

INFORMATION TO USERS

This material was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.
2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.
3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in "sectioning" the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again — beginning below the first row and continuing on until complete.
4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from "photographs" if essential to the understanding of the dissertation. Silver prints of "photographs" may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.
5. PLEASE NOTE: Some pages may have indistinct print. Filmed as received.

Xerox University Microfilms

300 North Zeeb Road
Ann Arbor, Michigan 48106

76-21,329

WISE, George, 1944-
TECHNOLOGICAL PREDICTION, 1890-1940.

Boston University Graduate School, Ph.D., 1976
History, United States

Xerox University Microfilms, Ann Arbor, Michigan 48106

© 1976

GEORGE WISE

ALL RIGHTS RESERVED

BOSTON UNIVERSITY

GRADUATE SCHOOL

TECHNOLOGICAL PREDICTION, 1890- 1940

by

George Wise

M.S., University of Michigan, 1968

submitted in partial fulfillment of the

requirements of the degree of

Doctor of Philosophy

1976

Approved by

First Reader Robert V. Bruce
Robert V. Bruce
Professor of History

Second Reader Saul Engelbourg
Saul Engelbourg
Professor of History

PREFACE AND ACKNOWLEDGMENTS

This dissertation seeks to answer the question: "how accurate have been predictions about future technological developments?" I thank Dr. Robert V. Bruce for the suggestion which led to my choice of this topic, for his help during the initial stages, and for his comments and suggestions on earlier drafts of this dissertation.

I also thank Dr. Saul Engelbourg and Bonnie A. Wise for reading a draft and for making comments and suggestions.

While writing most of this dissertation I was an employee of the General Electric Company. However, nothing expressed in this dissertation should be attributed to that company or to any other employee of it. General Electric in no way supported my work on this dissertation, and no person in a responsible position in the company has read it (although one of them was offered the opportunity to do so).

I thank the Houghton Library, Harvard University, Cambridge, Mass., for permission to examine the papers of Edward Bellamy; the Columbia University Library, New York City, for permission to examine the Nikola Tesla Collection; the Schenectady Archives of Science and Technology, Schenectady, New York, for permission to examine the papers of Charles Proteus Steinmetz and Ernst F. W. Alexanderson; and the Whitney Library of the General Electric Research and Development Center, Schenectady, New York, for permission to use much of their reference material on GE scientists and engineers.

Finally, I thank Mr. R. Ned Landon, my boss at the General Electric Research and Development Center, Schenectady, New York, for his encouragement to finish my doctoral work at Boston University; and Bonnie A. Wise for supporting me during the first three years of my graduate work.

TECHNOLOGICAL PREDICTION, 1890- 1940

(Order No.)

George Wise, Ph.D.

Boston University Graduate School, 1976

Major Professor: Robert V. Bruce

Professor of History

ABSTRACT

Many Americans living during the period 1890 to 1940 sought to predict future technological achievements, and the expected social effects of those achievements. Simple quantitative analysis of the outcomes of such predictions supplies a rough measure of ability to make such predictions correctly. More detailed study of the themes of prediction, and the changing emphasis on various themes over time, shows how hopes, fears, and expectations influence each other.

The quantitative results indicate that roughly one prediction in three of a sample of some 1500 predictions about technology made from 1890 to 1940 was confirmed by events. An equal percentage was proven wrong. Of the remaining unproven predictions, only one-fourth seem presently to be in the process of coming true.

Predictions about the effects of technology proved far less accurate than predictions of future technological events. Persons with technical training proved slightly better predictors than those without such training. Other attributes which might have been expected to affect

predictive accuracy, such as specialized technical knowledge of a particular field, tendency to predict change (as opposed to predicting maintenance of the status quo), and predicted time lag between prediction and realization, appear not to have had a significant effect on accuracy.

Eight specific cases exemplified three dominant themes of prediction. Some predictors saw technological change as a pervasive influence, shaping future society in discernable ways. Others saw resource limitations imposing limits on future progress. Still others sought to identify aspects of technology that might become threats to mankind.

In pursuing each theme, predictors used one or more of six basic methods of prediction: intuition; analogy; trend extrapolation; leading indication (the effort to identify turning points); scenario writing; and deduction. Each of these methods led to some successful predictions; but none stood out from the others as especially productive of useful insights about the future.

Biases or choices of method by forecasters do not seem to explain the modest record of accuracy achieved by forecasters. The record seems rather to reflect the

existence of genuine uncertainty and the possibility of a wide range of choice on the part of society as to which technologies to develop (and therefore which predictions to prove correct). A better understanding of the nature of this uncertainty can serve as a warning against basing policy solely on predictions. It can also help historians form a more balanced assessment of past technological decisions than is allowed by an assumption of technological determinism.

TABLE OF CONTENTS

PREFACE AND ACKNOWLEDGMENTS

Chapter I:	The Climate of Prediction	11
Chapter II:	A Vision of A White City: 1890-1914	33
Chapter III:	Thinking About Resources: 1890-1914	75
Chapter IV:	Technology as a Threat to Man: 1890-1914	104
Chapter V:	An Age of Efficiency: 1915-1929	135
Chapter VI:	When the Oil Runs Out: 1915-1929	176
Chapter VII:	The Destructive Potential of Technology: 1915-1929	209
Chapter VIII:	The Next Big Industry: 1930-1940	239
Chapter IX:	Technology's Early Warnings: 1930-1940	263
Chapter X:	Conclusions: From Prediction to Fore- casting	296
APPENDIX:	Statistics and Data on the Climate of Prediction	316
BIBLIOGRAPHY		334

CHAPTER I

THE CLIMATE OF PREDICTION

The novel Looking Backward, published in 1888, made Edward Bellamy one of America's most popular novelists. But Bellamy's forte was social commentary, not literature. In Looking Backward he described a model society of the year 2000 whose political and economic institutions were, he thought, suited to realizing the utopian promise of twentieth century technology.

To gather material for a sequel, Bellamy sought technological detail to fill out his picture of future society. Among those supplying information was a young Boston engineer named Sidney A. Reeve, an expert on the construction and installation of steam and gas engines. Bellamy's conclusions included the following notebook entry:

Talks with an engineer.

There is at present a simply boundless supply of costless power at the disposal of man.¹

In Bellamy's sequel, Equality, this concept played a central role. "Let me tell you now," stated a scholar of the year 2000 to a time-traveling visitor from the 1890's

¹ Bellamy Notebooks, Plots #2, p. 6; and letter from Sidney A. Reeve to Arthur E. Morgan, Jan. 4, 1950. Edward Bellamy Papers and Arthur E. Morgan Letters Concerning Bellamy, Houghton Library, Harvard University.

as a first step toward the understanding of modern conditions, that power, with all its applications of light, heat, and energy is today practically exhaustless and costless, and scarcely enters into our calculations. ²

In this way, an engineer's technical prediction about energy found its way into a popular political and social tract. Not only Bellamy, but also contemporaries like Henry George and Henry Adams, began in the 1890's to include technological considerations in their social, economic, and political writings.

Nearly half a century later, three physicists met at Peconic, Long Island, to discuss another prediction about energy. Leo Szilard, Eugene Wigner, and Albert Einstein sought to assess the indications, arising from some recent experiments, that a uranium bomb of previously undreamed-of explosive power could be built. As Szilard later recalled:

The possibility of a chain reaction in uranium had not occurred to Einstein. But almost as soon as I began to tell him about it he realized what the consequences might be and immediately signified his readiness to help us and if necessary "stick his neck out."

At a second meeting, Einstein signed a letter to President Roosevelt endorsing the prediction. The letter, delivered to the president by financier Alexander Sachs in October, 1939, played a small part in convincing the president that work on the atomic bomb

2 Edward Bellamy, Equality (Boston: Appleton, 1897), p. 69.

should be carried forward.³

These two examples indicate roles played by technological predictions in spurring discussion and decision from 1890 through 1940. Whether the aim is to change society (as Bellamy hoped to do) or to establish political control over a grave technological threat (as Szilard, Wigner, and Einstein sought to do), directed action is impossible without prediction.

But if action without prediction is aimless, action based on incorrect predictions can be harmful. Excessive confidence in predictions about the future can cause decision makers to ignore dangers or ethical problems inherent in a course of action. On the other hand, ignoring valid predictions can be just as disastrous.

This situation seems especially marked in the case of decisions regarding technological developments. The final decision maker (for example, President Roosevelt in the atomic bomb example cited above) usually knows little about the technical matter involved. He must rely on the predictions and assessments made by his advisors (some, but not all, of whom are experts in the technical field involved) about the practical consequences of a decision to go ahead or to halt. How much

³ Robert Jungk, Brighter Than a Thousand Suns (New York: Grove Press, 1958), pp. 83-84; see also Ronald W. Clark, Einstein (New York: Avon, 1971), pp. 668-683. Note that there is still debate as to whether the Einstein letter accelerated the atomic bomb program; some sources say it had no effect, while others suggest it may even have retarded efforts.

confidence should he place in those predictions and assessments?

The object of this study is to give a partial answer to that question. The study is based on a collection of some 1500 predictions made by Americans between the years 1890 and 1940 about the probability of success, and expected effects, of specific technological developments. The dates mark off a period recent enough for ample records, but remote enough for a provisional evaluation of predictive accuracy. The subject area of technology was chosen because it was often a field for predictors, because its content was rapidly changing, and because I was, and still am, interested in it.

The universe of such predictions includes all made orally or in writing, publicly or privately, and on any level of specificity, by any American in the given period. To arrive at a manageable sub-universe, I imposed several restrictions. First, predictions had to be written down within a short time after being made. Memories about what an individual believed some time in the past are not included. Predictions made in interviews or congressional hearings are included if printed within a year after the event.

Second, only predictions included in publicly available sources were used. A check of the private papers of several predictors

included in this study⁴ did not reveal major differences between the predictions these individuals made in published articles, interviews, speeches, and other public utterances and the views they expressed in private letters or papers.

Third, to make the predictions comparable, they were restricted to statements made about the probability of occurrence or effects of generic classes of technological developments.⁵ On the one side, this excluded sweeping statements about entire fields of activity (for example, a prediction that transportation methods will continue to improve). On the other side, it excluded predictions comparing two technological developments differing in technical details only (for example, a prediction that a gas-filled incandescent lamp would prove superior to a vacuum incandescent lamp), unless the technical details made a qualitative difference in the services provided by the development (as in the case of the electric railroad as compared to the steam railroad).

These three restrictions defined a sub-universe. The sample

4 Letters and papers of Alexander Graham Bell, Edward Bellamy, Elihu Thomson, Nikola Tesla, Charles P. Steinmetz, and the "Reports of Work" of scientists and engineers at the General Electric Research Laboratory (now the General Electric Research and Development Laboratory, Schenectady, New York).

5 A generic class of technology is a distinct method of fulfilling a technological need. For example, the generic class "automobiles with internal combustion engines" is a generic class within the need area "transportation technology."

of over 1500 predictions was collected systematically, not randomly, from that sub-universe. It cannot be said to be statistically representative of that sub-universe. However, to avoid biases: 1) I searched all public sources I was able to locate that seemed likely to include predictions about technology (that is, my search was limited by time and lack of imagination, not by deliberate biases); and 2) whenever any prediction was used from a given article, speech, or other such source, all predictions from that source were collected (that is, I did not pick and choose among predictions I found, but included all that met the three criteria mentioned above).

What kinds of questions have I asked about these predictions? Obviously, the principal one is, were they mostly right or mostly wrong? But other issues are also of interest. Are there characteristics of a prediction (such as the identity of the predictor, or the subject matter of the prediction) that increase the likelihood that the prediction will prove correct? How were errors of predictions divided between two main types: the error of overlooking or rejecting something that does eventually happen, and the error of predicting something that does not happen?

The remainder of this chapter will offer some rough answers to these questions. (Statistics supporting the conclusions detailed in this chapter are in the Appendix). Succeeding chapters will go beyond

statistics to discuss specific examples of prediction in the period 1890 to 1940: instances wherein forecasters went wrong, and instances wherein they went right. A final chapter will speculate upon the lessons to be learned from the performance of predictors of technology in the period 1890 to 1940, particularly as they might help evaluate the claims of the forecasters active in the 1970's.

In selecting the sample, the subject area, technology, was defined to include "those developments which affect the way people satisfy their needs for energy, transportation and communication, automation, materials, domestic shelter and convenience, and weaponry."

A prediction is defined as a statement about the future that is sufficiently definite to admit of being eventually proved true or false. Predictions fall into two classes. Event predictions state that a certain event will occur or achievement will be recorded in the future. An example of an event prediction is the 1928 statement that "aviation experts confidently forecast transatlantic dirigible services which will set Manhattan less than 40 hours from London."⁶ The other type of prediction, an effect prediction, deals with the effect that a technological event would have, were that event to occur. An example is the 1931 prediction: "as long as outside-home electrical-powered

⁶ Time, IX (2 January 1928), p. 22.

entertainments are cheaper than home ones, the family's importance will diminish."⁷

In judging the validity of both event and effect predictions, four categories are defined. These categories are:

(1) Right: the event or effect predicted occurred within the time limit set in the prediction (or it occurred eventually, and no time limit was set). An example of a "right" prediction is this one, made in 1896: "there are some (alive today) who will live to see the time when the steam locomotive will be considered a curiosity."⁸

(2) Established: at the time of judging validity, the prediction appears to be coming true.⁹ This process must be manifested in facts (for example, a pilot plant, or definite evidence of the beginnings of an effect) not merely in new predictions. An example of a prediction that was classed as established, is this one from 1936: "with our present light we do not see probable (future energy) sources as readily and cheaply available as those we are now enjoying."¹⁰ A prediction may reach the established stage without advancing into the classifica-

7 William F. Ogburn, "The Future of Man in Light of His Past, Scientific Monthly, XXXII(1931), 297.

8 Louis D. Duncan, "The Future of Electricity in Railroad Work, " Journal of the Franklin Institute, CXLI (1896), 416.

9 July-August, 1974.

10 William Durand, quoted in Transactions of the Third World Power Conference, 1936 (2 Vols.; Washington: Government Printing Office, 1938) I, 190.

tion "right." Predictions favorable to large producer-gas engines would have been regarded as established in the decade 1900-1910; those favoring the dirigible would have seemed established around 1930. Neither of these types of predictions would be classed as either established or right today.

(3) Not proven: at the time the judgment of validity was made, the prediction had not been fulfilled, nor was it judged to be in the process of occurring; but nothing had come about to make the prediction impossible of fulfillment. An example of a "not proven" prediction is the 1895 statement that "it is not impossible that transmission plants of various kinds may from the winds and waters furnish an overflowing supply of energy, thus forever setting at rest the minds of those who fear an exhaustion of the coal fields."¹¹ The replacement of fossil fuel by wind and water power has not occurred. I doubt that it will ever occur. But I cannot prove it impossible.

(4) Wrong: the predicted event has not yet occurred, and cannot occur. A prediction can be wrong because it labels as an impossibility a development which later occurs. Such is the case with the 1924 prediction that "no hope apparently exists for any known

¹¹ Arthur Vaughn Abbot, "Industrial Niagara," Review of Reviews, XII (1895), 295.

additional supply to the present known gas wells."¹² A prediction can be wrong because it contains a time limit that has expired. An example that is wrong only because of its timing is the 1931 statement that television would be "a commonplace in our business and social life within five years."¹³ Finally a prediction may be wrong because it specifies the wrong order for the occurrence of two events or effects. For example a 1938 predictor stated that the use of atomic energy as a power source was even further off than the general use of solar, wind or tidal power.¹⁴

A last bit of categorization will simplify the following discussion. The term "good" prediction will be applied to a prediction which is either "right" or "established"; predictions that are "not proven" or "wrong" will be called "bad" predictions. The "batting average" of a predictor or class of predictions is defined as the number of good predictions by that predictor or in that class, divided by the total number of predictions made by that predictor or in that class.

The total collection of predictions for the years 1890-1940 can be divided among the above-defined categories as follows:

12 Robert H. Fernald, "Fuel Wastes: Causes, Effects, Remedies," Annals of the American Academy of Political and Social Science CXI (1924), 232.

13 Floyd W. Parsons, "A Look Ahead," Saturday Evening Post, CXCH (Aug. 9, 1931), 150.

14 Vannevar Bush, "Significant Trends in the Development and Utilization of Power Resources," Trans. Third World Power Conference, 1936 (2 Vols.; Washington: GPO, 1938), I, 656.

Right: 499 predictions (32% of the total)

Established: 121 predictions (8% of the total)

Not Proven: 420 predictions (27% of the total)

Wrong: 516 predictions (33% of the total)

Total: 1556 predictions (100% of the total)

Putting it another way, the batting average of all predictors for all predictions was .399. Whether this is surprisingly low depends on one's preconceptions, but it seems very unlikely that anyone could consider this a remarkably high batting average. At first glance it appears absurd that a batting average below .500 should be obtained. One could bat .500 by turning each prediction into a question with a 'yes' or 'no' answer, and flipping a coin to choose answers. For the sample of 1556 predictions, an even better batting average would have been obtained by predicting that no predictions would come true. But is a prediction of what will not happen valued as highly as a prediction of what will happen? As will be seen, predictors make much more than half their predictions positive. Apparently they prefer occasionally to predict accurately what will happen rather than more frequently predicting accurately what will not happen.

The overall batting average can be compared directly and indirectly with data obtained in previous studies. The only directly comparable predecessor is a study done by S. C. Gilfillan for the federal government's National Resources

Committee in 1937.¹⁵ He considered a total of 160 predictions, made at dates ranging from fifteen to thirty-seven years earlier. He found 63 of them to have been correct, and 41 of them "destined" to be correct (in his opinion). This percentage -- 64% correct or destined predictions -- led him to conclude that experts could predict accurately the future of invention.

This result is really not as much different from mine as it appears at first glance. The main difference is in the large number of predictions placed in the category "destined." In my system of categorization, they would be divided between "established" and "not proven." This means that the batting average of the predictions gathered by Gilfillan is somewhere between 39% and 64%, depending on the status of the destined predictions. Unfortunately, Gilfillan does not list them, so it is impossible to evaluate them from the present viewpoint.

Two experimental tests of prediction also yielded interesting results that are indirectly comparable to those in this study. Both indicate that people are able to make short-range predictions with an accuracy better than that which would have been obtained by chance

15 S. C. Gilfillan, "The Prediction of Inventions," Subcommittee on Technology, National Resources Committee, Technological Trends and National Policy (Washington: GPO, 1937), pp. 15-23.

alone. In a 1938 experiment¹⁶ four hundred subjects each predicted whether each of nine events would or would not occur within the next year. They succeeded on 66% of their predictions. A 1950 test presented a panel of twenty-six predictors with a list of ten to sixteen events.¹⁷ For each event, a set of four "exhaustive and exclusive" outcomes was listed. The predictors were able to pick the possible outcome which correctly described the actual outcome (a year later) on 53% of the trials.

A possible explanation of the high batting averages obtained is the very short time (one year) between prediction and evaluation. For such a short time predictors saying that the status quo would continue would have scored 67% in the first test, and 62% in the second test. Such a persistence of the status quo cannot be assumed for intervals of 34 years or longer, as are those in this study.

The aggregate batting average tells only part of the story. Some kinds of predictions might be more accurate than others. Three characteristics of prediction which might be expected to affect success are: who predicted, what was predicted, and when the event was predicted to occur. I looked at the effects of each of these character-

16 Douglas McGregor, "The Major Determinant of the Prediction of Social Events," Journal of Abnormal and Social Psychology, XXXIII (1938), 179-204.

17 A. Kaplan, M. A. Girschick, L. Skogstad, "The Prediction of Social and Technological Events," Public Opinion Quarterly, XIV (1950), 93-110.

istics.

Who makes predictions? Predictions about technology are most frequently made by engineers and scientists; but some are made by military men interested in the impact of technology upon warfare, or by writers interested in the impact of technology upon society. Some people predict more frequently than others. The fifty most frequent predictors appearing in my sample (out of over 500 predictors represented) accounted for about half of the total number of predictions. These frequent predictors scored slightly, but not significantly, above the mean batting average, registering a collective average of .414.¹⁸

Who were the fifty most frequent predictors? There does not appear to be a single reason why certain individuals are more concerned with the future than are others. But the frequent predictors do share certain traits.

By occupation, 12 of the frequent predictors were novelists or journalists; 11 were engineers; 11 were physical scientists; 4 were natural or social scientists; 9 were inventors; and there was a mathematician, a soldier, and a business forecaster in the group. The inventors made most of their predictions in the early part of the 50 year

¹⁸ Unless otherwise indicated, "significant" will refer to the .05 level, that is, "significant" will be taken to mean "could not be duplicated as often as once in twenty tries by a simple chance model of the phenomenon in question." See the Appendix for further details.

span being covered, being especially important sources of prediction before 1914. The scientists, on the other hand, made a much greater share of predictions after 1925 than before. The predictions of engineers were spread more evenly over the entire period.

A closer look at eight representative individuals will suggest the backgrounds of the frequent predictors. (A full list, with occupations and batting averages, is given in the Appendix.)

Waldemar Kaempffert, like nine other writers in the group, specialized in scientific subjects. Beginning as a freelance writer, he became science editor of the New York Times. In that position, he understandably concentrated on picking out discoveries and inventions with a major social impact.

Another of the writers, Stuart Chase, took the opposite approach, seeing social change as the source of technical trends. Chase surveyed social trends, and his interest in technology lay in aspects related to such trends. In his concern for a decentralized society, for example, he followed developments in generating and transmitting power inexpensively; in pointing out the vulnerability of the city, he surveyed the use of military aviation against urban targets. Chase and Kaempffert suggest a categorization for the frequent predictors: the 'society conscious,' like Chase, and the 'gadget conscious,' like Kaempffert.

The scientists, engineers, and inventors among the frequent predictors shared one characteristic. Their predictions appeared prominently in public print some ten to thirty years after they began doing important technical work. The scientific or industrial recognition that would make them good copy took some time to accumulate. By the time it had accumulated, they had usually moved on to new work, or even new careers. This delay gave them the advantage of experience and the disadvantage of diminished contact with the fields in which they were presumed expert.

The physicist Robert A. Millikan, for example, had been in close touch with the physics of the first two decades of the twentieth century, which he taught and worked on. His precise experiments verified two major hypotheses of those decades -- the existence of the electron, and Einstein's theory of the photoelectric effect. But when he made most of his predictions, after 1925, he was principally a scientific administrator at the California Institute of Technology rather than a working experimental physicist.

Engineer Charles Steinmetz did his major technical work in the 1890's, applying mathematical techniques to the analysis of electrical machinery. His vogue as a predictor, however, came between 1915 and 1922. It was based not on his technical reputation alone, but also on the publicity he received because of his eccentricity, his unfortunate handicap (he was a hunchback) and his activity in local

politics, professional society affairs, and engineering education. Like Stuart Chase, he was a 'society conscious' predictor. His technical predictions were animated by a watered-down form of socialism, under which the industrial corporations (such as his employer, General Electric) would bring into being a cooperative commonwealth.

