is not at all a foregone conclusion that they will be plentifully available in time to keep ahead of the increasing world population, or what is more, that effective means of an equitable world distribution of such assets will have been found and agreed upon. To solve these problems in time will clearly be a great contribution toward the prevention of (big or small) wars.

Social reorganization. The anticipated explosive growth in the amount of automation is likely to reshape the societies of industrialized nations considerably, perhaps beyond recognition. While improved and highly automated methods of education will make the acquisition of technical skills available to a larger fraction of the population, only the very ablest people are likely to be needed to manage the new, automated, economy. Since robots are apt to take over many of the services, especially the more menial ones, large segments of the population may find themselves without suitable employment within an economy of potential abundance. Far-sighted and profoundly revolutionary measures may have to be taken to cope with this situation and to create new patterns within which a democratic form of society can continue to flourish. "Earning" a livelihood may no longer be a necessity but a privilege; services may have to be protected from automation and be given social status; leisure time activities may have to be invented in order to give new meaning to a mode of life that

may have become "economically useless" for a majority of the populace.

Eugenics. Finally, to mention a problem which, though not upon us as yet, will require much forethought and wisdom, there is the possibility—now just below the horizon but expected to be realized within a generation or two—of selectively extending an individual's life span through biochemical methods and of selective eugenic control through molecular genetic engineering. The potential dangers of mismanaging these capabilities are too obvious to require formulation.

16. CONVERGENCE OF OPINIONS

We now turn briefly to an examination of some of the methodological features of our experiment.

Many of the questions put before Panels 1, 3, 4, and 6 (Science, Automation, Space, and Weapons) were asked more than once. This gave us an opportunity to determine the amount of opinion convergence that was taking place in the process of interrogation.

A convenient measure of the spread of opinions is the quartile range, QR, of the responses. Figure 16.1 shows a scatter diagram of the final quartile range, QR_2, versus the original quartile range, QR_1, for each repeated question. (The numerals used to spot these points refer to the panel number.)*

It can be seen at a glance that the quartile range decreased, since the majority of the points lie well below the 45°-line. The median ratio of QR_2/QR_1 is almost exactly 5/8. Broken down by panels, the median reductions in quartile range are as follows:

Panel	Median or QR_2/QR_1
1 (Science)	.60
3 (Automation	.73
4 (Space	.63
6 (Weapons)	.61

*A detailed graphical report on the convergence of opinions, by individual questions, is given in the Appendix to this report.

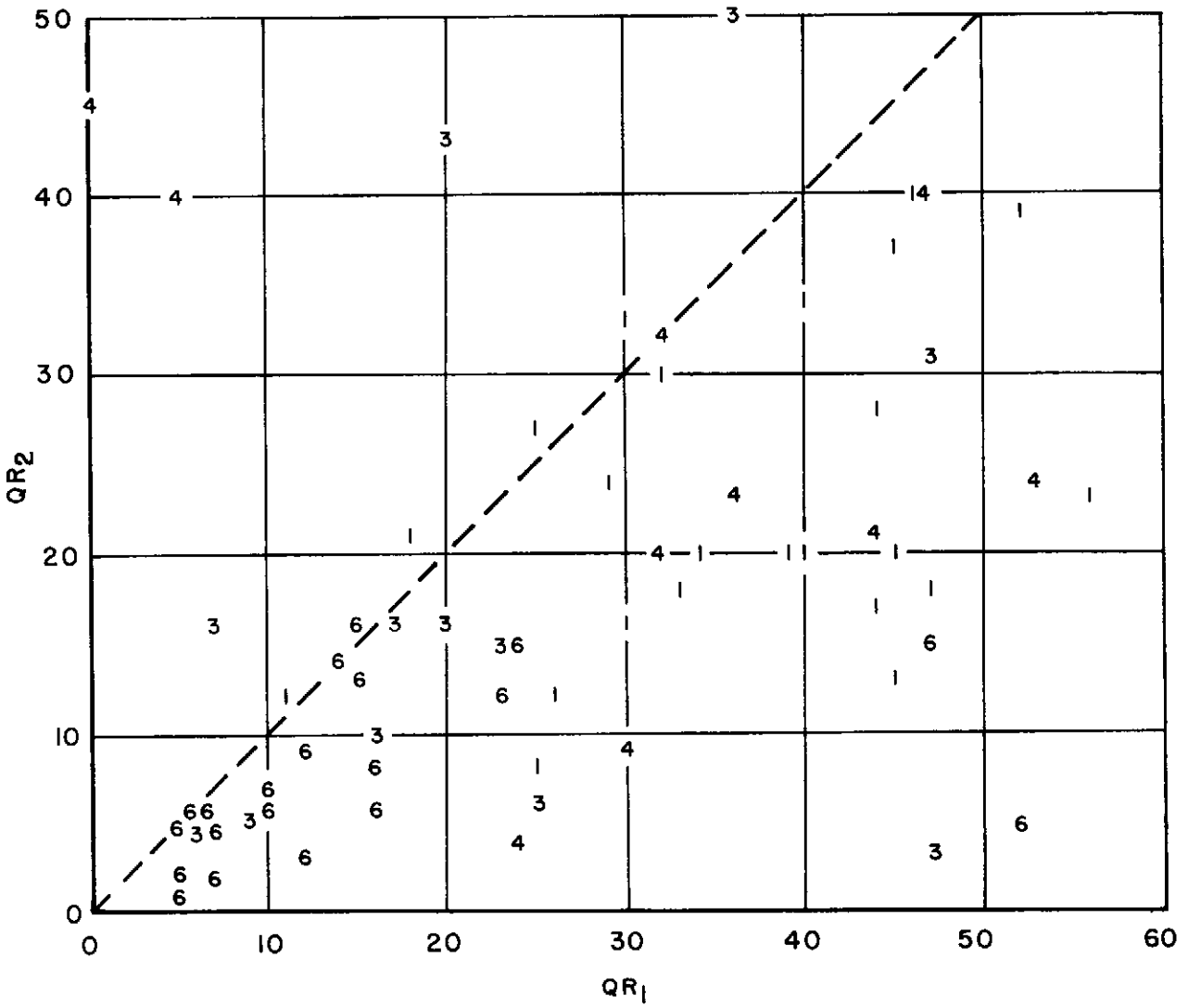


Fig. 16.1 — Opinion convergence: Final versus initial quartile ranges

The question for Panel 2 regarding future birth and death rates was also repeated, but the composition of the panel membership changed so much as to make a comparison not very meaningful. We report, for the record, that the median and quartile population curves computed on the basis of the panel's original and final responses did not differ significantly.

For Panel 5, the questions of the probability of war and of the likely causes of outbreak were raised twice. The response has already been recorded and discussed in Section 10 above. As for the questions relating to measures for reducing the probability of war, while the descriptions of these measures were repeated, the solicited modes of appraisal were too different to permit direct numerical comparison; qualitatively speaking, reasonably good convergence was generally observed.

In a number of "repeated" questions in Panels 1, 3, 4, and 6, the precise wording had been changed in an effort to eliminate ambiguities that had been brought to our attention. While we cannot point to a general pattern of success in achieving a better consensus through this device, an example may illustrate the effect which we had hoped to achieve:

The original wording of the question labelled "Social 6" addressed to the Automation panel mentioned

> "Computing machines becoming the most significant intelligence on earth";

this was subsequently changed to

> "Availability of a machine which comprehends standard IQ tests and scores above 150,"

and finally amended in the last questionnaire by the parenthetic addition

> "...where 'comprehend' is to be interpreted behavioristically as the ability to respond to questions printed in English and possibly accompanied by diagrams."

Here are the statistical characteristics of the successive sets of responses, which speak for themselves:

Questionnaire	Median	Quartile range
3.2	2050	2010 – never
3.3	1995	1985–2025
3.4	1990	1984–2000

While the results reported here indicate a reasonably satisfactory convergence of opinions—as exhibited in particular in Fig. 16.1—we do not wish to make exaggerated claims in this regard. Hence we are adding these cautionary comments:

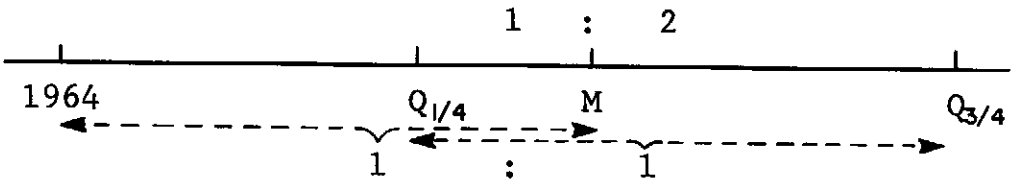
A number of questions were not pursued because of their relative unimportance in the face of an initial highly divergent response. We cannot guess whether a satisfactory process of convergence would have been observed, had we taken the trouble to continue the inquiry on these topics. Also, in a number of cases where a question was pursued through several rounds, a considerable divergence of opinions persisted. To cite just two examples, the Science and Automation panels each disagreed on predictions regarding the feasibility of direct electromechanical man–machine symbiosis (medians: 2020, 2010; quartile ranges: 1990 – never, 1985 – 2600, respectively); and in the Space panel there was a dissensus as to when (but not whether) propellent materials might be mined and manufactured on the Moon (median: 1990, quartile range: 1980 – 2020).

Whether or not the convergence observed in the Delphi procedure compares favorably in amount and rationality with that obtained by more traditional modes of consensus formation, such as a round–table discussion, is a moot question. We submit, though, that even if the effectiveness of the Delphi technique in producing a consensus is not superior to other methods, it can conceivably offer considerable advantages in cost and reliability—the former by avoiding the need for assembling the experts in one place, the latter by not subjecting them to the persuasiveness of oratory or to the bandwagon effect of prominent authority and of face–to–face confrontation with majority opinion, but merely to the milder form of anonymous social pressure exerted by the feedback of some information on the range of opinions held by the group.

17. PREDICTION PRECISION AS A FUNCTION OF TIME

The precision with which a panel as a group predicts the date of a future event, as measured by the narrowness of the quartile range, must be expected to diminish with increasing distance in the future. The scatter diagram in Fig. 17.1, which covers all items with a median date no later than 2020, not only confirms this but reveals the additional fact that the size of the quartile range on the average is about equal to the expected distance in the future. (The numerals again refer to the panel number; in the case of the Weapons panel (Panel 6), the absolute rather than the status-quo or crash-program forecasts have been used.)

We mention in passing that the position of the median within the quartile range, on the average, is about one third of its length from the lower end:



Hence, if an event has a median predicted date x years in the future then, on the average, the corresponding quartile range will span the interval from $\frac{2}{3}$x years in the future to $\frac{5}{3}$x years in the future (e.g., for an event with a median year of 2000, the ends of the quartile range would average approximately 1988 and 2024).

In this connection we may briefly refer to the rather special case of Panel 6, where we had asked for predictions of the availability of new weapon systems under two different assumptions—namely, that of the status quo and that of a crash program—to be followed in the final questionnaire by an absolute prediction.

As a preliminary observation we take cognizance, through Fig. 17.2, of the dependence of the potential speed-up due to a crash program (the quantity SQ-CP, where SQ

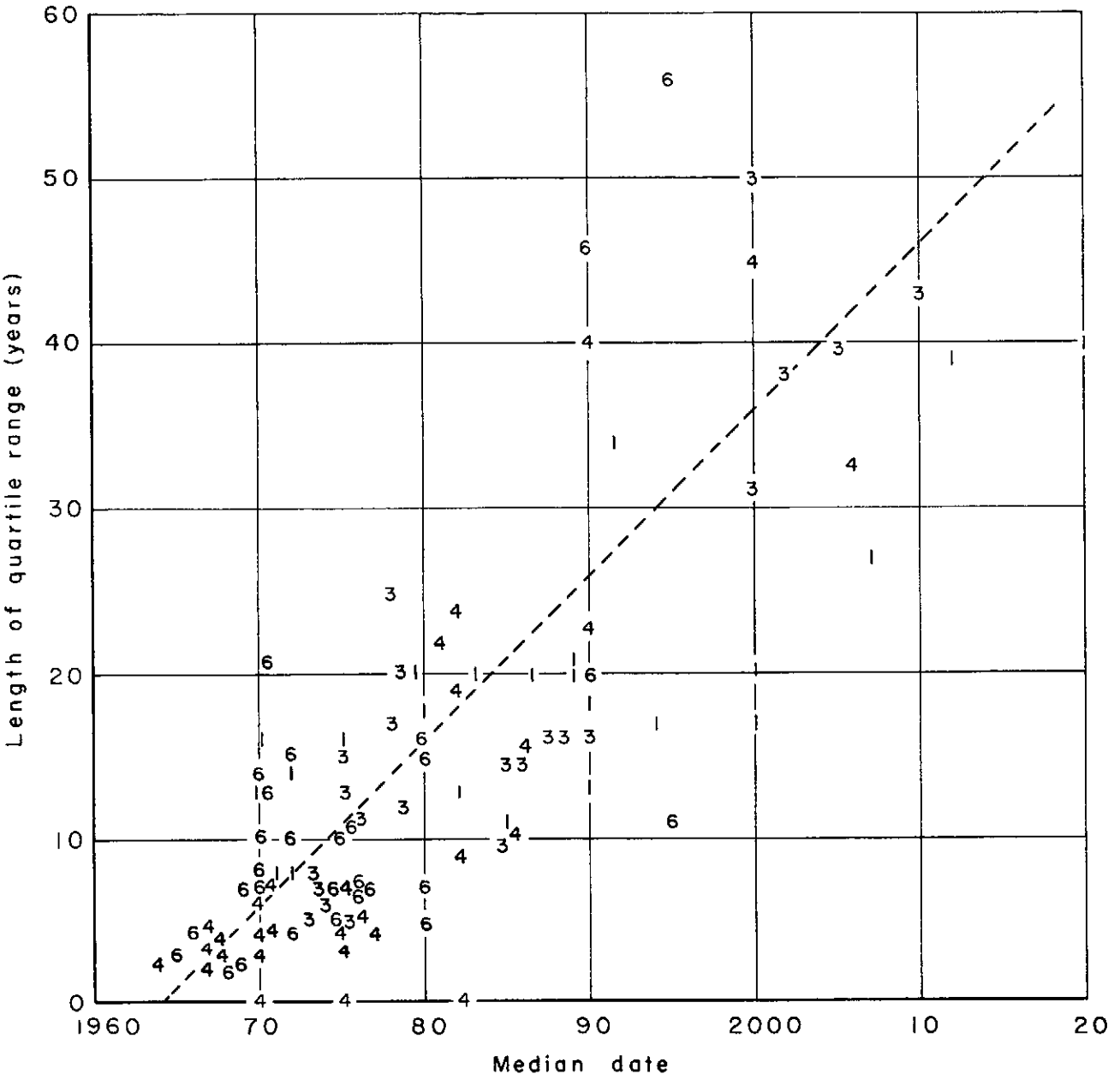


Fig. 17.1 — Prediction precision

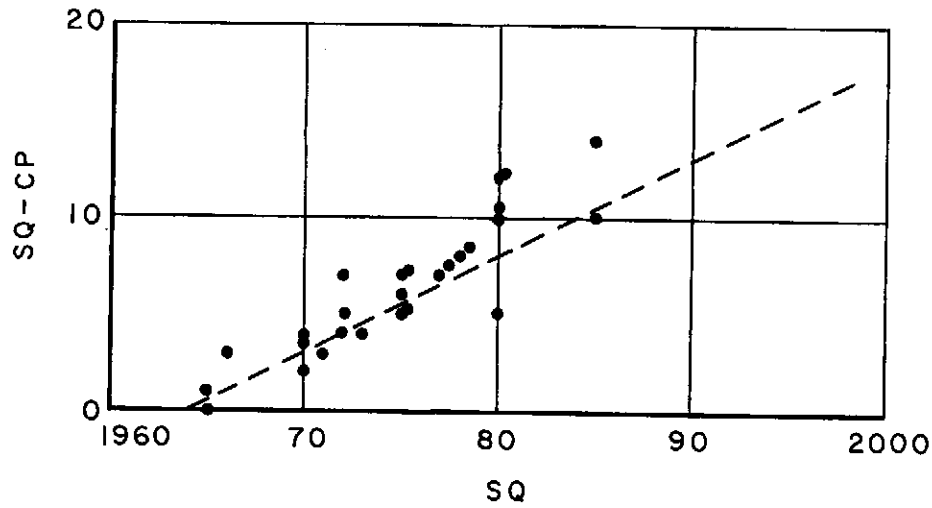


Fig. 17.2 — Speed-up due to crash program

and CP are the median dates of availability under the two assumptions) on the predicted date under the status quo (=SW). Points above the dotted line are those for which the expected time from the present to operational readiness is expected to be cut at least in half by instituting a crash program. The figure shows that this is the case for more than half the weapon systems considered.

The next figure, 17.3, gives the quartile range of each absolute prediction of a weapon system's operational readiness as a function of the quartile range of the corresponding status-quo prediction. The prediction precision, as measured by the inverse of the quartile range, is reduced in the median (broken line in Fig. 17.3) by 30% when we go over from status-quo to absolute forecasts. This deterioration is accounted for by the additional uncertainty as to the engagement in a crash program, which the respondents had to assess in naming absolute dates.

18. PREDICTION FREQUENCY AS A FUNCTION OF TIME

The median dates for which Panels 1, (Science) 3, (Automation) 4, (Space) and 6(Weapons) predicted occurrences in their areas of concern were distributed noticeably differently for these four panels, as shown in Fig. 18.1, where the relative frequencies of predictions by 10-year intervals are displayed separately for each panel.

Panel 1, on scientific breakthroughs, is seen to have the comparatively most uniform distribution over time. The forecast dates of Panel 3, on automation, show a surprisingly smooth distribution peaked at the 1975-84 interval. Panels 4 and 6 both produced U-shaped distributions, with the notable difference that Panel 4 gave almost equal weight to both ends of the time interval, while Panel 6 concentrated heavily on the decade lying immediately ahead.