Inventors put less confidence in industrial leadership than did engineers. Thomas Edison had scored his major technical successes by 1890, and had yielded control of his electrical businesses to businessmen. For the rest of his life, however, he remained good newspaper copy, and a source of published predictions. And, in fact, his shrewd predictions in many areas show that his sense of technical possibilities remained sharp.

Nikola Tesla suffered from an early and unrepeatable success. His invention of the induction motor insured that alternating current electricity would be useful for power as well as for lighting. To his credit, after 1890, Tesla did not rest on his laurels, but sought new inventions. But his success in his chosen field, wireless transmission of messages and energy, was severely hampered by his rejection of Maxwell's Laws, which other physicists recognized as the best available description of electromagnetic phenomena. Nevertheless, as Tesla moved further and further away from scientific and engineering respectability, he retained good contacts with the press, and a continued ability -- right up to 1940 -- to secure a hearing for his

predictions.

Predictors not in technical fields also found outlets for technical predictions. General William "Billy" Mitchell is remembered today for his advocacy of a separate Air Force with a strategic role. His controversial views on air power, and his willingness to defend them to the point of insubordination, kept him in the public eye. He sometimes used this prominence to comment on aviation's technical developments, a field he had neither the time nor the inclination to keep informed on. Similarly, business forecaster Roger Babson gained a reputation as a shrewd predictor of the movement of stock prices. This assured that he could get a hearing for his views on everything from private aviation to atomic energy.

To sum up, the frequent predictors earned the right to be heard more by past achievements and controversial stands than by current expertise on the matter under discussion. This may partly explain the modest batting average scored by predictors, although I have no evidence of how predictors chosen by more objective methods would have fared. As far as I can tell, such persons generally did not volunteer -- or were not asked for -- predictions about the future of technology.

A related question involves the effect of expertise upon prediction. Do people with knowledge about the principles of science and engineering predict the future of technology better than those who lack such knowledge? To find out, I divided the group of fifty most frequent

predictors into two subgroups. One subgroup consisted of thirty-one individuals whose occupations (physicist, chemist, engineer, or inventor) required scientific or technical knowledge. The other subgroup included nineteen individuals whose occupations (reporter, writer, military man, biologist, geologist, business analyst, physician, mathematician) did not require such knowledge in areas relating to technology. The technically knowledgeable subgroup scored a batting average of .444 on all its predictions -- significantly better (at the .05 level) than the .337 batting average scored by the non-technical subgroup.

Asking an expert provides one means for improving the accuracy of prediction, according to this result. Can we carry the process of improvement further? Scientists, engineers, and inventors are known to make predictions outside of their own specialties. For example, astronomer Charles G. Abbot, participating in a 1929 symposium, did not restrict himself to predictions about his specialty (some of which were prescient, like the statement that future astronomers would use high altitude or extraterrestrial rockets to photograph the ultraviolet spectra of stars).¹⁹ He also ventured the speculation that "some Langley of telepathy" would soon make that field as technically respectable as Samuel Langley had tried to make aeronautics.²⁰

¹⁹ Charles G. Abbot, "Vanguard," in The Drift of Civilization (London: Allen & Unwin, 1929), p. 118.

²⁰ Ibid.

Would restricting experts to their own specialties improve the accuracy of prediction? The above example indicates that it would. But a test performed on 211 predictions made by eleven, technical experts indicates that they did not predict much better in their own specialties than in other areas. Their collective batting average for predictions in the area of specialization of the predictor was .478, not significantly better than the .446 batting average obtained for other predictions. A possible interpretation of these results is that general technical knowledge helps an expert improve his batting average by avoiding predictions which violate the laws of nature (such as perpetual motion machines); but specialized knowledge offers only a little further help in choosing which possible ideas will actually be realized.

Another question is whether significant differences exist in the accuracy of individual predictors. To answer this question, the batting averages of the fifty most frequent predictors were calculated. There was a wide range among the batting averages (from a low of .000 to a high of .800). But such extreme values were achieved by individuals who made relatively small numbers of predictions. Thirty-one of the fifty scored between .300 and .550. Over all, the variations among individual batting averages do not differ significantly from the results that would be expected if every prediction made by a predictor with a technical background had a 45% chance of being correct, and

every prediction made by a non-technical predictor had a 35% chance of being correct. This result does not rule out the possibility that there are significant differences in accuracy among individuals. It merely says that it is possible to account for the observed results with a chance model not requiring the assigning of different accuracies to different predictors. For example, the fact that inventor Thomas Edison scored .590 on thirty-four predictions may very well be due to luck, rather than superior foresight. In a sample of fifty chance processes, some of them are likely to score a better than average record of "success."

This conclusion about technology prediction agrees with conclusions reached about two other varieties of forecasting -- weather and economic. Meteorologist Frederick Sanders summed up a six-year experiment in weather forecasting as follows: "few if any individuals who make a substantial number of forecasts outperform consensus on the average."²¹ And economist Geoffrey Moore similarly described the results of a five-year evaluation of economic forecasters:

²¹ Frederick Sanders quoted in "There's No More Blood in the Synoptic Turnip," Technology Review, LXXVII (Feb., 1974), 85-86.

Of course, the consensus among fifty forecasters obscures the variation among them. At any given time some come much closer to the mark than others. A few may achieve a consistently better record. But we have found that relatively few forecasters are that consistent.²²

The question "who predicted it?" leads to only a small improvement in prediction accuracy. Does the question "what was predicted?" present a better guide?

In one way, it definitely does. As earlier mentioned, some predictions concern events that are to happen; others concern the effects of technological events. Which kind is more accurate? A comparison shows that event predictions are significantly more accurate than effect predictions. It is not a matter of event predictions being remarkably accurate (their collective batting average is .421); rather, effect predictions are remarkably inaccurate (collective batting average .253). This result confirms an earlier suggestion that predicting the social consequences of invention is the "most chimerical" part of prediction.²³

A second aspect of the "what?" question is the effect of subject matter on prediction. To study this, event predictions in the six general areas taken as constituting technology (energy, transportation

²² Geoffrey Moore, "Look at What Forecasters Do Right," New York Times, 3 February 1974, Section III, p. 14.

²³ John Jewkes, David Sawers, Richard Stillerman, The Sources of Invention (2nd Ed.; Edinburgh: Macmillan, 1969), p. 172.

and communication, automation, materials, domestic shelter and convenience, and weaponry) were subdivided into eighteen more specific categories. Energy, for example, was divided into "energy sources," "energy conversion," and "energy handling"; each other major category was similarly subdivided. (See the Appendix for a full list).

The variation among the batting averages for each specific category was wide (ranging from .182 to .780) and significant (although just barely). A simple chance model does not account for these variations nearly as well as it accounts for the variations among individual predictors. The categories with highest batting averages turned out to be those with rapidly changing technology -- for example, home heating and cooling (with innovations such as oil heat, gas heat, air conditioning, refrigeration all occurring since 1890); energy sources (oil, natural gas, large scale water power, and uranium all being introduced since 1890); and products employing new materials (aluminum, concrete, polymers and many more post-1890 developments). The categories with the lowest batting averages seemed to be those in which a dominant technology took hold around 1900 (or earlier) and has resisted challenge since. Examples are: energy conversion (the steam turbine and the internal combustion engine); house construction (traditional "stick building" methods); and land transport (automobile and railroad).

These results support the view that most predictions of future technology foresee a change, rather than preservation of the status quo. The overall statistics further back up this view. Among all the event predictions, those foreseeing change outnumbered those calling for a preservation of the status quo by a three-to-one margin.

In other words, the expectation of continuing technological change seems to have become built into American society (or at least that part of the society which made public predictions about technology) by 1890. The expectation persisted at least until 1940.

Certainly the perceived pace of technological change from 1890 to 1940 seems to have verified the views of the predictors who foresaw change. But the specific changes they foresaw did not occur with great regularity. In fact, there was no significant difference in the accuracy of predictions of change and predictions of a continuing status quo.

This result runs counter to a popular view that it is excessive pessimism, or "failure of nerve," which accounts for most of the past inaccuracy in technological prediction.²⁴ Selection of evidence can certainly provide support for this view. Among the frequently quoted errors of pessimistic prediction is Admiral George W. Melville's comment on the prospects for aviation in 1901:

²⁴ see, e.g., Arthur C. Clarke, Profiles of the Future (2d. edition; New York: Bantam, 1964), pp. 1-11.

Outside of the proven impossible, there probably can be found no better example of the speculative tendency carrying man to the verge of the chimerical than in his attempt to imitate the birds.²⁵

An equally spectacular underestimate was made concerning atomic energy by physicist Robert A. Millikan in 1928:

The energy available to him (mankind) through the disintegration of radioactive or any other atoms may perhaps be sufficient to keep the corner peanut and popcorn man going on a few street corners in our larger towns for a long time to come, but that is all.²⁶

Even the top experts (Melville was the U.S. Navy's Chief Engineer when he made his prediction; Millikan was a Nobel laureate in physics when he made his) can miss the signals of coming change. But this does not imply that optimism is more accurate than pessimism. Indeed, the batting average of pessimistic (status quo) predictions was slightly, though not significantly, higher than that of optimistic (change) predictions (by a margin of .419 to .380).

The third dimension in the assessment of predictions is summed up in the question: when was the prediction made? This question has two aspects, the absolute and the relative.

25 George W. Melville, "The Engineer and the Problem of Aerial Navigation," North American Review, CLXXIII (1901), 820.

26 Robert A. Millikan, "Available Energy," Science, LXVIII (Sept. 28, 1928), 1761.

The data indicates that absolute timing -- that is the year when a prediction is made -- has no effect on the accuracy of prediction. To arrive at this conclusion, the set of predictions was divided among three time periods, whose span was chosen on grounds of historical significance. The first period, 1890 - 1914, covered the period before the outbreak of the war in Europe. The second, 1915 - 1929, extended until the stock market crash which signalled the end of the prosperity of the 1920's. The third covered from 1930 to 1940.

From the viewpoint of validity, there is no difference in the predictions of different periods. In each time span, roughly one-third of the predictions proved right; another third proved wrong; about one quarter fell into the 'not proven' class; and the remainder were 'established'.²⁷

Relative timing of predictions involves the anticipated time span between prediction and realization. To examine it, some 300 predictions for which relative timing was clearly indicated were divided among three time classes. These classes were:

Short range: predictions specified to occur within the next ten years; or including such qualifiers as "soon," "within the next few years," "in the near future," "in sight," "impending," or "just around the corner." These specifically indicate a short time span.

²⁷ See the Appendix for exact figures.

Middle range: predictions specified to occur within the next twenty-five years, but not within ten years; or including such qualifiers as "at a not distant date," "before too long," "in the next generation," or "not far ahead." These, while ruling out a long time span (not far ahead) don't explicitly indicate a short span.

Long range: predictions scheduled to occur more than twenty-five years in the future; or including such qualifiers as "not soon," "eventually," "in the long run," "within a few generations," or "ultimately."

There was no significant difference among the batting averages obtained by the three groups (each was within .050 of the overall batting average of .414). Long range predictions scored slightly better than the others, but the difference was so slight as to be very possibly a result of chance.

This seems contrary to intuition, especially in light of studies like McGregor's, and Kaplan, et. al., which showed very short range predictions to have a batting average of over .600. But my results indicate that predictions for five years in the future are no more accurate than those for fifty years. Apparently, in choosing subjects on which to predict, the predictor automatically compensates for the time lag, coming up with equally likely long-, middle-, and short-range predictions.

To sum up this survey of the characteristics of prediction: overall, 40% of the sampled predictions have proven right or established; predictions by experts are, for this sample, significantly better than those by non-experts; technologists do not predict much better about their own specialties than about other areas of technology; predictions about the effects of future events are significantly less accurate than predictions of the events themselves; three-fourths of the predictions involve change, rather than continuation of the status quo (in spite of the fact that predictions of change are not more accurate than predictions of status quo); and neither absolute nor relative timing seems to affect the accuracy of prediction.

However, the uniformity of predictors' accuracy was not matched by a uniformity of predictors' interest in all areas of technology. A total of 216 generic classes of technological events showed up in the sample of predictions. Of these 216 classes, 3 drew more than 70 predictions each -- civilian airplanes, military airplanes, and electrified railroads. On the other hand, 128 classes -- more than half of the total number -- drew less than 4 predictions each.

Of course, there were technological events which have occurred since 1890, but which all predictors sampled completely overlooked. The number of such events is impossible to define precisely. However, an estimate has been made by listing technological events that were

included in a survey 'history of technology' ²⁸ published in 1967. These events were grouped in classes corresponding in generality to the generic classes of predicted events.

This test (which, although imperfect, seemed preferable to ignoring the problem of "errors of omission" entirely) yielded the result that predictors made at least one prediction regarding 85% of the generic classes of events mentioned in the survey history. More exactly, major developments in ninety-nine specific classes were predicted, while seventeen specific areas were missed .

This result can be combined with the ones discussed earlier to judge the value of a prediction collection as an early-warning system for detecting technological change. Of a total of 232 generic classes of technological events in which either major developments were predicted to occur, or in which major developments actually did occur by 1967 (or both):

Seventy-eight classes (33% of the total) drew little attention from predictors (fewer than four predictions for each class) and were not classes in which major developments occurred. Examples of these correctly low-rated classes are atmospheric electricity as a power source, and production of gold by transmutation of other elements.

Fifty-seven classes (24% of the total) drew little attention from predictors and were classes in which major developments occurred. Among these underrated classes were catalytic refining of oil, the jet airplane, and man-made fibers.

Seventeen classes (7% of the total) were totally overlooked and were classes in which major developments occurred. Semiconductor electronics and communications satellites are among the most glaring examples.

Forty classes (17% of the total) drew much attention from predictors (four or more predictions per class) but were not classes in which major developments occurred. This group of overrated classes includes tidal power, and use of farm wastes as a major source of raw materials for the chemical industry.

Finally, forty classes (17% of the total) drew much attention from predictors, and were, in fact, classes in which major developments occurred. This correct category includes the airplane, television, and the internal-combustion powered automobile.

To summarize these results: of every two classes receiving major attention from predictors, one was in fact to undergo significant development, while the other was merely the subject of a false alarm; for every three classes receiving little attention from predictors, one would in fact undergo important development. And, about one in seven

classes in which major technological events occurred was totally missed.

Increasing the size of the collection would probably decrease the number of classes totally missed; but it would probably increase the number of overrated predictions. The statistics provided by this collection indicate the point from which a science of prediction must start; and give a base line for the measurement of improvement in predictive accuracy. They also give a quantitative measure of the difficulty of prediction of technology -- a difficulty hinted at qualitatively in several papers and books.²⁹

But numbers can give only a partial picture of predictions made in the past about coming technology. Batting averages and the like can verify that the portrait of the future painted by the forecasters was far from a photographic representation of the actual course of events. But what kind of a picture was it? Does it not tell us a great deal about the attitudes of the forecasters themselves? Does it not help us to keep in mind that the apparently inevitable developments of our technological society (such as the choice of the automobile, rather than the electric trolley, as American's main means of mass transport) were not as obvious to foresight as they are to hindsight?

²⁹ e.g., Charles H. Townes, "Quantum Electronics and Surprise in Development of Technology," Science, CLIX (16 February 1968), 699-703; John Jewkes, David Sawers, Richard Stillerman, The Sources of Invention, 170-176; Peter Drucker, "Is Technology Predictable?" Technology and Culture, X (1969), 520 - 522.

And, perhaps more significantly, past forecasts show us that many of our present new ideas (such as coal gasification and solar power) were new ideas of the past also. Have conditions changed sufficiently that a forecast for success of such technologies is more realistic now than it was in the past? On the other hand, past forecasts show us how apparently established technologies (like the electric locomotive in the U.S.) hover on the brink of success for decades, but never quite make it. Will this also be true of today's 'established' technologies, such as nuclear power?

The statistics developed in this chapter suggest that it is impossible to answer these questions with confidence. But they say nothing about the larger context of prediction. To examine this, I shall discuss in detail eight general cases in which predictors with a variety of viewpoints tried to foresee general technological trends and specific technological developments. Looking forward in this way, they tried to guide society's decisions. Looking back at these efforts, we can perhaps better understand the real technological choices that our predecessors believed were open to them.

CHAPTER II

A VISION OF A WHITE CITY: 1890-1914

The World's Columbian Exposition, held in Chicago in 1893, was America's preview of the twentieth century. Unlike modern world's fairs, often little more than vehicles for political and commercial advertising, the Columbian Exposition earnestly sought to illuminate tomorrow's trends in architecture, the arts, and technology.¹ It forms a perfect introduction to the two decades of technological prediction preceding the First World War.

Even many who were critical of American social trends in the nineties (or downright hostile to them) were enthusiastic about the future nation pictured at the Fair. William Dean Howells, speaking through his fictional Altrurian traveler, viewed the Fair as "little American in the accepted sense," and as "the work of an armistice between the commercial interests." He saw in it "a glimpse of the glorious capitals which will whiten the hills and shores of the East and the borderless plains of the West."² Edward Bellamy, unable to attend because of poor health, grudgingly praised it from a distance as "the best that the despotic industrial system has accomplished at the very moment that it

1 Lowell Tozer, American Attitudes Toward Machine Technology, 1893-1933 (Ph. D. diss., University of Minnesota, 1953) contrasts this Fair with the 1933 Chicago Fair.

2 William Dean Howells, Letters of an Altrurian Traveler (Gainesville, Fla.: Scholars Facsimiles and Reprints, 1961), pp. 23-25;30.

was being replaced by an industrial democracy."³ Henry Demarest Lloyd was inspired to write "the only utopian dream in which he ever indulged" (according to his daughter), picturing "the ideal city that was to rise from our slums."⁴

The Fair itself was a prophecy of social progress, and the technology of the Fair was a harmonious part of that prophecy. The Exposition's nickname, "The White City," referred not only to the use of imitation marble facades of the main buildings, but also to the lavish use of electrical arc and incandescent lamps for night illumination.⁵ The young technology-based corporations represented there did not lay aside their bitter rivalries. But their exhibits complemented each other, to suggest the kind of "commercial armistice" that Howells had perceived. Thus the Westinghouse Electric Company, demonstrating the polyphase power inventions of Nikola Tesla, showed how long-distance transmission of power could revolutionize twentieth-century industry; the General Electric Company, with its "intramural electric railway," emphasized a major use of the newly available power; and the Bell Telephone Company, by timing the opening of its New York to Chicago line to coincide with the scheduled opening of the Fair drama-

3 Sylvia E. Bowman, The Year 2000 (New York: Bookman, 1958), p. 313.

4 Caro Lloyd, Henry Demarest Lloyd (New York: Knickerbocker, 1912, p. 163.

5 Chicago Tribune, June 2, 1893, p. 1.

tized the fact that communication was keeping pace with energy.⁶

The names of two of these corporations still suggested individuals - George Westinghouse and Alexander Graham Bell. The third had been created just one year earlier when the Thomson-Houston and Edison companies merged under the unimaginative title of General Electric. The Fair not only presented a good sample of the technology expected to help shape tomorrow's society; it also sought from individuals the clues to future technological breakthroughs.

Most of the men whose technical prophecies would fill the public press for the next twenty years put in at least an appearance at Chicago. It made little difference to the public that Thomas Edison was regarded as an antique by many of the scientists and college-trained engineers at the Fair's Electrical Congress.⁷ To the common man he still represented both the ideal of American ingenuity and the harbinger of progress.⁸ The same could be said of some of the other pioneers who visited the Fair, including George Westinghouse, Elihu Thomson, and Elisha Gray.

Alongside these veterans, vying for the prophet's mantle, were

⁶ Murat Halstead, "Electricity at the Fair," Cosmopolitan, XIV (1894), 577-579 (Note that while the fair had been scheduled to open in October, 1892, and was dedicated then, it did not actually open until May, 1893).

⁷ David O. Woodbury, Beloved Scientist (New York & London: Whittlessey House, 1944), p. 213.

⁸ Charles D. Lanier, "Thomas A. Edison," Review of Reviews, VIII (1893), 50-53.

younger men, in the midst of their most active work. Charles P. Steinmetz delivered at the Fair a path-breaking lecture on the application of advanced mathematical techniques to electrical engineering, symbolizing the increasing complexity of electricity's advance. Flamboyant young Nikola Tesla, demonstrating his newest inventions, hinted at a new world of technical advance related to high-frequency electrical oscillations.⁹

However, the line dividing the future-minded from the conservative was not based strictly on age. Sixty-one-year-old Octave Chanute, a respected civil engineer, defended the most futuristic of the dreams represented at the Fair. Presiding at the Third International Conference on Aerial Navigation, he claimed that the subject of flight, now in the hands of "mechanicians and investigators" rather than "cranks," was ready to take its place among the respectable branches of technology.¹⁰

The message that Edison, Steinmetz, Tesla, and Chanute sent out from Chicago - confidence in the works of technology and in their beneficial effect on society - was to be the dominant message in technology prediction for the next twenty years. Of course, as one

⁹ Proceedings of the International Electrical Congress, Chicago, Aug. 21st to 25th, 1893 (N. Y.: Amer. Inst. Elec. Engrs., 1894), pp. 33-75; 475-482.

¹⁰ Proceedings of the International Conference on Aerial Navigation (N. Y.: American Engr. & R. R. Journal, 1894), p. 6.

excellent study has reminded us, there were "doubters and dissenters" who forecast a gloomier future.¹¹ In connection with technology, these doubts played on two main themes. The stronger of the two was a doubt not of technology itself, but of the indefinite availability of the resources which sustained it, particularly the world's fuel supplies. The weaker doubt was the fear that technology might enslave man while disguising itself as his servant.

In Edward Bellamy's novelistic essay Equality the future world suggested by the Columbian Exposition got a fuller description. Like its predecessor, Looking Backward, Equality was labeled by its author as social commentary and forecasting, not as what would today be called science fiction.

Bellamy's target date was the year 2000, but in the 1970's his future seems already archaic. The batting average - so far - of his specific predictions is .358, which is just barely above the average for all predictors in professions not requiring technical training. He was most accurate when discussing television and its applications, and least accurate in predicting that man's energy problems would be easily solved, and man's aviation inventiveness would be channeled entirely into peaceful applications.¹²

11 Frederick Jaher, Doubters and Dissenters (New York: Free Press, 1964).

12 Edward Bellamy, Equality, p. 69; 157; 205; 251; 271.

Bellamy did not assume that technological progress automatically brought social change in its train. Society had to exert positive control, or else technology would merely reinforce inequality. But technology at least created the potential for true equality.

Publicist and political organizer Ignatius Donnelly had a similar view of technology in his fictionalized political tract Caesar's Column. While condemning the misuse of technology for exploitation and war, he was by no means pessimistic about man's ability to develop limitless energy supplies and new ways to use that energy. The following passage is typical:

But the wonderful city! Let me tell you of it.
As we approached it in our air-ship, coming from the east, we could see, a hundred miles before we reached the continent, the radiance of its millions of lights reflected on the sky, like the glare of a great conflagration. These lights are not fed, as in the old time, from electric dynamos, but the magnetism of the planet itself is harnessed for the use of man ... the force is so cunningly conserved that it is returned to the earth, without any loss of magnetic power to the planet.¹³

Writing in the 1880's and 1890's, these two authors, and many others foresaw a new society. Conceived in the energy revolution, it would be free of the blemishes of the industrial revolution. With electric power replacing the steam engine's belts and shafts, the factory would be made safer. Using the electric arc lamp, the gloom

¹³ Ignatius Donnelly, Caesar's Column (Cambridge: Belknap, 1960), p. 8.

of the slums would be dispelled. Incandescent gas and electric lamps would brighten the interior of the workingman's home. With soft coal and the horse removed beyond the city limits, city air would be free from soot and smell. And best of all, the concentration of population dictated by the steam railroad would give way to the dispersion of population made possible by the electric railroad.

John Bates Clark of Columbia University, no Bellamy or Donnelly, but rather a leading economist, showed that this dream was held by conservatives as well as radicals. In an article written in 1902, he adopted a by then familiar literary device: a history lecture given in the year 2001. The technological basis of society was to be

the introduction of newer and better ways of obtaining mechanical power by utilizing, first waterfalls, then waves of the sea, and finally the electric currents which are generated within the earth itself.¹⁴

But far more important than the industrial value of the new technology was the social transformation that it made possible. Rejecting the label already so commonly attached to the twentieth century -- "the age of electricity" -- Clark chose instead to call it "the era of organization."¹⁵

A connection between advances in power technology and a movement

¹⁴ John Bates Clark, "Recollections of the Twentieth Century," Atlantic, LXXXIX (1902), 6.

¹⁵ Ibid., p. 7.

toward a more humanely organized society was often made in the period presently being considered. Of course, the word organization meant a different thing to each predictor. To one, it meant the creation of huge, carefully planned cities. To another, it meant that no new cities need be built, and that the population of old cities could be diminished by a return to the countryside. Some saw the new technology strengthening the government's ability to deal with social problems; others saw the benefits of technology flowing directly to the individual, making bigger government unnecessary.

Two common features, however, linked all of these predictions. First, there was an assumption that a technical revolution in the means of converting energy from one form to another impended. Second, this new mastery over power seemed to mean more than merely providing cheaper power for old purposes. It appeared to make possible a wide range of new applications, each with socially important consequences. The sources of these two predictions are worth examining separately, for they exemplify the two main parts of technology prediction: determining which of technology's tools will achieve practical use; and judging what difference this will make to ordinary people.

Exhaustless and Costless Power

Today the electric power industry is one of the most conservative of our industries. In the period 1893-1914, it was one of the most rapidly changing and dynamic. In the 1890's two "traditional" sources of power -- falling water and coal-fired steam -- turned the generators of that infant industry. But a host of prophets saw them as soon to be supplemented -- or replaced -- by new types of energy. Some favored "free" energy from the waves, the tides, the sun, or the wind. Others hoped that remarkable recent chemical discoveries, such as new methods of synthesis of liquid air and acetylene, would find practical use. Those with an interest in engineering foresaw an early triumph for internal combustion engines using gas as the working fluid, or held out hopes for a new type of battery that could turn the energy latent in coal directly into electricity. More scientific types spoke grandly, if vaguely, about the limitless power locked up in radium.¹⁶

Statistics presented in Chapter I have described the limited success of generic predictions. Turn-of-the-century predictions about power generation exemplify this conclusion. A dozen ideas were

¹⁶ J. A. Fleming, "The Sources of Energy Available to Man," Scientific American, Supplement, LXXIV (1912), 341-342; Waldemar Kaempffert, "Harnessing Nature", Scientific American, CVIII (1913), 308-309.

seriously predicted. Two proved commercially successful. Only one was definitely 'disproved.' The other nine remained -- and remain to this day -- in the limbo between good and bad ideas.

The two successful ideas were the fossil-fuel-fired steam turbine and hydroelectric power. The one idea which was shown to be definitely impractical was the liquid air motor. The other nine, which rested somewhere between theoretical possibility and commercial practicality, are solar power, wind power, tidal power, wave power, geothermal power, the gas engine, the fuel cell (and related means of direct conversion of chemical to electrical energy), the alcohol engine, and the use of "intra-atomic energy."

This three-fold division of technological ideas illustrates a general characteristic of technical progress. Only a minority of ideas follow the popular metaphor of birth, struggle for survival, extinction of the "unfit" ideas, and survival of the "fittest" ones. Most follow a more periodic course: they are tried by one generation, abandoned as impractical, and then come bobbing up again when a later generation faces conditions which make them once again attractive. The steam turbine was such a recurring idea in the nineteenth century. The fuel cell, tidal power, and solar power have been such ideas in the
17
twentieth.

17 R. H. Thurston, "The 'Rotary' Steam Engine," Scientific American, LXXVI (April 3, 1897), p. 211; K. V. Kordeseh, "Low Temperature Fuel Cells," Proc. I.E.E.E., LI (1963), 806; Willy Ley, Engineers' Dreams, (New York: Viking, 1954), pp. 205-210.

To put it another way: technology predictors are usually capable of separating the demonstrably impractical ideas from the possible ones. But no predictor yet examined has scored consistently high at choosing from among the collection of potentially good ideas the ones which will actually pass the tests of technical practicality and public acceptance. Society is accumulating a growing store of good ideas whose time has not -- and may never -- come. Let us see how the twelve suggestions for prime movers illustrate this general rule.

The "disproved" idea of the period 1893 - 1914 shows one source of error in technical judgment. The liquid air motor was delusively attractive because it was connected with a glamorous scientific field of the turn of the century, the liquefaction of gases. Many people believed that a development with so much scientific interest (air liquefaction had for example, enabled scientists to discover the inert gases argon and neon) had to have practical uses. Leading engineers of the years 1897 - 1899 saw the application of liquid air to power generation as one of the most tempting fields beckoning inventors. Reginald Fessenden, later a radio pioneer, ranked its appeal alongside that of wireless telegraphy and x-rays. Elihu Thomson and Charles Brush were enthusiastic about its coming impact upon the electric

power industry which they had been so instrumental in building up.¹⁸

The invention causing this enthusiasm was a method of using the phenomenon of cooling by expansion to achieve the conditions of temperature and pressure needed for air to condense from a gas to a liquid (just as steam, at a much higher temperature, condenses to water). Two inventors who developed such processes, and proceeded to predict a great future for the resulting substance, were Carl von Linde of Germany and Charles Tripler of the United States.¹⁹

There was some confusion over exactly how liquid air was to become a source of power. Its advocates recognized that it was no more a reservoir of stored energy than was water. However, like water, it could be used as a working fluid in an external combustion engine. And, it had the advantage over water of forming a natural low temperature reservoir (or 'heat sink'). Ordinary atmospheric heat would be sufficient to "boil" it and create the pressure needed to drive an engine's piston. According to Charles Tripler, liquid air was a substance which "can be used at ordinary temperatures with as great,

18 Helen M. Fessenden, Fessenden, Builder of Tomorrows (New York: Coward-McCann, 1940), p. 76; Elihu Thomson, "Possibilities of Liquid Air in Electrical Work," Scientific American, LXXVII (1897), 118; Harold J. Abrahams and Marion B. Sawin, eds., Selections from the Scientific Correspondence of Elihu Thomson (Cambridge, Mass.: M.I.T. Press 1971), pp. 22-23.

19 Dr. Carl von Linde, "Practical Liquid Air Possibilities," Cassier's XXIV (1903), 139-144; New York Times, May 13, 1899, pp. 2-4.

or greater effect than steam."²⁰

If the exact operation of the new force was unclear, its reception was enthusiastic. As a reporter for the Boston Herald put it:

If Mr. Tripler's prophecies prove true we are on the eve of a new mechanical revolution. If his new motor, as he claims, proves the possibility of harnessing this awful force in such manner to apply it economically to the practical purposes of life and labor, what may not follow?²¹

During the next year, extravagant promises about the future of liquid air led to at least one stock promotion swindle.²² However, two eminent scientists made correct predictions (based on theoretical physics considerations) that liquid air could never become a large scale power source. Edwin H. Hall, a Harvard physicist, explained that a reasonable-sized reservoir of liquid air did not have enough heat capacity to serve as a heat sink for any useful length of time. And, using similar reasoning, Henry Morton, the president of Stevens Institute, showed that a liquid air motor would have to be "as big as a house" to put out even a modest amount of power.²³

20 Ibid., p. 2.

21 Boston Herald, Jan. 1, 1899, p. 5.

22 Scientific American, LXXXII (1900), 162.

23 Edwin H. Hall, "Liquid Air and Motive Power," Forum, XXVII (1899) 713-716; Henry Morton, "Liquid Air as a New Source of Power -- Another Engineering Fallacy," Scientific American, LXXX, (1899), 245.

Informed prediction was capable, therefore, of trimming the list of prime mover possibilities from twelve to eleven. But from here on, the prophet found the going rougher. Judging from the frequency with which predictions were made for the various methods the several forms of "free" energy, the gas engine, and the fuel cell were the most frequently discussed devices. But each expert had his unique order of probabilities. To illustrate this, let us look at the views of five outstanding experts.

Thomas Edison was confident that great improvements in prime movers were coming in the early twentieth century. From his repeated comments, it appears that Edison saw the direct production of electrical energy from chemical energy -- the fuel cell -- as the impending replacement for the reciprocating steam engine. An interviewer at the Columbian Exposition reported that the great inventor "confidently predicts" that direct production of electricity from oxygen and coal was soon to come.²⁴ Another reporter, also in 1893, was told that "the direct control of the energy which is stored up in coal" was the target of one of Edison's inventive "campaigns."²⁵ In 1901, Edison continued to hold that "the most important line of investigation is the production of electricity direct from the combustible."²⁶

²⁴ Lanier, "Thomas A. Edison," p. 50.

²⁵ "Unsolved Problems that Edison is Studying," Scientific American, LIX (1893), 25.

²⁶ Electrical World, XXXVII (Jan. 5, 1901), 22.

In spite of this fact, Edison's own researches at the time were focused on the storage battery rather than the fuel cell.²⁷ By 1910, however, he was mentioning the energy stored in radium -- "intra-atomic energy" -- tidal power, and solar power as promising energy sources for the future.²⁸

Elihu Thomson, Edison's early rival in the field of electrical invention, had very different views on the future of prime movers. As mentioned earlier, Thomson was enthusiastic about the possibilities of liquid air in electrical work, although he stopped short of the optimism of Charles Tripler. In the area of prime movers, he saw in 1892 that the likely limit to efficiency would be between 40 and 50% -- a prediction that has held good to this day.²⁹ Unlike Edison, he felt that there was little promise of achieving the theoretically higher efficiencies available from direct conversion of fuel energy directly into electrical energy.³⁰ By 1901, he saw the gas engine as "without doubt" having a bright future in electrical generation,³¹ and had obtained several patents on that device.³² By 1903, he had decided

27 Thomas Edison, "The Storage Battery," North American Review, CLXXIV (1902), 1.

28 Thomas Edison and John McMahon, "Inventions of the Future," The Independent, LXVIII, (1910), 15.

29 Elihu Thomson, "The Future of Electricity," New England Magazine, VI (1892), 629.

30 Elihu Thomson, "Fuel into Electrical Energy," Electrical World, XXIX (Jan. 2, 1897), 4.

31 Elihu Thomson, "Electricity in the Coming," Electrical World, XXXVII (Jan. 5, 1901), 20-21.

32 E. g., U.S. Pats. 564,806; 580,020; 643,176; 669,737.

that the steam turbine might also be important, "Professor Thomson appears to conclude," wrote another engineer:

that as compared to the older types of generating equipment, the steam "turbo generator" possesses such marked advantages as to insure its adoption to some extent, but proceeds to point out that the recent development in this field of yet another type of prime mover -- the gas or oil engine -- gives promise of successful competition.³³

A third elder statesman of technology gave a third unique view of the future. Robert H. Thurston, professor of mechanical engineering at Cornell, and a pioneer in both power engineering and engineering education, made several predictions of technological developments around the turn of the century. Unlike Elihu Thomson, he doubted that the gas engine would prove very practical. He saw the high cost of coal gasification as a decisive handicap to gas power (as indeed it has proved, down to the present day).³⁴ The steam turbine was his choice for the next major prime mover.³⁵ But he saw its reign as the major power source to be a short one. The invention of a means of directly converting fuel energy to electricity was, he felt, "more than probable."³⁶ But "within a few generations," our coal

33 Edward C. Warren, "Lines of Progress in the Gas Engine," Engineering, XXVI (1904), 664.

34 R. H. Thurston, "The Last Days of the Steam Engine," North American Review, CXLVIII (1889), 697-710.

35 R. H. Thurston, "The Rotary Steam Engine," p. 211.

36 R. H. Thurston, "The Next Great Problem of Science," Forum, XIV, (1892), 45.

supplies would have to be significantly supplemented by solar power.³⁷

Two younger prophets indicated no more agreement within their generation than there was among their elders. Dr. Louis Bell, a Ph. D. in physics from Johns Hopkins and a leader in the power industry, was under thirty at the time of the Columbian Exposition. In the following years, he came to believe that the gas engine offered "perhaps the best promise at present," but that in the long run, solar power would be man's principal energy source.³⁸

Nikola Tesla, on the other hand, was skeptical of the value of solar power. He saw steam turbines and gas engines as close competitors during the early years of the twentieth century, with the fuel cell never becoming practical.³⁹ In the more distant future, Tesla stated:

We have to obtain means for obtaining energy from stores which are forever inexhaustible, to perfect methods which do not imply consumption and waste of any material whatsoever ... I feel sure that the realization of that idea is not far off.⁴⁰

37 R. H. Thurston, "Utilizing the Sun's Energy," Smithsonian Report, 1901, (Washington: GPO, 1902), p. 263.

38 Dr. Louis Bell, "Natural Sources of Energy," Cassier's XXIV, (1903), 306; 308-311; Cassier's XXIX, (1906), 466-476.

39 Nikola Tesla, Nikola Tesla: Lectures, Patents, Articles, (Beograd, Yugoslavia: Nikola Tesla Museum, 1956), p. 107; Nikola Tesla, "The Problem of Increasing Human Energy," Century, LXIX (1900), 199.

40 Nikola Tesla, Nikola Tesla: Lectures, Patents, Articles, p. 107.

He suggested at least two ways of reaching this aim: wind power (employed in conjunction with a new type of storage battery), and the use of natural thermal gradients to power heat engines.⁴¹

As the opinions of some of the leading experts indicate, there was no consensus prediction of the successful prime mover of the future. A further conclusion can also be drawn: that technological prediction often depends on a previous economic prediction. For, in this case, economic assumptions about the future relative costs of coal and of electric power seem to have influenced predictions about the future of prime movers. Attached to each of the eleven plausible predictions was an economic condition which would make it the most practical energy choice -- if that condition obtained. Let us look at each of these conditions separately, from the point of view of a turn-of-the-twentieth-century predictor.

If the cost of mineral fuel were to rise sharply relative to construction and equipment costs in the twentieth century, it would become the main influence on energy costs. In that case water power, solar power, wind power, wave power, tidal power, and geothermal power would become the dominant energy sources. If fuel costs were to rise in the future, but less sharply than other costs, then fossil-fueled energy sources would continue to dominate, but with a premium

⁴¹ Nikola Tesla, "The Problem of Increasing Human Energy," pp. 199-200.

placed upon efficiency. This would give the gas engine and the fuel cell their chance. If fossil fuels remained abundant, and fuel costs remained low compared to other costs of energy generation and distribution, then the oil engine or steam turbine appeared to have greatest promise. Of course, in the early twentieth century view, if any method was found of letting loose the enormous energy known to be latent in the atom, then all of these economic considerations would be eliminated. Such were the arguments advanced in several predictions of the future of energy supplies.⁴²

Only occasionally did a predictor realize that economic conditions other than the price of fuel would help determine the future of prime movers. Elihu Thomson was one who recognized that problems on the demand side of the energy supply-and-demand equations would be a prime importance. If a way of levelling out demands during the day (instead of having a short period of peak use) could be found, then problems of supplying enough energy to meet the demands upon power stations would be made much easier. "The question of uneven loads and peaks in the load," Thomson wrote, "becomes one of far greater importance than saving fuel alone."⁴³ Thus flexibility in

42 "The Trend in Electrical Development," Scientific American, LXXIII (1895), 267; Alton B. Adams, "Twentieth Century Energy," Scientific American, LXXXIII (1900), 19; John Joseph Flather, "Modern Tendencies in the Use of Power," Science, n. s., XVII (Jan. 9, 1903), 48-53; Calvin M. Woodward, "Lines of Progress in Engineering," Science, n. s., XXI, (Jan. 6, 1905), 8-14.

43 Elihu Thomson, "Fuel Into Electrical Energy," p. 4.

meeting varying loads was one feature needed in the twentieth century prime mover; and another was small size in relation to power output, in order to meet growing demands without making energy generation equipment unmanageably large.

The fact that the most popular choices of predictors in the decade 1895 - 1905 were direct conversion devices (the ancestors of the modern fuel cell), and the gas engine indicate how most predictors overestimated the need for more efficient energy generation methods to counter rising fuel costs.

An 1895 article summed up the prevailing confidence in the rapid development of a direct conversion device -- a primary galvanic battery. It concluded:

The next step will be that the dynamo, by familiarizing us with electro-chemical processes, will enable us to produce electricity itself by electro-chemical processes. There seems to be no question that galvanism is to be reenthroned, somewhere in the near future.⁴⁴

Science writer William Baxter, Jr. in a discussion of "Forecasting the Future of Invention" in 1897, placed direct conversion second only to aerial navigation on the list of predictions made by "nearly all those who succumb to the fascination of meditating upon the changes that may be wrought by inventive genius in the days to

44 "The Trend in Electrical Development," p. 267.

come."⁴⁵ A New York Times editorial in 1896 called direct conversion "the most important industrial problem of the day."⁴⁶ The enthusiasm that experts like Edison and R. H. Thurston felt for such devices was communicated to the public. Edward Atkinson, a Boston economist and amateur inventor, opined in 1898 that "we have reason to believe that the conversion of the carbon of coal into power, without waste of light or heat, is close at hand."⁴⁷

What was the reality behind these enthusiastic predictions? Direct conversion devices produce electricity through a pair of chemical reactions. Electrons are given up by reacting substances in one reaction, allowed to pass through an external circuit, and then returned to the device as part of a second reaction. Energy conversion in such a fuel cell takes place through reversible reactions, unlike those of the steam engine. Consequently fuel cell efficiencies of over 50% are available at reasonably low temperatures (less than 500 degrees F.), while steam engine efficiencies at such temperatures are below 25%. In practice, a number of inventors, including some prominent electrical engineers, demonstrated working direct conversion devices, and accompanied them with predictions of a bright future for their devices. Dr. William Jacques of Boston pro-

⁴⁵ William Baxter, Jr. "Forecasting the Progress of Invention," Popular Science Monthly, LI (1897), 308.

⁴⁶ New York Times, Nov. 23, 1896, p. 4.

⁴⁷ Edward Atkinson, "Coal is King," Century, LV (1898), 828-829.

duced a prototype cell consisting of a vat containing molten potash, which could transport electric charge. Immersed in the potash, a carbon electrode reacted to release part of the carbon's chemical energy as electricity. A second half-reaction at a metal electrode completed the circuit. Jacques saw this concept as having the potential "to do away with the dynamo and the steam engine," although he cautioned that "it will be some time yet before the dynamo is relegated to the attic."⁴⁸

Other fuel cell inventors of the late nineteenth century included New York "electricians" Willard Case and Charles S. Bradley, and Sidney Short, a pioneer in electric traction. Short claimed in 1897 that the fuel cell was "an accomplished fact," and that "its application to street railway service is but a question of time."⁴⁹

Unfortunately, such predictions were far too optimistic. Lured by the promise of greater efficiency, the people who made them had overlooked the serious material and fabrication problems of practical fuel cells. Furthermore, they were unable to build devices which produced enough power to be useful. After the turn of the century, the emerging science of physical chemistry enabled a critique of early fuel cell work to be made, and this good idea was discarded as impractical.

48 William Jacques, "Electricity Direct from Coal," Harper's XCI (1896), 144-150.

49 New York Times, Feb. 25, 1897, p. 12; Electrical World, XXIX (1897), 100.

As one commentator put it:

The production of electricity direct from coal without intermediary processes has been the dream of inventors for many years past; but energy and ingenuity in this field seem to have been largely misspent. Certainly no progress worth mentioning has been made in the past ten or twelve years.⁵⁰

In spite of the failure to develop a fuel cell, predictors did not stop overemphasizing efficiency of fuel use. Most statements on the trend of prime mover development continued to stress efficiency. But from 1900 until 1914, the device expected to make the greatest contribution toward more efficient fuel use was the gas-burning, internal combustion engine. This type of engine, which burned natural gas or gas produced from coal (not gasoline), and drove its pistons by the direct expansion of the gas (rather than using an intermediate working fluid, like steam), was capable of operating at higher temperatures than the steam engine. Therefore it was theoretically capable of turning a greater part of the energy put into it into useful work than was the steam engine.

A stream of predictions foretold the imminent triumph of the gas engine. In 1903, one writer saw the development of large gas engines as giving promise of "an entire revolution in our methods of procuring power," and predicted that "within a very few years the gas

⁵⁰ "Current Topics," Cassier's Magazine, XXV (1904), 377-378.

engine will make very great inroads upon the generation of power by steam."⁵¹ In the same year, Joseph W. Richards, a prominent chemist, saw the use of gas engines employing blast furnace waste gases or gas produced from cheap coal as one of the United States' major undeveloped sources of energy.⁵² A leading mechanical engineer predicted in 1905 that "for a great many purposes, both steam engines and electric motors may be ultimately replaced by gas engines."⁵³

At the Louisiana Purchase Centennial Exposition, held at St. Louis in 1904, the gas engine was hailed as one of the outstanding technological features. One observer ranked it alongside radium, the submarine, wireless telegraphy, and the automobile in the list of "great inventions and discoveries that are changing the world."⁵⁴

The Louisiana Purchase Exposition also marked the beginning of an intensive investigation of the possibilities of gas power, undertaken by the U. S. Department of the Interior. This began with tests of coal gasification at the Exposition, and continued with five years of laboratory tests and surveys of the use of gas producers and gas engines. The study's director, Robert H. Fernald, summed up the conclusions:

53 John J. Flather, "Modern Tendencies in the Utilization of Power" 48 - 53.

54 John B. Walker, "Great Inventions and Discoveries Which Are Changing the World," Cosmopolitan, XXXVII (1904), 621.

The logical conclusion from a careful study of the producer-gas power situation is that the time is not distant when financial interests in power production will be directed toward the centralization of the producer-gas power plant at the mines and the distribution of the energy developed..."⁵⁵

The high expectations held for the gas engine were doomed to failure. The idea was basically a good one: clean and efficient transformation of coal, the United States' most abundant fossil fuel, into a gas to be burned in an engine. In the 1970's this idea of coal gasification has emerged again as a promising energy conversion method. But in the early years of the twentieth century, the technology for building large gas engines or turbines was lacking; and the cost of coal gasification could not be reduced enough to make it economically attractive.