Taking the median, marked M, of the predicted median dates as an indicator of how far, on the average, each

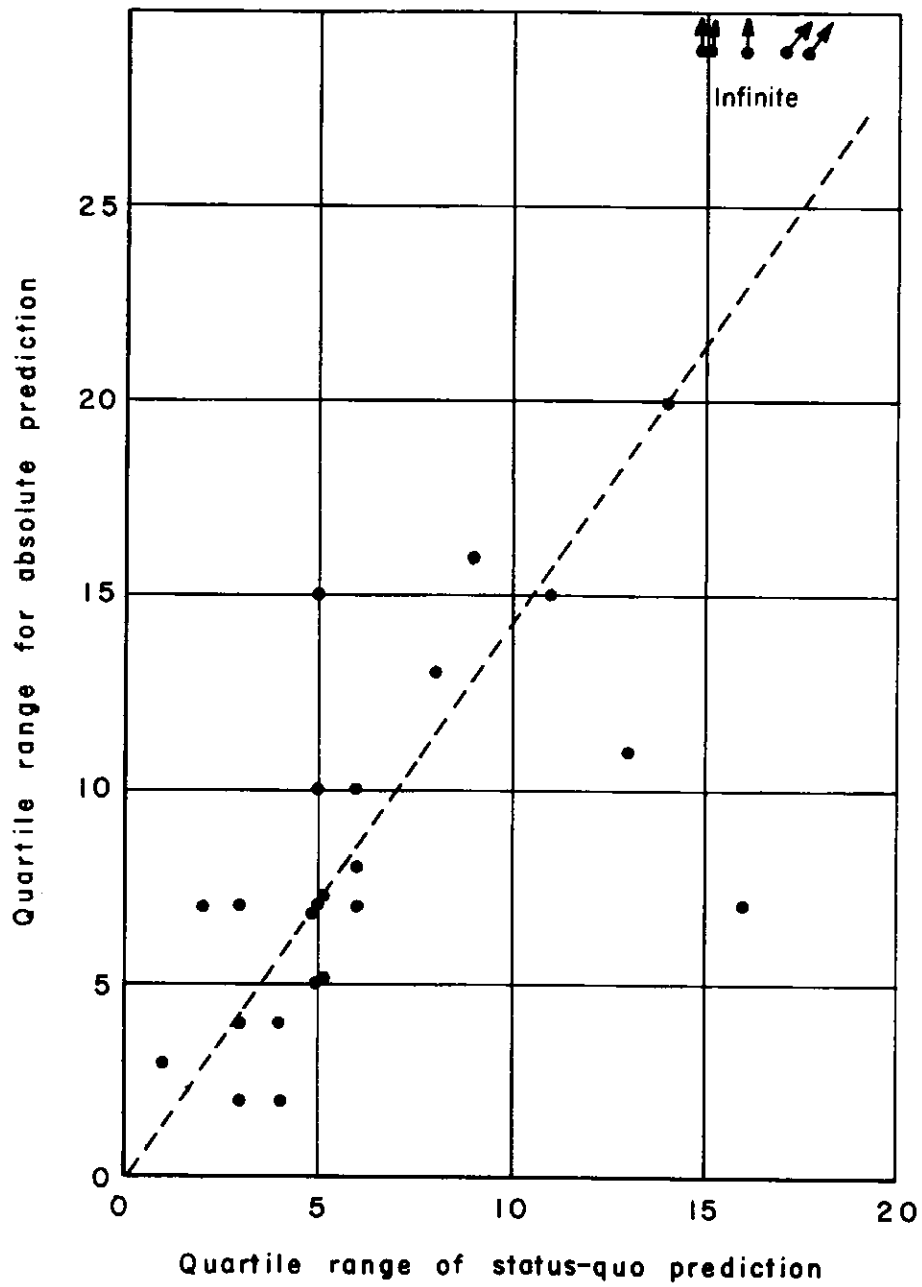


Fig. 17.3 - Comparison of prediction precision for absolute versus status-quo dates of operational readiness of weapon systems

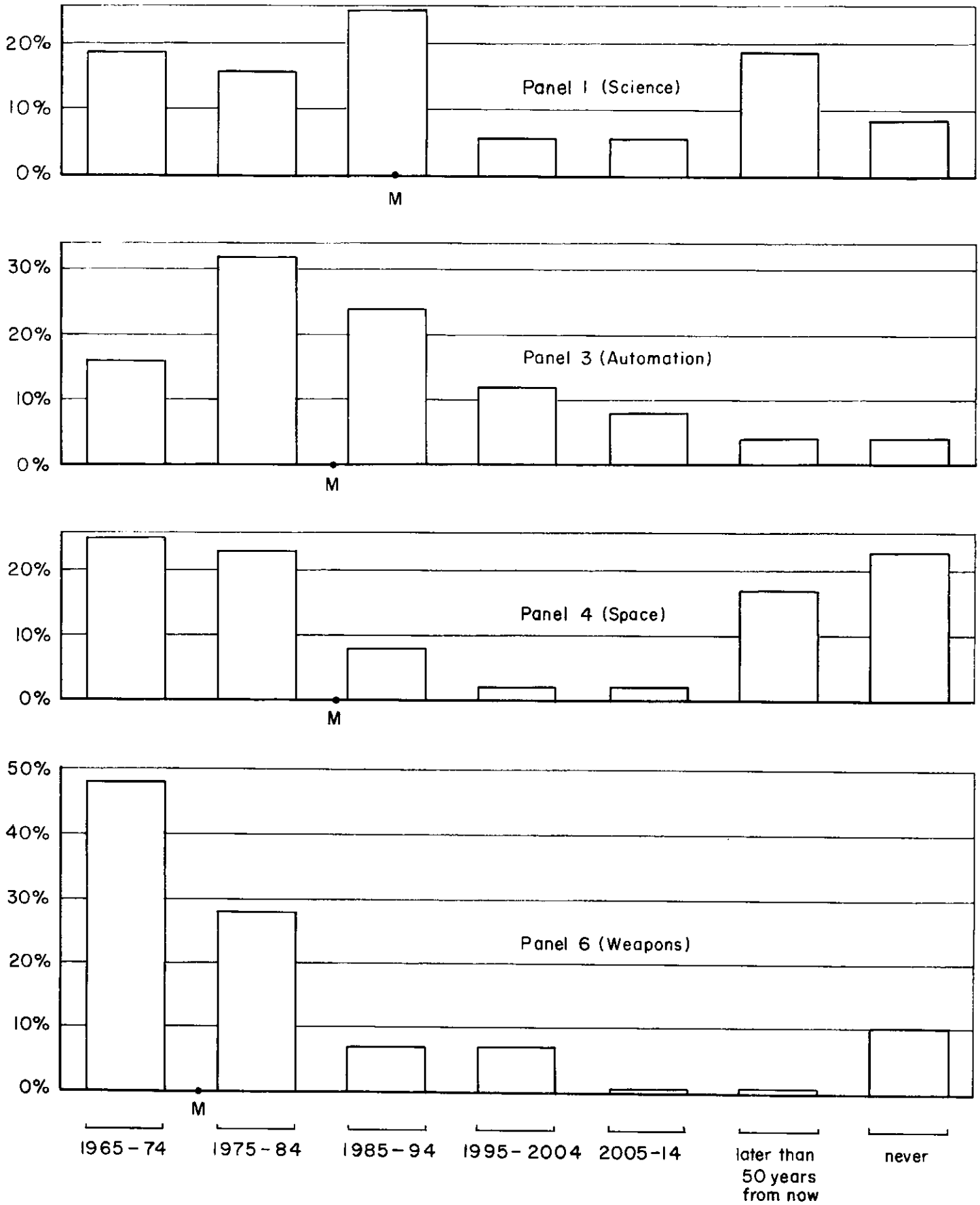


Fig. 18.1 — Frequency distribution of predicted median dates

panel is looking into the future, we note that this median time horizon is about 10 years for Panel 6, 20 years for both Panels 3 and 4, and 25 years for Panel 1.

While these differences are sizeable, they are not at all surprising, considering the subject matters of the panels concerned.

19. CONFIDENCE AS A FUNCTION OF PREDICTED DATE

The members of Panels 1, 3, and 4 were asked, in several questionnaires, to state not only the year by which they thought an event had a 50% probability of occurrence, but also by what year they felt 90% confident that the event would occur. In Fig. 19.1 we have plotted the medians of these 90%-confidence years against the medians of the corresponding 50%-confidence years for all events for which the latter was no later than 2000.

The graph, not unexpectedly, shows a close correlation. Denoting the distances in the future of the medians of the 50%- and 90%-years by $M_{.5}$ and $M_{.9}$ respectively, we note as a matter of curiosity that

$$\text{median } (M_{.9}/M_{.5}) = 9/5 = 1.8,$$

with a corresponding quartile range from 1.6 to 2.0, as indicated by dotted lines in the figure.

20. CRITIQUE OF EXPERIMENTAL PROCEDURE

The procedure we have followed in this experiment is open to many criticisms. Some shortcomings we were aware of from the beginning, some became clear as we went along, others were brought to our attention through comments by our respondents, still others will undoubtedly occur to the readers of this report.

It is precisely because of our conviction of the basic soundness of our approach that we wish to devote some space to a critical discussion of our procedure. In particular,

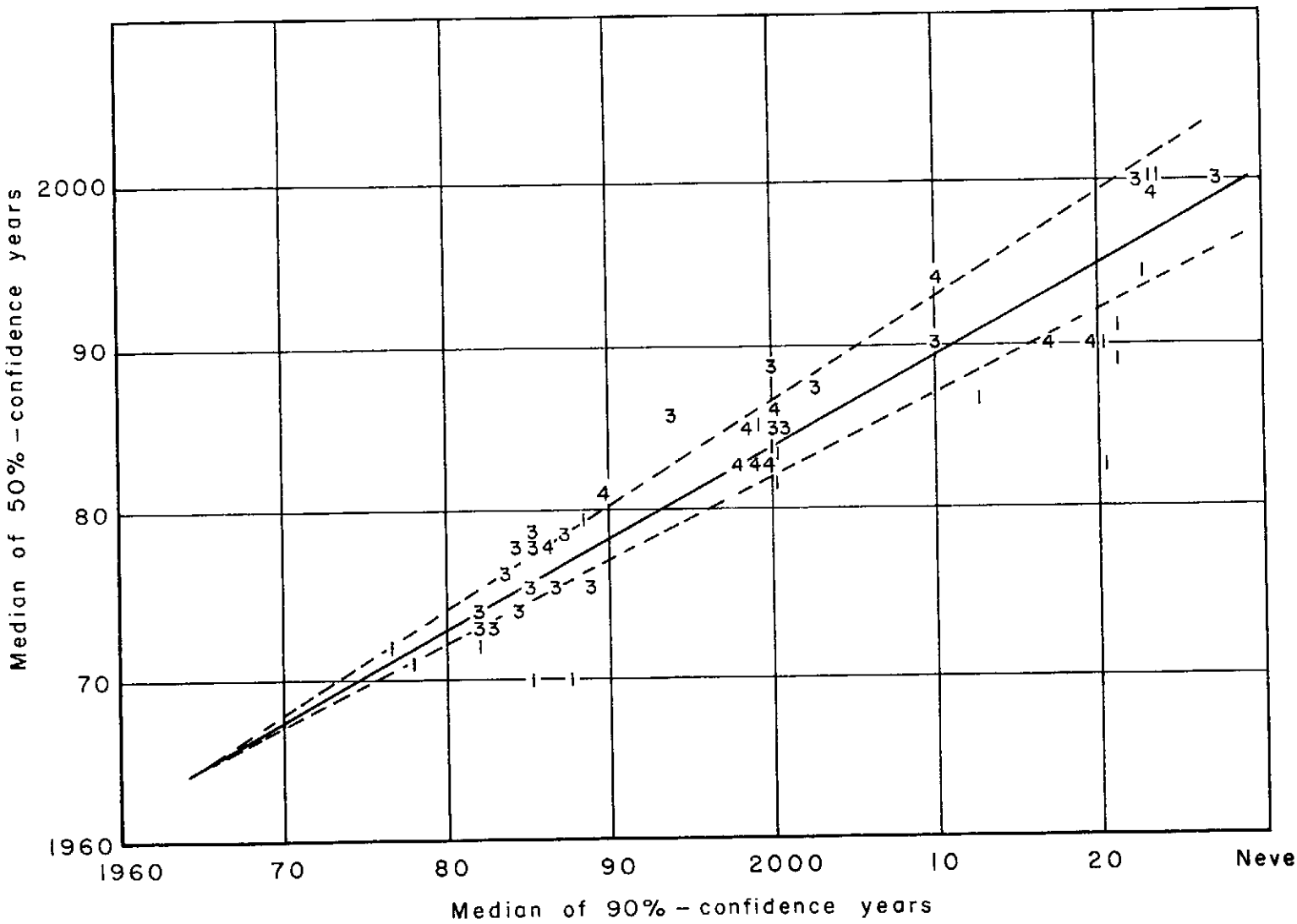


Fig. 19.1 — 50% Confidence versus 90% Confidence

we would like to establish, for possible future reference, which deficiencies could have been corrected and thus are in principle avoidable, and which others are weaknesses inherent in the method.

(a) Instability of panel membership. The make-up of each of our six panels of respondents fluctuated considerably; some early participants dropped out others were added after the initial round. While in principle we see no objection to some changes in panel membership—in fact, scientific progress in general relies on the constantly changing collaboration of many contributors— we have no doubt that the convergence of opinions is impeded by too many substitutions. To eliminate the latter entirely would be virtually impossible in view of unforeseeable circumstances and of the many competing demands on their time to which a group of experts is bound to be subjected. One means of keeping changes in personnel within reasonable bounds for the duration of an experiment might be to have some form of contractual arrangement with the participants.

(b) Time lapse. Too much time elapsed between successive rounds, the average lapse having been about two months. Better advance organization plus possibly the omission of overseas respondents might have reduced this to one month per round. The excessive length of time presumably was partly responsible for some of the drop-outs mentioned under (a); it also may have caused some genuine shifts of opinion due to the mere passage of time, with its concomitant change in the state of our knowledge generally.

(c) Ambiguous questions. Many of the questions put to the respondents, perhaps even a majority, were worded ambiguously. To some extent we regard this as unavoidable, because precision of meaning can often be bought only at the expense of legalistic phraseology, whose cumbersomeness would be repellent to many respondents. Yet an even greater effort should be made, by being reasonably specific, to

avoid the possibility that two respondents may form widely disparate interpretations of the same question. We are conscious of having violated this prescription in several instances—for example, when we asked for a specific date for the occurrence of an event that was inherently a matter of gradual development.

(d) Respondents' competence. The questions put to each panel ranged over a large field. With all due regard for our eminent respondents, it is not reasonable to expect that each could be equally competent with regard to all of the areas touched upon by our questions. Thus the answers by highly competent experts were somewhat diluted by less-highly informed estimates on the part of others. This effect was even slightly enhanced by including among the responses those of volunteers from other panels who submitted answers to questionnaires not addressed to their own panel. There are several remedies for this defect. On the one hand, the members of a panel might be selected for their known expertise within a narrowly defined area, and questions be confined rigidly to the latter. On the other, the respondents might be encouraged to leave blanks in the questionnaires whenever they feel unsure of their judgment, thus leaving the matter of their qualification to their own discretion. Our own preference would be in the direction of this second alternative, with the possible further modification that the respondents answer every question, but add in each case a self-appraisal of their degree of competence in answering it. Precisely how this should be done is an open question which might be made the subject of a separate study. We merely mention that there are problems concerning scale comparability of different respondents' self-appraisals and concerning the optimal use of such self-appraisals in devising a consensus formula.

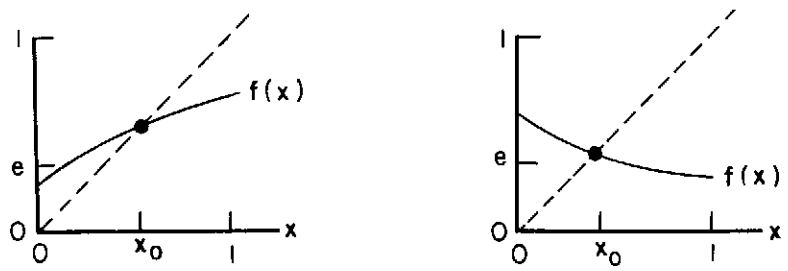
(e) Self-fulfilling and self-defeating prophecies. If a person of great authority and trustworthiness were to announce that the condition of the U.S. economy for the

foreseeable future is excellent, the strengthening effect on business morale might be such as to improve the state of the economy, thereby making the statement to some extent a self-fulfilling prediction. Conversely if, say, it were announced that we are about to lose our race with the Russians to the Moon, the effect might be a redoubling of our effort, thereby turning the statement into a self-negating prediction. It has been objected by one of our panelists that some of the predictions which we solicited might be of one of these types. Leaving aside the implication--to which we emphatically do not subscribe--that the publication of the answers to some of our questions might in fact affect the future course of history with regard to the subject of the questions (e.g., by hastening or retarding a predicted event), there still remains the possibility that a respondent's answer might be biased by his expectation (whether conscious or not) that the announcement may affect the truth of the prediction's content. If this were so, then the respondent would cease to be acting as a pure predictor but would in part become a would-be manipulator of the future; in addition, so it has been said, the very act of his stating a probability for some future event would involve a logical circularity, because by stating it he would affect it. While the first possibility, of attempting to play politics as it were, must be admitted to be a real one, which may place a respondent in the position of having to choose between what he thinks is right and what he thinks is true, there seems to us to be no real evidence of a logical circularity. In other words, if a respondent wishes to make an objective forecast, he can do so without getting involved in a logical fallacy. To see that this is so, let us consider the case where the probability of the event E at some future date is to be estimated. Let e be the probability, according to the respondent's opinion, that E will occur provided no public announcement of the outcome of the questioning process is made, and let f(x) be his estimate of that

probability if an announcement is made stating that the probability has been estimated to be x. Then, if the announcement in itself were ineffectual, we would have

$$f(x) = e$$

for all x. If it were self-fulfilling or self-defeating, f(s) would be monotonically increasing or decreasing respectively, as shown in the figure below.



In either case, there will be at least one point (in the second case, exactly one point) x_0 for which

$$f(x_0) = x_0,$$

so that a forecast of x_0 as the probability of E induces a probability x_0, thus making x_0 a logically consistent estimate.*

f. Consensus by undue averaging. The objection has been raised that the emphasis we place on the median as a descriptor of the group opinion and on the quartile range as a measure of the degree of consensus biases the outcome unduly against the far-out predictor, whose judgment may after all prove to be right while the majority opinion may be wrong. We regard this objection as not entirely unjustified with respect to the present experiment, but as invalid as a criticism of the technique in general. It should be remembered that it is an essential feature of our method that a respondent who disagrees with the majority is invited to state his reasons for such disagreement, and that all the members of the panel are given an

*Since writing this, our attention has been drawn to the following similar but more detailed treatment of this subject: Herbert Simon, "Bandwagon and Underdog Effects and the Possibility of Election Predictions," Public Opinion Quarterly, Vol. 18, 1954, pp. 245-53.

opportunity to accept or reject such reasons and to reevaluate their opinions on the basis of whatever merits they believe these reasons deserve. Thus a far-out opinion is in principle rejected only if its proponent fails to justify it before the rest of the panel. The valid part of the objection against the overly averaging influence of our procedure appears to us to be directed at our not having sufficiently observed this principle in practice. In retrospect, it seems that we should indeed have been more insistent on eliciting explicit reasons for minority opinions, and should have provided an opportunity for explicit critique of such reasons, even at the expense of an additional round if necessary. We might thus have retained items that were rejected early, and explored them more thoroughly through further questioning; this material still forms part of the record of the experiment (see the questionnaires reprinted in the Appendix), but without our having been able to make any satisfactory disposition of it.

(g) Substantive breadth. The above points are all concerned with method. Substantively, although we had aimed for coverage of most of the major aspects of the world of the future, we would have done better in this respect had we also included in our survey a panel explicitly devoted to exploring the future of international relations. The War Prevention panel, of course, was concerned with perhaps the most important issue in this area, and other panels incidentally touched upon various aspects of the international scene, but it would have been greatly desirable to attempt a more systematic examination of this subject.

21. CONCLUSIONS

In trying retrospectively to assess the merits of our experiment in forecasting, we may summarize the outcome as follows:

Substantive forecasts. For many items whose occurrence is generally expected within the next few decades, the

predicted time of this occurrence has been narrowed down somewhat. For others in the same category, we have found that even among experts there is little agreement as to the date, indicating perhaps that relatively greater uncertainties are involved, which preclude more precise predictions at this time. As for the more remote future, we have observed that some events are definitely expected to happen (though at an uncertain date), some are considered of dubious realizability, still others have been ruled out altogether by our respondents. None of these predictions should be endowed with excessive reliability, because of the smallness of the sample of respondents, the variability of their expertise, and the possible intervention of unforeseeable breakthroughs. Still, the number of surprises in store for us may have been reduced a little.

Warnings of potential dangers. Among the contingency forecasts implicit in the responses were indications of potential danger areas that call for preventive action (see Section 15 above). Among these are the possibilities of war, of a continuing maldistribution of food and other commodities in the face of plenty, of social upheaval due to progressive automation, and of unbridled biological applications of molecular engineering.

Effect on the participants. Although the filling in of our questionnaires must have had its nuisance aspects, there is evidence—or at least we like to think so—that the questions were thought-provoking to many of our respondents, who may have found some reward for their labor through the mental stimulation to which the experiment exposed them.

Expediency of the method. Nothing that occurred in the experiment seemed to us to discredit the method in principle, and at least moderate consensus was usually obtained without excessive effort. The dependence of the outcome on certain subjective features, such as ambiguity in the wording of questions, uncertainties regarding the degree of expertise

among the respondents, and the possibility of deliberate or subconscious bias in the answers (see Parts (c), (d), (e) of Section 20 above), while not totally unavoidable, is equally present—if not more so—in traditional modes of reliance on expert judgment in decision-making.

Feasible improvements in method. The experiment has pointed up the need for various kinds of methodological and procedural improvement. Some of these could be introduced without much difficulty. In particular, one would want to see to it that the panel membership remain reasonably stable, that the time between questionnaires be held within more acceptable limits, that questions be phrased with greater care to avoid unnecessary ambiguity, and that enough cycles be provided to allow for adequate feedback, not only of the primary reasons for opinions, but also for a critique of such reasons.

Potential improvements through further research. A more effective use of experts in a Delphi context might be achieved through further methodological research in several areas: (a) Improvements in the systematic selection of experts.* (b) Experimentation with various schemes for the respondents to give a self-appraisal of competence, either absolute or relative to that of their fellow respondents. (c) Methods of improving reliability of forecasts through suitable consensus formulas, possibly based on appropriate self-ratings. (d) Experimentation with various methods of leeding back information, in order to learn more about the sensitivity of opinion changes to both the form and the contents of such feedback. (e) Comparative analysis of social pressure and persuasive reasoning as determinants of opinion convergence. (f) Formulation of a statistical model of the question-and-answer operation of an expert panel, in which the latter would be viewed as a measuring instrument for the substantive quantities which form the subject of the

*See "On the Epistemology of the Inexact Sciences," l.c., p. 43.

questions; each respondent would here have to be represented by an error distribution, and some hypotheses would have to be stated as to the relative independence of the measurement thus obtained. (g) Development of techniques for the formulation of sequential questions that would probe more systematically into the underlying reasons for the respondents' opinions, in a deliberate effort to construct a theoretical foundation for the phenomena under inquiry.

This concludes our report. The appendix contains reprints of the essential portions of the questionnaires, a breakdown of the roster of respondents, a set of graphs exhibiting the amount of convergence observed in the case of repeated questions, and a small collection of comments, criticisms, and other opinions expressed by our respondents which we thought particularly worthy of quotation.

BIBLIOGRAPHY

There exists a large volume of literature concerned with serious forecasts of future trends. The following represents a small selection of publications, which the authors of this report found particularly useful and thought-provoking and which may be of interest to the reader.

Army Research Office, Long-Range Technological Forecast (1963)

Baade, Fritz, The Race to the Year 2000, Doubleday (1962).

Brown, Harrison, James Bonner, and John Weir, The Next Hundred Years, Viking Press (1958).

Clarke, Arthur C., Profiles of the Future, Harper and Row (1960).

Gabor, Dennis, Inventing the Future, Secker and Warburg, London (1963).

Galton, Lawrence, "Science Stands at Awsome Thresholds," New York Times Magazine (Dec. 2, 1962).

Goushev, Sergei (Editor), Russian Science in the 21st Century, McGraw-Hill (1960).

Institute of Radio Engineers, Symposium on Communications and Electronics - 2012 A.D., with contributions by Lloyd V. Berkner, Henri Busignies, J. H. Dellinger, Peter Goldmark, W. D. Lewis, G. A. Morton, Ernst Weber, Harold Wheeler, and Harold A. Zahl; I.R.E. (May 1962).

Landsberg, Hans H., Leonard L. Fischman, and Joseph L. Fisher, Resources of the Future, Johns Hopkins Press (1963).

Lundberg, Ferdinand, The Coming World Transformation, Doubleday (1963).

Neumann, John von, "Can We Survive Technology?," Fortune (June 1955).

New York Times Magazine, Symposium on The Future, with contributions by H. S. Commager, H. L. Dryden, J. B. S. Haldane, Margaret Mead, Clarence Randall, and Arnold Toynbee (April 19, 1964).

Scientific American, Symposium on Technology and Economic Development, with contributions (among others) by Asa Briggs, Kingsley Davis, J. W. Feiss, Frederick Harbison, Wassily Leontief, E. S. Mason, Roger Revelle, S. H. Schurr, and N. S. Scrimshaw (September 1963).

PART A1

QUESTIONNAIRES ADDRESSED TO PANEL 1 ON SCIENTIFIC BREAKTHROUGHS

LONG-RANGE FORECASTING STUDY

Questionnaire 1

1.1. SCIENTIFIC BREAKTHROUGHS

One of the major problems of conducting a predictive study which poses its questions on the basis of extrapolations of current technology is the almost unavoidable exclusion of discontinuous state-of-the-art advances.

In this current study a period of 50 years is being considered. It is possible that inventions and discoveries not yet visualized could have a major impact on our society during this interval. It is easy to observe that the pace of scientific and technological innovation has been steadily increasing and that the time between origination and application has been decreasing. Therefore we believe that many generations of inventions can find application during the period under study.

Some insight even into discontinuous state-of-the-art advances might perhaps be gained by examining the world's need for such advances, in view of the old truism that necessity is the mother of invention. Therefore, you are asked to list below major inventions and scientific breakthroughs in areas of special concern to you which you regard as both urgently needed and feasible within the next 50 years:

Do you know of the existence of any information, in the form of tabulations or analyses, that might be particularly valuable in reaching projections of the kind requested?

Questionnaire 2

1.2 SCIENTIFIC BREAKTHROUGHS

a. Listed below in Table 1.2a are most of the scientific breakthroughs suggested by the respondents as potentially possible during the next 50 years. Please indicate your judgment of the probability of implementation during each period. Note that the numbers inserted by you in each row should add up to 100. (In the case of items involving gradual development such as synthetic food production or automated education, "implementation" should be interpreted as referring to the time from which the effect on our society will no longer be negligible.)

b. Considering the breakthroughs suggested in Table 1.2a are there other potential breakthroughs which you would care to add? When do you believe they will occur? Please make your additions in Table 1.2b.

Table 1.2a

SUMMARY OF OPINIONS ON SCIENTIFIC BREAKTHROUGHS

	Probability of Implementation During Period								
Biological	1963-65	65-68	68-72	72-78	78-86	86-97	97-2013	Later	Not at any time
1. Chemical control over heredity - molecular biology									
2. Biochemical general immunization									
3. Biochemicals to stimulate growth of new organs and limbs									
4. Synthetic generation of protein for food									
5. Oral contraceptive									
6. Other means of fertility control									
7. New organs through transplanting or prosthesis									
8. Use of telepathy and ESP in communications									
9. Understanding of the physiology of mind-brain behavior									
10. Chemical control of the aging process, permitting extension of life span by 50 years									
11. Cancer cure									
12. Man-machine symbiosis, permitting man to extend his intelligence directly through the use of computing machines									
13. Creation of artificial life									

TABLE 1.2a

	1963-65	65-68	68-72	72-78	78-86	86-97	97-2013	Later	Not at any time
Sociological									
1. Communication with animals									
2. Breeding of intelligent animals (apes, cetaceans, etc.) for low-grade labor									
3. Education by automation									
4. Education by other means, such as direct information-recording on the brain									
5. Education or conditioning in social behavior to reduce the likelihood of war									
6. Automatic language translators									
7. Efficient idea-coding to convey precise information independent of language									
8. Popular use of personality control drugs									
9. Long-duration coma to permit a form of time travel									
10. Solution to the problem of distribution of goods--computer identification of points of need									
11. Computing machines becoming the most significant source of intelligence on earth									
12. Discovery of life on Mars									
13. Communication with extra-terrestrials									
Physical									
1. Reformation of physical theory, eliminating confusion in quantum-relativity and simplifying particle theory									
2. Experimentation with anti-matter									
3. Control of gravity									
4. Controlled thermo-nuclear power									
5. Commercially efficient transmutation of elements									
6. Focused electromagnetic radiation for power transmission									
7. Relay of solar energy via satellite									
8. Efficient electric storage device									
9. Limited weather control									
10. Reliable weather forecasts									
11. Miniaturization of electronics carried to the molecular level									
12. Automated highways									
13. Measurement of curvature of the universe									
14. Ballistic transport - 2 hours to anywhere on earth									
15. Theory of the earth's crust permitting accurate earthquake prediction									
16. Development of new synthetic materials for ultra-light construction									
17. Operation of nuclear power systems providing electricity @ 3-4 mills/kw-hr 5-10 year refueling period									
18. Collection and concentration of solar energy, used for power or in man-made organic chemistry manufacturing processes									
19. Operation of a central data storage facility with wide access for general or specialized information retrieval									
Food and Raw Materials									
1. Rise in world agricultural gross yields by a factor of ten									
2. Economically useful desalination of sea water									
3. Economical working of low-grade metal ores									
4. Exploitation of the ocean bottom through farming and mining									

Q u e s t i o n n a i r e 3

1.3 SCIENTIFIC BREAKTHROUGHS

Of the list of potential scientific and technological breakthroughs submitted to you previously we are now proposing to drop a large fraction from further consideration. Some do not seem important enough to warrant further examination. On others some form of consensus has already emerged (see Part (a) below). Those resubmitted to you (as Items 1-17) in Part (c) below, therefore, are potential breakthroughs on which no satisfactory consensus has been obtained to date but which are important enough to justify looking for an explanation as to why opinions on their occurrence differ so widely.

a. The following summary represents a consensus of a large majority of respondents:

Table 1.3a

Item	Description	Predicted time of occurrence
Biological 7 Sociological 6 Physical 16	New organs through transplanting or prosthesis Automatic language translators Development of new synthetic materials for ultra-light construction	Within 25 years
Physical 10 Physical 19	Reliable weather forecasts Operation of a central storage facility with wide access for general or specialized information retrieval	Not within 5 but within 35 years
Sociological 9 Sociological 13	Long-duration coma to permit a form of time travel Communication with extra-terrestrials	Not within 25 years but eventually
Biological 3	Biochemicals to stimulate growth of new organs and limbs	Not within 25 years if ever
Sociological 2	Breeding of intelligent animals (apes, cetaceans, etc.) for low-grade labor	Not within 35 years if ever
Biological 8	Use of telepathy and ESP in communication Computing machines becoming the most significant source of intelligence on Earth	Not within 50 years if ever

1.3 p.2

Do you, by and large, agree with the opinion represented by the consensus tabulation given on the preceding page? If you disagree with any particular item, please indicate which, and briefly state your reason for your differing opinion:

b. It has been suggested that major breakthroughs are urgently needed in the organizational and operational methods of scientific investigation. The following table lists three examples of such. Please add others at the end of the table. Give us your opinion of the probability of occurrance and of the desirability of each item:

Table 1.3c

	Breakthrough	Probability of occurring within 10 yrs	25 yrs	50 yrs	Benefit to society if occurring High	Mod	Low	None	Neg.
1	A reform of present modes of scientific communication through the use of automated information retrieval systems								
2	Reorientation of scientific methodology toward greater interdisciplinary cooperation								
3	Widespread use of simulation for experimentation in the social sciences								

c. The following table gives a list of potential scientific and technological breakthroughs on which thus far no satisfactory consensus has been obtained. It consists mostly of items previously submitted to the panel and judged to be sufficiently important to deserve further exploration, plus a few afterthoughts suggested by panel members in response to Questionnaire 2. You are being asked to reestimate the time of occurrence of each item and in certain cases to state briefly your principal reason for this opinion.

Table 1.3c

#	Description of potential breakthrough	Consensus or dissensus to date	In your opinion, by what year does the probability of occurrence reach 50%	90%	If your 50% estimate falls within either the earlier or the later period indicated, briefly state your reason for this opinion
1	Feasibility of chemical control over hereditary defects through molecular engineering	Consensus that it will occur; disagreement as to when			Why before 1987 or after 2013?
2	Biochemical general immunization against bacterial and viral diseases	Consensus that it will occur; disagreement as to when			Why before 1987 or after 2013?
3	Feasibility of commercial generation of synthetic protein for food	Consensus that it will occur: disagreement as to when			Why before 1979 or after 2013?
4	Effective fertility control by oral contraceptive or other simple and inexpensive means	Majority opinion that it will be feasible within 25 years			Why before 1969 or after 1986?
5	Chemical control of the aging process, permitting extension of life span by 50 years	Virtual consensus that it will occur (though not within 10 years); disagreement as to when.			Why before 1979 or after 2013?
6	Man-machine symbiosis, enabling man to extend his intelligence by direct electro-mechanical interaction between his brain and a computing machine	Widely divergent opinions, possibly due to differing interpretations of the original question			Why before 1973 or after 1997 (or never)?

Table 1.3c (continued)

#	Description	Consensus	50%-year	90%-year	Reason
7	Creation of a primitive form of artificial life	No consensus, but a majority opinion that it will occur, though not within 25 years			Why before 1998 or after 2013 (or never)?
8	Feasibility of education by direct information recording on the brain	No consensus			Why before 1987 or never?
9	Substantial reduction in the likelihood of war through education or other conditioning in social behavior	No consensus			Why before 1979 or after 2013 (or never)?
10	Widespread socially accepted use of nonnarcotic personality control drugs producing specific psychological reactions	Divergent opinions, possibly due to differing interpretations of the original question			Why before 1987 or after 2013 (or never)?
11	Reformation of physical theory, eliminating confusion in quantum-relativity and simplifying particle theory	Consensus that it will occur; disagreement as to when			Why before 1973 or after 2013?
12	Control of gravity through some form of modification of the gravitational field	Majority opinion that it will probably never occur, and at any rate not within 50 years			Why before 2013 or never?
13	Controlled thermo-nuclear power	Consensus that it will occur; disagreement as to when			Why before 1979 or after 2013?
14	Commercially efficient manufacture of arbitrary chemical elements from sub-atomic building blocks	No consensus, possibly due to differing interpretations of original question			Why before 1998 or never?
15	Limited weather control, in the sense of being able to exert a substantial effect on regional weather at acceptable cost	Consensus that it will occur; disagreement as to when			Why before 1979 or after 2013?
16	Economically useful exploitation of sea water	Consensus that it will occur; disagreement as to when			Why before 1973 or after 2013?
17	Economically useful exploitation of the ocean bottom through farming and mining	No consensus			Why before 1987 or after 2013 (or never)?
18	Use of drugs to raise average intelligence level	Newly proposed item			Why before 1987 or after 2013 (or never)?
19	Direct cure for serious mental illness	Newly proposed item			Why before 1987 or after 2013 (or never)?
20	Stimulated emission ("lasers") in X and Gamma ray region of the spectrum	Newly proposed item			Why before 1987 or after 2013 (or never)?
21	Implanted artificial organs made of plastic and electronic components	Newly proposed item			Why before 1987 or after 2013 (or never)?
22	Wide-spread use of ground-effect machines, providing travel above the ground on a cushion of air, for commercial transportation	Newly proposed item			Why before 1979 or after 1998 (or never)?

Questionnaire 4

1.4 SCIENTIFIC BREAKTHROUGHS

This is the last questionnaire in our present inquiry into opinions on scientific breakthroughs.

Before giving you an account of what further consensus seems to have emerged in the preceding round and putting some further substantive questions before you, we would like to ask your preference as to whether or not a report on this study should mention your participation as a respondent. Under no circumstances will any direct quotations be attributed to you.

a. Check here if you have no objection to having your name mentioned as that of a respondent in this current study: ☐

b. Table 1.4b on the next page lists a number of potential developments in the organizational and operational methods of scientific investigation. Of these, the first three are repeats from Questionnaire 3; the others are additional items proposed by the respondents for consideration.

Thus far, there is no clear-cut consensus regarding either the probability of occurrence or the desirability of the first three items. All are considered rather likely and, on the average, of moderate benefit. Over the next 25 years, Item 3 is considered slightly more likely than Item 2, and Item 2 slightly more likely than Item 1. As for their potential benefits, the order is reversed: Item 1 is thought to be slightly more beneficial than Item 2, and Item 2 slightly more beneficial than Item 3.

In concluding the consideration of these potential developments in the organizational and operational methods of scientific investigation, we would like you to rank the eight items in Table 1.4b from 1 to 8 in two respects: The probable degree of their realization within the next 25 years, and the desirability of their realization.

Table 1.4b

#	Potential developments in the organizational and operational methods of scientific investigation	Rank* by expected degree of realization within 25 years	Rank* by desirability in terms of expected benefit to society
1	Reform of present modes of scientific communication through the use of automated information retrieval systems		
2	Reorientation of scientific methodology toward greater interdisciplinary cooperation		
3	Widespread use of simulation for experimentation in the social sciences		
4	Increased emphasis on basic research in government-supported R + D		
5	Widespread use in scientific research of more intelligent machines, with computers on the level of "colleagues" rather than of "servants"		
6	Synthetic stimulation of individual inventiveness (by chemical ingestion, cerebral manipulation, external rewards, etc.)		
7	Reformation of educational processes toward an increased interdisciplinary understanding of science		
8	Shift in approach to biomedical problems from predominant experimentation to more theoretical ground		

*Use Rank 1 for highest degree and greatest desirability, Rank 8 for lowest degree and least desirability.

Of the twenty-two specific potential breakthroughs put before the panel in the previous questionnaire, Items 9 (on reducing the probability of war through education) and 22 (on ground-effect machines) are being dropped from further consideration (9 because of inherent vagueness of the question, 22 because of comparative unimportance in the face of a considerable divergence of opinions).

On eleven other items a sufficient consensus has been established to warrant our bringing their consideration to a close, – unless you wish to take explicit exception to any one of them. They are listed below (Table 1.4c) together with the majority opinion on the expected time of their occurrence.

Table 1.4c

Items on which at least a moderate consensus seems to have been obtained

#	Description of breakthrough	Majority opinion	x
16	Economically useful exploitation of sea water	Already accomplished in certain areas (magnesium, desalination); considerable further progress likely within 10 years	
4	Feasibility of effective large-scale fertility control by oral or other simple and inexpensive means	During the 1970's	
20	Stimulated emission ("lasers") in the X and Gamma ray regions of the spectrum	About 20 to 25 years from now	
21	Implanted artificial organs made of plastic and electronic components	Plastic tubes, heart valves, electronic heart pacers already in use; whole organs within 20 to 25 years	
11	Reformation of physical theory, eliminating confusion in quantum-relativity and simplifying particle theory	Probably gradual development, by about 2000	
13	Controlled thermo-nuclear power	During the period from 1980 to 2000	
2	Biochemical general immunization against bacterial and viral diseases	Extensive, though not necessarily universal, immunization during the period from about 20 to 40 years from now	
5	Chemical control of the aging process, permitting an extension of the average life span by 50 years	During the period from 1990 to 2050	

Table 1.4c (continued)

#	Description of breakthrough	Majority opinion	x
6	Feasibility of man-machine symbiosis, enabling man to extend his intelligence by direct electro-mechanical interaction between his brain and a computing machine	During the period from 1990 to 2050	
12	Control of gravity through some form of modification of the gravitational field	Not for 100 years, if ever	
8	Feasibility of education by direct information recording on the brain	Not for 200 years, if ever	

c. Please mark with a cross in the last column of the above table any items regarding which you find yourself in substantial disagreement with the stated majority opinion. For each such case, state below the nature of your disagreement and, very briefly, the reason for your differing opinion:

There are now nine residual items requiring further examination. They are listed in Table 1.4d below. The table also includes, as Items 23 to 25, three items about which a tentative consensus had already been announced in Table 1.3a of the previous questionnaire; their consideration is being resumed here because in each case several respondents explicitly voiced disagreement with the opinion stated.

d. Please reconsider the potential scientific and technological breakthroughs listed in the following table. They are the remaining items on which thus far no satisfactory consensus has been obtained. In some cases, the description has been reworded in an effort to eliminate vagueness (which may have been partly responsible for the apparent discrepancy of opinions).

In giving us once more your estimates of the years when the probability of occurrence reaches 50% and 90% respectively, please take such reformulations into account, as well as the merits of any statements of minority opinions:

Table 1.4d

#	Description of potential breakthrough	Majority consensus to date	Minority opinion	50%-year	90%-year
1	Feasibility (not necessarily acceptance) of chemical control over some hereditary defects by modification of genes through molecular engineering	By 2000	Will take longer or occur never, because it would necessitate intervention during embryonic development, when the foetus is inaccessible, hence would require prior development of techniques of gestation in vitro		
3	Economic feasibility of commercial generation of synthetic protein for food	By 1990	If in-vitro generation of proteins with all essential amino acids is intended, then such perfect control of polymer synthesis and grafting chemistry are required that more than 50 years are needed		
7	Creation of a primitive form of artificial life (at least in the form of self-replicating molecules)	Not for 10 years but by 2000			
10	Widespread and socially widely accepted use of nonnarcotic drugs (other than alcohol) for the purpose of producing specific changes in personality characteristics	By 2000	Will take 50 years or more, because research on psychopharmaceuticals has barely begun, and negative social reaction will cause delays		
14	Economic feasibility of commercial manufacture of many chemical elements from subatomic building blocks	Not within 25 but within 60 years	Never, despite technical feasibility, because other methods will be cheaper, such as processing of low-grade natural sources or reprocessing from waste		
15	Feasibility of limited weather control, in the sense of substantially affecting regional weather at acceptable cost	within 25 years			
17a	Economically useful exploitation of the ocean through farming, with the effect of producing at least 20% of the world's food	Not within 50 years, if ever			
17b	Economically useful exploitation of the ocean bottom through mining (other than off-shore oil drilling)	Within 25 years	Not within 50 years, because costs will remain too high		
18	Feasibility of using drugs to raise the level of intelligence (other than as dietary supplements and not in the sense of just temporarily raising the level of apperception)	Not within 25 but within 50 years	Never, because the use of molecular engineering to raise the IQ will come first; also, the effect of drugs is limited because they cannot affect the basic synaptic connectivity of the brain		
19	Increase by an order of magnitude in the relative number of psychotic cases amenable to physical or chemical therapy	Within 30 years	More than 50 years, because an entire science of biopsychiatry must be built		
23	Long-duration coma to permit a form of time travel (former "Sociological 9")	Not within 25 years but eventually	Never, because organisms are too delicate to be kept in long coma; also because the demand is questionable		
24	Two-way communication with extra-terrestrials (former "Sociological 13")	Not within 25 years but eventually	Never, because the elapsed time between message and response would be unmanageably long		
25	Biochemicals to stimulate growth of new organs and limbs (former "Biological 5")	Not within 25 years and possibly never	Definitely eventually, at least for artificial regeneration of limbs		

e. Do you wish to add any comments? In particular, is there anything further you wish to say in support of your views as expressed in your entries in the foregoing table?