The emphasis on the gas engine further served to distract the attention of predictors from the prime mover which was to revolutionize the large-scale transformation of energy -- the steam turbine. The idea of using the expansion of steam to produce rotary, rather than back-and-forth, motion was already an old one in 1900. In fact, the principle was included in James Watt's first patent, in 1769.⁵⁶

⁵⁵ Robert H. Fernald, "Present Status of Producer Gas Power Plant in the United States," U. S. Geological Survey Bulletin #316 (1907) pp. 439-459.

⁵⁶ Robert H. Thurston, "The 'Rotary' Steam Engine," p. 211.

There are two reasons for the lack of attention given to the steam turbine, as compared to the gas engine. First, the ideas of a rotary steam engine and a steam turbine were already old by 1900. They had already been tried unsuccessfully many times (they were the subject of about 270 U. S. patents by 1901).⁵⁷ Second, as already discussed, the criterion usually applied to judge the value of a prime mover at the turn of the century was efficiency -- and the theoretical maximum efficiency of the gas engine was thought to be higher than that of either the steam engine or the steam turbine. The criterion which would actually determine the type of prime mover to be adopted by the young electric utility industry was to be the ability to build reasonably small-sized single units which would produce large amounts (more than a few millions of watts) of power. For reference, a million watts represents the peak power demand of about 100 houses wired for typical electrical loads of the 1970's. Only the steam turbine could meet this need.

Indicative of the neglect of the steam turbine is the fact that neither of the electrical machinery manufacturing companies that have come to dominate turbine manufacturing in the United States -- General Electric and Westinghouse -- invented its own type of steam turbine. Each was fortunate, however, in having a minority of engineers who

57 R. H. Thurston, "The Steam Turbine," Scientific American Supplement, LI (1901), 20930.

understood the value of the innovation when it was brought to them.

In 1899, GE was about to drop its option on the turbine invented by the independent consulting engineer Charles G. Curtis. But William L. Emmet, a perceptive GE engineer, persuaded his superiors to support an ultimately successful development of the device.⁵⁸ At the rival company, it was George Westinghouse himself who led the successful effort at licensing and adapting for American use the turbine developed by Charles Parsons of Great Britain.⁵⁹

The development of the steam turbine came rapidly enough to take most predictors by surprise. As one commentator summed things up in 1904, when a few people were beginning to become aware of turbine developments: "the layman is apt to think that the turbine may possibly become the steam engine of the future. As a matter of fact, the turbine is emphatically the engine of the present time."⁶⁰

By 1914, the revolution in prime movers had become a steam turbine revolution. The main source of energy for the years ahead would be the steam turbine (supplemented, where convenient and economical, by turbines driven by falling water). Ideas like solar

⁵⁸ William L. Emmet, The Autobiography of an Engineer, (Albany, N. Y.: Ft. Orange Press, 1931), pp. 146 - 147.

⁵⁹ Benjamin Garver Lamme, Benjamin Garver Lamme, Electrical Engineer, (New York: G. P. Putnam's Sons, 1926), pp. 107-108.

⁶⁰ Arthur Warren, "The Turbine: A New Era of Steam," Review of Reviews, XXIX (1904), 695.

power, wind power, tidal power, and geothermal power were reserved for those pessimists who feared that the world's fuel supplies would soon be exhausted (as will be seen, there were such people). The liquid hydrocarbon engine found its major field of application in small sizes, in airplanes and in automobiles. The enormous energy "locked up in the atom" was recognized, and some hope was held for its ultimate release. But no definite means of accomplishing this end was held out. As a speaker before the American Institute of Electrical Engineers explained in 1913:

Uranium thus has an enormous store of energy contained in its atoms. We must believe that all the elements contain equivalent amounts of energy in their atoms. But no means is known of drawing upon this supply of energy, or even hastening its liberation from those elements which do disintegrate spontaneously.⁶¹

The predictors of prime mover development in the period 1893 to 1914 had predicted with mixed success. Most had correctly sensed that a great improvement in the transformation of energy was forthcoming. But their emphasis on criterion of the past -- an over-estimation of the importance of thermal efficiency -- had blinded most of them to the arrival of the "engine of the present" -- the steam turbine.

⁶¹ Edwin Plimpton Adams, "Radioactivity," Transactions of the American Institute of Electrical Engineers, XXXIII (1913), 998.

Power and People

Few prophets of the period 1893 doubted that abundant and inexpensive energy would be made available by technological advances. And most of these prophets expected that the energy would be distributed in the form of electricity. But how would the use of electric power change the lives of people: the way they worked and traveled; and where and how they set up their homes? Two basic pictures of the future emerged. Each was based on specific predicted technological developments, and on a reaction against things as they were. Each was an idealization of elements of the actual future, accurate in some details but on the whole an oversimplification.

The condition of life rejected by both visions was the lot of the nineteenth-century city dweller. One vision saw new, efficient, perfectly planned cities, fulfilling a new industrial function. Its technological symbol was a new type of factory, using techniques developed by the new science of electrochemistry. The other vision saw cities made unnecessary. Its symbols, and the technological developments that would make a decentralized national life possible, were the long-distance electrical transmission line and the electric railway. Both visions found inspiration in the great water power development at Niagara Falls.

The Niagara power project, which went into operation

in 1895, is most often remembered in the history of technology for the decision (taken against the advice of both Thomas Edison and Lord Kelvin) to use alternating current for electric power transmission.⁶² But in the twenty years following its completion, it was equally well known as the model for a new type of city based on a new type of industry, the electrochemical industry.

In an age of rapidly growing amounts of energy under man's control, it was easy to identify energy with progress. As one enthusiastic magazine writer saw it, the history of American industrial towns was the story of water power:

Whereas Lowell was built by less than 12,000 horse-power, and Minneapolis by 25,000, Greater Buffalo, i.e., Niagara, has 120,000 already in sight, and will soon have at its disposal 500,000. The falls themselves afford a total of 7,500,000. To watch the effects of such prophecies is a sociological lark.⁶³

But predictors saw Niagara Falls and the other new industrial cities as more than larger versions of Lowell and Minneapolis. In the 1890's, new industrial processes had been developed, based on the use of electricity to stimulate chemical reactions. Among these were Charles M. Hall's electrolytic process for producing aluminum; Thomas L. Willson's electric arc process for making calcium carbide;

62 Edward D. Adams, Niagara Power (Niagara Falls, N. Y.: Niagara Falls Power Co., 1928), pp. 203-238.

63 Rollin L. Hartt, "The Future City By Niagara," Review of Reviews, XXII (1905), 604.

and Edward Acheson's electrical process for making a new abrasive, carborundum.⁶⁴ As Acheson summed it up in 1909,

the electrochemist could provide substitutes for, and in some cases improve upon, the natural exhaustible resources, and in other instances, provide the country (with) products which are now being bought abroad at an annual expenditure of many millions of dollars.⁶⁵

Even more promising developments seemed to be on the horizon. The experiments of Charles S. Bradley and D. S. Lovejoy showed that electric power could be used on a large scale to convert the nitrogen of the air into oxides of nitrogen needed for fertilizer production. And the experiments of the French physicist Henri Moisson hinted (incorrectly, as it turned out) that diamonds could be produced in the electric furnace. Such progress led one observer to proclaim that "with the aid of electric conversion apparatus, there is nothing that Niagara will fail to give us, from manure to diamonds."⁶⁶

The planned industrial city of the twentieth century, according to one group of predictors, would use the new twentieth century energy sources not to turn looms and spindles, but for the basic processes of

64 Arthur D. Little, The Handwriting on the Wall (Boston: Little, Brown, & Co., 1928), p. 13.

65 Edward G. Acheson, "The Electrochemist and the Conservation of Our Natural Resources," Transactions of the American Electrochemical Society, XV (1909), 19.

66 Thomas Commerford Martin, "'Fixing' Nitrogen from the Atmosphere," Review of Reviews, XXVI (1902), 338-342; C. Guy Suits, Speaking of Research (New York: John Wiley & Sons, 1965), p. 314.

creation.⁶⁷ Edward Bellamy's utopian version of Boston in the year 2000 and Ignatius Donnelly's fictional "great city" both expressed this dream. A more concrete non-fictional example was given in a book by two Boston inventors. One of them, King Gillette, became famous as the inventor of the Gillette safety razor; the other, Melvin Severy, was a novelist who held patents in the areas of solar power, printing presses, and electrical musical instruments. In two books written in 1894 and 1908, they proposed the creation of a new city called Metropolis, stretching from Buffalo to Rochester, that could use the power generated by Niagara Falls. The city would be planned by a single Bureau of Architecture; would be entirely constructed on a platform twenty feet above the ground; and would be served by a centralized utility system which would deliver heat, cool air, and cooked meals to each home. Linked to the sea by a St. Lawrence Seaway, Metropolis would use the transportation services of hydrofoils, airplanes and gyroscopically balanced monorail railroads. This one city would serve all of the nation's industrial needs, leaving the rest of the country free for farming and recreation.⁶⁸

The details of the Gillette-Severy scheme were unique. The spirit behind them was not. The creation of new industrial cities based

⁶⁷ Eugene R. White, "Niagarics," Munsey's, XXIX (1903), 29-30.

⁶⁸ Melvin L. Severy, Gillette's Industrial Solution (Boston: Ball, 1908), pp. 55-567

on cheap, inexhaustible power was a frequently expressed idea. As Gillette said, these plans did not wait on any scientific breakthroughs, but were instead well within the reach of "that which we have now of art, science, and invention in its most economic application."⁶⁹

There were others who denied that new industrial cities were the most economic application of the new technology -- or the most desirable.

This second school of predictors saw electricity not as a means of centralization of industry, but as a means of its decentralization. They saw the cities being reduced in size, as the countryside became one again (as it had been in early nineteenth-century New England) the focus of industry.

The technological basis of this school of prediction was the long-distance transmission of electricity. Thus the two properties of electric power which the electrical engineer Charles Steinmetz called the two unique properties of electricity -- its ability to be concentrated to a higher energy density than any other type of energy (most useful in electrochemistry); and its ability to be efficiently converted into thermal and mechanical energy (which made it a useful energy transmission means) -- each became the source of a vision of future social organization.⁷⁰

⁶⁹ Ibid.

⁷⁰ Charles P. Steinmetz, "The Effect of Electrical Engineering on Modern Industry," General Electric Review, XVII (1914), 392-396.

For the creation of a truly decentralized national life, at least two things were needed. One was to supply power economically to all locations in the nation. The other was a system of rapid, inexpensive, and flexible transportation. The steam engine and the steam locomotive had enforced the logic of urban concentration; perhaps the high voltage power line and the electric locomotive could change the basis for population distribution. It seems likely that these hopes partly explain the fact that energy transmission and railroad electrification were two of the most popular subjects for predictions in the period 1893 to 1914.

The techniques of electrical transmission were advancing rapidly in the period.⁷¹ At the field's leading edge, some accomplished engineers, such as Nikola Tesla and vacuum-tube pioneer John Ambrose Fleming, spoke seriously of wireless power transmission as a future possibility.⁷² And even when predictors stuck to conventional wire transmission, their predictions were optimistic enough. Tesla saw Niagara's power being transmitted economically as far as Chicago. Edwin J. Houston and Arthur E. Kennelly, consultants to the Niagara power project, predicted in 1894 that Niagara's waterpower could be sold over 300 miles away.⁷³

71 W. S. Moody, "General Trend of Development in Transmission and Distribution of Electric Power," General Electric Review, XI (1912), 337-341.

72 Nikola Tesla, "On Electricity," (1897), in Nikola Tesla: Lectures, Patents, Articles, p. 108; John Ambrose Fleming, "Obstruction of Progress," Nineteenth Century, XLIX (1901), 361.

73 Review of Reviews, XII (1895), 294; New York Times, May 6, 1894, p. 17.

For several years, it appeared that the range of electric transmission would continue to increase exponentially. It is a rough rule of thumb in electrical engineering that every kilovolt (1000 volts) of transmission voltage on the high voltage line corresponds to a mile of economical transmission distance. Beginning from a maximum voltage of two kilovolts in 1888 (making possible a two-mile transmission), maximum voltages had doubled about every three years, until in 1902, maximum transmission distances were about eighty miles.⁷⁴ Optimistic "electrical enthusiasts" could easily foresee a continuation of the exponential trend until every home in the United States was within transmission distances of an electric generator.⁷⁵

This extension of electric power would be, in the eyes of many predictors, more than a technical triumph. It would make possible a new way of life. The reasons for creating the concentrated city would be removed. With electricity, the farm could undergo an industrial revolution which would make the farmer as productive as the city dweller.⁷⁶

But the most important reason seen by predictors for the coming birth of a decentralized society was the replacement of the steam railroad by the electric railroad. The technology of the steam

74 W. S. Moody, "General Trend of Development . . .," 337-341.

75 William Baxter, Jr., "The Electric Transmission of Water Power," Popular Science Monthly, LII, (1898), 730-742.

76 George E. Walsh, "An Electric Farm," North American Review, CLXIII (1895), 509.

railroad -- a single powerful locomotive, pulling a long train of cars -- was economical only under the condition of long runs between centralized stations. The electric railroad, on the other hand, represented flexibility in transportation. The power source was independent of the train, so many short trains making short-distance runs to widely scattered locations created the most even and efficient drain on the power station. From 1888 to 1903 -- the period of forty-fold increase in maximum transmission distance--a steady stream of predictions forecast the coming of the electric railroad.

In 1888, the electric railway was still engaged in proving its superiority to the horse.⁷⁷ Less than four years later Frank J. Sprague, the outstanding inventor of electric railroad equipment, could already foresee the extension of the electric beyond urban use to interurban transportation, and perhaps eventually to competition with the steam locomotive. The demographical implications were enormous, considering that the amount of densely settled land served by street railways would grow as the square of the radius of the electric lines from their central stations.⁷⁸

For the next decade, a steady stream of predictions linked the coming electric railway with a decentralization of society. One

77 "Advantages of Electricity for Railroad Work," Electrical Engineer, VII (1888), 302.

78 Frank J. Sprague, "Future of the Electric Railway," Forum, XII (1891), 120-130.

79 Henry J. Fletcher, "The Drift of Population to the Cities: Remedies," Forum, XIX (1895), 737-745.

commentator saw the electric railroad as a means of emptying the cities, and the transmission of electric power to rural factories as a means of supporting the new rural population. "The telephone, the electric railway, (and) the manual training school," he concluded, were the potential cures for the present drift of population to the cities.⁷⁹ "The next century," stated another, "whatever it may have in the way of aerial flight in store for us, will have no difficulty, if it desires the honor, of being christened 'the trolley age.'"⁸⁰

Two of the leading electrical engineers of the 1890's, Louis Duncan and Charles Steinmetz, agreed in 1895 that electrification of all railroads was coming.⁸¹ A third engineer, Joseph Wetzler, added his "firm belief" in the same year "that all railroads will be eventually operated electrically." He saw "the single car or small train unit, operated at frequent intervals, taking the place of the present long train."⁸²

This flexibility was the key to the predicted changes. The ultimate in flexible electric transportation was put forward in 1893 by a Scientific American editor, who spoke of a plan

⁸⁰ Appleton Morgan, "The Successor of the Railway," Forum XXXXVI, (1895), 750.

⁸¹ Louis Duncan, "The Substitution of Electricity for Steam in Railway Practice," Transactions of the A.I.E.E., XII (1895), 386; Charles Steinmetz, ibid., p. 388.

⁸² Joseph Wetzler, "Will the Electric Motor Supersede Steam?" Scribner's, XVII, (1895), 599-600.

considerably agitated among electrical engineers and manufacturers to lay electric railways on all the country roads, and through the general distribution of electric power, to enable the farmers to not only travel wherever they please to go at about any rate they are willing to risk, in vehicles under their own private control, but to do a large part of their farm labor by electrically propelled agricultural implements.⁸³

Some veteran railroad men (including Cornelius Vanderbilt, grandson of the Commodore) defended the use of steam on the railroads.⁸⁴ But the majority of predictions made in the popular press favored the coming of the electric railroad to all phases of transportation, from city transit to long distance passenger and freight service.⁸⁵ By 1902, the future of transportation seemed clear to at least one newspaper editor:

With good roads, and with trolley cars to carry one to the shop, the prayer meeting, the library, the school, the sewing circle, and the village improvement society, country industries will be made easier, touch with the markets more rapid, amusements more generous, and life will be broader, freer, more diverse.⁸⁶

83 "Country Roads and Electricity, Scientific American LXIX, (1893), 231.

84 Cornelius Vanderbilt, "Electricity as a Motive Power," North American Review, CLXXV (1902), 779-790.

85 B. A. Behrend and A. G. Wessling, "The Future of the Electric Railway," Electrical World, XXXVII (1901), 82-83; A. N. Brady, "Electricity in the Service of Man," North American Review, CLXXIII, (1902), 677-678; Albert L. Johnson, "The Trolley Age," Scientific American Supplement, LI (1901), 21180.

86 Charles M. Skinner, "The Electric Car," Forum LXXXIX, (June, 1902), p. 807.

Another writer, linking the themes of electrification and decentralization, forecast that "cities will become more and more places for business and special forms of amusement, while the country will be the home of the people."⁸⁷

However, the peak of public optimism about electrification, just after the turn of the century, coincided with a dawning realization among electrical engineers that future progress could not possibly be as swift as that of the past. In particular, the transmission distance of electric power could not go on doubling every three years without running into some severe economic problems. "There is no real limit beyond which it is impossible to deliver electric power," wrote electrical engineer Paul M. Lincoln in 1904, "provided no limit be put upon the amount of money to be spent."⁸⁸ His forecast of the actual trend of development was cautious:

The present state of the art of long-distance transmission is the result of evolution. No engineer is prepared to believe that this process of evolution has just begun and that epoch-making and revolutionary improvements in the art of long-distance transmission are impending, as some electricity-in-its-infancy paragraph writers would have

87 George E. Walsh, "A New Era of Rapid Transit," New England Magazine, XXXVII (1904), 181-186.

88 Paul M. Lincoln, "Limitations of Long-Distance Electric Power Transmission," Cassier's, XXVI (1904), 129.

us believe. On the other hand, no engineer is prepared to believe that the process is complete.⁸⁹

In other words, progress would continue, but at a measured pace rather than a gallop. This prediction, made in 1905, was extremely accurate. The growth of maximum transmission voltages, and therefore of maximum transmission distances, was reduced from an exponential to a linear function of time. In other words, the longest transmission distance, which had been doubling every three years from 1888 until 1902, doubled only once more between 1902 and 1920, and did not double again until 1940.⁹⁰ The technical problems of increasing voltage - especially the failure of insulators, losses due to the corona effect, and system stability problems - could be met, but only at a large expense of money and time. As such considerations became evident, predictions of a revolution in power transmission became less common.⁹¹

As enthusiasm over the revolutionary advances to be made in long-distance transmission died down, the prophecies that electricity

⁸⁹ *ibid.*, p. 137.

⁹⁰ Moody, "General Trend of Development," pp. 337-341; G. W. Alexander, "Trends in EHV Transmission Equipment," IEEE Spectrum, II (1965), 80.

⁹¹ Louis Bell, "Electric Power Transmission," Electrical World and Engineer, XXXVII (1901), 32; Ralph D. Mershon, "Long-Distance Power Transmission," Engineering Magazine, XXVIII (1905), 830-832.

would replace steam in rail transportation also became less common. The electric railway not only failed to live up to the optimistic predictions that its backers had made from 1888 to 1903; it also underwent a surprise attack on a front that had apparently been secured -- urban trolley service.

The automobile only began to appear in predictions as a threat to the electric railway, and as a potential form of mass transport for the future in about 1902 or 1903. This fact is agreed upon both by a contemporary observer,⁹² and by a leading recent historian of automobile development, James Flink, who notes that "after 1902, predictions began to be made quite freely that an automobile for the masses would inevitably be produced in the near future."⁹³ This is not to say that there was not widespread interest in the automobile before 1902, only that most of the predictions before 1902 dealt with the automobile as a sporting or luxury vehicle. Of course, there were exceptions, such as a Scientific American article in 1897 which forecast that the automobile "will be as indispensable to the everyday life of the race as are the steam locomotive and the electric car of our day."⁹⁴ But for the most part, the electric railway was the main hope

⁹² James P. Holland, "The Present and Future Status of the Automobile," Munsey's Magazine, XXIX (1903), 172.

⁹³ James J. Flink, America Adopts the Automobile (Cambridge: MIT Press, 1970), p. 40; see also John B. Rae, American Automobile Manufacturers (Philadelphia: Chilton Co., 1959), pp. 32-45.

⁹⁴ Scientific American, LXXVII (1897), 35.

for mass transportation up to about 1903, and the automobile the main subject of predictions in that area from 1903 on.⁹⁵

Just as the turn-of-the-century forecaster in the area of prime movers had correctly foreseen a big change coming, but had for the most part failed to pick out the agent of that change, prediction in transportation was correct in general but not in specifics. An agent of flexible mass transportation was on the horizon; but that agent was to be the automobile, not the electric railway.

The effects predicted from the power and transportation revolutions proved equally elusive. The broader social goals aimed at by many of those interested in electric power transmission and the electric railway were only partly achieved. The actual suburbs made possible by trolley and automobile little resembled the bucolic decentralized world of the predictors' dreams. The electric railroad failed to empty the central cities of either their populations or their problems. The hope that Thomas Edison voiced in 1893, that

when the fathers of such families as we now see
in Mulberry and Cherry Streets can go every
night to their country homes thirty miles away

⁹⁵ Examples: Holland, "The Present and Future Status of the Automobile," (1903); Winthrop Scarritt, "The Future of the Automobile," Cassier's, XXIX, (1906), 427-430; Harry B. Haines, "The Automobile," World's Work, XI (1906) 7346; Herbert L. Towle, "The Automobile of Tomorrow," Scribner's, XLIII (1908), 581-586.

from work in half as many minutes for five cents, then we shall be well on our way to a solution to one of the ugliest problems of our day,⁹⁶

was fulfilled at least in part by the automobile. But the central cities were refilled by new social groups with new problems. The power and transportation revolutions had helped transform the problem of the city, but had not solved it. As so often happens, the actual future was not one of several perceived alternative futures, but rather a mixture of elements of the various alternatives.