PART A2

QUESTIONNAIRES ADDRESSED TO PANEL 2 ON POPULATION CONTROL

LONG-RANGE FORECASTING STUDY

Questionnaire 1

2.1. POPULATION CONTROL

(a) It is well recognised that the present trend in world population growth cannot long continue. What is not clearly understood, though, is the mechanism by which this so-called population explosion will be slowed down. In an effort to shed more light on this problem, we are asking you to give us your opinion about world birth and death rate changes by completing the following table:

	Year			
	1963	1975	2000	2050
World population (10^9)	3.1			
Birth rate (per 1000)	36			
Death rate (per 1000)	19			
Life expectancy at age 1	about 55			

(b) If the present growth rate were to continue unchecked, the world population by 2050 might well be between 10×10^9 and 13×10^9. If your estimate given above for the year 2050 falls outside this interval, what are your principal reasons for this opinion?

(c) In your opinion, what constructive steps might be taken to slow down the population explosion enough to result in world population figures substantially below those given by you for the years 2000 and 2050?

Do you know of the existence of any information, in the form of tabulations or analyses, that might be particularly valuable in reaching projections of the kind requested?

Questionnaire 2

2.2 POPULATION CONTROL

a. Table 2.2a summarizes the panel's opinions on the reasons why the world population of the year 2050 may be less than 7 billion or more than 13 billion people. Even though your estimate may have been between these limits, please indicate your opinion of the probable relative importance of each item by checking one box under "Effectiveness" and one box under "Probability."

Table 2.2a

REASONS FOR EXTREME OPINIONS IN POPULATION ESTIMATES

Reasons for low population:	Effectiveness in limiting population if occurring				Probability of occurrence		
	nil	minor	moderate	high	never	maybe	certain
1. Rapid increase in use and effectiveness of birth control measures							
2. Increased economic prosperity							
3. Progress in welfare and education in under-developed nations							
4. Legislation penalizing large families							
5. Attrition due to war							
6. Attrition due to disease							

Reasons for high population:	Effectiveness in expanding population if occurring				Probability of occurrence		
	nil	minor	moderate	high	never	maybe	certain
1. Medical advances, resulting in lower death rates							
2. Insufficient general acceptance of birth control measures							
3. Advances in agriculture							
4. Increased financial ability to support children							
5. Development of centralized world government providing efficient distribution of food, shelter and services, thus permitting the world to accommodate large population							

2.2 POPULATION CONTROL (continued)

b. Table 2.2b summarizes the panel's opinions about means of limiting population. Please review and evaluate these, again by checking one box under "Effectiveness" and one box under "Probability."

Table 2.2b

CONSTRUCTIVE STEPS FOR SLOWING POPULATION EXPLOSION

	Effectiveness in limiting population				Probability of occurrence		
	nil	minor	moderate	high	never	maybe	certain
1. Aid governments of depressed countries in increasing level of material culture							
2. Continued publicity							
3. Develop effective and cheaper physiological methods of fertility control							
4. Bring social opinion to approval of contraception							
5. Change moral views of religious bodies							
6. Conclude international agreement on population control measures							
7. Raise level of education							
8. Redistribute population or land							

It is also significant to note that the panel on scientific breakthroughs tentatively predicted achievements which could materially affect the gross numbers of people. For example:

Development of oral contraceptives
Control of aging process
Rise in agricultural yields by a factor of 10
Limited weather control
Economically useful desalination of sea water
Exploitation of the ocean bottom through farming and mining
Synthetic generation of protein for food
Solution to problem of distribution of goods; i.e., hunger control
Cheap power and distribution systems
Economic working of low grade ore

c. In light of your appraisal of these predictions and the reasons given in Tables 2.2a and 2.2b, please revise your previous estimates:

	1963	1975	2000	2050
World Population				
Birth Rate				
Death Rate				
Life Expectancy				

d. Opinions have been advanced that the population explosion should not be slowed down, since technology can be expanded to provide for all people in the next one hundred years. Since the first questionnaire was phrased to assess means of population control rather than means of dealing with the inevitable population explosion, please state your opinion on the following:

If world population continues to grow at the same increasing rate, what is the probability that technology will be able to provide at least subsistence food and shelter for all people for the next 100 years? (Check one.)

Over 90%: ☐ 60 to 90%: ☐ 40 to 60%: ☐ 10 to 40%: ☐ Under 10%: ☐

Questionnaire 3

2.3 POPULATION CONTROL

While straight-forward extrapolation of the world population trend would lead to a total population figure for the year 2050 of between 10 and 13 billion, our panel seems to agree that the figure will be substantially lower, namely between 6 and 10 billion, with a median around 8 billion. In this phase of our inquiry, we would like to go a little more deeply into the matter of the mechanism by which this lowering of the trend might occur.

The projections given by the panel members indicate a consensus that death rates will continue to fall off steadily but that birth rates will decline even faster.

a. The panel previously estimated that the annual death rate would drop by the year 2050 from the present 19 per thousand to a figure between 10 and 17 per thousand, with a median of 13. We would like you to reestimate this figure, on the assumption (which presumably had been implicit also in your earlier estimate) that no thermo-nuclear war will occur:

Reestimate of death rate per thousand in the year 2050: ☐

b. If this estimate is

less than 14, what relative weights do you give to the following factors to account for such a low estimate [distribute 100 percentage points over the 5 boxes below]:

A. Medical advances . . . . . ☐
B. Advances in agricultural food production . . . . . ☐
C. Advances in synthetic food production . . . . . ☐
D. Advances in food distribution . . . . . ☐
E. Other (specify:) ☐

100

more than 16, what relative weights do you give to the following factors to account for such a high estimate [distribute 100 percentage points over the 5 boxes below]:

F. Insufficient further medical advances . . . . . ☐
G. Insufficient advances in agricultural or synthetic food production . . . . . ☐
H. Insufficient advances in food distribution . . . . . ☐
I. The increase in average age due to an earlier decline in the death rate . . . . . ☐
J. Other (specify:) ☐

100

c. Present daily world food consumption, measured very crudely in terms of caloric intake, amounts to approximately 7.5 trillion calories.

To sustain the world population at this present caloric intake rate and at levels indicated by your previous estimates would require the daily amounts of calories (in trillions) given in the table below.*

In the last row of this table, please give your estimate (in trillion* calories) of potential world food production for each year indicated:

Year	1963	1975	2000	2050
Your previous estimate of population				
Calorie requirement				
World food production potential				

+If no previous population estimates had been supplied by you, the second and third rows have been left blank; you may, if you wish, insert such estimates now.

* = 10^{12}

d. If your estimates given in the last row of the preceding table differ substantially from the calorie requirement figures in the row above, please indicate your principal reason for this:

e. The panel previously estimated that the annual birth rate would decline by the year 2050 from the present 36 per thousand to a figure between 15 and 26 per thousand, with a median of 20. We would like you to reestimate this figure, again on the assumption that no thermo-nuclear war will take place:

Reestimate of birth rate per thousand in the year 2050: ☐

f. If this estimate is

less than 19, what relative weights do you give to the following factors to account for such a low estimate [distribute 100 percentage points over the 8 boxes below]:

A. Availability of inexpensive and effective birth control measures . . . . . ☐
B. Greater public acceptance of birth control, due to
B_1. a general rise in the level of education . . . ☐
B_2. propaganda for birth control . . . . . ☐
B_3. a cessation of religious prohibitions . . . . . ☐
B_4. economic necessity . . . ☐
B_5. governmental coercion (e.g. through tax reform) ☐
B_6. other (specify:) ☐
C. Other (specify:) ☐

100

more than 21, what relative weights do you give to the following factors to account for such a high estimate [distribute 100 percentage points over the 8 boxes below]:

D. Unavailability of sufficiently inexpensive and effective birth control measures . . . ☐
E. Insufficient public acceptance of birth control, due to
E_1. insufficient education . ☐
E_2. propaganda for larger families . . . . . ☐
E_3. continuing religious prohibitions . . . . . ☐
E_4. increasing economic affluence . . . . . ☐
E_5. governmental benefits to large families . . . . ☐
E_6. other (specify:) . . . . ☐
F. Other (specify:) ☐

100

Questionnaire 4

2.4 POPULATION CONTROL

This is the last questionnaire in our present inquiry into opinions on population trends and population control.

Before giving you a summary of the result of the preceding round and putting some further substantive questions before you, we would like to ask your preference as to whether or not a report on this study should mention your participation as a respondent. Under no circumstances will any direct quotations be attributed to you.

a. Check here if you have no objection to having your name mentioned as that of a respondent in this current study: ☐

The responses thus far do not give any evidence that there exists anything like a consensus regarding the absolute size of the future world population. Yet a good deal of light has been shed on the various contingencies determinant of the population size and on the relative magnitude of the latter as a function of such contingencies.

The divergence of opinions on the absolute size of the future world population is due to the obvious fact that the latter depends very sensitively on the rate of growth, i.e. the difference between birth and death rates, and even minor differences in estimates regarding these can lead to sizeable differences in population estimates.

Not surprisingly, the three principal factors affecting birth and death rates have emerged as being

(i) the degree of acceptance of birth control measures,
(ii) the rate of further medical progress, and
(iii) advances in the production and distribution of food.

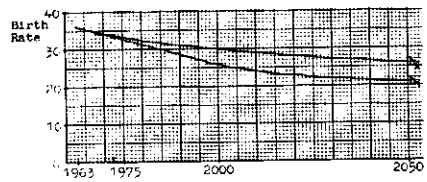
Of these, the first seems to be the least predictable. While the rate of acceptance of birth control measures is affected by appropriate education and the availability of simple and inexpensive instrumentalities*, it is basically a function of the rapidity with which the culture perceives the value of a reduced birth rate and with which it reacts to this recognition by conferring social acceptance to the practice of birth control. This rate of recognition and consequent acceptance is likely to be different for each culture and in each case does not lend itself easily to prognostication.

An analysis, collation, and "purification" (in the sense of eliminating internal inconsistencies) of the responses reveal several distinguishable opinions, of which the following are typical:

*Panel 1, incidentally, predicted the availability prior to 1980 of simple and inexpensive means of fertility control.

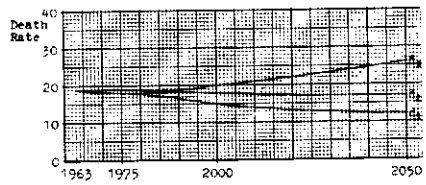
A. Birth rate:

The birth rate will decline, the amount of the decline depending primarily on public acceptance of birth control measures. Typical estimates are represented by the two curves below.



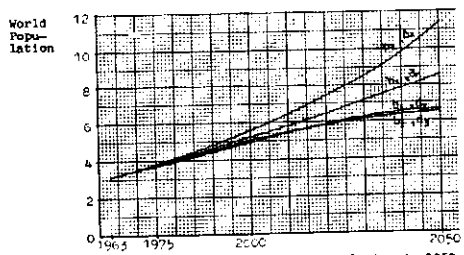
B. Death rate:

Depending on further medical progress, the decline of the death rate is shown by the solid-line estimates in the figure below; both assume that there is enough food for all. Those who believe that food production and distribution will not keep up with population pressures predict a consequent eventual rise in the death rate as shown in the dotted curve. (In all cases, and throughout this study, it is assumed that no cataclysmic war will take place.)



C. Population expansion:

Various combinations of birth rates (b_1, b_2) and death rates (d_1, d_2, d_3) lead, of course, to very different population growth curves. Of the six possible combinations, the following four in fact summarize the respondents' opinions:



We note, in particular, that the hypothesis of a world population in 2050 of about 6½ billion could be the result of two different pairs of assumptions, namely, either a rapid drop in the birth rate coupled with a slight decline in the death rate, or a more moderate drop in the birth rate coupled with an eventual (famine-induced) rise in the death rate.

b. In concluding the present inquiry, we are asking you to reconsider the pros and cons for high or low birth and death rates and to give us your (possibly revised) estimate of population trends from now until 2050. This time we are asking you to do this by superimposing a curve representing your estimate on each of the three diagrams on this page and the preceding one. (Or draw any two of the three curves, and we will approximately compute the third from them.)

c. Do you wish to add any comments? In particular, is there anything further you wish to say in support of your view as represented by the curves drawn in response to Part b?

PART A3

QUESTIONNAIRES ADDRESSED TO PANEL 3 ON AUTOMATION

LONG-RANGE FORECASTING STUDY

Questionnaire 1

3.1. AUTOMATION

There has been much discussion in recent years about the impact of industrial automation on the world's economy. Similar discussion has centered on the application of automatic devices in fields such as medicine, communication, education, data handling, etc.

Would you please compose a list, giving your opinion as to the major developments in the field of automation to be expected over the next 50 years, in approximate order of occurrence, with estimated dates:

Do you know of the existence of any information, in the form of tabulations or analyses, that might be particularly valuable in reaching projections of the kind requested?

Questionnaire 2

3.2 AUTOMATION

a. Listed below in Table 3.2a are most of the developments in automation suggested by the respondents as being potentially possible in the next 50 years. Please indicate your judgment of probability of implementation during each period shown. Note that the numbers inserted by you in each row should add up to 100. In the case of items involving gradual development (such as automation of farm equipment), "implementation" should be interpreted as referring to the time from which the effect on our society will no longer be negligible.

b. Considering the developments suggested in Table 3.2a, are there other items which you would care to add? When do you believe they will occur? Please make your additions in Table 3.2b.

c. One panelist suggested that unemployment would entail a revolution against automation. Clearly some industries which have recently automated have increased productivity while decreasing personnel. Do you believe that revolutionary social upheavals are likely to result from our current drive toward automation?

Yes_____ No_____

d. If yes, what means might be employed to benefit from automation while minimizing the impact of the unemployment thereby produced?

e. If no, what factors do you believe will mitigate against technological unemployment?

Table 3.2a

DEVELOPMENTS IN AUTOMATION

	Probability of Implementation During the Period								
	1963-65	65-68	68-72	72-78	78-86	86-97	97-2013	Later	Not at any date
Manufacture, Business and Commerce									
1. Rise by an order of magnitude in automated process control									
2. Automated rapid transit									
3. Automation of office work and services leading to displacement of 25% of the current work force									
4. High-speed facsimile handling of mail									
5. Air traffic control - positive and predictive track on all aircraft									
6. Construction on a production line of computers with motivation by "education" (possibly with individual differences									
7. Automated highways and adaptive automobile autopilots									
8. Widespread use of computers in tax collection, with access to all business records - automatic single tax deductions									
9. Robot services - refuse collection, household slaves, sewer inspectors, etc.									
10. Widespread use of automatic decision-making at management level for industrial and national planning.									

TABLE 3.2a

	1963-65	65-68	68-72	72-78	78-86	86-97	97-2013	Later	Not at any date
Human Convenience (continued)									
1. Automatic language translator - crude model									
2. Automatic language translator - correct grammar									
3. Automatic libraries, looking up and reproducing copy									
4. Widespread use of simple teaching machines									
5. Sophisticated teaching machines, with next question based on analysis of last response									
6. Automated schools based on television									
7. Education becoming a respectable leisure pastime									
8. Automated looking up of legal information									
9. Development of computer systems which make most legal decisions									
10. Automated interpretation of medical symptoms									
11. Automated medical diagnostic clinic									
12. Remote medical instrumentation and monitoring									
13. Financial transactions by credit card only									
14. Direct link from stores to banks to check credit and to record transactions									
15. Permanent phone number for each individual									
16. Phoneme typewriter									
17. Automated voting by computed polling of voters									
18. Governmental record centralization resulting in the elimination of county and state units									
19. Personal "pocket size" high-speed computers									
20. Remote facsimile newspapers and magazines, printed in home									
Social									
1. Social explosion due to unemployment resulting from automation									
2. Anti-automation legislation									
3. Centralized wire tapping (possibly on a random basis)									
4. Creation of a society which guarantees certain economic minima to the world population as a result of high production from automation									
5. Universal language from automated communication									
6. Computing machines becoming the most significant intelligence on earth									
Man-Machine									
1. Man-computer-machine symbiosis using electrical brain pick-offs for command signals									
2. Understanding of how the brain functions, based on the study of computers									

Table 3.2b

OTHER POTENTIAL DEVELOPMENTS IN AUTOMATION

	1963-65	65-68	68-72	72-78	78-86	86-97	97-2013	Later

Questionnaire 3

3.3 AUTOMATION

Of the list of potential developments in automation breakthroughs submitted to you previously we are now proposing to drop a large fraction from further consideration. Some do not seem important enough to warrant further examination. On others some form of consensus has already emerged (see Part (a) below). Those resubmitted to you (as Items 1-11) in Part (c) below, therefore, are potential breakthroughs on which no satisfactory consensus has been obtained to date but which are important enough to justify looking for an explanation as to why opinions on their occurrence differ so widely.

a. The following summary represents a consensus of a large majority of respondents:

Table 3.3a

Item	Description	Predicted time of occurrence
Manuf/Bus/Comm 5	Air traffic control - positive and predictive track on all aircraft	Within 25 years
Manuf/Bus/Comm 8	Widespread use of computers in tax collection, with access to all business records – automatic single tax deductions	
Manuf/Bus/Comm 10	Widespread use of automatic decision-making at management level for industrial and national planning	
Human Conv 2	Sophisticated automatic language translator	
Human Conv 3	Automatic libraries, looking up and reproducing copy	
Human Conv 4	Widespread use of simple teaching machines	
Human Conv 10	Automated interpretation of medical symptoms	
Human Conv 14	Direct link from stores to banks to check credit and record transactions	
Manuf/Bus/Comm 2	Automated rapid transit	Not within 5 but within 35 years
Manuf/Bus/Comm 6	Construction on a production line of computers with motivation by "education"	
Human Conv 7	Education becoming a respectable leisure pastime	
Human Conv 8	Automated looking up of legal information	
Manuf/Bus/Comm 7	Automated highways and adaptive automobile autopilots	Not within 15 years but eventually
Human Conv 20	Remote facsimile newspapers and magazines, printed at home	Not within 25 years but eventually

Do you, by and large, agree with the opinion represented by the consensus tabulation given on the preceding page? If you disagree with any particular item, please indicate which, and briefly state your reason for your differing opinion:

b. To resume consideration of the problem of unemployment resulting from automation, it seems fair to summarize the opinions of the panel members as follows: Almost all agreed that the problem is a very serious one. While one third of the panel felt that social upheavals will accompany automation, the majority opinion indicated that suitable counter-measures, taken either preventively or at least therapeutically, will forestall severe social disruptions.

In this present phase of our inquiry, we would like you to assess the relative merits of such remedies. In so doing, you may wish to keep in mind the following detrimental effects of unemployment which these remedies seek to overcome:

(i) the reduction in national productivity;
(ii) the failure to provide a livelihood for the unemployed individual;
(iii) the demoralization resulting from inactivity.

There is no intended implication that these detrimental effects should be weighed equally; by all means give each the weight in your mind that in your opinion it deserves.

In the following table, please check one box each under "Effectiveness", "Desirability", and "Probability":

Table 3.3b

Constructive Steps for Reducing Unemployment Resulting from Automation

Proposed measure	Effectiveness in reducing unemployment: neg	nil	minor	mod	high	Overall desirability of proposed measures: neg	neut	mod	high	Probability of implementation: nil	maybe	certain
1 Legislation shortening the work week by 20%												
2 Legislation lowering the retirement age by 5 years												
3 Two years of compulsory post-high school education												
4 Legislation protecting household and other service jobs from automation												
5 Retraining of persons unemployed because of automation												
6 All-out vocational training programs												
7 Education for better leisure time enjoyment												
8 Massive WPA-type programs												
9 Massive aid to underdeveloped regions (including parts of the U.S.)												
10 Creation of new types of employment*												
11 Other (specify:)												

* Any suggestions?:

c. The following table gives a list of potential developments in automation on which thus far no satisfactory consensus has been obtained. It consists mostly of items previously submitted to the panel and judged to be sufficiently important to deserve further exploration, plus a few afterthoughts suggested by panel members in response to Questionnaire 2. You are being asked to reestimate the time of occurrence of each item and in certain cases to state briefly your principal reason for this opinion.

Table 3.3c

#	Description of potential development	Consensus or dissensus to date	In your opinion, by what year does the probability of occurrence reach 50%	90%	If your 50 estimate falls within either the earlier or the later period indicated, briefly state your reason for this opinion
1	Increase by a factor of 10 in capital investment in computers used for automated process control	Majority opinion that it will occur during the Seventies			Why before 1969 or after 1978?
2	Automation of office work and services, leading to displacement of 25% of current work force	Majority opinion that it will occur during the Seventies			Why before 1973 or after 1978?
3	Widespread use of robot services, for refuse collection, as household slaves, as sewer inspectors, etc.	Consensus that it will occur; disagreement as to when			Why before 1979 or after 1997?
4	Widespread use of sophisticated teaching machines	None			Why before 1973 or never?
5	Development of computer systems which make most legal decisions	Consensus that, if at all, it will not occur within 15 years			Why before 1987 or after 2013 (or never)?
6	Automated voting by computed polling of voters	None			Why before 1979 or after 2013 (or never)?
7	Centralized (possibly random) wire tapping	None			Why before 1979 or never?
8	International agreements which guarantee certain economic minima to the world's population as a result of high production from automation	Majority opinion that it will occur, but not within 15 years			Why before 1998 or after 2013 (or never)?
9	Evolution of a universal language from automated communication	Majority opinion that it will not occur for 25 years, if ever			Why before 1979 or never?
10	Availability of a machine which comprehends standard IQ tests and scores above 150	Consensus, with regard to a differently worded question, that it will not occur within 25 years			Why before 1987 or never?
11	Man-machine symbiosis, enabling man to extend his intelligence by direct electro-mechanical interaction between his brain and a computing machine	Divergent opinions due to different interpretations of the original question			Why before 1987 or never?
12	Electronic prosthesis (radar for the blind, servomechanical limbs, etc.)	New item			Why before 1979 or after 2013 (or never)?
13	Self-reproducing machines (as a manufacturing technique)	New item			Why before 1998 or after 2013 (or never)?
14	TV telephones	New item			Why before 1987 or never?

Questionnaire 4

3.4 AUTOMATION

This is the last questionnaire in our present inquiry into opinions on the future of automation.

Before giving you a summary of the result of the preceding round and putting some further substantive questions before you, we would like to ask your preference as to whether or not a report on this study should mention your participation as a respondent. Under no circumstances will any direct quotations be attributed to you.

a. Check here if you have no objection to having your name mentioned as that of a respondent in this current study:

We begin our report on the outcome of Questionnaire 3 with a summary of the responses to Question 3b on constructive steps for reducing unemployment resulting from automation.

It has turned out that the averages of the estimates of effectiveness, desirability, and probability for the ten proposed measures are highly correlated. This has enabled us to relist the measures in such an order that those at the top of the list are considered effective, desirable, and probable, while those at the bottom are considered ineffective, undesirable, and improbable:

#	Proposed Measure	Average Effectiveness*	Average Desirability	Average Probability
10	Creation of new types of employment	mod/high	high	68%
5	Retraining of persons unemployed through automation	mod	mod/high	80%
6	All-out vocational training programs	min/mod	mod/high	70%
7	Education for better leisure time enjoyment	min/mod	mod/high	65%
9	Massive aid to underdeveloped regions (including parts of US)	mod	mod	55%
3	Two years of compulsory post-high school education	mod	mod	46%
1	Legislation shortening the work week by 20%	min/mod	neut/mod	67%
8	Massive WPA-type programs	min/mod	neut	55%
2	Legislation lowering the retirement age by 5 years	min/mod	neut	46%
4	Legislation protecting household and service jobs from automation	nil/min	neg	21%

*mod = moderate, min = minor, neut = neutral, neg = negative

Suggestions for the creation of new types of employment (Item 10) included the following:

Arts and labor-intensive crafts (gardening, decorating, etc.)
Companions for older people
Changing the social-status image of service personnel (maids, gardeners, etc.)
Changing attitudes regarding civic beauty; twenty billion dollars could be spent on massive park and road landscaping development and on getting utilities underground
Organized leisure time, development of skills for personal enjoyment

Of the fourteen specific potential developments in automation put before the panel in the previous questionnaire, Items 5 (computers for legal decisions) and 13 (self-reproducing machines) are being dropped from further consideration because of their relative unimportance in the face of a considerable divergence of opinions.

On nine other items a sufficient consensus has been established to warrant our bringing their consideration to a close, — unless you wish to take explicit exception to any one of them. They are listed on the next page (Table 3.4b), together with the majority opinion on the expected time of their occurrence.

b. Please mark with a cross in the last column of Table 3.4b (on the next page) any items regarding which you find yourself in substantial disagreement with the stated majority opinion. For each such case, state below the nature of your disagreement and, very briefly, the reason for your differing opinion:

Table 3.4b

Items on which at least a moderate consensus seems to have been obtained

#	Description of development	Majority opinion	x
1	Increase by a factor of 10 in capital investment in computers used for automated process control	Within 5 to 10 years	
2	Automation of office work and services, leading to displacement of 25% of the current work force	Within 7 to 12 years	
3	Widespread use of robot services, for refuse collection, as household slaves, as sewer inspectors, etc.	Within 15 to 30 years	
4	Widespread use of sophisticated teaching machines	Within 10 to 15 years	
7	Centralized wire tapping	Never	
9	Evolution of a universal language from automated communication	Feasibility within 25 years, actual development never, because automated communication makes a universal language less necessary	
11	Man-machine symbiosis, enabling man to extend his intelligence by direct electro-mechanical interaction between his brain and a computing machine	Not in this century, if ever	
12	Electronic prosthesis (radar for the blind, servomechanical limbs, etc.)	In rudimentary form available now; widespread use of sophisticated devices by 1990	
14	TV telephones	Within 10 to 20 years	

There are now three residual items from our former list of potential developments requiring further examination (namely Items 6, 8, and 10). They are listed in Table 3.4c below. The table also includes, as Items 15 and 16, two items about which a tentative consensus had already been announced in Table 3.3a of the previous questionnaire; their consideration is being resumed here because in each case several respondents explicitly voiced disagreement with the opinion stated.

c. Please reconsider the potential developments in automation listed in the following table. They are the remaining items on which thus far no satisfactory consensus has been obtained. In some cases, the description has been reworded in an effort to eliminate vagueness (which may have been partly responsible for the apparent discrepancy of opinions).

In giving us once more your estimates of the years when the probability of occurrence reaches 50% and 90% respectively, please take such reformulations into account, as well as the merits of any statements of minority opinions:

Table 3.4c

#	Description of potential development	Majority consensus to date	Minority opinion	50%-year	90%-year
6	Automated voting, in the sense of legislating through automated plebiscite	By the year 2000 (with some doubt, however, whether the respondents interpreted this item as now reformulated)	The network required to reach up to 100 million voters is so large that this may, for that reason, not occur until after 2000		
8	International agreements which guarantee certain economic minima to the world's population as a result of high production from automation	Not in this century, if ever			
10	Availability of a machine which comprehends standard IQ tests and scores above 150 (where "comprehend" is to be interpreted behavioristically as the ability to respond to questions printed in English and possibly accompanied by diagrams)	Not for at least 20 years, but eventually	Within 20 years, since such problems as generalized pattern recognition will have been solved before then		
15	Widespread use of computers in tax collection, with access to all business records — automatic single tax deductions (former "Manufacture/Business/Commerce" 8)	Within 25 years	Not within 25 years, because of legal difficulties and political conservatism		
16	Automated interpretation of medical symptoms (former "Human Convenience 10")	Within 25 years	Not within 25 years, because some symptoms do not lend themselves to quantification and because the adaptability of bacteria and viruses necessitates continual revision of the kind of judgment on which automated diagnosis would have to be based		

d. Do you wish to add any comments? In particular, is there anything further you wish to say in support of your views as expressed in your entries in the foregoing table?

PART A4

QUESTIONNAIRES ADDRESSED TO PANEL 4 ON SPACE PROGRESS

LONG-RANGE FORECASTING STUDY

Questionnaire 1

4.1. SPACE PROGRESS

In the past several years, predictions about future progress in space have originated from many sources. For instance, the National Aeronautics and Space Administration has published a time table projecting planetary voyages; a RAND report to the U.S. House of Representatives (Space Handbook, edited by R W Buchheim, Random House, 1959) has predicted a space time table; the present Administration has forecast an American on the Moon by 1970.

Would you please list the major events and developments in space which, in your opinion, may be expected over the next 50 years, in approximate order of occurrence, with estimated dates:

Do you know of the existence of any information, in the form of tabulations or analyses, that might be particularly valuable in reaching projections of the kind requested?

Questionnaire 2

4.2 SPACE PROGRESS

a. Table 4.a contains a summary of space developments suggested by the panel in the first round of questions. In Table 4.2a please check the interval during which you believe attainment will be most likely. Note that the final columns ask for your judgment of the effect of certain changes in the political climate on the date of space accomplishments.

b. Considering the items suggested in Table 4.2a, are there other items you would care to add? Please list these in Table 4.2b indicating the date you believe these will be attained under the same assumptions.

c. Do you believe that efforts to explore space are justified in terms of expected significant scientific or technological by-products?

Yes_____ No_____

If yes, what specific potential benefits do you foresee?

Table 4.2a

SPACE PROGRESS

MOST LIKELY DATE OF OCCURRENCE

	1963-65	1965-68	1968-72	1972-78	1978-86	1986-97	1997-13	Later	Improbable	Interval of Occurrence if: US-SU Cooperate In Space	Interval of Occurrence if: US Budget Sharply Reduced
EARTH ORBIT OPERATIONS											
1. S.U. orbital rendezvous											
2. U.S. orbital rendezvous											
3. Rescue of astronauts stranded in orbit											
4. Establishment of global satellite communication system											
5. Manned scientific orbital station - 10 men											
6. Increased use of near-earth satellites for weather prediction and control											
7. Manned orbital sanitarium											
USE OF MATERIALS OF THE SOLAR SYSTEM											
1. Manufacturing of propellants and raw materials on Moon											
2. Permanent lunar colony (500 men indefinitely)											
3. High-cost commercial lunar traffic											
4. High-cost resort passenger traffic to Moon											
5. Economically competitive use of lunar materials on earth											
6. Regularly scheduled commercial traffic to lunar colony											
7. Permanent research stations on near planets											
8. Competition for planetary raw materials											
9. Extra-terrestrial farming											
10. Deepspace laboratories and observatories											
11. Routine use of moon as Solar system launching base											
12. Asteroid mining											
INNOVATIONS IN SPACE											
1. Development of reusable booster launch vehicle											
2. Operational readiness of laser for space communications											
3. Meaningful international legal agreement on colonization of planets											
4. Lunar-based laser beam for use in space vehicle propulsion											

*For simplicity, unmanned planetary probes have been deleted from this list.

TABLE 4.2a

	1963-65	1965-68	1968-72	1972-78	1978-86	1986-97	1997-13	Later	Improbable	Interval of Occurrence if: US-SU Cooperate In Space	Interval of Occurrence if: US Budget Sharply Reduced
5. Solid-core nuclear reactor propulsion											
6. Gas core nuclear reactor propulsion											
7. First human born extra-terrestrially											
8. Radiation immunization pill											
9. Ionic propulsion (nuclear-generator powered)											
10. Biostat for equilibrium of plants and life - carbon dioxide and oxygen manufactured on planets											
11. Fusion-energy propulsion											
12. Long-duration comm to permit a form of time travel											
13. Non-rocket space drive - anti-gravity											
14. Development of reusable maneuverable orbiting spacecraft											
15. Development of intelligent decisionmaking robots for exploration of hostile environments											
16. Commercial global ballistic transport											
17. Space hydrogen ram jet											
18. Inter-gallactic communication											
19. Pulsed nuclear propulsion (as in Orion project)											
20. Earth weather control - "magnetospheric meddling"											
MILITARY IN SPACE											
1. Unmanned inspection and capability for destruction of satellites											
2. Manned co-orbital inspection of satellites											
3. Military space station operational											
4. Military nuclear-propelled scout ships roving cislunar space											
5. Capability for military combat in space											
6. Military force on Moon											
7. Space-to-space attack fleets											
8. Geocentric bombardment fleet											
9. Heliocentric strategic fleet											
10. First extra-terrestrial war											
EXPLORATION OF SOLAR SYSTEM*											
1. S.U. manned lunar fly-by											
2. U.S. manned lunar fly-by											
3. Manned lunar landing and return											
4. Temporary lunar base (2 men, 1 month)											
5. Manned Mars and Venus fly-by											
6. Discovery of life on Mars											
7. Communication with extra-terrestrials											
8. Temporary Mars base (2 men, 1 month)											
9. Permanent base established on Moon (10 men, indefinite stay)											
10. Manned Saturn fly-by											
11. Manned landing on asteroids											
12. Manned landing on Saturn's moons											
13. Manned landing on Mercury											
14. Scientific probe to the sun											
15. Permanent base established on Mars (10 men, indefinite stay)											
16. Manned Venus landing											
17. Manned landing on Jupiter's moons											
18. Manned Jupiter fly-by											
19. Probes out of the solar system											
20. Rendezvous with a comet											
21. Manned multi-generation mission to other solar systems											

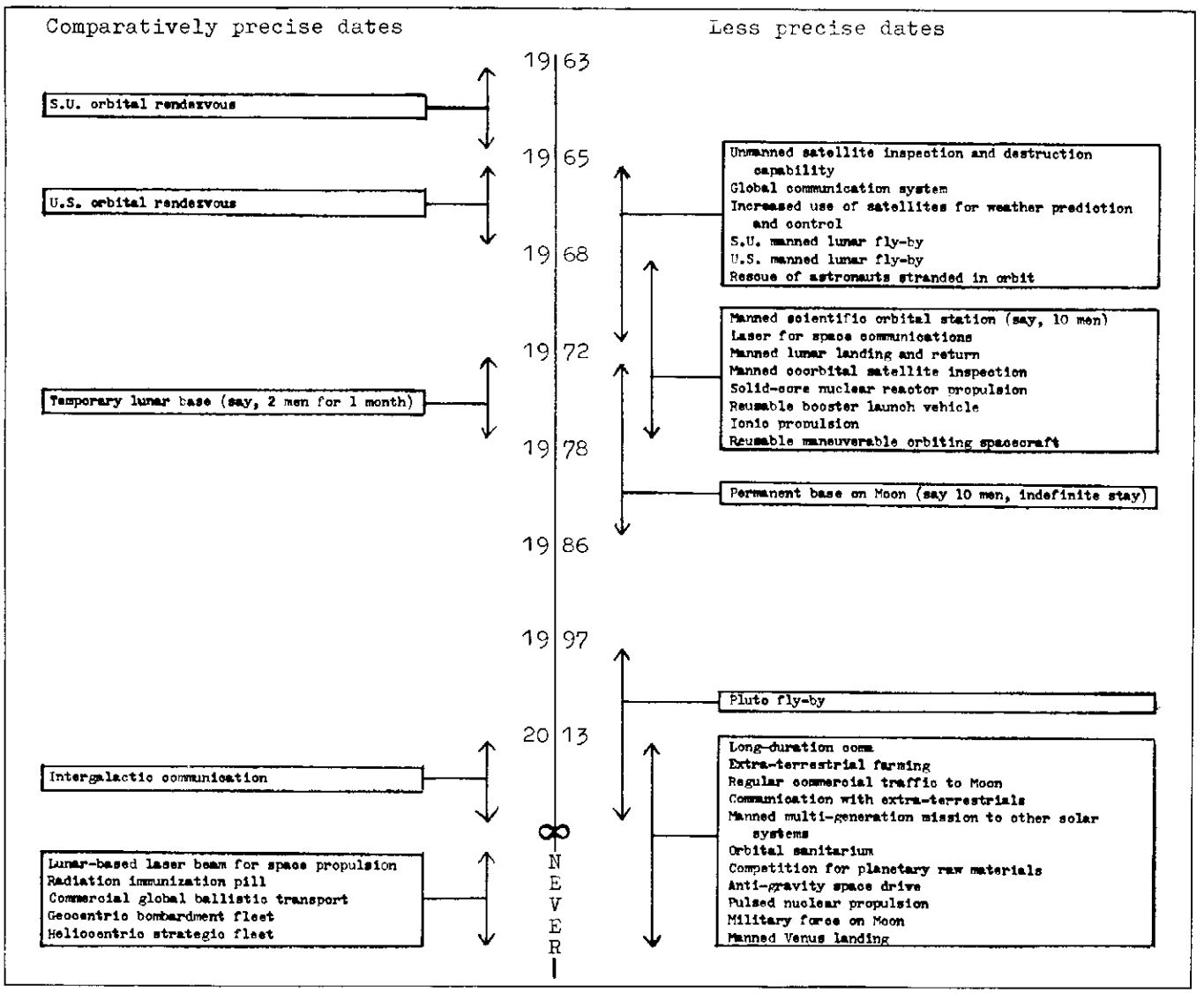
Q u e s t i o n n a i r e 3

4.3 SPACE PROGRESS

a. Table 4.3a, on the following page, presents the consensus of a large majority of the panel members with regard to some of the potential developments in space listed in the preceding questionnaire. Do you, by and large, agree with the opinion represented by this consensus? If you disagree with any particular item, or with the order of any particular pair of items, indicate which, and briefly state your reason for your differing opinion:

b. Table 4.3b gives a list of potential developments in space exploration on which thus far no satisfactory consensus has been obtained. It consists mostly of items previously submitted to the panel and judged to be sufficiently important to deserve further examination, plus a few afterthoughts suggested by panel members in response to Questionnaire 2. You are being asked to reestimate the time of occurrence of each item and, in certain cases, to state briefly your principal reason for this opinion.

Table 4.3a: CONSENSUS ON SPACE PROGRESS



Questionnaire 3 (continued)

TABLE 4.3b

	Description of potential development	Consensus or dissensus to date	In your opinion, by what year does the probability of occurrence reach 50%	90%	If your 50% estimate falls within either the earlier or the later period indicated, briefly state your reason for this opinion
1	Manufacturing of propellents and raw materials on moon	Widely divergent opinion, many believing that this is not feasible			Why before 1987 or never?
2	Establishment of permanent research stations on near planets	Virtual consensus that it will occur (though after 15 years); disagreement as to when			Why before 1990 or after 2013 (or never)?
3	Deep space laboratories and observatories for high vacuum, zero-g, and space research	Virtual consensus that it will occur (though after 15 years); disagreement as to when			Why before 1987 or after 2013 (or never)?
4	Meaningful international legal agreement on colonization of planets	No consensus			Why before 1973 or never?
5	Development of intelligent decision making robots for exploring hostile environments	Virtual consensus that it will occur (though after 15 years); disagreement as to when			Why before 1987 or after 2013 (or never)?
6	Earth weather control ("magnetospheric meddling") in the sense of having a highly reliable ability to cause precipitation from certain types of clouds	Widely divergent opinions, possibly due to differing interpretations of the original question			Why before 1979 or after 2013 (or never)?
7	Manned Mars and Venus fly-by	Majority opinion that it will occur between 1972 and 1986			Why after 1997 (or never)?
8	Manned landing on Mars and return	Newly proposed item			Why before 1979 or after 2013 (or never)?
9	Permanent base established on Mars (say, 10 men, indefinite stay)	Majority opinion that it will eventually occur, but not before 1987			Why before 1998 or after 2013 (or never)?
10	Probes (small instrumented unmanned payloads) out of the solar system	Widely divergent opinions, possibly due to differing interpretations of the original question			Why before 1979 or after 2013 (or never)?
11	Re-execution of critical experiments in deep space (Michelson-Morley, speed of light, equality of gravitational and inertial mass, etc.)	Newly proposed item			Why before 1987 or after 2013 (or never)?
12	Sweeping up Earth-trapped radiation zones	Newly proposed item			Why before 1987 or after 2013 (or never)?
13	Manufacturing of atmospheres suitable for human beings on Moon or planets	Newly proposed item			Why before 2013 or never?

Questionnaire 4

4.4 SPACE PROGRESS

This is the last questionnaire in our present inquiry into opinions on future progress in space.

Before giving you a summary of the result of the preceding round and putting some further substantive questions before you, we would like to ask your preference as to whether or not a report on this study should mention your participation as a respondent. Under no circumstances will any direct quotations be attributed to you.

a. Check here if you have no objection to having your name mentioned as that of a respondent in this current study: ☐

On six of the thirteen specific items concerning space developments that had been put before the panel in the previous questionnaire a sufficient consensus has been established to warrant our bringing their consideration to a close, — unless you wish to take explicit exception to any one of them. They are listed below (Table 4.4b) together with the majority opinion on the expected time of their occurrence.

Table 4.4b

Items on which at least a moderate consensus seems to have been obtained

#	Description of development	Majority opinion	x
7	Manned Mars and Venus fly-by	Between 10 and 20 years from now	
8	Manned landing on Mars and return	Between 12 and 25 years from now	
3	Deep-space manned laboratories and observatories for high-vacuum, zero-g, and space research ("deep-space" in the sense of higher than orbital)	Between 12 and 25 years from now	
10	Probes (small instrumented unmanned payloads) out of the solar system	During the 1980's	
11	Re-execution of critical experiments in deep space (Michelson-Morley, speed of light, equality of gravitational and inertial mass, etc.)	By 1990	
12	Sweeping up Earth-trapped radiation zones	Never, since not economically practical; it will probably be cheaper to build radiation-resistant equipment	

b. Please mark with a cross in the last column of the preceding table any items regarding which you find yourself in substantial disagreement with the stated majority opinion. For each such case, state below the nature of your disagreement and, very briefly, the reason for your differing opinion:

Of the remaining 7 of the 13 items of Questionnaire 3, we shall drop Item 4 (on international agreements regarding planetary colonization) and Item 5 (on intelligent decision-making robots for exploring hostile environments) from further consideration, because in both cases the widely divergent responses suggest that we may expect a gradual development, with no specific dates that can be meaningfully attached unless the questions were (rather arbitrarily) phrased much more specifically.