⁹⁶ Charles D. Lanier, "Thomas A. Edison," p. 51.

CHAPTER III

THINKING ABOUT RESOURCES: 1890- 1914

Mankind has never learned to use a natural resource without almost immediately considering the possibility of its imminent exhaustion. Wood was the principal resource of America in the eighteenth century. As early as 1744, complaints began to be heard about localized wood shortages.¹

As coal succeeded wood in fuel uses during the nineteenth century, concern about shortages diminished. But by the end of that century, several Americans were at least beginning to set limits upon the expected duration of America's coal age.

Such a concern was only one manifestation of a general attitude toward the future of technology concerned with the probable limits of the resource base underlying society's industrial techniques. To holders of such a view, the hope of "exhaustless and costless energy" was a delusion. At some future time, whether generations, centuries, or millenia away, the limits of nature would be felt.

The outlook of this school of forecasters brought a different type of technology to attention than had the outlook of the prophets of a power age. For persons concerned with the possibility of future

1 Glenn Hueckel, "A Historical Approach to Future Economic Growth," Science, CLXXXVII (14 March 1975), 927.

resource shortages, the following three questions are of major importance. How much of each major resource do we have, and how long will it be until the scarcest among them are exhausted? Is there any chance that society can be powered by its annual energy "income" (fully replenished resources like water power or crops) instead of by its energy "capital" (its progressively depleted mineral resources)? And how can we stretch out our perishable resources, and store for future use reserves that are not presently needed?

The Limits of Resource Supply

Estimates of resource supplies tended to be impressionistic at the turn of the century, and the general impressions created for the three major fuels were not cheerful ones. Coal's life time was measured in centuries, oil's in generations, and that of natural gas in decades or less. Physicist Louis Bell gave our coal supplies "perhaps a few hundred years,"² while engineer R. H. Thurston, even more vaguely, suggested that

civilization, the life of the race, dependent upon our coal-beds, is only assured of ultimate and, on the geologist's scale of time, early extinction, unless, indeed, again, consulting nature and the lessons of life, as we have so often profitably

2 Dr. Louis Bell, "Natural Sources of Energy", Cassier's, XXIV (1903), 305.

done before, we can learn of new ways of availing ourselves of existing forms of energy in nature.³

Though their estimates were faintly alarming, Bell and Thurston were by no means the most extreme pessimists about the future of energy supply. Partly to answer the questions of the more alarmed elements, who feared an immediate coal shortage, the U. S. Geological Survey made a full investigation. By 1909, it arrived at the conclusion that (as of 1907) there were about 2200 billion tons of coal lying within the boundaries of the United States. Of this, 1400 billion tons were considered of high grade and easily accessible for mining.⁴

What did this result mean in terms of the future? Looking at the bright side, over 99% of the initial supply of coal of the United States was still in the ground in 1907.⁵ If consumption remained at its current level - about 500 million tons a year - this was enough to last 4000 years.⁶ On the other hand, the rate of consumption had not

3 R. H. Thurston, "The Next Great Problems of Science," p. 43.

4 U. S. Congress, Senate, Report of the National Conservation Commission, 60th Congress, 2nd Session (Feb., 1909), Senate Doc. 676, I, 97; Marius R. Campbell, "How Long Will the Coal Reserves of the United States Last," National Geographic, XVIII (1907), 137.

5 Marius R. Campbell, "Letter," The Nation, XC (1910), 400.

6 Boston Globe, May 7, 1911, p. 3.

remained constant in the past, but had been increasing. According to Marius R. Campbell, one of the directors of the Geological Survey's study,

if the constantly increasing rate which has marked the consumption during the past 90 years be maintained, our coal will be practically exhausted within 100 years.

Trying to balance between these two extremes - forty centuries and one century - Campbell guessed that around two hundred years was a reasonable estimate for the lifetime of our coal fields.⁷ Campbell's estimates of total supply of coal, later slightly revised, remained the most commonly accepted ones until 1953, when a revision of the definition of easily accessible reserves caused them to be revised sharply downward.⁸ However, increases in coal use have also lagged behind his assumptions, and his estimate of roughly two-hundred-year lifetime for coal reserves is still a widely held one. Modern predictors typically see the U. S. coal supply as lasting well into the twenty-second century. Predictions about oil and gas were both less soundly based and more pessimistic. The general impression was that shortages were not far away. Herbert H. Suplee,

7 Marius R. Campbell, "How Long Will the Coal Reserves of the United States Last?," p. 138.

8 Sam H. Schurr and Bruce C. Netschert, Energy in the American Economy, 1850 - 1975 (Baltimore: Johns Hopkins, 1960), pp. 303 - 306.

editor of Cassier's Engineering Monthly, summed up a common feeling:

Petroleum and its derivatives can be used only with the certainty that the continually decreasing supply will mean a continually increasing cost. Natural gas has already passed the days of plenteousness which led to reckless extravagance.⁹

The Conservation Commission, looking at the oil situation in 1909, endorsed and quantified this conclusion. Dr. David Day, the Geological Survey's oil and gas expert, noted that the known oil reserve of 15 billion barrels was being drained at a rate which currently stood at 166 million barrels a year (about one per cent of known reserves). Current annual rates of increase in oil use led Dr. Day to the belief that oil supplies would last less than a half-century. He did not try to estimate the size of natural gas reserves, but he believed it "safe to predict that within twenty-five years the known fields will be exhausted."¹⁰ Of course, rising costs with growing scarcity would prolong the time until the literal exhaustion of oil fields well beyond the half-century mark. But the main point was that oil could not long continue to be a major fuel.

For realists, the fuel picture in the early nineteenth century may have been bright in the short range but it was definitely bleak in the long. For the long pull, the world had two choices. These were

9 Herbert H. Suplee, "Applied Science," Forum, XXIX, (1907), 211.

10 U. S. Congress, Senate, Report of the National Conservation Commission, pp. 100-101.

often portrayed in the metaphor of the inheritor of a large but finite fortune. He could choose to either live on the interest from his fortune, or, by efficient management, try to make the principal last as long as possible.

Living on the Interest

The idea of living on the nation's energy "interest" meant obtaining power from those sources of energy that were renewed continually by nature. One such source was the gravitational attraction between the moon and the earth, which powered the tides. Another was solar power, either used directly, by trapping the sun's rays for heat, or indirectly, through processes like photosynthesis or placing a turbine in the path of the solar-powered energy flows of wind and water.

The direct use of solar power had been one of the fixtures of earlier utopian fiction. But the great capital costs and land requirements of a solar power installation far exceeded those of a coal power plant. John Ericsson confirmed the impracticality of this type of power in a series of experiments in the 1880's.¹¹ At the turn of-the-century, interest in solar power was low.

However, concern about mineral fuel reserves gave a new

11 A. S. E. Ackermann, "The Utilization of Solar Energy", Annual Report of the Smithsonian Institution, 1915 (Washington: Gov't. Printing Office, 1916), p. 150.

impetus to consideration of this type of energy. According to those prophets mindful of diminishing resources, solar power had an assured place in tomorrow's world. It would never be a direct competitor with coal. But, as Louis Bell explained, when fuel becomes scarce

the steady tendency must be to cause emigration to regions where less artificial heat is needed than at the present centres of the world's activity, and to concentrate the new civilization in such of these regions as are supplied with natural sources of energy.¹²

Such predictions gave a nice symmetry to the course of world history. Civilization, which had arisen in sunny river valleys of the Middle East, but had later advanced furthest in the chillier northern latitudes, would return to its birthplace when the coal supply gave out. The technology and economics of this return were sketched out by some prominent engineers. And on a more practical level, some pilot projects were actually put forward to test the idea of a movement of civilization to the deserts and river valleys. The decade from 1904 to 1914 was one of eager interest in the future of solar power.

Other engineers who studied the feasibility of solar power and found it to be a promising energy source for the future included Reginald A. Fessenden, a pioneer in the development of radio; and I. Thornton Osmond, a professor of engineering at Pennsylvania State

12 Dr. Louis Bell, "Natural Sources of Energy," p. 307.

University. Of these, Fessenden made the most detailed prediction of the future of solar power, in a paper presented to the British Association for the Advancement of Science in 1911.¹³

Like most other advocates of a bright future for the sun, Fessenden either deliberately or accidentally manipulated his figures to improve the prospects of a practical power plant. For example, he gave the solar energy annually falling on a patch of land ten meters on a side as between five and fifteen million kilowatt-hours. This figure is at least five times higher than the value computed using contemporary measurements by astronomers of the amount of solar energy which reaches the earth.¹⁴ Likewise, he greatly underestimated costs. His calculated 1911 value for the first cost of a solar power plant was \$62.50 for each horsepower installed. According to an inventor who had already built solar engines, the actual 1911 cost was \$300 per horsepower.¹⁵

When an experienced engineer could be so far off in his estimates, it is no surprise that laymen would have greatly exaggerated ideas about the potential of solar power. One enthusiast, writing in 1903, saw both energy-saving and political advantages to solar power.

13 "Power Production From Solar Radiation," Scientific American Supplement LXXI (1911), 39.

14 "A. S. E. Ackermann, "The Utilization of Solar Energy", p. 142.

15 Frank Shuman, "Letter," Scientific American Supplement, LXXI (1911), 78.

Recalling the 1902 coal strike, he contrasted "the slavery of coal consumers" with "the freedom of people who receive daily gifts of fuel from the creator," and concluded:

Pure country power may be had as well as 'pure country milk'; and the costless engine may replace the expensive ones now enjoyed by but a small part of the people who need them.¹⁶

More surprising than the enthusiasm of the uniformed was the decision of at least two groups of investors that the future prospects of solar power warranted the initiation of projects for its utilization.

The first group into the field was a group of Boston businessmen, who in 1901 formed the Solar Motor Company based upon the inventions of one Aubrey G. Eneas. After three unsuccessful attempts to build a solar motor in Boston, and a fourth in Denver, Eneas eventually succeeded in constructing a successful 15 horsepower solar-powered pumping engine in South Pasadena, California, in 1905. The company seems to have gotten no further than this in achieving Eneas's stated aim of using solar power to develop the arid regions of the American west.¹⁷

16 Charles H. Pope, Solar Heat: Its Practical Applications (Boston: Pope, 1903), pp. 122 - 123; 154.

17 U. S. Patent 670, 916; Current Literature, XXX (1905), 582-583.

A more ambitious effort was the Sun Power Company of Camden, New Jersey. The main engineer for this project was Frank Shuman, a veteran Philadelphia inventor who had patented numerous devices for the construction industry.¹⁸ The company also called upon the services of other well known experts. Physicist C. V. Boys was a consultant, and Charles S. Bradley, inventor of the rotary converter and many other electrical devices and chemical processes, contributed at least one patent.¹⁹

After the successful operation of a pilot plant built by Shuman at Tacony, Pennsylvania, the Sun Power Company actually attempted a commercial solar power project. In line with prophecies of the eventual return of civilization to its cradle, the site chosen for this test was at Meadi, Egypt, on the Nile River south of Cairo. The plant was built to provide up to 100 horsepower for irrigation pumps. Its operating principle was the same simple one used by John Ericsson and other solar power pioneers. A parabolic mirror focused the sun's rays on a water-filled tube producing steam. The steam was used to run a low pressure steam engine. The Meadi plant remains to this day the most ambitious practical application of solar power.

As a testing ground for the future of solar power, the success

18 Frank Shuman, "Letter", p. 78.

19 A. S. E. Ackermann, "The Utilization of Solar Energy", pp. 163-166; U. S. Pat. 995219.

of the Meadi plant was uncertain. A. S. E. Ackermann, a British consulting engineer, performed extensive tests on the project and concluded that the maximum power output had been 63 horsepower; that the engine required 22 pounds of steam per brake-horsepower hour (twice that of a comparably-sized conventional steam engine, which operated over a wider temperature difference); and that 183 square feet of absorbing surface were necessary to gather enough solar power to produce one horsepower of mechanical output. Theoretically, such an area gathered enough energy for 30 horsepower, implying a 3% efficiency for the Meadi engine.²⁰

As a commercial venture, the Meadi plant faded away during the First World War. As a prediction of the future of technology, it led to debates which restated previous attitudes. Solar power would be costly and cumbersome but would it be necessary in a coalless future? The editors of Scientific American concluded, regarding the Ackermann tests, in 1914:

These results show how little promise there is of obtaining mechanical energy from the sunshine on a commercially economical scale.

They gave as reasons the plant's large area, its "costly cumbersomeness," and the "great variability in the rate of power production."²¹ Solar power advocates were undaunted. In spite of these

20 A. S. E. Ackermann, "The Utilization of Solar Energy", pp. 163-166; "Solar Energy and Solar Engines", Scientific American Supplement, LXIV, (Sept. 21, 1907), pp. 185-186.

21 "Energy From the Sun", Scientific American, CX (1914), 424.

disadvantages of a solar-powered economy, Frank Shuman concluded,

Certain it is that it must be done within the next one hundred years or so, or else we shall have to revert to barbarism, because eventually all coal and oil will be used up.²²

As a substitute for coal, direct use of solar energy was a long range possibility. But due to the size and unreliability of solar motors, it was clear that a different substitute for the apparently rapidly diminishing oil supplies of the country was needed. The automobile had hardly become firmly established as a major means of transportation when there were speculations about the probable automobile fuel of the future.

A prediction made by a large number of people in the years 1900-1910 was that our unrenovable oil supplies would be first supplemented, and then replaced, by an annually renewable fuel -- alcohol, made from surplus farm products. Like many other predictions of the future of technology, the vision of an "alcohol economy" had its social and political implications. Alcohol production, in the view of one of its advocates,

would place the rapidly growing motor industry on a secure basis, because the production of alcohol can be extended almost without limit. It would give our chemical manufacturers a chance of gaining some share of the enormous trade now in other hands. Its production might be made, by suitable legislation, to encourage agriculture, to

22 Frank Shuman, "Letter", Scientific American, CX (June 27, 1914), 519.

take back to the land some of the 900,000 workers
who have left it since 1851.²³

Three major problems stood in the way of the adoption of alcohol as a substitute for petroleum. Two of these were technical ones. It remained to be demonstrated that internal combustion motors could be adapted to run smoothly and efficiently on alcohol, and the cost of present processes for producing alcohol was prohibitive. The third problem was a political one. Although processes had been developed to denature alcohol to make it unfit to drink, the tax on denatured alcohol had not been lowered to reflect its intended use as fuel.

A number of predictors believed that the first two problems would be quickly solved, and therefore put pressure on the government to remove the third. One leading advocate of the use of alcohol as a solution to our future fuel problems was Elihu Thomson, whose shrewd commercial appreciation of the promising areas of electrical technology had helped build the Thomson-Houston Company into one of the leaders of the electrical machinery industry. Another was Robert Kennedy Duncan, professor of chemistry at the University of Kansas, and a leader in the encouragement of industrial applications of chemical knowledge.

23 W. R. Ormandy, "Alcohol as a Motive Power", Engineering Magazine, XXVII (1904), 430.

Thomson, who had built electric automobiles and held several patents on steam automobiles had come to accept the internal combustion engine as the automobile's power plant. But he believed that the imminent increase in the price of mineral fuels made it "reasonable to predict" that ethyl alcohol would supersede gasoline in the not too distant future. Compensating for the fact that a pound of alcohol had less than half the energy content of a pound of gasoline was the fact that alcohol could be compressed further than gasoline without igniting, thus making it a more efficient fuel. Thomson's own experiments convinced him that the problem of converting gasoline engines to alcohol power was a simple one. He also was convinced that the selling price of alcohol could eventually be brought down to twelve cents per gallon.²⁴

Robert Kennedy Duncan professor of chemistry at the University of Kansas and a leading proponent of industrial research examined "The Problems of Industrial Alcohol" in detail for the readers of Harper's in 1907. He held that in addition to being inexhaustible, alcohol had other advantages over gasoline. It was less susceptible to explosive accidents. It could be produced anywhere in the country, lessening the burden upon pipelines and tank cars. And the exhaust

24 Elihu Thomson, "Alcohol and the Future of the Power Problems, Cassier's, XXX (1906), 310-312; Elihu Thomson, "Alcohol Engines as a Future Power," Scientific American Supplement, LXIII (1907), 26017-26018.

from alcohol motors had a much less offensive odor than gasoline's exhaust. Against these advantages was balanced the present high cost of alcohol production.

Duncan concluded that the combination of falling alcohol prices (due to greater experience in alcohol production, and the resulting improvements that would be discovered) and rising gasoline prices (due to diminishing supplies) "will, before very long throw the advantages to the side of alcohol." He saw a day when the price of alcohol would stand at 30¢ a gallon or less, and farm-grown cellulose would make up the nation's major fuel resource.²⁵

The assertions of Thomson and Duncan regarding alcohol's higher compressibility as a vapor, cleanliness, and safety were borne out in a series of tests run by engineers of the U. S. Geological Survey technological branch in 1909. The government engineers concluded that "it seems reasonable to expect that the price of denatured alcohol will eventually become as low or lower than the price of gasoline, especially as the price of gasoline advances."²⁶ The tax barrier blocking the production of cheap alcohol was lowered at the urging of the industrial alcohol groups. But the idea of an alcohol

25 Robert Kennedy Duncan, "The Problems of Industrial Alcohol", Harper's, CXV (1907), 463 - 469.

26 Robert M. Strong, "Commercial Deductions from Comparisons of Gasoline and Alcohol tests on Internal-Combustion Engines", U. S. Geological Survey, Bulletin 392 (Washington: Government Printing Office, 1909), pp. 6-8; 34-36.

based motor fuel remained an unfulfilled prediction.

So, by 1914, the use of the earth's solar energy income, as collected either by parabolic mirrors or by growing plants, seemed to offer the likeliest long range alternative to coal and oil. But a more indirect form of solar energy seemed more immediately available. For solar energy, powered the flow of winds, waterfalls, and waves. With electrical transmission, all of these became at once potential replacements for coal.

Wind and wave power had strong adherents. The technology of windmills attracted diminishing interest during the period from 1893 to 1914. The number of patents listed in the annual report of the Patent Office under the title "windmill" fell from 54 in 1893 to 15 in 1914. Still, some prophets gave wind power a place in the future world. One who did was Dr. Harvey Wiley, chief chemist of the Department of Agriculture and noted leader of the movement to reform the laws regarding food and drug inspection. Wiley held that "the great social and economic trio of the future is 'The Windmill, the Dynamo, and the Storage Battery'," and looked to these three devices to provide the electrical energy needed in a future in which coal had run out and the earth's climate was turning colder.²⁷

27 Dr. Harvey Wiley, "Zero at the Equator Some Day," New York Times Magazine, Jan. 1, 1911, p. 3.

Interest in the wave motor began to grow at the turn of the century. The basic idea was simple. A buoy floating offshore, rising and falling with the ocean's waves, tapped the energy represented by the water's up-and-down motion. A pulley, driving a ratchet mechanism on the shore, converted the up-and-down motion of the waves into useful mechanical energy. Alternatively, the waves could be used to force water into an elevated reservoir, which could drive a hydroelectric power plant. About fifteen patents per year were granted by the United States on such devices in the last few years of the nineteenth century. By 1915, the figure was over twenty patents per year. A California prototype drew wide attention, claiming a power output of two or three horsepower for every square foot of floating surface.²⁸

For most predictors, however, the answer to the coming coal shortage was not wind or waves. It was falling water, used to turn a water wheel or turbine. The two main questions for predictors were: how much waterpower was potentially available in the United States? and how did the economies of hydroelectric power compare with other

28 U. S., Annual Report of the Commissioner of Patents, 1898-1915 (Washington: Government Printing Office, 1899 - 1916), count of all patents under the titles "wave motor," "tide motor," or "surf motor"; George Sutherland, Twentieth Century Invention (London: Longmans, Green & Co., 1901), p. 37; George B. Waldron, "Harnessing the Sea and Sun," Current Literature, XXXI (1901), 735 - 736.

methods for making electricity?

A widely accepted answer to the first question appeared in the National Conservation Commission's report in 1909, in a study by M. O. Leighton, chief hydrographer of the U. S. Geological Survey.²⁹ Calculating first the total waterpower available to in the United States, assuming that all possible sites and storage facilities are used, Leighton arrived at an absolute maximum installed power capacity of at least 200,000,000 horsepower, "and probably much more."³⁰ This figure for the absolute maximum of waterpower development was refined in 1912 to 230,000,000 horsepower.³¹ This estimate still holds in the 1970's. But this maximum figure, Leighton explained, gave a false picture of the future of waterpower developments. Only 66,518,000 horsepower was available half of the year or more often, without the construction of costly storage facilities. And only 37,000,000 horsepower was "now available at a cost comparable with steam installation." Of this available resource, about 5,300,000 horsepower were in use in 1909.³²

29 M. O. Leighton, "Undeveloped Water Power," in U. S. Congress, Senate, Report of National Conservation Commission, I, 41.

30 Ibid., p. 162.

31 U. S., Congress, Senate, Report of the National Waterways Commission on Development and Control of Water Power, U. S. Senate Doc. 274, 62nd Congress, 2nd Session, (1914), #6174, p. 674.

32 ibid., p. 274; Report of the National Conservation Commission, I, 41.