This leaves us with 5 residual items from our former list of potential space developments that require further examination. They are listed in Table 4.4c on the following page. The table also includes, as Items 14 to 16, three items about which a tentative consensus had already been announced in Table 4.3a of the previous questionnaire; their consideration is being resumed here, because in each case several respondents explicitly voiced disagreement with the opinion stated.

c. Please reconsider the potential space developments listed in the following table. They are the remaining items, on which thus far no satisfactory consensus has been obtained. In some cases, the description has been reworded in an effort to eliminate vagueness (which may have been partly responsible for the apparent discrepancy of opinions).

In giving us once more your estimates of the years when the probability of occurrence reaches 50% and 90% respectively, please take such reformulations into account, as well as the merits of any statements of minority opinions:

Table 4.4c

#	Description of potential development	Majority consensus to date	Minority opinion	50%-year	90%-year
1	Manufacturing of propellants and raw material on the Moon	By 1986	Not for 30 to 50 years, if ever, because transport of required machinery to the Moon would be prohibitively expensive		
2	Establishment of permanent research stations on near planets	Between 1980 and 2000	Not for at least 50 years because of extremely difficult logistics		
6	Earth weather control, in the sense of having a highly reliable ability to cause precipitation from certain types of clouds	Not for 20 or more years	Within 15 years, because current techniques are promising, and efforts for expanding them are in progress		
9	Establishment of a permanent Mars base (say, 10 men for an indefinite period)	Between 1985 and 2000	Not for at least 50 years because of extremely difficult logistics		
13	Manufacturing of atmospheres suitable for human beings on Moon or planets (no implication of surrounding entire Moon or planet with an atmosphere is intended)	Could be done at any time; will be done when first permanent lunar base is established (that is, probably by 1986)	Not until 2000 or later, because transport of required facilities would be prohibitively expensive		
14	Radiation immunization (through pills or other means)	Never	Definitely eventually, at least in the sense of a statistically significant improvement; this view is supported by recent Soviet claims of already having conducted successful experiments in this regard		
15	Commercial global ballistic transport (including boost-glide techniques)	Never	Definitely within this century, by boost plus boost-glide method, at least for mail and for military purposes, and to remote areas such as polar regions		
16	Manned maneuverable geocentric bombardment fleet	Never	Probably not in this century, but by no means to be ruled out entirely		

d. Do you wish to add any comments? In particular, is there anything further you wish to say in support of your views as expressed in your entries in the foregoing table?

PART A5

QUESTIONNAIRES ADDRESSED TO PANEL 5 ON WAR PREVENTION

Questionnaire 1

5.1. WAR PREVENTION

In recent years the conviction has grown in some quarters that another major war, involving direct confrontation of at least two of the great powers, is most unlikely to occur except possibly through inadvertence (such as a nuclear accident or a misinterpretation of signals), or through an escalation (mutually undesired) of a political crisis situation, leading to a preemptive attack out of the fear of an enemy attack being imminent.

(a) Do you agree or disagree with this view? In fact, if a major war were to occur, say, during the next 10 years, how do you assess the probability that its outbreak would be due to:

(i) inadvertence . . . . . ☐
(ii) escalation of a political crisis . . ☐
(iii) escalation in the level of violence in an on-going minor war . . . . . ☐
(iv) surprise attack at a time when there is no ostensible acute crisis . . . ☐
(v) other reasons (specify) . . . . . ☐

100%

(b) In your opinion, how high is the probability that another major war will, in fact, break out

(i) within the next 10 years . . . . . ☐
(ii) within the next 25 years . . . . . ☐

(c) Numerous ideas have, of course, been put forth as to how one might go about reducing this probability of another major war. They range all the way from attainable but inadequate to adequate but unattainable. In your opinion, and in view of your estimates given above in response to (a), what specific measures that you regard as both realistic and effective might be undertaken in the future, and by whom, in order to reduce the overall probability of the occurrence of another major war?

[Use reverse side for more space]

Do you know of the existence of any information, in the form of tabulations or analyses, that might be particularly valuable in reaching projections of the kind requested?

Questionnaire 2

5.2 WAR PREVENTION

a. Table 5.2a contains a summary of most of the suggestions made for reducing the probability of the occurrence of another major war. Please indicate your appraisal of the effectiveness of the items listed. In the second column, indicate your evaluation of the probability that the measure suggested will be enacted.

b. Are there any additional measures which you would now care to add to the list? How would you regard their effectiveness and probability? Please indicate these additions in Table 5.2b.

TABLE 5.2a

SUGGESTED METHODS OF LOWERING THE PROBABILITY OF WAR

	Effectiveness if implemented				Probability of implementation		
MILITARY MEASURES	nil	minor	moderate	high	never	maybe	certain
1. Increased security of command & control and retaliatory capability							
2. Offer of nuclear weapons to countries that agree to support our stated national policies							
3. Strengthening of NATO alliance to insure a guaranteed response to prestated provocations							
4. Build-up of conventional forces							
5. Improved defensive warfare techniques to reduce probability of escalation in limited wars							
6. Development of invulnerable delayed-response weapons that are incapable of surprise attack							
7. Establishment of meaningful world-wide U.N. police force							
POLITICAL MEASURES							
1. US-initiated unilateral steps toward disarmament							
2. Bilateral arms control agreements							
3. Bilateral reduction of armaments enforced by U.N. police force							
4. Strategic arms control (halt production but not R and D)							
5. SU-initiated gradual improvement of political atmosphere							
6. US-SU political agreement to seek peace and restrain other nations from developing nuclear weapons							
7. US-SU political association against China or other third party							
8. Central-European disengagement to reduce military activity, induced by an improving SU-US atmosphere							
9. Sharing of technological innovations between US and SU							
10. Holding the status quo against even minor aggressions							
11. Clear US statement as to which national interests are to be protected by nuclear deterrents, and orientation of our policies to that end							
12. Establishment of National Assessment Centers which would evaluate crisis situations and transmit policy statements to the potential enemy to clarify US intent; statements would be unpublished to prevent his "loss of face" but would contain contingency plans to show our clear intent.							
13. Creation of buffer zones to avoid direct confrontation of major powers							
14. Development of a new system of international political cue "signals" which would indicate real intent to go to war unless political situation changes, such as "general mobilization" in the past							
15. Support of NATO, SEATO & OAS to increase number of world forums where political differences can be resolved with minimum "loss of face"							
16. US or SU demonstration of the intent to use force of increasing levels (in identifiable increments) to specific provocations							
17. Studies by the "soft sciences" (sociology, group psychology) seeking clues to war prevention							
18. Strengthening of the UN with the objective of forming a world government							
19. Institute population control in all nations according to UN decisions							
ECONOMIC MEASURES							
1. Recognition of Communist China and East Germany - creation of a realistic policy							
2. Removal of trade barriers with Communist countries							
3. Greater political and economic unity among free advanced democracies							
4. UN economic and military aid to areas threatened by political upheaval							
5. US-promoted rapid technological and economic advancement of underdeveloped nations							
6. Increased cooperative economic, political and military ventures with the USSR & China to promote interdependency							
7. Development of a cadre of international UN civil servants dedicated to world values							
8. Fostering educational & propaganda measures designed to amend or establish values of mutual toleration of various ideologies and the right to self-determination							

Questionnaire 3

5.3 WAR PREVENTION

In the previous questionnaire you had been asked to evaluate the potential effectiveness and the probability of implementation of certain suggested methods of lowering the probability of another major war. These measures have now been ranked by a combined index of the average effectiveness and average probability assigned to them by the panel. Table 5.3a (p.3) reproduces the fifteen top-ranking among these measures, in their ranked order; in addition, it lists eight newly proposed measures for your consideration.

The first fifteen entries of Table 5.3a may be regarded as representing a tentative formulation of a consensus of the majority of the panel members as to the more promising among the list of suggested measures.

We are now asking you to reappraise these suggestions. While you may have given some thought to future weapon systems in your previous appraisal, we would now like you to give explicit consideration to certain military devices which, in the opinion of Panel 6, are likely to be available to both the Western and the Soviet blocs in the near future:

- Orbiting space reconnaissance stations
- Temporarily incapacitating as well as lethal biological agents
- Lasers used both offensively and as anti-ICBM weapons
- Small tactical nuclear weapons
- Advanced types of submarines and anti-submarine devices
- Rapidly mobile and highly automated limited-war forces
- New techniques of thought control and opinion manipulation

a. For each of Measures 1–15, Table 5.3a lists the averages of the panel's previous assessments of the measure's potential effectiveness and of the probability of its implementation. The effectiveness is measured on a scale of

0 for "nil", 2–3 for "minor", 5 for "moderate", 10 for "high".

Probability is given in percent.

Please fill in your own, possibly revised, numerical estimates, using the same scales. Whenever one of your estimates differs substantially from the previous panel average, briefly state your reason for this opinion in the adjacent column. (You might interpret a "substantial difference" as one of 3 or more in effectiveness or of 20% or more in probability.)

b. Fill in similar numerical estimates of potential effectiveness and probability of implementation for Measures 16–23.

c. If you were an advisor to the President of the U.S., in what order would you be inclined to recommend implementation of the 23 measures listed? Assign ranks from 1 to 23 accordingly, in the column headed "Desirability rank", using Rank 1 for the most desirable measure. In making these "recommendations", consider the overall effects of each measure, including its cost.

d. In the previous questionnaire, your copy of which is being returned to you for reference, the fifteen measures included in the present tabulation have been circled. In your opinion, should any further measure, because of its potential desirability, have been included for further consideration in our present listing? If so, indicate these in the blanks at the end of Table 5.3a, and fill in your estimates of effectiveness and probability of implementation, and state your reason for thinking that they ought to be included.

Table 5.3a

	Average of panel's previous assessments of potential effectiveness	probability of implementation	Your effectiveness estimate	Reason	Your probability estimate	Reason	Desirability rank
1 Increase[illegible] [illegible] of [illegible] and control [illegible] of retalia-tory capabil[illegible]	[illegible]	85%					
[illegible] Build-up of Western-Bloc conventional forces	[illegible]	[illegible]0%					
[illegible] Development on both sides of invulnerable delayed-response weapons that are incapable of surprise attack	[illegible]	[illegible]0%					
[illegible] Greater political and economic unity among free advanced democracies	[illegible]	55%					
5 US-promoted rapid technological and economic advancement of underdeveloped nations	4	65%					
6 [illegible] economic and military aid to areas threatened by political upheaval	[illegible]	70%					
7 US/SU political agreement to seek peace and restrain other nations from developing nuclear weapons	[illegible]	50%					

Table 5-3a (continued)

	Average of panel's previous assessments of potential effectiveness	probability of implementation	Your effectiveness estimate	Reason	Your probability estimate	Reason	Desirability rank
8 Establishment of a standing world-wide U.N. police force, not subject to veto	8	35%					
9 Studies by sociology, group psychology, etc., seeking clues to war prevention	4	65%					
10 Strengthening of the UN with the objective of forming a world government	7	35%					
11 Development of a cadre of international UN civil servants dedicated to world values	4	55%					
12 Bilateral US/SU arms control agreements	5	55%					
13 Holding the status quo against even minor aggressions	5	50%					
14 Improved defensive warfare techniques to reduce probability of escalation in limited wars	5	55%					
15 US-SU political association against China or other third party	5	55%					

Measure	Effectiveness estimate	Probability implementation	Desirability rank
16 Invitation to other nations to become member states of the U.S.A.			
17 Support and promotion of the United States of Africa, Latin America, Europe, Asia			
18 Development of a code of international law and establishment of effective world courts of justice and a world supreme court			
19 Development of realistic understanding among Western Allies of dynamics of nuclear warfare, by techniques including joint US/Allied crisis- and war-gaming and systems analyses			
20 Settlement of the division of Germany on terms acceptable to West Germany and compatible with German membership in NATO			
21 Military alliance between U.S. and S.U. (and India)			
22 Organized encouragement of conscientious objection on the part of scientists to cooperation in the improvement of weapon systems			
23 Simulated US/SU war games, played by professional military planners of both sides (possibly with sides interchanged)			
Additional measures			Reason for inclusion

Q u e s t i o n n a i r e 4

5.4 WAR PREVENTION

This is the last questionnaire in our present inquiry into opinions on war prevention.

Before giving you an account of what further consensus seems to have emerged in the preceding round and putting some further substantive questions before you, we would like to ask your preference as to whether or not a report on this study should mention your participation as a respondent. Under no circumstances will any direct quotations be attributed to you.

a. Check here if you have no objection to having your name mentioned as that of a respondent in this current study: ☐

To turn now to substantive matters, we begin this last questionnaire in the series by essentially repeating the basic questions put before this panel in the opening round. We are doing this, firstly, because a few respondents, having joined the panel after the first questionnaires had been processed, have had no chance to express their opinions in this regard. Secondly, the passage of time since the beginning of this inquiry may, in the opinion of some respondents, have brought about a change in the world situation warranting an adjustment of the original estimates. And finally, some respondents may simply have changed their minds, possibly by giving consideration to some of the thoughts of the panel's other members, which have been transmitted to them via the present and earlier questionnaires by implication.

b. In your opinion, how high is the probability that another major war, involving direct confrontation of at least two of the great powers, will break out

(i) within the next 10 years . . . . . ☐

(ii) within the next 25 years . . . . . ☐

c. If such a major war should break out during the next 10 years, how do you assess the probability that its outbreak would be due to:

(i) Inadvertence (such as a nuclear accident, a misinterpretation of signals, unauthorized action by an individual, initiation by a third power ["catalytic war"] etc) . . . . . ☐

(ii) escalation of a political crisis (including a unilateral domestic crisis) . . . . . ☐

(iii) escalation in the level of violence in an on-going minor war . . . . . ☐

(iv) planned surprise attack at a time when there is no ostensible acute crisis . . . . . ☐

100%

We next return to the twenty-three suggested methods of lowering the probability of another major war, that had been submitted for your appraisal in the preceding questionnaire. They now seem to fall into three groups, namely, those on which there is a consensus that they ought to be rejected, those on which there is a consensus that they are commendable, and those on which a considerable divergence of opinions is apparent.

The first group, of rejected measures, consists of the following four, which we are listing in Table 5.4d together with the median estimates of their effectiveness and of their probability of implementation as well as the median of the desirability rank attributed to them. (It should be remembered that effectiveness ranges over the scale from 0 to 10, with 10 as most effective, and desirability over 1 to 23, with 1 as most desirable.)

Table 5.4d

Suggested measures for lowering the probability of war that were rejected by the majority

#	Suggested measure	Median effectiveness	Median probability	Rank of desirability median	x
16	Invitation to other nations to become member states of the U.S.A.	2	10%	20	
17	Support and promotion of the United States of Africa, Latin America, Europe, Asia	3	20%	19	
22	Organized encouragement of conscientious objection on the part of scientists to cooperation in the improvement of weapon systems	2	10%	23	
23	Simulated US/SU war games, played by professional military planners of both sides (possibly with sides interchanged)	2	20%	22	

d. Please mark with a cross in the last column of the above table any items regarding which you find yourself in substantial disagreement with the stated majority opinion that they ought to be rejected. For each such case, state below the nature of your disagreement and, very briefly, the reason why you think the measure should not be rejected:

Table 5.4e below similarly lists those ten suggested measures regarding the desirability of which there seems to be a consensus:

Table 5.4e

Suggested measures for lowering the probability of war that were accepted by the majority

#	Suggested measure	Median effectiveness	Median probability	Rank of desirability median	x
1	Increased U.S. security of command and control and of retaliatory capability	7	90%	2	
2	Build-up of Western-bloc conventional forces	6	70%	1	
3	Development on both sides of invulnerable delayed-response weapons that are incapable of surprise attack	7	70%	4	
4	Greater political and economic unity among free advanced democracies	8	55%	3	
7	US/SU political agreement to seek peace and restrain other nations from developing nuclear weapons	6	50%	6	
8	Establishment of a standing world-wide U.N. police force, not subject to veto	8	33%	5	
12	Bilateral US/SU arms control agreements	5	60%	12	
14	Improved defensive warfare techniques to reduce probability of escalation in limited wars	5	50%	7	
18	Development of a code of international law and establishment of effective world courts of justice and a world supreme court	5	30%	10	
20	Settlement of the division of Germany on terms acceptable to West Germany and compatible with German membership in NATO	5	20%	15	

e. Please mark with a cross in the last column of the above table any items regarding which you find yourself in substantial disagreement with the stated majority opinion that they would be effective and/or desirable. For each such case, state below the nature of your disagreement and, very briefly, the reason for your differing opinion:

This leaves us with nine suggested measures on which a considerable divergence of opinions has been recorded. We would like you to reconsider these, giving consideration to the brief indications of reasons stated in support of minority opinions.

f. Please indicate, by writing "M", "–", or "+" in the last column of the following table, whether your opinion falls in the middleground (M), whether you are definitely opposed to the measure (–), or whether you are definitely in favor of it (+). (It should be understood that writing "–" or "+" does not mean that you are necessarily subscribing to the stated reason against or for the measure.) You are reminded once more that Effectiveness ranges over the scale from 0 to 10, with 10 as most effective, and the Desirability rank from 1 to 23, with 1 as most desirable.

Table 5.4f

Suggested measures for lowering the probability of war on which opinions diverge

#	Suggested measure	M represented by a majority: Effectiveness	Probability	Desirability	Minority reason against measure	Minority reason in favor of measure	Your opinion (write "M", "–" or "+")
5	US-promoted rapid technological and economic advancement of underdeveloped nations	2 to 5	30% to 70%	6 to 15	Impatient advancement of underdeveloped countries may not be conducive to lowering the probability of war	This already is current US policy and has proved effective; political preventatives to war must not be underestimated	
6	U.N. economic and military aid to areas threatened by political upheaval	3 to 5	35% to 80%	6 to 13	The UN could not agree as to what countries are threatened; supporting the status quo of doubtful nations may not promote war prevention; The UN has insufficient funds	This is consistent with current policy; it implies a stronger UN and therefore is desirable	
9	Studies by sociology, group psychology, etc., seeking clues to war prevention	3 to 7	60% to 80%	7 to 16	A waste of time and effort	A better understanding of the causes of war is mandatory; a small investment may produce breakthrough ideas	
10	Strengthening of the UN with the objective of forming a world government	6 to 8	30% to 40%	7 to 13	Extremely unlikely, unless nuclear war occurs	This is our only hope	
11	Development of a cadre of international UN civil servants dedicated to world values	3 to 5	50% to 70%	13 to 20	Civil servants lack political power	Desirable if only in view of the beneficial influence these people will exert when they go back home	
13	Holding the status quo against even minor aggressions	1 to 7	20% to 60%	8 to 17	Continual fighting would increase tension; The risk of escalation would be increased	Our policy to this effect thus far has been successful	
15	US-SU political association against China or other third party	2 to 6	50% to 55%	10 to 19	It might dissipate the US image; it would be ineffective or worse because of China's irrationality and the possibility of a desperate reaction	This could mean world stability	
19	Development of a realistic understanding among western Allies of dynamics of nuclear warfare, by techniques including joint US/Allied crisis- and war-gaming and systems analyses	2 to 7	30% to 70%	8 to 18	A mere pipe dream	Essential for effectiveness of the NATO alliance	
21	Military alliance between US and SU (plus possibly India)	0 to 7	10% to 35%	17 to 21	Not possible short of fighting a war together	This could mean world stability	

In conclusion we would like you to make an estimate of the potential overall effect of pursuing certain of the measures that have been considered above. When you stated the probabilities of a major war occurring within 10 or 25 years in response to Question (b) on p.1 you presumably made some implicit assumption as to which of these measures would in fact be part of the policy of our government and with what success they were likely to meet.

g. Assuming now that those measures listed in Tables 5.4e and 5.4f for which you expressed a favorable opinion were pursued vigorously by our Administration in the years to come, then, in view of the success you would expect such efforts to have, what would be

(i) the probability of war within the next 10 years ..... ☐

(ii) the probability of war within the next 25 years ..... ☐

h. Do you wish to add any comments? In particular, is there anything further you wish to say in support of your views as expressed in your responses?