To the technically trained observer, these figures made it clear that while waterpower could go a long way toward adding to our energy resources, it could not fulfill all future demands for power, heat, and light. One calculation found that the world's maximum waterpower resources could provide in one year only 40% of the energy annually obtained from burning coal.³³

The general public, however, was not aware of these limitations upon waterpower capacity and entertained exaggerated hopes about the future of "free" waterpower, and the "harnessing" of our rivers. To many, waterpower represented an indefinitely expansible source of power. This came out clearly in a congressional debate over development of the Coosa River in Alabama, in 1912. "No man is willing to say," said a representative from Mississippi,

that in the near future some wizard like Edison will not appear who will make it possible to produce 100,000 horsepower at this Coosa River plant instead of 10,000; that instead of 35,000,000 as exist today, we will have 350,000,000 primary horsepower in this country, and then every home in the land may be lighted and heated by hydroelectric power, and every wheel that is turned will be turned by that power.³⁴

Such an overemphasis upon the potential of waterpower as a solution to future energy problems brought on a counter-attack from

33 Georg Von Dem Borne, "Energy Sources of the Future," Scientific American Supplement, LXXVII (1914), 80.

34 U.S. Congressional Record, XLVIII 62d Congress, 1st Sess. (1912), p. 11579.

those with interests in coal-fired power generation. It was obviously in the interest of the president of the American Association of Heating and Ventilating Engineers to deflate the "overestimated value" of waterpower. Condemning those who had painted hydroelectric power as "a gift of Nature and a national resource, 'white coal', harnessed energy, or other phantasmagorical assumptions," he held that steam power was indispensable for most power uses.³⁵

By 1914, predicting the future of waterpower was becoming less a technological issue than a political and economic one. At hearings held to assess the future of waterpower, a series of witnesses attempted to put the role of waterpower into perspective. Such experts as Gano Dunn, president of the American Institute of Electrical Engineers, Oscar T. Crosby, an engineer and transit company executive, and Calvert Townley, assistant to the president of the Westinghouse Electric and Manufacturing Company, all told the same basic story. They contended that the hydroelectric resources of the country had been exaggerated. Those resources were not actually capable of replacing steam power. Furthermore, steam power was superior to waterpower on grounds of continuous availability and cost. The main future role of waterpower was, they said, not as a substitute for coal,

35 Reginald Pelham Bolton, "An Overestimated Value," Cassier's XLIV (1913), 69; 74.

but rather as a supplement to it, particularly in applications where large amounts of cheap power were needed, such as in electro-chemistry.³⁶

The search for means of living on the annual energy interest had therefore bogged down by the First World War. The direct use of solar power had been shown to be theoretically adequate, but possessing many practical difficulties. The use of solar energy indirectly, through photosynthesis and alcohol production, seemed practical. But none of its advocates seemed interested in developing an alcohol substitute for gasoline until absolutely forced to by the oil shortage, which most still believed to be inevitable. And finally, the panacea of waterpower was shown to be a limited one. The calculated upper limit on waterpower resources was roughly equal to the total installed mechanical power capacity of the country, and already well below the country's total energy needs in 1914. Unable to depend on energy interest, prophets sought ways of stretching the principal as far as possible.

Stretching the Principal

Awareness of the limits of energy resources, and concern for assuring to posterity the benefits of the technological revolution,

36 U.S. Congress, Senate, Report of the National Waterways Commission on Development and Control of Water Power pp. 9-125.

caused a change in the nature of technological predictions in the years before 1914. The emphasis began to shift toward conservation of existing supplies of fuel. The elimination of waste began to take on a high priority. The chemist and the physicist began to replace the independent inventor as the most vocal prophets of the future of technology.

An example of the role which chemistry could play in prolonging the world's supply of natural resources was given by the case of the world's supply of nitrates. In 1898, Sir William Crookes, an eminent physicist, had made a widely publicized prediction to the British Association for the Advancement of Science. Comparing the supply of nitrates available from the natural deposits in Chile with the expected world fertilizer needs, he concluded that the world faced starvation within a century unless a means of artificially preparing nitrates was found. The best method to be found for doing this, Crookes predicted, was by electrically fixing the nitrogen in the air. That the heat created by an electric arc would combine nitrogen and oxygen in the air to form nitric acid had been shown by Joseph Priestly in the eighteenth century. What was needed was a commercial process taking advantage of this effect.³⁷

37 Thomas C. Martin, "Fixing Nitrogen from the Atmosphere," Review of Reviews, XXVI, (1902), 338 - 342; F. B. Carpenter, "The Fixation of Nitrogen", Journal of Industrial & Engineering Chemistry, I (1904), 4-5.

No sooner was the problem stated than attempts at its solution were put forward. Electrical inventor Charles S. Bradley and his associate D. R. Lovejoy set up the first electrical nitrogen fixation plant at Niagara by 1902. Within the next decade two Norwegians, Birkeland and Eyde, had achieved a commercial success in a similar plant which took advantage of Norway's cheap electrical power. The entry of numerous chemists into the race with other suggestions made it seem assured by 1914 that one or another of the artificial processes would solve the world's nitrogen problems.³⁸

The lesson for the future to be derived from the nitrogen fixation story seemed clear. Chemical ingenuity could meet the problems created by resource shortages.³⁹

One application of chemistry to the problem of future fuel reserves was in trying to find ways to use present fuel stocks more efficiently. Robert Kennedy Duncan, in an inquiry into recent chemical patents in 1908, undertaken on the theory that in patents "lie actually in statu nascendi to-morrow's ways and the implements of to-morrow's civilization," concluded:

38 Martin, "'Fixing' Nitrogen from the Atmosphere," p. 340; E.F. Roeber, "Some Economic and Aesthetic Aspects of Electro-chemistry," Journal of Industrial & Engineering Chemistry, VI (1914), 436-439.

39 Thomas C. Martin, "'Fixing' Nitrogen from the Atmosphere," p. 339.

First in obviousness among the patents are those which deal with waste. Thus with fuel: Through the gradual depletion of the fuel resources of the older countries, and the conservation of our own through combinations of capital, the consequent rise in the price of fuel the world over has forced contemporary men to look for burnable material in what was the waste of former days.⁴⁰

The most obvious approaches toward stretching out man's fuel supply were first, more efficient use of energy, and second, more efficient methods of energy conversion.

However, the goal of efficiency in energy use often conflicted with the goal of convenience. Lighting provides an excellent example. Methods of arc and discharge lighting developed by such inventors as Peter Cooper Hewitt, Nikola Tesla, and Daniel Macfarlan Moore, proved far more efficient than the Edison-type incandescent lamp. In the 1890's, many predictors expected that further developments along such lines would lead to lighting combining high efficiency with the color distribution of daylight.⁴¹ Even the secret of the firefly's light seemed within the reach of lamp technology.⁴²

But the Edison-type lamp was far from defeated. Intensive research efforts in Austria, Germany, and the United States led to the

40 Robert K. Duncan, "On the Trend of Chemical Invention," Harper's CXVII (1908), 866-867.

41 New York Times, May 7, 1896, p. 8.

42 R. A. Fessenden, "Light Without Heat," Electrical World, XXXVII (Jan. 5, 1901), 26.

use of tungsten in filaments, tripling lamp efficiency. Although its efficiency never caught up to the Hewitt and Moore lamps, the tungsten lamp, unlike its competitors, came in small (100 watts or less) sizes, was rugged and moderately long lived (about 1000 hours), and ran off conventional electric power outlets. In the mean time, research on arc, discharge, and firefly-type lamps met with numerous dead ends.⁴³ The eventual development of commercially successful fluorescent lamps in the 1930's partly vindicated the judgment of predictors. But, as in the case of prime movers, in the short run they had been misled by overemphasis upon the easily quantifiable consideration of efficiency.

Achieving more efficient energy conversion in the first decade of the twentieth century meant making more efficient use of coal. In part, this involved the gasification of low grade coal, to make a fuel suitable for powering the gas engines that (as has been mentioned) were among the most promising of the new types of prime movers.

A five-year study undertaken in 1904 by the U.S. Geological Survey sought "to determine the value of the gas producer as a means of increasing efficiency in the use of the coal supplies of the United States."⁴⁴ Its conclusion was:

43 "Inventing the Light of the Future," Scientific American, CIV (1911), 382-383.

44 Robert Heywood Fernald, "Recent Development of the Producer Gas Plant in the United States," U. S. Geological Survey Bulletin, No. 416 (Washington: Government Printing Office, 1909), p. 5.

In the United States cheaper power is constantly sought. The water power possibilities of the country are being realized and the hydro-electric power plant is a wholesome cause of competition. The supply of fuel of marketable grade is not unlimited. Prices for such fuel must necessarily increase. The cost of transporting coal from the mines is high, and the possibilities of obtaining a sufficient supply of cars to handle low grade fuels is questionable. The power demands of the country are increasing, and this power must be developed at a reasonable cost. The time is approaching when the cheapest fuel available must be used to the best economic advantage in order to develop power at a unit cost consistent with commercial progress.⁴⁵

The Geological Survey Report projected a vision of future power production which was to recur frequently in the following decades. This vision was one of great power plants, located in the major coal fields, and equipped with gas-producing equipment. Gasifying the coal would result in the most efficient possible fuel use. The produced gas could be used as the fuel for electric power generation or could be piped directly to the cities for home and industrial use.⁴⁶ World War I fuel shortages would bring this idea to later popularity under the names of "superpower" and "giant power."

In the years from 1910 to 1914, many indications suggest that a picture of a future in which conservation, rationalization of industry, and efficiency would be major concerns was beginning to challenge the

45 *ibid.*, p. 81.

46 *ibid.*, p. 81-82.

picture in which an age of exhaustless and costless power was confidently expected. One straw in the wind was a prize of \$100,000, put up by the International Association of Recognized Automobile Clubs, for the discovery of a cheap and inexhaustible substitute for gasoline.⁴⁷ A more significant straw was the most comprehensive study yet undertaken of the future of the world's energy supply, the British Science Guild Report of 1912.

This report was drawn up by a panel of Great Britain's most prominent scientists and engineers, each one studying that aspect of the energy problem with which he was especially familiar. Not only traditional means of power generation, but also unconventional ones, were examined. None seemed promising as a substitute for coal.

The unconventional sources of power were judged unpromising under existing conditions of technology and economics. Sir William Ramsay, a leading student of radioactive processes, looked at the question of the possibility of useful amounts of power from "atomic transformations" and concluded that "no source of energy capable of being converted into work on a large scale" could be hoped for. R. J. Strutt found practical use of geothermal power to be "very unlikely." On the side of conventional energy sources, Sir Charles Parsons, pioneer in the development of the steam turbine, saw ahead only minor improvements in heat transfer to boilers, and some gain in efficiency

47 Waldemar Kaempffert, "What Shall We Do for Gasoline," Outlook, CV (1913), 755.

due to the use of superheated steam.⁴⁸

Summing up the situation in his presidential address to the British Association for the Advancement of Science in 1912, Ramsay compared the energy situation of Britain with that of a patient who had been told by his doctor to slow down if he wished to live longer. The principal means suggested for slowing down were the gasification of coal, the movement of power plants to the coal fields, and the ending of inefficient home heating practices (such as domestic furnaces with efficiencies well below 50%).⁴⁹

The United States, with coal supplies over ten times as large as Britain, had less need for immediate alarm. But there were good indications that from 1905 to 1914 concern about future coal supply was increasing among Americans who tried to peer into the future. In 1905, Harvard geologist Nathaniel Shaler had surveyed the "future of power" and come to an optimistic conclusion:

We may look forward with an assured mind to the future of man on this planet. He is young and the sphere for all its age is young. We may well rejoice in our anticipation of the great and long continued work they⁵⁰ are to do together before their great task is done.

48 London Times, Mar. 28, 1912, p. 3.

49 "Address by Professor Sir William Ramsay," Report of the Eightieth Meeting of the British Science Guild, (London: John Murray, 1912), pp. 16-32.

50 Nathaniel S. Shaler, Man and the Earth (New York: Fox Duffield & Co., 1905), p. 171.

Five years later, this optimism had been somewhat tempered. There was no fear of immediate fuel shortages, but rather a cautious attitude emphasizing the necessity of conserving. As the chemist Arthur D. Little summed it up:

Evidence is everywhere at hand that the day of cheap raw material is passing if indeed it is not already past. To those who read the signs the watchword of the future is even now clearly outlined; it is not longer "increased production" but "increased efficiency of production!"⁵¹

51 Arthur D. Little, "The Chemist's Place in Industry", Journal of Industrial and Engineering Chemistry, II (1910), 64.

CHAPTER IV

TECHNOLOGY AS A THREAT TO MAN: 1890-1914

A third future presented in the writings of Americans in the period 1890-1914 denied the futures heretofore discussed. Man would not use technology to create a new and higher society founded on inexhaustible energy supplies. Neither would the world run down due to lack of vital resources. Instead, the acceleration of technological advance would establish the mastery of machines over men. The society of the future would be shaped by, rather than shaping, its technological environment.

This vision of a runaway technology received its most explicit treatment in Henry Adams' essay "The Rule of Phase Applied to History." Adams summed up his argument in three well-known pictures: an exponentially rising curve of human development; a vision of human progress following the course of a comet; and, above all, his phase rule which was to bring "thought to the limit of its possibilities in the year 1921." A student of Adams' work has paraphrased the moral of this essay as being that "nonhuman energies increasingly imprisoned man."¹

1 Henry Adams, "The Rule of Phase Applied to History," in Perry Miller, ed., American Thought: Civil War to World War I (New York: Holt, Rinehart, & Winston, 1964), p. 302; William H. Jordy, Henry Adams, Scientific Historian, (New Haven, Conn.: Yale U. Press, 1952), p. 154. Adams' phase rule states, roughly speaking, that human thought passes through definite and predictable phases over time. The phases deal with concepts of increasing scientific sophistication (mechanics is succeeded by electricity, which in turn gives way to study of the aether) and succeed each other at an accelerating rate.

Others were much less alarmed about the exponential growth of technology, and the imminent phase changes in human existence. The arbitrary and unscientific nature of Adams' use of the Gibbs phase rule has often been pointed out. But the metaphor of the phase rule as a description of recent history appealed even to those who understood its scientific content. For example, the electrochemist E. F. Roeber, in 1914, put the phase rule metaphor to optimistic use:

That the scientific and concomitant engineering advances of the last century have brought an entirely new phase (in the phase rule sense) into the play of human reactions which make up the history of mankind is not open to question.²

Whether one viewed the new phase optimistically, as Roeber did, or pessimistically, as Adams did, there was agreement as to its outlines. Its main characteristic was a changing role of technology in man's life. Increasingly, man would have to adapt himself to the world shaped by his machines. Technology had assumed such enormous potential for either creation or destruction that it had become an arbiter of man's future.

Those expressing this view of the future saw two main realms of technological determinism in the period 1893 to 1914. The first was warfare. New or prospective weapons, especially the airplane and

2 E. F. Roeber, "Some Economic and Aesthetic Aspects of Electrochemistry, Journal of Industrial and Engineering Chemistry, VI (1914), 437.

the submarine, threatened to make obsolete traditional methods of waging war. The second was economics. Man's increasing command of mineral and hydroelectric energy threatened to create a new economic structure in which energy and machinery had replaced capital and labor in the trinity of factors of production.

Warfare's Third Dimension

The question of aerial navigation seems to have been the most widely discussed problem of technological prediction in the last decade of the nineteenth century, if impressions of the periodical press and the testimony of a contemporary can be relied upon.³ At the turn of the century predictions about the future of the submarine also became common. For both these developments, the assumption was usually made that their uses would be mainly military at first, with peaceful applications coming later.⁴

The airship and submarine were not the first new technological devices expected to revolutionize warfare. The self-propelled torpedo and fast torpedo boat, for example, had been at one time expected to make great battle fleets obsolete. But the torpedo boat threat had been

3 William Baxter, Jr., "Forecasting the Progress of Invention", Popular Science Monthly, LI (1897), 308.

4 Edward Bellamy, Equality, p. 272; John Bates Clark, "Recollections of the Twentieth Century", p. 6.

met by the adoption of quick-firing guns, and the use of fast torpedo boat destroyers.⁵ It was not merely their novelty, but also their introduction of the vertical dimension to the formerly two-dimensional world of warfare that accounted for the particular fascination of the airplane and submarine.

The prediction of the airplane's future falls into two periods. Before the exploits of the Wright brothers, there was a period of unrestrained speculation as to the potential of aerial navigation. During the years from 1903 to 1914, as realization gradually spread that the long awaited feat had been achieved, there was a scaling down of expectations to match the modest dimensions of the craft that actually had taken to the air. This period included a variety of prophecies of the military uses of the new weapon, but few attempts to test these prophecies.

Speculation that the flying machine was soon to come was not confined to publicity-seeking inventors and utopian novelists in the 1890's. A wide sample of those men whom Americans generally looked to as guides in scientific and technological matters endorsed the principle of heavier than air navigation before 1903. These included inventors Thomas Edison and Alexander Graham Bell; engineers

5 Richard Hough, Death of the Battleship (New York: McFadden, 1965), p. 18.

R. H. Thurston and Octave Chanute; and scientists Lord Rayleigh and Samuel P. Langley.⁶

Of course, there were dissenters who held that the search for a flying machine was a futile one. Astronomer Simon Newcomb's pair of articles in this vein (one published before, the other after, the Wrights' success) are examples, but represent a minority opinion, as Newcomb himself makes clear.⁷ The debate over the possibility of aerial navigation before 1903 illustrates two general properties of technological predicting. First, they show the frequent combination of an accurate feeling that a big development is about to occur in a certain field, combined with a complete misconception of the crucial problems blocking that impending development. Second, they show the futility of trying to predict the social consequences of an invention before the exact outlines of that invention are known.

The main misconception by prophets of aerial navigation was in seeing the problem as a contest between the lifting power of an

6 Charles D. Lanier, "Thomas A. Edison", p. 52; Robert V. Bruce, Bell (Boston: Little, Brown, 1973), p. 362; Proceedings of the Conference on Aerial Navigation (New York: American Engr. & Railroad Journal, 1894), pp. 6-8; 344; "Lord Rayleigh on Flight", Scientific American Supplement, XLIX (1900), 20195.

7 Simon Newcomb, "Is the Airship Coming?", McClure's, XXII (1903), 432-435; Simon Newcomb, "The Prospect of Aerial Navigation", North American Review, CLXXXVII (1908), 337-347.

engine and the weight of the lifted vehicle. There was a widespread belief that only a new light motor or a new form of construction could make an airplane possible. The following widely publicized predictions on the future of aviation make this attitude clear.

Proponents of aerial navigation for the most part recognized the limitations of the dirigible balloon as a means of air transport. However, they wished to preserve the main advantage of the balloon, its buoyancy, while dispensing with its air resistance. Henry Elsdale, a British military officer, expressed this requirement in 1894:

I believe that a really safe, workable and reliable flying machine must be based upon the principle of dissociating the vertical suspension in the air, if required, from horizontal locomotion through it.⁸

Boston aviation enthusiast James Means, writing in 1895, imagined a flying machine which could "acting as a kite, ride as steadily to its anchor as a ship rides when anchored."⁹ Alexander Graham Bell's vision of manned flight also took the shape of a man-carrying kite, capable of a safe and slow descent if the power failed.¹⁰

8 Henry Elsdale, "Scientific Problems of the Future," Annual Report of the Smithsonian Institution, 1894, (Washington: Government Printing Office, 1896), p. 670.

9 James Howard Means, James Means and the Problem of Manflight (Washington, D. C.; Smithsonian, 1964), p. 29.

10 Robert V. Bruce, Bell, pp. 430-431; 446.

Engineer Calvin M. Woodward went even further toward insuring safety, suggesting that aerial experiments be carried out only with airplanes suspended from balloons.¹¹

The assumption that lift could be separated from forward motion in aerial navigation (actually, part of an extremely difficult problem, to be struggled with for years by the helicopter and autogyro makers of the next generation) led to an excessive concern with the necessity of lightening the engine of the future flying machine. The International Conference on Aerial Navigation of 1894, the first technically respectable gathering of manned flight enthusiasts, focused much of its attention upon the engine problem. Respective advantages of the steam engine, gasoline engine, gas engine, and elastic fluid turbine were discussed at length, to the partial exclusion of other aspects of the aerial navigation problem.¹²

The logical conclusion of the lack of understanding of the actual relation between power for propulsion and power for suspension was the opinion expressed by Simon Newcomb. His ideas are worth examining in some detail, since they represent one of the most embarrassing recorded examples of an error in technological prediction by a

11 Calvin M. Woodward, "Lines of Progress in Engineering," Science, n. s. XXI (1905), 14.

12 Proceedings of the International Conference on Aerial Navigation, pp. 7-9; 13 - 16; 120 - 123.

person who should have known better.

Besides being one of America's leading astronomers Newcomb enjoyed trying to apply the scientific method to problems considered non-scientific. He wrote on such topics as economics and spiritualism. In 1891 he used some simple physical arguments to debunk a popular scheme for rainmaking by means of artillery barrages.¹³

Newcomb's aerial navigation article was meant to be a similar performance. To place the airship in what he believed was its proper place - alongside the mathematician's dream of squaring the circle - he resorted to three arguments. One was practical, another was economic, but the main one was theoretical.

The practical argument concerned the vulnerability of the aircraft to engine failure. "A flying machine could remain in the air only by the action of its machinery," he noted, and would "fall to the ground like a wounded bird the moment any accident stopped it." The economic obstacle was the impossibility of making aerial navigation cheaper than present methods of transportation.¹⁴

The theoretical argument relied on the fact that doubling the linear dimensions of an object quadruples its surface area, but multiplies its volume by eight. This led to the conclusion that the

13 Simon Newcomb and Gen. Robert G. Dyrenforth, "Can We Make it Rain?", *North American Review*, CLIII (1891), 383-402.

14 Simon Newcomb, "Is the Airship Coming?", pp. 434, 435.

weight of a flying machine (assumed to be proportional to the cube of any linear dimension) would quickly outstrip its lifting capacity (assumed proportional to the surface area, or the square of any linear dimension). Thus a bird or model airship might fly, while a scaled-up, man-carrying version would never get off the ground. Newcomb concluded that "the construction of an aerial vehicle which could carry even a single man from place to place at pleasure requires the discovery of some new metal or some new force."¹⁵

Newcomb's conclusion has been rightly condemned as an example of superficial criticism masquerading as scientific detachment. But it is also true that even some believers in the future success of the airplane accepted his arguments. For some, the "new metal" which would make flight possible was aluminum, since that lightweight metal was being produced in quantity by the late 1890's.¹⁶ For others, the "new motor" needed was the internal combustion motor. Even long after the invention of the airplane, it was still widely (and wrongly) believed that a new engine had been the key invention which had made manned flight possible.¹⁷

15 *ibid.*, p. 435.

16 "The Effect of Inventions on the People's Life," Scientific American, LXXV (July 25, 1896), 50; H. Elsdale, "Scientific Problems of the Future," p. 669.

17 Norbert Wiener, "Putting Matter to Work," Technology Review, XXXVI, 2, (Nov., 1933), p. 47; Alec Ogilvie, "Application of Power to Air Transport," Transactions of the First World Power Conference, (London: Percy Lund Humphries, 1925), p. 787.

Only a few prophets of aerial navigation caught the essence of the problem, which was, as Samuel Langley put it, that "it is not so much power as the skill to guide it, which we lack."¹⁸ In 1894, discussing the experiments of Hiram Maxim, the physicist Lord Rayleigh noted that of the five main problems of flight, three (propelling power, motive power, and lifting power) could be regarded as solved (by the combination of light steam or gasoline engine, propellor, and wing). The remaining problems were the tricky ones of steering and manoeuvring.¹⁹ It was the problem of control that was the key to achieving flight.