PART A6

QUESTIONNAIRES ADDRESSED TO PANEL 6 ON WEAPON SYSTEMS

LONG-RANGE FORECASTING STUDY

Questionnaire 1

6.1. WEAPON SYSTEMS

Having reliable predictions about future weapon systems would be of great importance for planning in the area of national security. This applies equally to military procurement planning and to its counterpart, the organization of arms control.

In your opinion, what major developments in the field of novel weapon systems have a reasonable chance of occurring in the next 50 years? [In answering this question, by all means include in your consideration not only defensive and offensive weapons, but also passive defense measures, military intelligence, warning devices, and "para"-military and outright political weapon systems.]

Do you know of the existence of any information, in the form of tabulations or analyses, that might be particularly valuable in reaching projections of the kind requested?

Questionnaire 2

6.2 WEAPON SYSTEMS

a. Table 6.2a contains a listing of most of the weapons suggested by the panel's responses to the first questionnaire. In the first column please indicate your judgment of the effectiveness of the weapon. (Here, "effectiveness" means that significant political advantages will accompany the acquisition of the system). In the second column indicate your judgment of the technical feasibility of developing the weapon to operational status. In the third column indicate your opinion about two dates: earliest possible operational date given a crash program, and operational date assuming a status-quo political situation.

b. Considering the weapons suggested in Table 6.2a, please list in Table 6.2b any further suggestions you would care to add, completing the table as above.

TABLE 6.2a

Suggested Weapon Systems

	Effectiveness if developed				Feasibility of development			Operational date under	
DEFENSIVE WEAPONS	nil	minor	moderate	high	simple	possible	very difficult	crash program	status quo
1. Massive civilian defense and post-war recovery plan									
2. Underground location of key production facilities									
3. Rapidly mobile public works & logistics units for war recovery & refugee support									
4. Under-ocean bases & factories									
5. Effective terminal defense by ground-launched anti-missiles									
6. Effective terminal defense by air-launched anti-missiles									
7. Effective terminal defense by directed energy beams									
8. Military control of space close to earth for satellite inspection and destruction									
9. Orbiting space reconnaissance station									
10. Bigger or invulnerable deterrents, approaching the doomsday machine - 1000's of megatons									
11. Hardened low-radiation, low-blast, high-neutron, nuclear weapons									
12. Electron curtain - ionized sheath to prevent electromagnetic radiation penetration									
OFFENSIVE WEAPONS									
1. Lethal biological agents									
2. Incapacitating biological agents									
3. Biological agents destroying the will to resist									
4. Use of drugs or electrical stimulation to create artificial motivation to undertake superhuman tasks									
5. ICBM's with other than nuclear warheads such as snipers									
6. Weather manipulation									
7. Directed-energy weapons including electromagnetic radiation, particle beams, wide-aperture lasers									
8. Control of weapons to target by space-based reconnaissance									
9. Lunar bombardment stations									
10. Large orbiting satellite weapons for blackmail									
11. Space-to-space or earth-to-space attack fleets									
12. Thermonuclear weapons with non-atomic triggers									
13. Military bases on Mars									

TABLE 6.2a

	Effectiveness if developed				Feasibility of development			Operational date under	
OFFENSIVE WEAPONS (cont'd)	nil	minor	moderate	high	simple	possible	very difficult	crash program	status quo
14. Agent-carried thermonuclear weapons									
15. Development of nuclear warheads with directional blast properties									
16. Ballistic transport of troops									
17. Nuclear weapons with no or greatly reduced fallout									
18. Antimatter bombs									
19. Military decision systems, with direction by automated central battle-computers									
COLD- AND LIMITED-WAR DEVICES									
1. Automated war capability with tactical battlefield computers, robot sentries, TV surveillance of occupied countries, etc.									
2. Tactical kiloton nuclear weapons for use by ground troops									
3. Use of lasers for radar type range sensors, illuminators, communications									
4. Devices such as selective means of destroying automatic computers									
5. Longer-endurance aircraft, perhaps nuclear-powered, for logistic supply or bombardment									
6. Development of effective systems to move men and light weapons rapidly to any point on earth to promote world-wide police action									
7. Perishable counter-insurgent arms									
8. Accurate intelligence correlation through use of computers									
POLITICAL WEAPONS									
1. Extensive use of devices which persuade without killing, such as water cannons, fire hoses, electric wands, tear gas									
2. Miniature and improved sensors and transmitters for snooping, reconnaissance, arms control inspectors, etc.									
3. Use of "economic showmanship" (i.e., lunar exploration) and new foreign-aid techniques to influence nations									
4. Biological agents for covert use over long periods									
5. Further development of techniques of propaganda, thought control, and opinion manipulation									
6. Mind reading									
7. Mass hypnotic recruitment of forces from enemy population									
NAVAL WEAPONS									
1. Use of unmanned guided underwater sentries									
2. Assignment to Navy of strategic attack as primary mission									
3. Completely submarine navy									
4. Effective anti-submarine capability, at least against contemporary subs									
5. Domesticated porpoises or dolphins for anti-submarine reconnaissance									
6. Deep-diving submersibles made of materials which decrease detection probability									
7. Fixed undersea strategic missile systems									
8. National occupation of ocean floors									
9. Large intercontinental undersea transport pipelines									

Questionnaire 3

6.3 WEAPON SYSTEMS

Of the 55 items submitted to you in Questionnaire 2 we are now dropping almost one half from further consideration. This is being done on the grounds that a majority consensus has indicated either that their feasibility is so low as to make development in the foreseeable future very unlikely or that their effectiveness, even if developed, would be too low, or both.

The remaining items are listed for your reconsideration in Table 6.3a, together with four new items which represent afterthoughts suggested by panel members in response to Questionnaire 2.

For each of the old items, Table 6.3a also lists the averages of the panel's previous assessments of the item's potential effectiveness and of the feasibility of its development, as well as the median years in which operational readiness has been forecast under the assumptions of either a crash program or the status quo.

Both effectiveness and feasibility have been measured on a scale from 0 to 10, as follows:

Effectiveness: 0 for "nil", 2-3 for "minor", 5 for "moderate", 10 for "high".
Feasibility: 0 for "impossible", 2 for "difficult", 6 for "possible", 10 for "simple".

a Please fill in your own, possibly revised, numerical estimates, using the same scales, as well as the years when you expect operational readiness under a crash program or under the status quo. Whenever one of your estimates differs substantially from the previous panel average or median, briefly state your reason for this opinion in the adjacent column. (You might interpret a "substantial difference" as one of 3 or more in the case of Effectiveness or Feasibility or a Year prior to 1990, and as one of 10 or more for a Year beyond that.)

b In the previous questionnaire, your copy of which is being returned to you for reference, the items included in the present tabulation have been circled. In your opinion, should any further item from that earlier list, because of its feasibility and potential effectiveness, have been included in our present listing for further consideration? If so, indicate these in the blanks at the end of Table 6.3a, and fill in your estimates of effectiveness, feasibility, and years of readiness, and state your reason for thinking that they ought to be included.

c Please look over the questionnaires which are being submitted to Panels 1 (SCIENTIFIC BREAKTHROUGHS) and 5 (WAR PREVENTION). If this perusal suggests any further weapon system items to you, please list these too at the end of Table 6.3a, and likewise estimate their effectiveness, feasibility, and years of readiness, and briefly indicate your reason for inclusion.

Table 6.3a

Item	Description	Average of panel's previous assessment: Potential Effect	Feas of Dev	Year ready under Crash Progr	Status Quo	Your revised assessment: Potential Effect	Feas of Dev	Year ready under Crash Progr	Status Quo	Reason for your opinion if any of your assessments differ substantially from the previous panel average
Def 1	Massive civilian defense and post war recovery plan	7	5	1968	1980					
Def 3	Rapidly mobile public-works and logistics units for war recovery and refugee support	5	7	1967	1980					
Def 5	Effective terminal defense by ground-launched anti-missiles	7	4	1970	1977					
Def 6	Effective terminal defense by air-launched anti-missiles	6	2	1970	1980					
Def 7	Effective terminal defense by directed energy beams	8	3	1975	1985					
Def 9	Orbiting space reconnaissance station	6	7	1969	1973					
Off 1	Lethal biological agents	4	8	1966	1970					
Off 2	Incapacitating biological agents	5	7	1967	1970					
Off 3	Biological agents destroying the will to resist	7	4	1970	1980					
Off 5	ICBMs with other than nuclear warheads (such as robot snipers)	5	8	1969	1972					
Off 6	Weather manipulation	7	4	1975	1980					

Table 6.3a (continued)

Item	Description	Previous average: Effect	Feas	Crash Progr	Status Quo	Revised assessment: Effect	Feas	Crash Progr	Status Quo	Reason
Off 7	Directed-energy weapons (electro-magnetic radiation particle beams, lasers)	8	3	1970	1978					
Off 10	Large orbiting satellite weapons for blackmail	2	7	1970	1975					
Lim 1	Automated tactical capability (battlefield computers, robot sentries, TV surveillance)	6	5	1969	1980					
Lim 2	Tactical kiloton nuclear weapons for use by ground troops	5	9	1965	1965					
Lim 3	Use of lasers for radar-type range sensors, illuminators, communications	6	7	1968	1970					
Lim 5	Longer-endurance aircrafts perhaps nuclear powered, for logistic supply or bombardment	5	7	1970	1975					
Lim 6	Rapid mobility of men and light weapons to any point on Earth for police action	8	7	1970	1975					
Lim 7	Perishable counter-insurgent arms	4	7	1965	1972					
Lim 8	Accurate intelligence correlation through use of computers	6	8	1968	1975					
Pol 1	Extensive use of devices which persuade without killing (water cannons, tear gas, etc.)	4	9	1964	1965					
Pol 2	Miniature improved sensors and transmitters for snooping, reconnaissance, arms control	6	6	1968	1971					
Pol 3	"Economic showmanship"; new foreign-aid techniques to influence nations	4	7	1963	1966					
Pol 5	Advanced techniques of propaganda, thought control, opinion manipulation	6	6	1968	1971					
Pol 6	Mind reading	3	2	2003	>2013					
Pol 7	Mass hypnotic recruitment of forces from enemy population	7	2	2003	>2013					
Nav 4	Effective anti-submarine capability, at least against contemporary subs	7	3	1970	1976					
Nav 5	Domesticated porpoises or dolphins for anti-submarine reconnaissance	2	7	1970	1980					
Nav 6	Deep-diving submersibles made of materials which decrease detection probability	6	4	1970	1977					

Questionnaire 4

6.4 WEAPON SYSTEMS

This is the last questionnaire in our present inquiry into opinions on weapon systems in the future.

Before going into further substantive questions, we would like to ask your preference as to whether or not a report on this study should mention your participation as a respondent. Under no circumstances will any direct quotations be attributed to you.

a. Check here if you have no objection to having your name mentioned as that of a respondent in this current study: ☐

To turn now to substantive matters, Table 6.4b on the following pages presents a summary of the panel members' opinions regarding the weapon systems submitted for their consideration previously. In addition to recording the majority opinions on each item's potential effectiveness, the feasibility of its development, the time when it might be operationally ready if a crash program toward its development were instituted, and the time of operational readiness if present attitudes regarding the system were to remain unchanged ("status quo"), we have also tabulated minority opinions on these questions together with brief statements of the reasons offered as to why they differ from those of the majority.

b. For each of the items in the following table, consider not only the stated majority opinions but also the merits of whatever reasons have been indicated for differing minority opinions; then, using your judgment as to whether the status quo will persist or a crash program is likely to be initiated, give us your estimate in the last column of the year when you expect the item to begin to be in operational use. (Write "N" for "never" if you think that this will never be the case.)

Table 6.4b

Item	Description	Panel's opinion on potential effectiveness (on a scale from 0 to 10)	Panel's opinion on feasibility of development (on a scale from 0 to 10)	Panel's opinion on time of operational readiness in case of a crash program	Panel's opinion on time of operational readiness if present status quo persists	Your opinion on time of operational readiness
Def 1	Massive civilian defense and post-war recovery plan	Majority: 5 to 8 Minority: 2 because the effect is more psychological than real Minority: 9 because even primitive shelters can be quite effective	Majority: 5 to 8 Minority: 2 because high cost of structures and relocation would cause great psychological and political resistance	Maj: 1968 to 70 Min: 1965 because in an emergency some shelters could be constructed in 2 months Min: 1972 because lead times make even a crash program slow starting	Maj: 1978 to 93 Min: 1971 because a CD program is now part of our official policy Min: never, because under the status quo there will not be enough public support	
Def 3	Rapidly mobile public-works and logistics units for war recovery and refugee support	Majority: 4 to 7 Minority: 2 because the effect is more psychological than real	Majority: 6 to 7	Maj: 1967 to 70 Min: 1972 because the assumption of a shorter development time would be unrealistic	Maj: 1975 to 80 Min: 1978 because ten years are ample for organizing and funding the status-quo program	
Def 5	Effective terminal defense by ground-launched anti-missiles	Majority: 6 to 9 Minority: 10 because of operational advantages over other anti-missile defenses	Majority: 2 to 6 Minority: 1 because penetration aids can keep ahead of anti-missiles	Maj: 1970 to 75 Min: 1967 because solution of key propulsion problems already started Min: 1980 because discrimination and saturation will remain major problems	Maj: 1975 to 90 Min: 1973 because NIKE improvements are under development Min: never, because the defense will always lag the offense at current relative pace	
Def 6	Effective terminal defense by air-launched anti-missiles	Majority: 4 to 8 Minority: 2 because greater effectiveness would require huge expense Minority: 9 because the enemy, in trying to knock out defenses, would be faced with a highly distributed target system	Majority: 2 to 4 Minority: 1 because it would require accurate maneuverable, and therefore heavy, missiles unlikely to be lifted by aircraft	Maj: 1970 to 75 Min: 1985 because of the difficulties of airborne control devices	Maj: 1980 to 85 Min: 1975 because under the status quo only a few years should be added to the readiness date under a crash program Min: 1990 because of the difficulties of airborne control devices	
Def 7	Effective terminal defense by directed energy beams	Majority: 8 to 10 Minority: 5 because technical difficulties would preclude higher effectiveness	Majority: 1 to 3 Minority: 0 because the energy requirements are too high	Maj: 1975 to 80 Min: 1990 because excessive power requirements will delay this approach	Maj: 1985 to 95 Min: 2000 because, unless there is a crash program, funds will be insufficient	
Def 9	Orbiting space reconnaissance station	Majority: 5 to 8 Minority: 4 because by 1970 low-quality reconnaissance will be of limited value Minority: 9 because it will be useful for bomb damage assessment	Majority: 6 to 8	Maj: 1968 to 70	Maj: 1972 to 75	

Table 6.4b (continued)

Item	Description	Effectiveness	Feasibility	Crash program	Status quo	Your opinion
Off 1	Lethal biological agents	Majority: 3 to 5 Minority: 1 because their uncontrollability makes them difficult to use operationally Minority: 7 because they are lethal by definition	Majority: 6 to 10 Minority: 4 because delivery presents a real problem, and development of antidotal medication will make lethality less feasible	Maj: 1968 to 70 Min: 1975 because public resistance must first be overcome	Maj: 1968 to 75 Min: 1968 because they are in fact in existence now Min: 1980 to 85 because of public resistance and the difficulty of the delivery problem	
Off 2	Incapacitating biological agents	Majority: 3 to 6 Minority: 8 because of covert and limited-war applications	Majority: 6 to 10 Minority: 4 because delivery presents a real problem, and development of antidotal medication will make lethality less feasible	Maj: 1968 to 68 Min: 1970 to 75 because public resistance must first be overcome	Maj: 1968 to 75 Min: 1968 because they are in fact in existence now Min: 1985 because of public resistance and the difficulty of the delivery problem	
Off 3	Biological agents destroying the will to resist	Majority: 5 to 10 Minority: 2 because they are difficult to use operationally	Majority: 3 to 8 Minority: 1 because no promising work on new agents seems to be going on Minority: 10 because they are in fact in existence now	Maj: 1967 to 75 Min: 1968 because they are in fact in existence now	Maj: 1975 to 85 Min: 1968 because they are in fact in existence now	
Off 5	ICBMs with other than nuclear warheads (such as robot snipers)	Majority: 2 to 6 Minority: 1 because delivery is too dramatic and observable for effective surprise tactics	Majority: 6 to 10	Maj: 1965 to 70 Min: 1972 because accurate guidance requirements will cause delays	Maj: 1969 to 76 Min: 1980 because there is not much current interest, and cost will be a considerable factor	
Off 6	Weather manipulation (for military purposes)	Majority: 5 to 8 Minority: 3 because of possible negative effect on Allies	Majority: 2 to 6 Minority: 1 because nothing promising under development Minority: 8 because something of the kind is already possible	Maj: 1968 to 75 Min: 1980 because of difficulty of eliminating negative side-effects	Maj: 1975 to 85 Min: 1973 because active work on this is now in progress Min: 2000 because of difficulty of eliminating negative side-effects	
Off 7	Directed-energy weapons (electromagnetic radiation, particle beams, lasers)	Majority: 8 to 10 Minority: 3 because directionality is seldom important in offensive weapon systems	Majority: 2 to 5 Minority: 1 because of prohibitive costs	Maj: 1968 to 72 Min: 1975 to 85 because much development work is still necessary	Maj: 1975 to 85 Min: 88 to 2000 because prohibitive energy requirements, and therefore costs, will cause delays	
Off 10	Large orbiting satellite weapons for blackmail	Majority: 0 to 4 Minority: 6 because the psychological cold-war advantage might be great	Majority: 6 to 8	Maj: 1965 to 70 Min: 1975 because safety requirements would cause delays	Maj: 1970 to 80 Min: 1969 because both weapons and boosters will be available Min: never, because an agreement exists not to do this	
Lim 1	Automated tactical capability (battlefield computers, robot sentries, TV surveillance)	Majority: 5 to 8 Minority: 2 to 5 because of power demands, maintenance difficulties, and vulnerability Minority: 9 because of the large advantage over insurgents	Majority: 5 to 7 Minority: 2 because of enormous system complexities	Maj: 1968 to 70 Min: 1975 because of considerable technical and cost problems	Maj: 1975 to 80 Min: 1973 because this is already under development	
Lim 2	Tactical kiloton nuclear weapons for use by ground troops	Majority: 3 to 7 Minority: 2 because of the danger represented by the tenuousness of the nuclear/non-nuclear line Minority: 8 because it may prevent escalation by offering one more opportunity for controlled, graduated response	Majority: 9 to 10	Maj: 1964 to 65	Maj: 1964 to 66	
Lim 3	Use of lasers for radar-type range sensors, illuminators, communications	Majority: 5 to 8 Minority: 2 because this would be no big improvement over ordinary radar Minority: 9 because this is so important as to be already under intensive development	Majority: 6 to 9	Maj: 1965 to 70	Maj: 1970 to 75 Min: 1967 because it is already under intensive investigation Min: 1980 because of difficulties in overcoming problems of thermospheric attenuation	

Table 6.4b (continued)

Item	Description	Effectiveness	Feasibility	Crash program	Status quo	Your opinion
Lim 5	Longer-endurance aircraft, perhaps nuclear-powered, for logistic supply or bombardment	Majority: 5 to 7 Minority: 2 because this is no big improvement over present aircraft Minority: 9 because of many uses in a long war, such as delivery of air-to-surface weapons, tactical airlift, command and control, tankers	Majority: 6 to 9	Maj: 1970 Min: 1975 because of boundary layer control problems and delays in power plant development	Maj: 1973 to 78 Min: 1985 because of boundary layer control problems and delays in power plant development	
Lim 6	Rapid mobility of men and light weapons to any point on Earth for police action	Majority: 7 to 10	Majority: 6 to 10	Maj: 1965 to 70 Min: 1964 because this is essentially available now Min: 1975 because it will take that long to build up transport capability	Maj: 1967 to 75 Min: 1964 because this is essentially available now Min: 1980 because it will take that long to build up transport capability	
Lim 7	Perishable counter-insurgent arms	Majority: 2 to 5 Minority: 7 because it would prevent enemy use of captured weapons if given to friendly indigenes	Majority: 5 to 8	Maj: 1965 to 68 Min: 1970 because a suitable mechanism has yet to be invented, and extended tests would be required	Maj: 1970 to 75	
Lim 8	Accurate intelligence correlation through use of computers	Majority: 6 to 9 Minority: 3 because of need for judgment, which cannot be mechanized away	Majority: 5 to 8	Maj: 1966 to 70 Min: 1978 because of the absence of an adequate theory as to what data should be processed and how	Maj: 1970 to 80 Min: 1964 because appropriate computers are essentially available now Min: 1990 because of the absence of an adequate theory as to what data should be processed and how	
Pol 1	Extensive use of devices which persuade without killing (water cannons, tear gas, etc.)	Majority: 3 to 5	Majority: 9 to 10	Maj: 1964 to 65 Min: 1970 because it would take some time to decide what weapon systems are promising	Maj: 1964 to 69 Min: 1980 because there is little active interest in this area now	
Pol 2	Miniature improved sensors and transmitters for snooping, reconnaissance, arms control	Majority: 4 to 7 Minority: 9 because this will make it possible to make use of pinpointed information	Majority: 6 to 8 Minority: 9 because something like this is already in existence	Maj: 1965 to 68	Maj: 1968 to 73	
Pol 3	"Economic showmanship"; new foreign-aid techniques to influence nations	Majority: 3 to 6 Minority: 0 because past efforts have been unimpressive Minority: 9 because display of economic power is evidence of military power	Majority: 6 to 7	Maj: 1964 to 65 Min: 1966 because we are at present moving away from this	Maj: 1964 to 72	
Pol 5	Advanced techniques of propaganda, thought control, opinion manipulation	Majority: 4 to 7 Minority: 9 because Madison Avenue experts could make baseball fans of bushmen	Majority: 5 to 7 Minority: 2 because you can't buy a lot by manipulating minds that are vulnerable to manipulation	Maj: 1964 to 70 Min: 1975 because significant progress is slow in an area like this	Maj: 1968 to 75 Min: 1985 because significant progress is slow in an area like this	