The more perceptive prophets realized that the skills required of the first aviators would be not so much "aerial navigation" as a combination of kite flying and acrobatics. The automobile pioneer Charles Duryea caught this image in his vision of the first airplane, given in 1894:

The pioneer machine will, he prophesies, be a large kite-like affair with ample surface and even more ample power in the shape of a gasoline motor and screw propeller. It will be provided with a means of guiding ... and it will carry but one operator, who must feel that the machine is almost part of himself.²⁰

18 U. S. Congress, Senate, Report on Bill S. 1344 to Secure Aerial Navigation, Senate Report No. 992, 53d Cong., 3d Sess., 1895, pp. 6-7.

19 New York Times, Oct. 7, 1894.

20 Review of Reviews, X (1894), 434.

For all the variation in realism and accuracy in the many predictions of the coming of flight made before 1903, there was one common denominator. Such various prophets as Captain W. A. Glassford of the Army Signal Corps, Lord Rayleigh, Hiram Maxim, and John Brisben Walker, editor of Cosmopolitan, agreed that one of the first applications of the flying machine would be in warfare.²¹

Only an occasional commentator, however, went beyond the general statement of military value to present a detailed picture of the proposed innovation. One such picture was presented by a Navy lieutenant, John K. Cree, in 1896. He started from the assumption that

Since the perfecting of the air-ship in the near future seems so probable, it is certainly not out of place to speculate as to what would be its effect on warfare, since it would probably be first used for that purpose.²²

While granting the value of the airship as an instrument of communication and reconnaissance, Cree asserted that it was to be in offensive operations that the airship would prove its value. He proceeded to outline the tale that countless air power enthusiasts were to repeat from that day to this: the flying machine armed with

21 "Report on Bill S. 1344 to Secure Aerial Navigation," pp. 5, 12; "Lord Rayleigh on Flight," Scientific American Supplement, XLIX (1900), 20195.

22 John K. Cree, "The Influence of the Air-Ship on War," North American Review, CLXII (1896), 30.

light rapid-firing guns for battles with its own kind, and projectiles to drop upon the helpless troops below; the initial battle between great air fleets, the outcome of which would decide the war; the aerial torpedo, so powerful that "one torpedo exploded in the vicinity of a man-of-war would annihilate it": and, most important, the introduction of a means of fighting which, by bringing the battle immediately to civilian areas, would render all future wars nasty, brutish, but mercifully short.²³

However frightening the aerial weapon may have appeared, almost every predictor who mentioned it included a note of optimism. In the era before the First World War, there seemed to be a belief that all inventions could be turned to man's benefit. The pervading hopefulness is caught in the following remarks of a participant in the 1894 Conference on Aerial Navigation:

Pardon me that I add, civilization will undergo a crucial test of its moral stability in the tremendous economic revolution which must attend the successful introduction of aerial navigation, when everybody the world over shall become neighbor to everyone else, and neither fortifications nor battle ships nor Chinese Walls, nor cordons of customs officers can offer any barrier to enemies or intruders.

But the world is safe for the present; great inventions do not appear until the moment when civilization

23 *ibid.*, pp. 81-83.

becomes ripe for them. The flying ship is a certainty of the future, and with equal certainty must come the moral climax of universal brotherhood.

God speed the day.²⁴

Compared to the airship of these optimistic predictions, the actual airplane, when it finally appeared, was a poor production indeed. From the years after 1903, as the news of the Wright brothers' achievement began slowly to become known, until the beginning of the First World War, there was a scaling down of expectations about the role of the airplane in commerce and war.

The slowness of general perception that the Wright brothers had achieved powered flight was in itself remarkable. In January, 1904, a group of men interested in the possibilities of aerial navigation, including Samuel Langley, Charles Francis Adams, Jr., and Elihu Thomson, met at a dinner at the Waldorf Astoria in New York. Although both the host, John Brisben Walker and Elihu Thomson made confident predictions that the problem of aerial navigation was near solution, no one present was aware of the Wright brothers' first flight which had been made one month earlier.²⁵ In the fall of the same year, the Saint Louis Exposition hoped to be the site of the first flight, and a speaker at that exposition, civil engineer Lewis Haupt,

24 J. H. Dow, "The Elastic Fluid Turbine", Proceedings of the Conference on Aerial Navigation, p. 123.

25 John Brisben Walker, "The Final Conquest of the Air," Cosmopolitan, XXXVI (1904), 501-514

voiced his "hope and expectation" that the problem of aerial navigation would soon be solved.²⁶

The realization that the hoped-for achievement had occurred, which filtered through to the general public by 1908, had the effect of giving concrete dimensions to vague hopes for the flying machine. Simon Newcomb, while admitting that criticisms by his friend Alexander Graham Bell had refuted his earlier assumption that the weight of a flying machine had to increase as the cube of each linear dimension, could still conclude in 1908 (the year before his death) that

The writer cannot see how anyone who carefully weighs all that he has said can avoid the conclusion that the era when we shall take the flyer as we now take the train belongs to dream-land.²⁷

The military use of the airplane was downgraded from the hoped-for ultimate weapon to an auxiliary of limited value. In a 1909 review of the expected military uses of aviation for the coming years, George Squier, the Signal Corps officer in charge of the Army's initial aviation program, pictured the military airplane not as the

26 Lewis M. Haupt, "The Present Problems of Technology," Congress of Arts and Sciences, Universal Exposition, St. Louis, 1904, Howard J. Rogers, ed. (Boston and N. Y., Houghton, Mifflin, 1906), p. 588.

27 Simon Newcomb, "The Prospect of Aerial Navigation," p. 347.

aerial leviathan of earlier dreams, but as a light reconnaissance craft, "limited to comparatively low tonnage, operating at relatively high velocity."²⁸

Ordinance expert and inventor Hudson Maxim also tried to deflate exaggerations about the military potential of aviation. While believing that some day in the far distant future we would see "aerial battleships," he saw the airplane of the near future as a scouting vehicle. The idea of dropping dynamite bombs from the air, a feature of earlier dreams, he held to be a useless one, since dynamite must be exploded in a confined space to be effective.²⁹ As for the use of conventional bombs, he concluded, according to a reporter, that "it might rain 10-pound bombs for a week on the modern battleship without any other result than the marring of its paint," and that therefore "the part flying machines would play in the war game has been greatly exaggerated."³⁰

In the five years leading up to World War I, almost all attempts to assess the future role of the airplane as an offensive weapon came to a negative conclusion. The idea of bombing with accuracy developed

28 George O. Squier, "The Present Status of Military Aeronautics," Annual Report of the Smithsonian Institution, 1908 (Washington: Government Printing Office, 1909), p. 165.

29 Hudson Maxim, "Warfare of the Future", Science, n. s., XXVIII (1908), 828.

30 Luke J. Minahan, "A Ramble in the Aeronautic Field," Independent, LXVIII (1910) 86.

many complications. British tests of bombing accuracy seemed to indicate that little could be hoped for from this form of attack.³¹

American aviation expert Frank P. Lahm, a witness to similar American tests, agreed, stating:

The idea of dealing death and destruction in the form of fire and explosives dropped from the air, of annihilating battleships, armies, and cities, has from the first appealed to the popular mind, But let not the imagination run riot, for experiments show that to produce its full effect, the explosion must be confined. Furthermore, experiments have shown that the chances of hitting the mark from an airship in flight are quite remote, unless the craft approaches within a distance at which it would itself be exposed to extreme danger from the enemy's fire.³²

In two congressional investigations held in 1911 and 1913, representatives of the Army and the War Department attempted to reassure the legislators that the airplane would not revolutionize warfare. But, at the same time, they sought to get a sufficient appropriation to keep the aviation program going. In the 1911 hearing, the Secretary of War stated that not only was the possibility of bombing from airplanes a doubtful one, but also that the flying machine could never even replace the cavalry as a reconnaissance arm.³³

31 Current Opinion, LIV (1913), 391-392.

32 Frank P. Lahm, "Airship and Aeroplane in War," Scientific American Supplement, LXXI (1911), 206.

33 U. S. War Department, Military Aviation, House Document 718, 62nd Congress, 2nd Session, in vol. 141, serial 6323, pp. 24-27.

In the hearings of 1913, Army witnesses hewed to the same line: the airplane was of military value as a reconnaissance craft; it supplemented, rather than render obsolete, existing weapons; its offensive value was as yet unproven; and while bombing with accuracy might be a development of the distant future, it was not something to be counted on in the short run. Concurring in this judgment were two Signal Corps officers, Lt. Henry H. Arnold and Captain William Mitchell. Both were eventually to become outspoken advocates of aerial warfare, but in 1913 willingly echoed the official Army line.³⁴

The most outspoken dissenter from the official Signal Corps position was a young Army aviator who had resigned from the service to devote his full time to the study of aerial bombing. Riley Scott claimed to have been developing bombsights and bombing techniques since 1908. In 1911 he had won a French prize of 150,000 francs by dropping 12 of 15 bombs into a circle of 40 meters radius from an altitude of 800 meters. Since then, he claimed, he had extended the altitude from which he could carry out accurate bombing to one mile. That he had succeeded at this height was significant, since (according to William Mitchell) the main lesson of the bombing that had been carried out in actual warfare, in the Tripolitan and Bulgarian Wars,

³⁴ U. S. Congress, House, Aeronautics in the Army: Hearings on H. R. 5304, 63rd. Cong., 1st Sess., Vol. 107, Part 1, pp. 6-88.

was that ground fire made it unsafe for airplanes to fly below 4000 feet.³⁵

Scott's vision of the future included the construction of bombers capable of carrying up to 1000 pounds of nitroglycerine bombs, capable of shattering fortifications or anchored battleships. For "operations against cities," he was one of the first to foresee the use of "incendiary bombs, small bombs filled with some material which would set fire to combustibles on contact."³⁶ In particular, he hazarded the prediction that by 1921, it would be feasible for an enemy to stage a devastating air raid upon New York City, launching bombers from an airplane - carrying battleship. As a defense against this possibility, he recommended an appropriation of \$1,000,000 for aviation.³⁷

In refutation of Scott's alarmist views, the Army presented translations or copies of views by leading foreign observers on military aviation. A French expert saw bombs as useless against troop concentrations, as the troops could easily spot the slowly falling projectiles and dodge them; the British expert saw bombing accuracy as a currently insurmountable problem, awaiting the invention of a flying machine that could hover in one spot. No doubt reassured by these views, Congress appropriated only \$125,000 for aviation in 1913, about one-third that

35 ibid., pp. 74; 102 - 104.

36 ibid., p. 106; Riley E. Scott, "Dropping Bombs From Flying Machines," Scientific American, CV (1911), 388.

37 ibid., p. 389.

appropriated by Mexico and about one-sixtieth that appropriated by France.³⁸

The pattern of prediction of the use of the airplane as an offensive weapon shows the difficult position in which the professional soldiers in charge of the flying program of the United States were placed before 1914. On the one hand, they had to debunk overly enthusiastic estimates made by laymen about the omnipotence of the air weapon. On the other hand, they had to keep up sufficient interest that an aviation program would continue to be funded. They seem to have succeeded much better at the first task than at the second. Aviation, which at the turn of the century had been a dream of revolution in commerce and war, was seen a decade later as a dangerous and not particularly useful sport.

The submarine, which had the same liabilities but little of the sporting glamor of the airplane, underwent the same reversal from predicted superweapon to de-emphasized auxiliary. Of longer standing than the airship as a serious possibility, the submarine had already accumulated a list of real or imagined liabilities by the time the first potentially useful underwater craft were being developed in the 1890's.

The official Navy point of view during the 1890's was one of

38 Aeronautics in the Army, pp. 145-267.

watchful waiting. No definite predictions were offered. Comments on French submarines emphasized the seemingly insurmountable problems of future underseas warfare. These included the impossibility of seeing anything while underwater; the difficulty of hitting a moving target with a torpedo; and the short range of the submarine boat.³⁹

Some idea of the Navy's expectations about submarine boat prospects can be seen in the requirements set for the submarine Holland (named for its designer, John F. Holland) in the original specifications released in 1893, and in the criteria for acceptance presented in 1898. Safety and "facility and certainty of action when submerged"⁴⁰ headed the specification list. The performance requirements set forth in the criteria for acceptance were modest, the major one being the need to travel underwater at a depth of ten to thirty-five feet, and to make a submerged speed of six knots.⁴¹ The most revealing sign of the attitude of the Navy's Board on Construction, however, was the stipulation, in 1898, that "it is not recommended that a member of the board be ordered to go down in the boat, as her safety is not an assured fact."⁴²

39 "The French Submarine Boats", Proceedings of the United States Naval Institute, XXV (1899), 247-248; "Professional Notes", Proc. of U. S. Naval Inst., XXV, 92, (1899), pp. 919-929; "Submarine Boats", Proc. of U. S. Naval Inst., XXVI, 94, (1900), pp. 380-383.

40 Simon Lake, The Submarine in War and Peace, (Philadelphia: Lippincott, 1918), p. 162.

41 U. S. Congress, Senate, Submarine Torpedo Boat Holland, 56th Congress, 1st Session, 1899, Senate Doc. 14, p. 1

42 Ibid., p. 3.

The success of the Holland in meeting these requirements in 1899, and again in a full scale test in naval maneuvers in 1900, brought on a debate on the future potential of the submarine which spilled over from the Navy Department to the popular press and the halls of Congress. Predicting a bright future for undersea boats were many leading naval heroes of the Spanish-American War, led by George Dewey. Defending orthodoxy against the innovation was the Navy's Board of Construction, led by the redoubtable Engineer-In-Chief of the Navy, George W. Melville.

A hero of a polar expedition as well as a trained engineer, Melville had earned a reputation for "absolute fearlessness." As Engineer-In-Chief, he was known for both progressiveness in insisting on application of engineering expertise to naval problems, and caution in the face of weapon panaceas.⁴³ In 1901, he had scoffed at the idea of aerial navigation, holding that "there probably can be found no better example of the speculative tendency carrying man to the verge of the chimerical than in his attempts to imitate the birds."⁴⁴

In considering the submarine, Melville did not dismiss the possibility of undersea travel; he merely sought to deflate claims about

43 "The Men Who Made Our Modern Sea Fighters," New York Times, Nov. 12, 1911, p. 12.

44 George W. Melville, "The Engineer and the Problem of Aerial Navigation", North American Review, CLXXIII, (1901), 830.

its military usefulness. He produced an impressive list of disadvantages of the submarine. The first in seriousness was the fact that "the craft is still without an eye." The periscope principle had been tried without success, and underwater navigation by compass was fraught with error. The boat was unstable below the surface, and slower than any other powered craft while on the surface. The three necessary power systems - gasoline motor for surface travel, compressed air for rising out of the water, and electric motors for submerged travel - introduced a triple danger. The crew members could destroy their own boat by accidentally exploding a compressed air cylinder or by igniting the explosive gasoline vapor; or they could be poisoned by chlorine fumes resulting from leakage of sea water into their electric batteries.⁴⁵

George Dewey and the other pro-submarine officers did not deny these liabilities. But they held that in spite of all failings, the submarine could perform one vital future role - that of harbor defense. "If they had had two of those things in Manila, I never could have held it with the squadron I had," Dewey wrote in 1901. "With two of those in Galveston all the navies in the world could not blockade that place."⁴⁶

45 George W. Melville, "The Submarine Boat: Its Promises and Performance," North American Review, CLXXII (1901), 584-590.

46 U. S., Congress, Senate, Holland Submarine Torpedo Boat, 56th Congress, 2d Session, 1901, Senate Doc. 115, p. 16.

Dewey's aide, Lt. Harry Caldwell, successfully demonstrated the Holland's harbor defense capability in maneuvers outside Newport, Rhode Island, harbor by "sinking" the U. S. S. Kearsarge in a simulated night attack. This feat converted several naval officers, including the Chief Naval Constructor, Admiral Philip Hichborn, to support of the submarine.⁴⁷

The predictors who believed that the submarine would become an important weapon in the future almost all saw it as an exclusively defensive weapon, useful only for making close blockade impossible. In the decade from 1895 to 1905, when this weapon was first seriously considered for use by the Navy, almost all arguments about it were conducted in this context. Only Simon Lake and John Holland, the two leading pioneer submarine designers, spoke seriously about future submarines capable of crossing the Atlantic under their own power.⁴⁸ And both of them saw any such offensive roles as mere supplements to the boat's main purpose. As late as 1918, Simon Lake could write: "Above all, I believe the submarine most fitted to act as a weapon in coast defense operations."⁴⁹ John Holland resisted attempts to develop

47 Ibid., pp. 1, 10-14.

48 U. S., Congress, Senate, Staff Corps Increase, Submarine Boats, 57th Congress, 1st Session, (1902), Senate Doc. 395, p. 54
John P. Holland, "The Submarine Boat and Its Future", North American Review, CLXXI (1900), 896.

49 Simon Lake, The Submarine in War and Peace, p. 190.

a large oceangoing submarine for naval use in 1901, holding that "a large submarine boat is practically valueless."⁵⁰

This misconception of the future role of the submarine was rooted more in political than in military considerations. First, the image of the submarine as a defender of our coasts against aggressive blockaders had an appeal both to pacifists and to those who resented the might of the British navy. John Holland was impelled by both motives. On the one hand, he proclaimed that with the advent of the submarine, "nations with sea ports will have to refrain from making war."⁵¹ On the other hand, as a patriotic Irishman, he had built his first submarine (in 1878) for the Fenian brotherhood.⁵²

A second motive behind the emphasis on the coastal defense value of the submarine was a result of the Spanish-American War. During that war, sections of the Northeastern United States had been in a near-panic at certain times, fearing a sudden attack from the Spanish fleet. A few submarines, Admiral Hichborn suggested in 1901, would be "a good cure" for such panics, by reassuring nervous civilians that the Navy was doing its job.⁵³

But perhaps the biggest reason behind the emphasis on the

50 Holland Submarine Torpedo Boat, p. 21.

51 John P. Holland, "The Submarine Boat and Its Future", p. 895

52 Richard K. Morris, John P. Holland (Annapolis: U. S. Naval Institute, 1966), pp. 29 - 32.

53 Holland Submarine Torpedo Boat, p. 9.

submarine as a weapon of local defense was the interest of the Holland and Lake Companies in selling their boats. To do this, they had to win the confidence of the Navy's Board on Construction. And to win this confidence, they had to reassure Admiral Melville and his fellow Board members that the submarine was not being put forward as a substitute for the battleship and other traditional naval weapons.

For Admiral Melville saw the submarine enthusiasm as a serious threat to the Navy's building program. It provided a grounds on which hostile forces in Congress could block that program. "The action of Congress in striking out of the Naval Appropriation Bill of 1901 all authorization for battleships and cruisers," Melville wrote, "can certainly, in part, be traced to the belief that the submarine possesses many of the qualities claimed by its advocates."⁵⁴

To placate the Board, the representatives of the two main submarine-building companies stressed the role of the submarine as as auxiliary to the fleet. As an officer of the Holland Company put it:

There seems to be a misapprehension, as I understand it, of what the function of these submarine boats is. They are not intended to be sea-going vessels. They are intended solely for harbor defense, and as one of the young officers suggested, to supplement the battle ships; not only to supplement the battle ships, but to supplement the land defenses.⁵⁵

54 George W. Melville, "The Submarine Boat: Its Promises and Performance," p. 597.

55 Staff Corps Increase, Submarine Boats, p. 41.

"There seems to have been an industrious effort made in certain quarters to prove that there is a conflict between the submarine boats and the battle ships," he added. "there is not the slightest conflict so far as we are concerned."⁵⁶

The submarine program adopted by the Navy from 1901 on reflected such views. Submarines were added to the fleet, but mainly on an experimental basis, and with coastal defense in mind. Indeed, for a short time they were attached to the Army, instead of the Navy. Builders and users of submarines combined to paint the picture of a weapon supplementing, not replacing earlier weapons. This set a precedent for predictions made by weapons contractors and their customers. Bombing-plane manufacturers from the 1920's to the present day would likewise reassure military men of their commitment to a balanced defense program, and deny the possibility of a "revolution" in warfare.

From 1905 to 1914, the submarine was much less in the news than it had been during its introductory period at the turn of the century. Those looking to its future role looked more at its frequent accidents than at its virtues. "Judged by the number of tragic disasters which has overtaken the submarine during the past few years," one commentator remarked, "the greatly dreaded instrument of war might seem to be as great a menace to friend as to foe."⁵⁷ The idea that the sub-

⁵⁶ Ibid.

⁵⁷ "The Menace of the Submarine," Scientific American, CII (1910), 474.

marine was a defensive weapon for harbor defense was well entrenched. Only on the eve of war did predictions begin to emerge that the craft would evolve into the ocean-going raider of earlier dreams.⁵⁸

By 1914 the airplane's predicted military role had receded, and the submarine was seen as a defender, rather than as a fearsome commerce destroyer. The insistence upon the bright side of technology was shown by even so objective an engineer as Elihu Thomson, who wrote in 1904 that the airplane

will naturally be a machine for emergency work; a most effective war engine, for example, and by a war engine, I, of course, mean a peace engine. The more effective it is the less likelihood there is of war being declared; and the menace of a sudden visit by a flying enemy would probably have the result of making those who declare war but do not fight battles a little more cautious as to such declaration.⁵⁹

There were respected scientists who took a less optimistic view. The chemist Leo Baekeland, for example, doubted that the development of more powerful weapons in the future would make war less likely. "The intervention of science of engineering has not only made war more horrible than before, but has shorn away its picturesqueness."⁶⁰

58 "Ocean Going Submarines," Scientific American, CIX (1913), 284.

59 Selections From the Scientific Correspondence of Elihu Thomson, Harold J. Abrahams and Marion B. Savin, eds., (Cambridge, Mass.: M.I.T. Press, 1971), p. 348.

60 Leo Baekeland, "Introductory Address, 1908 Chemist Club Banquet," Science, XXVIII, (1908), 817-819.

Another who believed that it was "entirely erroneous" to suppose "that the advent of the flying machine must bring on universal peace" was Nikola Tesla. In an article written for Century magazine in 1900, Tesla elaborated on this point to present his own view of the future relationship of man and his machines.⁶¹

Like most of Tesla's writings, this article was a mixture of interesting speculation and nonsense. His views on the future of warfare fell into the first category. His major predictions were the use of aviation in warfare; the adoption of the ideas of deterrence and arms limitation; and the ultimate replacement of armies by legions of machines, at first radio-controlled but ultimately possessing artificial intelligence.

Tesla's views on deterrence are a striking anticipation of views which became popular in the 1960's concerning a later arms race. As Tesla put it:

As regards the security of a country against foreign invasion, it is interesting to note that it depends only on the relative, and not on the absolute, number of the individuals or magnitude of the forces, and that, if every country should reduce the war-force in the same ratio, the security would remain unaltered. An international agreement with the object of reducing to a minimum the war-force which, in view of the present still imperfect education of the masses, is absolutely indispensable, would, therefore, seem to be the first rational step to take toward diminishing the force retarding human movement.⁶²

61 Nikola Tesla, "The Problem of Increasing Human Energy," Century, LXIX, 182.

62 Ibid., p. 183.

This approach, which stressed the achievable goal of arms limitation rather than the ideal of disarmament, was to arise anew at the Washington Conference of 1921, and again in the first SALT agreement of 1972.