Table 6.4b (continued)

Item	Description	Effectiveness	Feasibility	Crash program	Status quo	Your opinion
Pol 6	Mind reading	Majority: 6 to10 Minority: 2 because most minds aren't worth reading	Majority: 0 to 2	Maj: 84 to 2024 Min: 1970 because military projects aimed at this exist Min: never, because mind reading requires the subject's cooperation	Maj: after 2013 Min: 1980 because military projects aimed at this exist Min: never, because mind reading requires the subject's cooperation	
Pol 7	Mass-hypnotic recruitment of forces from enemy population	Majority: 6 to 9	Majority: 0 to 2	Maj: after 2000 Min: 1980 because of increased knowledge and control of thinking mechanics Min: never, because hypnosis requires the subject's cooperation	Maj: after 2013 Min: 1980 because of increased knowledge and control of thinking mechanics Min: never, because hypnosis requires the subject's cooperation	
Nav 4	Effective anti-submarine capability, at least against contemporary submarines	Majority: 6 to 8	Majority: 3 to 4	Maj: 1968 to 70	Maj: 1974 to 80 Min: 1972 because this is very nearly a crash program already	
Nav 5	Domesticated porpoises or dolphins for anti-submarine reconnaissance	Majority: 0 to 3	Majority: 3 to 7 Minority: because of training and communication problems and of obtaining enough animals	Maj: 1970 to 75 Min: 1967 because if it can be done at all it can be done soon Min: 1978 because of the difficulty of transforming a basic capability into a militarily useful system	Maj: 1975 to 93 Min: 1970 because if it can be done at all it can be done soon Min: never, because no such project exists at present	
Nav 6	Deep-diving submersibles made of materials which decrease detection probability	Majority: 4 to 8 Minority: 3 because the detection probability is already quite small	Majority: 4 to 6 Minority: 1 because the high-strength requirement is incompatible with anything but metals Minority: 8 because this is already under development	Maj: 1970 to 75 Min: 1968 because this is already under development Min: 1980 because progressive anti-submarine capabilities (Nav 4) have to be counteracted	Maj: 1975 to 85 Min: 1968 because this is already under development Min: 2000 because progressive anti-submarine capabilities (Nav 4) have to be counteracted	

c. The following three additional weapon systems have been proposed by respondents for consideration. Please give us your estimates of their potential effectiveness, the feasibility of their development, and of the expected time when first in operational use:

Table 6.4c

Item	Description	Effectiveness	Feasibility	Year of first operational use
Off 20	Penetrating nuclear weapons for deep cratering			
Off 21	Incapacitating chemical (as opposed to biological) agents			
Lim 9	Cheap light-weight rocket-type personnel armament (silent, plastic, match-lit projectiles, capable of single or gang-firing)			

d. Do you wish to add any comments? In particular, is there anything further you wish to say in support of your views as expressed in your responses in the foregoing tables?

PART B: THE RESPONDENTS

Of the 82 respondents, 35 were members of the RAND staff, 7 were RAND consultants, and the remaining 40 were unaffiliated with RAND; 8 of the latter were overseas participants.

The following is a list of those nonmembers of RAND who gave us explicit permission to mention their participation:

Clark Abt
Isaac Asimov
Robert E. Beerstecher
K. A. Brueckner
M. C. Bryson
Arthur C. Clarke
Starr J. Colby
Bertrand de Jouvenel
Ithiel de Sola Pool
John D. Durand
Leonard L. Fischman
Dennis Gabor
Peter C. Goldmark
Harold Guetzkow
Harold Gumbel
R. J. Gunkel
R. W. Hamming
T. C. Helvey
Carl G. Hempel
Werner Z. Hirsch
Eric Klippenberg
Ferdinand Lundberg
Alexander Mood
Frederick Osborn
John E. Pfeiffer
William H. Pickering
Martin Shubik
Stephen Toulmin
Warren W. Weaver
E. P. Wheaton
J. R. Woolpert

A breakdown of all panelists by professional background is as follows:

Economists	12
Engineers	20
Mathematicians and logicians	14
Military officers	1
Operations analysts	4
Physical scientists	17
Social scientists	9
Writers	5
Total:	82

The total number of responses (i.e., at least partly completed questionnaires) was 348. Many respondents participated in fewer than 4 rounds of questionnaires; on the other hand, quite a few volunteered responses to questionnaires addressed to panels other than their own, and such volunteers were thereafter considered to be members of those panels also.

Table 1 gives the total number of responses per round for each panel.

Table 1

NUMBER OF RESPONSES PER ROUND FOR EACH PANEL

Round	Panel					
	1	2	3	4	5	6
1	15	12	10	18	18	17
2	11	7	10	10	12	13
3	18	10	15	15	13	15
4	23	13	19	18	17	19
Total	67	42	54	61	60	64

Thus the average number of responses per round was 87, the average per panel was 58, and the average per questionnaire was $14\frac{1}{2}$.

To give some idea of the degree of stability of participation, we have tabulated below for each panel (including volunteers from other panels) the percentage of its participants who responded to all 4, to 3, to 2, and to 1 questionnaire, respectively.

Table 2

PERCENTAGE OF EACH PANEL
PARTICIPATING IN VARIOUS NUMBERS OF ROUNDS

Number of Rounds Participated in	Panel (%)					
	1	2	3	4	5	6
4	8	17	15	21	19	40
3	17	0	19	14	3	12
2	28	30	23	21	25	12
1	47	52	42	45	53	36

PART C: QUOTATIONS

As a byproduct of the study we received a large volume of comments in the form of correspondence or marginal notes added to the questionnaires. The following quotations represent a small selection of such comments, which seemed to us especially noteworthy.

"The descriptions...are so brief and vague that most guesses as to effectiveness, feasibility and earliest date are very hard to interpret... People who agree on every aspect of technology and political science might still find themselves on opposite ends of a range of guesses because of differences in interpreting the questions."

"We hesitate to call anything impossible... There seems to be a feeling that hardly anything is beyond us, that we can solve any precisely formulated problem...This confidence among scientists contrasts strangely with the lack of confidence among 'humanists' in man's future."

"I would prefer the opinion of one expert to the opinion of several diluted by a multitude of incompetent guessers."

"I believe that one overwhelming breakthrough which is imminent is in the field of behavioral science. It will be a realization that we cannot successfully predict the future because its nature depends on discoveries as yet unmade and inventions as yet uninvented."

"There is no relation between level of technology and level of employment. Technological change is no more rapid now than it has been over the past 100 years."

"Most minds aren't worth reading."

"China is working unwittingly toward US-SU agreement to seek peace and restrain other nations from developing nuclear weapons."

"...on some political questions I have become more optimistic...A minimum of sense will be enough to bring about if not a treaty but at least a working understanding with the USSR. Only for God's sake leave Germany divided!"

"I have seen with great interest the list of suggestions for lessening the probability of war. ...I have felt compelled to assign negative efficiencies to some of them...'The offer of nuclear weapons to countries that agree to support our (U.S.) stated national policies' seems to me of negative value...(since a) present government cannot bind its country for the future...I also regard as of negative value: 'Clear U.S. statement

as to which national interests are to be protected by nuclear deterrents, and orientation of our policies to that end.' Indeed its negative value seems to me considerable...By implication you will be giving permission to do all the things against which you do not promise a given reaction. The measure to which I attach far the greatest negative value is 'Strengthening of U.N. with the objective of forming a world government.' I regard the establishment of a world government with the utmost distrust...My concern is not for the collective independence of the nation but for the personal liberty of the individual. Throughout history, men have escaped from a realm of oppression to one where they were safe from oppression...If you reduce the planet to one realm, this escape hatch disappears...But, you will say, a world government does not mean the collapsing of all the various States into one realm, only a general supervision of the various States. That is what the advocates of World Government believe. But are they right? Is there a single instance in history of a super-authority which has not either become futile (like the Holy Roman Empire) or moved towards unitarian government..."

PART D: CONVERGENCE OF OPINIONS

The graphs on the following pages display the convergence of opinions in the case of questions which were asked more than once. (See Section 16 above.) Solid lines refer to medians, broken lines to quartiles of opinions. The numerals shown along the abscissa in Figures 1 and 2 indicate the questionnaire number. Labels below the figures identify the particular question.

MEDIANS AND QUARTILES OF REPEAT QUESTIONS

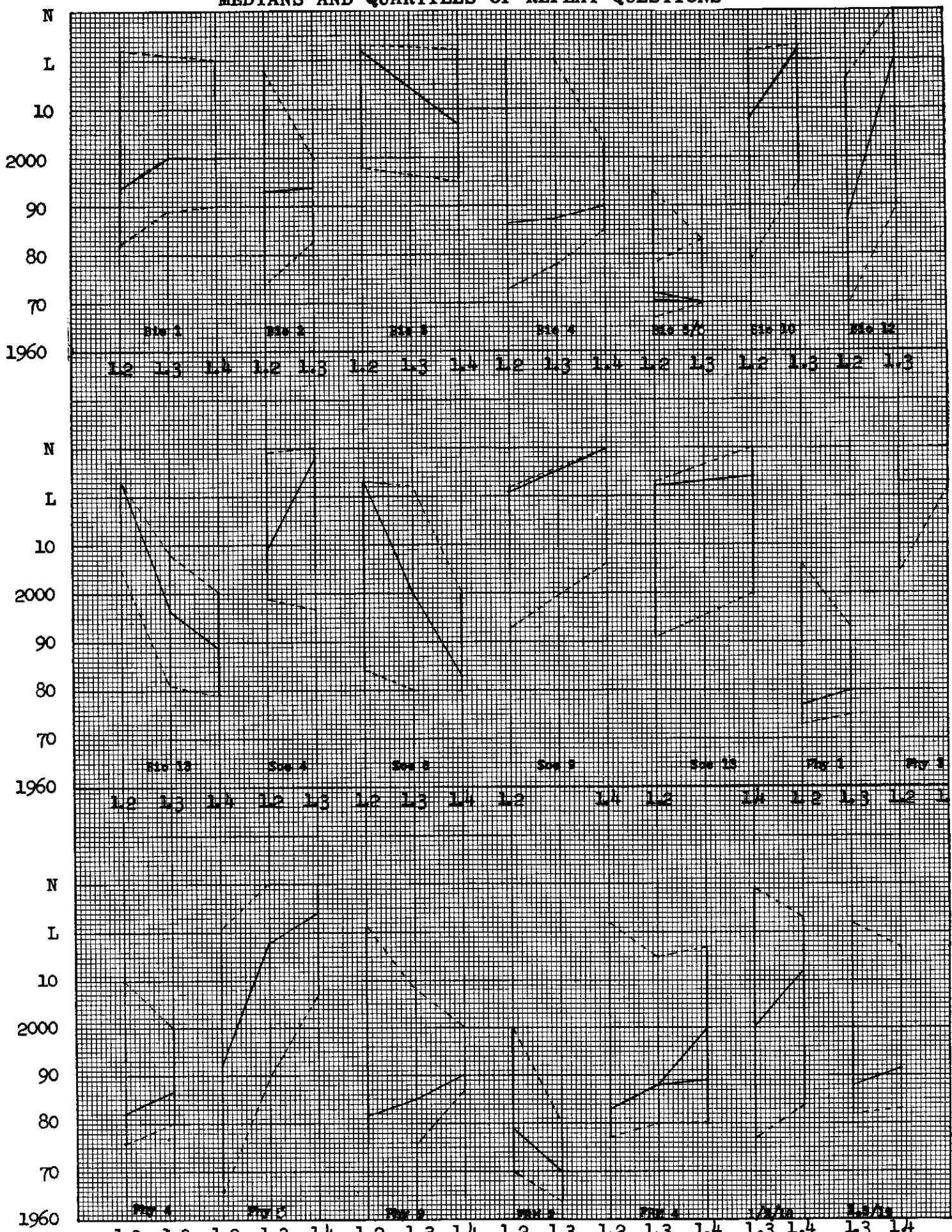


Fig. 1

MEDIANS AND QUARTILES OF REPEAT QUESTIONS

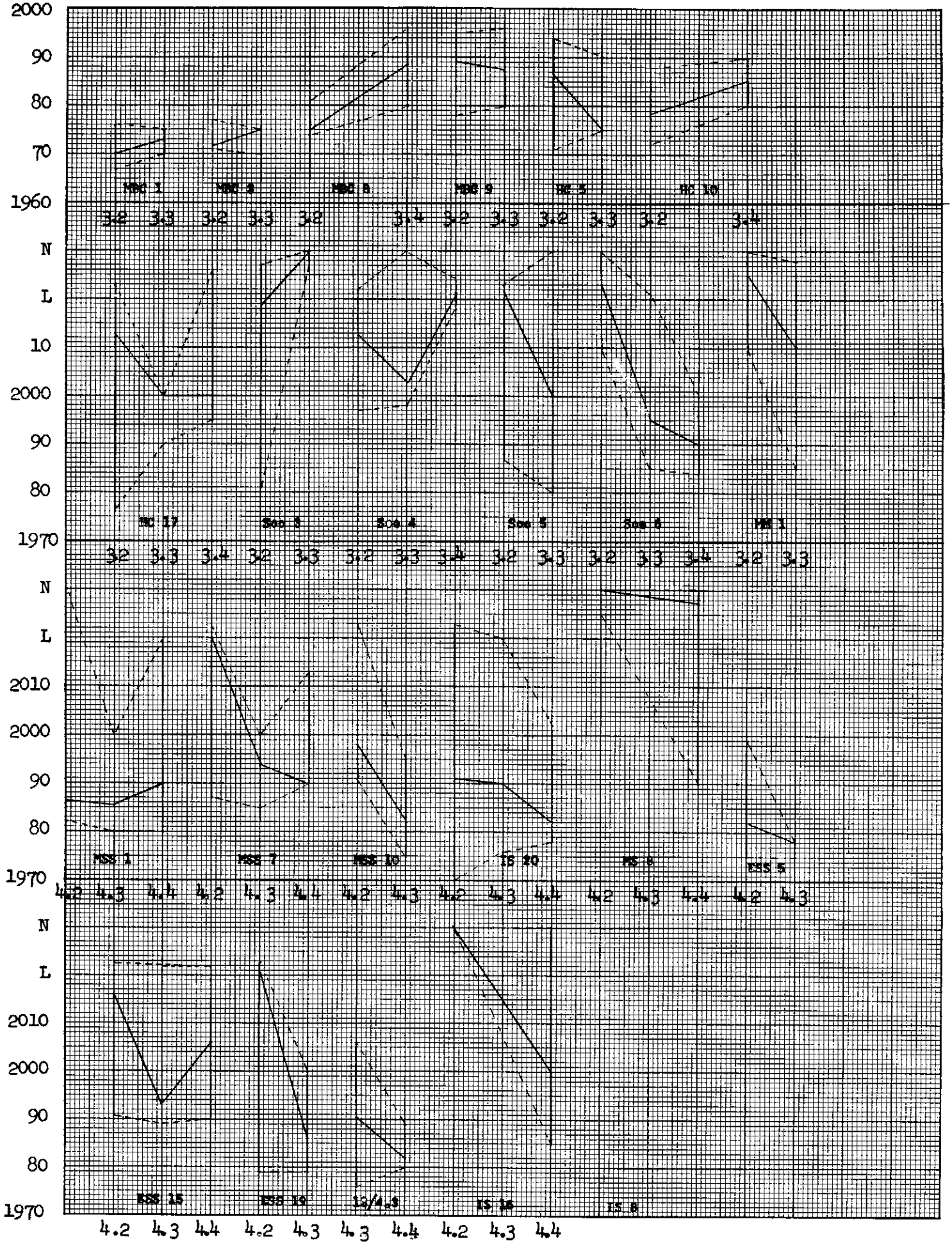


Fig. 2

MEDIANS AND QUARTILES FOR 6.2 AND 6.3

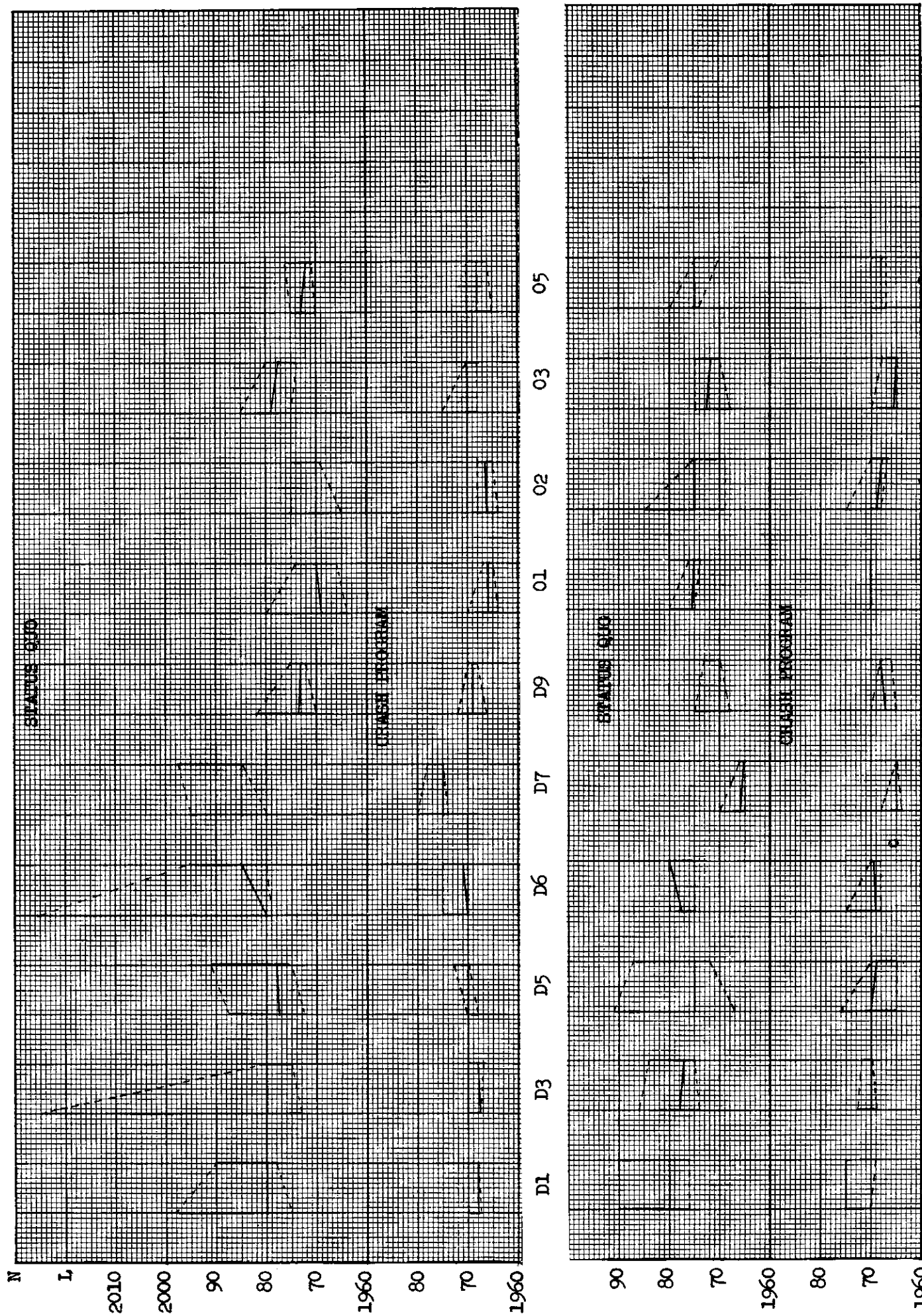


Fig. 3