The heart of Tesla's prediction about the future technology of warfare was the replacement of soldiers by machines. While the first generation of these military mechanisms were to be remotely controlled (Tesla himself had patented such a device at the time of the Spanish American War) the ultimate ones were to be self-contained.⁶³

"I propose to show, Tesla wrote, that

however impossible it may now seem, an automaton may be contrived which will have its 'own mind,' and by this I mean that it will be able, independent of any operator, left entirely to itself, to perform, in response to external influences affecting its sensitive organs, a great variety of acts and operations as if it had intelligence.⁶⁴

The technology of remotely controlled devices, or "telautomatics" as it was then called, began from the time of Nikola Tesla's first demonstrations in 1899 to be a subject of occasional sensational prediction, if not too much solid achievement.⁶⁵ The context for mention of such devices was usually that of the wireless-controlled torpedo, not the later automatic factory or "robot" (a word which did

63 "Wireless Torpedo Steering," *Electrical World*, XXXVII (1901), 589.

64 Nikola Tesla, "The Problem of Increasing Human Energy," p. 187.

65 New York Times, March 30, 1899, p. 3.

not even enter the English language until after the First World War). The most enthusiastic prophet of the wireless torpedo was the free-lance inventor, John Hays Hammond, Jr., who developed a prototype in 1911. By means of its "certain and unlimited destructiveness," Hammond claimed, "it will tend to bring about and maintain perfect peace among the nations."⁶⁶

The cheerfulness with which Tesla and Hammond accepted new mechanisms of warfare was typical of the pre-1914 years. Except for a minority of doubters, like Henry Adams and Leo Baekeland, there was little fear of the machine, even in warfare. Of course, there was still a considerable amount of fear that monopoly control of technology was a possible threat to economic and social justice. Predictions of a water power monopoly were a staple of congressional debate in the decade up to 1914 and again in the Muscle Shoals debate of the 1920's.⁶⁷

But a more common prediction was that the proliferation of technology would break down, rather than build up, monopoly. Did a telephone monopoly threaten? Then, suggested John Brisben Walker, the development of the telautograph (a means of transmitting facsimilies

⁶⁶ "To Guide Torpedoes by Wireless Ashore," New York Times, December 16, 1911, p. 1.

⁶⁷ U. S. Congress, House, Special Message of the President, 60th Congress, 2d Session, (1909), House Doc. 1350, pp. 1-6; U.S. Congressional Record, XLVIII 62d Congress, 1st Session, 1912, pp. 11579 - 11595.

of handwritten messages over telegraph lines) would remove that threat.⁶⁸ Similarly, with the electric motor applied to transportation, the power of the railroad monopolies would be broken; "the people," one commentator on the interurban railroads suggested, "have been passed from the tender mercies of the larger to those of the smaller capitalists."⁶⁹ Furthermore, advancing technology gave government a chance to regain that control over the economy that it had relinquished throughout the nineteenth century. "With the advent of electric roads and lights, and with such rivals of the telegraph and telephone as Prof. Gray's telautograph may prove," said so staunch a defender of free enterprise as Thomas Edison, "the advocates of government ownership will have their chance."⁷⁰

Thus the phase change warned of by Henry Adams was, for the most part, welcomed rather than feared. There was great confidence that while new machinery posed a challenge to old ways of doing things - whether the airplane and submarine in revolutionizing war, or the less clearly perceived possibilities in communication and automation - these innovations would not get out of man's control.

68 *Cosmopolitan*, XIV (1893), 623

69 Appleton Morgan, "The Successor of the Railway," *Forum* XLVI (1895), 759

70 Charles D. Lanier, "Thomas A. Edison", p. 52.

CHAPTER V

AN AGE OF EFFICIENCY: 1915 - 1929

In the winter of 1917-18 the American industrial system was stretched to its capacity. As resources flowed into the war effort, one commodity after another -- coal, electricity, meat -- became scarce. To use limited resources more effectively, the Federal government increasingly regulated the activities of industrial enterprises, and, in December, 1917, brought the railroads under Federal control.¹

This episode was short, but its lessons were remembered. Wartime government policy amplified an attitude which had already sprung up by 1914. This attitude saw the revolutionary period of technological development as ending. The individualistic inventors -- Edison, Bell, Westinghouse, Ford, and the Wrights -- were viewed as having finished their work. The task for the next generation would be to build an industrial structure worthy of them. The automobile was here; how could its use be expanded? The airplane was invented; how could commercial air transport be achieved? The key electrical inventions had been made; how could their use be made universal?

Efficiency, not invention, increasingly drew predictors'

1 Paul A. C. Kostinen, "The 'Industrial-Military Complex' in Historical Perspective: World War I," in Richard M. Abrams and Lawrence W. Levine, The Shaping of Twentieth Century America (Boston: Little, Brown & Co., 1971), p. 256.

attention. Extending this view to industry in general was a 1913 editorial in the technical periodical of the General Electric Company:

The cry for greater efficiency has well become the keynote of the age, and this would seem to indicate that we have progressed to the stage where the elimination of waste is an absolutely essential feature, whether it be in man or in machinery of his making. This of itself is a most marked sign of progress, as an increase in efficiency must necessarily await a certain soundness in development. This searching for an increase in efficiency or curtailment of waste is among the chief problems of the scientific and engineering world.²

It remained for an electrical engineer employed by GE to apply that philosophy to all of American society. Charles P. Steinmetz published his contribution to social philosophy, America and the New Epoch, in 1916. In it, he argued that the real meaning of the World War, regardless of its victor, was the triumph of the spirit of organization over the spirit of individualism, and of efficiency and planning over entrepreneurial improvisation. America had no choice but to adapt to this trend. And since the natural building blocks of the United States were "concentral . . . from the individual units to the central organism," the natural building block for the new society was that already established individual unit, the industrial corporation.³

Previous hopes of improved social organization based on new

2 General Electric Review XVI (1913), 616

3 Charles P. Steinmetz, America and the New Epoch (New York: Harper & Brothers, 1916).

technology had not been realized by 1914. Concepts like "the trolley age," "Niagarics," and "exhaustless and costless power" seemed oversimplified or misdirected when compared to the actual state of society and technology. The round of predictions beginning in 1914 was consequently less sweeping in tone than were the ones made by people like Edward Bellamy and Nikola Tesla. The emphasis was on efficient uses of technology. Among the questions exploring this theme were:

-- How can advances in "wireless" and electronics be put to use in improving communications, now that the inventions needed for radio communication systems had been made?

-- How can methods of transportation be made more generally available, at a lower cost in wasted resources, now that the automobile and airplane were developed?

-- How can electricity be made both less expensive and more reliably available, now that the turbine and long distance transmission line had been perfected?

Radio and Television: Some Missed Signals

Many predicted technologies never succeed commercially. Much rarer are technologies which are almost ignored until they suddenly gain commercial success. The steam turbine is one example. Another is radio broadcasting. While there was widespread interest in the use of "wireless" as a supplement to the telegraph, and later the telephone, hardly anyone predicted the actual form that the successful commercial

application of wireless would take.

This oversight led to an interesting complementary effect. To compensate for overlooking radio, predictors as early as the mid-1920's began predicting the imminence of television -- a decade before Zworykin's iconoscope put television technology on a firm footing, and twenty-five years before the combined technological and economic framework for television was ready.

Before 1920 only two of the fifty most frequent predictors even suggested that radio broadcasting would become an economically important technology. One of them was Charles Steinmetz, who hinted vaguely in 1915 that people would hear concerts in their homes -- without going into much detail as to the means.⁴

A much more specific prediction was made by Nikola Tesla eleven years earlier, in 1904. It deserves to be quoted in full, since it demonstrates so clearly the nature of Tesla's predictive writings -- the touch of uncanny foresight mixed in with the tone of pomposity and mysticism:

The results attained by me have made my scheme of intelligence transmission, for which the name of "World Telegraphy" has been suggested, easily realizable. It constitutes, I believe, in its principle of operation, means employed and capacities of application, a radical and fruitful departure from what has been done heretofore. I have no doubt

⁴ Charles P. Steinmetz, "You Will Think This a Dream," Ladies' Home Journal, XXXII (1915), 16.

that it will prove very efficient in enlightening the masses, particularly in the still uncivilized countries and less accessible regions, and that it will add materially to general safety, convenience, and maintenance of peaceful relations. It involves the employment of a number of plants, all of which are capable of transmitting individualized signals to the uttermost confines of the earth. Each of them will be preferably located near some important center of civilization, and the news it receives through any channel will be flashed to all points of the globe. A cheap and simple device, which might be carried in one's pocket, may then be set up somewhere on sea or land, and it will record the world's news, or such special messages as may be intended for it. Thus the entire earth will be converted into a huge brain, as it were,⁵ capable of response to every one of its parts.

This prediction is vague. Nevertheless, it shows that at a time when other experimenters were thinking of wireless solely in terms of point-to-point communication, Tesla had grasped its significance as a broadcasting medium.

Although some pioneers actually experimented with radio broadcasting (Reginald A. Fessenden was first on the air, with a Christmas Eve serenade in 1906; Lee DeForest broadcast a Metropolitan Opera performance in 1910),⁶ most predictions did not see broadcasting as a promising field.

By 1915, applications for the principal patents making radio possible had been filed by the American Telephone and Telegraph and

5 Nikola Tesla, "Transmission of Electrical Energy," Electrical World, XLIV (1905), 156-157.

6 Lee DeForest, Father of Radio, (Chicago: Follett & Wilson, 1950), p. 270.

General Electric companies. The predictions made by representatives of both indicated that they believed the most promising application for radio was as a supplement to the telephone.

For example, at General Electric's Research Laboratory, William C. White, who was applying the thermionic vacuum tube to radio reception, held that wireless telephony "will undoubtedly be of immense value in fields where the wire telephone is impracticable." In a 1915 survey of the field he omitted broadcasting altogether, predicting:

There are two promising fields for radio-telephony. The first is for long-distance, where wire telephony at present is impossible over submarine cables, and expensive on land. The other is for relatively short distance, for use between ships and from shore to nearby ships.⁷

The context of White's statement made it clear that he saw these two uses as the only commercially promising ones. The same view was expressed by the head of the American Telephone and Telegraph Company's research efforts. Frank B. Jewett wrote in 1919 that

a reasonable interpretation of the future of commercial radio telephony would seem to be one in which its use was confined solely to those services where telephonic communication was desired and where such service could not be given by ordinary means.⁸

7 William C. White, "Radiotelephony," General Electric Review, XVIII (1915), 38-41.

8 Frank B. Jewett, "Wireless Telephony," Review of Reviews, LIX (1919), 503.

Two engineers working in Jewett's laboratories agreed that the two most promising uses of radio were communication between moving vehicles and communication with inaccessible places. However, they showed somewhat more foresight in suggesting that

a third class of service is that which is concerned, not with single individuals, but with groups; such service as the broadcasting of news, time and weather signals, and warnings.⁹

On the whole, however, General Electric and AT&T expected so little from the commercial side of radio that both turned over their major patents to aid in the formation of the Radio Corporation of America. Broadcasting remained open to a third company, Westinghouse, which had a less impressive collection of patents. But it had an engineer named Frank Conrad who perceived broadcasting's possibilities and opened up radio's most promising field. The sudden growth of radio broadcasting in the 1920's was one of the least predicted technological developments of the twentieth century.

Having missed out on radio broadcasting, inventors and engineers-- and their employers -- were quick to expect that television would follow. Ernst F. W. Alexanderson, a pioneer in radio and television engineering at General Electric, noted this in 1927. He relates that Owen D. Young, the board chairman of GE, was already asking his engineers for a per-

⁹ E. B. Craft and E. H. Colpitts, "Radio Telephony," Transactions of the AIEE, XXXVIII (1919), 343.

fecting video transmission apparatus by the early 1920's.¹⁰

Television was one of the technological developments which enjoyed a cyclic resurgence of interest -- like the fuel cell and solar power -- before its final success. The first cycle of interest had begun in the 1870's -- spurred by the discovery of the light sensitive properties of the element selenium in 1877, and by Bell's invention of the telephone in 1876. Indeed, in 1880, a widely reprinted story -- eventually making the columns of the British journal Nature -- held that a practical method of "seeing by telegraph" had been invented. And, in 1884, the German inventor Paul Nipkow did set forth and patent a theoretically sound (though impractical) mechanical television camera, based on a spinning disk.¹¹

Both Mark Twain and Edward Bellamy employed this early television concept in fiction written during the 1890's.¹² But the next burst of progress on actual television devices did not occur until 1908, when the British inventor A. A. Campbell-Swinton proposed that the limitations of Nipkow's mechanical camera could be overcome through the use of electronic devices in both camera and receiver. Again, how-

10 E. F. W. Alexanderson, "Radio Photography and Television," General Electric Review, XX (1927), 78.

11 J. D. McGee, "Distant Electric Vision," Proceedings of the IRE, XXXVI, (1949), 496; George Shiers, "Early Schemes for Television," IEEE Spectrum, VII (1970), 24; Robert V. Bruce, Bell, pp. 336-337.

12 Mark Twain, "From the 'London Times' of 1904," (1898), in H. Bruce Franklin, Future Perfect (New York: Oxford, 1966) pp. 381-390.

ever, this theoretically sound idea could not be carried out with the technical means then available. The outburst of interest in television which occurred after 1920 was the third upsurge of optimism about the immediate practical realization of this technology.¹³

Conscious by then of having overlooked radio, experts were extremely optimistic about television. Willis R. Whitney, director of General Electric's Research Laboratory, spoke in 1924 of "talking motion pictures" in every home. Nikola Tesla, writing in 1926, suggested that soon "we shall be able to witness and hear events" via television. He held that television would certainly be a commonplace in the world of 1976.¹⁴

While some predictors vastly underestimated the difficulties in the way of a practical video device ("television is practically upon us," said inventor John Hays Hammond in 1926), many timetables were reasonably accurate. One such schedule saw television as a remote possibility by 1932, a fair possibility by 1937, and a sure thing by 1942. Rarely did anyone express outright pessimism concerning the possibilities of television (the only example of this among the fifty most frequent predictors was Michael I. Pupin, who wrote in 1929 that the idea of picture transmission would be of

13 McGee, p. 597.

14 Boston Herald, Sept. 7, 1924; Nikola Tesla, "When Woman is Boss," p. 17.

"not much use").¹⁵

In 1919 the rise of radio broadcasting had hardly been suspected. In 1929, the imminence of television was already taken for granted. Not only were engineers discussing its technical possibilities, but writers and dramatists were beginning to explore its uses. The playwright Robert Sherwood, for example, sketched the future uses of television for a magazine audience in 1929, with quite good accuracy. He foresaw television increasing advertising to "an absolutely inestimable extent"; as carrying much news and sports programming, but relying for its staple on film presentations; and as making a dent in the movie theatre business.¹⁶

Sherwood's prophecies were not radical ones in 1929. They merely spelled out some common expectations. Indeed, in the decade from 1930 to 1940, the job of the television promoter would not be to drum up interest in television, but rather to explain to an expectant public why it was being so long delayed.

Transportation: A Continuing Revolution?

Thomas Edison's optimism about the role of technology in satisfying people's needs may have contributed to his success as an inventor.

-
- 15 Boston Herald, June 6, 1926; Franklin F. Stratford, "Television Not Yet on Tap," Literary Digest, XCIV (Aug. 27, 1927), Michael I. Pupin, "From the Leyden Jar to Television," in Charles G. Abbott et. al., The Drift of Civilization (London: Allen & Unwin, 1929, p. 159.
- 16 Robert E. Sherwood, "Beyond the Talkies -- Television," Scribners, LXXXVI, (1929), 1-8.

He never lost that optimism. At the age of 77, in 1924, he saw transportation as the field ripe for revolutionary invention. "When the need for some new things becomes insistent men always find it. At present we need new means of transportation," he wrote. "The time approaches for air transport. Therefore we will have it."¹⁷

Edison's optimism was the main theme for predictions in the field of transportation. The formula "necessity is the mother of invention" served as the basis of most predictions. Of course, there was no agreement as to what the necessity was. To some it was accelerating the development of aviation. To others it was developing transportation methods which would conserve natural resources -- coal and oil. Yet others saw the necessity as being the relief of urban congestion.

An overreliance on such simple assumptions led to a large number of erroneous predictions in the period 1914-1929. In aviation especially, the turning of invention into innovation was predicted to be quick and easy. Only a few predictors foresaw the practical difficulties involved. Yet as late as 1940, the annual passenger revenue mileage flown by U. S. airlines was only one percent of the value it was to assume in 1970.¹⁸

While one could define the beginning of passenger aviation as

17 Thomas A. Edison, "If the Answer's Easy, It's Wrong," Collier's, LXXIV (Dec. 6, 1924), 5-6.

18 Horace M. Gray, "Air Transportation," in The Structure of American Industry, edited by Walter Adams (New York: MacMillan Co., 1950), p. 451; The World Almanac, 1974 (New York: Newspaper Enterprise Association, 1973), p. 463.

any year after 1903, certainly it did not become commercially significant until after 1945. And private aviation remains in 1975 a luxury or a hobby.

Predictions regarding aviation took two principal forms. Many predictions held that the advances in aviation made during World War I would enable passenger airline service to be immediately established. Others predicted that the private airplane would soon rival the automobile as a means of individual transportation.

Aviation pioneers on both sides of the Atlantic expected the immediate success of air travel in the years following World War I. Dutch airplane designer Anthony Fokker, for example, predicted in 1917 that

Passenger traffic on flying machines will assume great importance after the war...Immediately after the war the first flight to America will be attempted. Five years after the war, the service will have reached such a state of perfection that it will seem the most natural thing in the world.¹⁹

In 1919, an official committee of the British government expressed the unanimous belief that passenger air lines would be running to all parts of the world "within a few years." In the United States, airplane builder Glenn Curtiss saw the day of aerial passenger lines "not far off"; John North Willys (owner of the Willys-Overland automobile company) foresaw a flying boat, with a capacity of fifty passengers, "capable of being built in quantities of 50 or more, as cheaply as a first-class rail-

19 Scientific American, CXVI (1917), p. 615.

road passenger car." Senator Charles S. Thomas predicted that by 1924, aerial transportation of passengers and merchandise would be "firmly established."²⁰ An overestimate of the possibilities of commercial aviation was not confined to those with a financial interest at stake. Among the thirty-three frequent predictors active during the period 1914-1929, eleven predicted a quick success for air travel. Only one (Arthur D. Little) expressed skepticism about the rapidity of commercial aviation's development. The optimistic ones included several having no direct connection with the aviation industry. These included not only Edison, but also the chemist William J. Hale (in 1926);²¹ the astronomer Charles G. Abbott (in 1929);²² and journalists Floyd Parsons and Waldemar Kaempffert (whose prediction of commercial transatlantic travel in 1953 was most realistic as to timing among all these optimistic predictions).²³

There was, of course, no agreement about the most promising technical means for fulfilling these optimistic predictions. Aviation reporter C. H. Claudy claimed in 1920 that there would be no limit to

20 Willard Hart Smith, "The Wings of To-Morrow," Forum, LXI (1919), 197-209.

21 William J. Hale, "Prophecy of a Chemist," Scientific Monthly, XXII (Feb., 1926), p. 161.

22 Charles G. Abbott, "Vanguard," in The Drift of Civilization, p. 119.

23 Waldemar Kaempffert, "A Modern Jules Verne," Literary Digest, XCVII (May 12, 1928), 62-66; Floyd W. Parsons, Saturday Evening Post, CXCVII (March 14, 1925), 26.

the size of practical airplanes; Richard E. Byrd countered that the limit of wingspread would be 300 feet.²⁴ A panel of Scientific American experts set no size limit, but believed that the largest aircraft would have to be biplanes. Like most predictors, they foresaw a useful, if secondary role for the dirigible, particularly in the area of freight carrying.²⁵

Overemphasis on the dirigible's promise was part of a general trend toward predicting the adoption of safety devices as a means of gaining public acceptance. Safety seemed most likely to be assured through buoyancy in the air (the dirigible) or buoyancy on water making possible an emergency landing on water (the sea-plane). Summing up a decade of predictions in 1928, using the device of an imaginary retrospective from the year 1953, science writer Waldemar Kaempffert described the Wilbur Wright, a modern transoceanic transport. "Of course the Wilbur Wright is a hydroair plane," he wrote. "Land machines, for all the success they achieved in the early days, are absurd over the ocean."²⁶

Others suggested more imaginative safety devices. One, reported by Richard Byrd, was to lighten the plane by dropping the main

24 C. H. Claudy, "Aircraft of the Future," Scientific American, CXXIII (Nov. 20, 1920), 520; Richard Byrd, "Wings," in The Drift of Civilization, pp. 130-131.

25 "The Future as Suggested by Developments of the Last Seventy-Five Years," Scientific American, CXXIII (1920), 321.

26 Kaempffert, "A Modern Jules Verne," p. 99.

cabin (after, of course, gathering all the passengers into an emergency cabin permanently attached to the wing).²⁷ An engineer named E. R. Armstrong suggested anchoring man-made islands at intervals across the Atlantic to ease the ocean crossing. With these, Armstrong felt that ocean airways were "certain to be in operation" by 1932.²⁸

Of these temporary expedients for long distance travel, the dirigible was regarded as the most promising. America's most famous fliers, Charles Lindbergh and Richard Byrd, both stated in 1927-28 that the dirigible was still five years ahead of the airplane, and was at present unrivalled for transatlantic flight. The navigator of Germany's Graf Zeppelin was less generous to his rival 1928 technology. He held that it would be doubtful that airplanes would ever establish regular transatlantic service, barring some revolutionary technical breakthrough (such as atomic energy).²⁹

The consensus of predictions for airline service made during the period 1915-1929 thus saw rapid airline service of some kind as likely to be established immediately, based on some kind of special

safety device (the dirigible, the seaplane, the floating island, or another).

27 Richard Byrd, Skyward (New York: Blue Ribbon, 1928), p. 347.

28 New York Times, (Oct. 24, 1927), III, 5, Wilfred S. Ogden, "Deep Sea Anchor to Revolutionize Ocean Travel," Popular Science Monthly, C (1922), 29-32.

29 Richard E. Byrd, "Wings," p. 129; "The Coming Age of Aviation," Forum, LIV (1927), 607-610; New York Times (Dec. 30, 1928), XI, 2-3 Waldemar Kaempffert, "Aircraft and the Future," Outlook, CIV (1913), 452-456.

As public confidence was gained, and as technology developed, transition to a more advanced technical form would occur.

Those who predicted the widespread use of small private airplanes showed less caution. Waldemar Kaempffert, for example, who had predicted a slow and cautious development of transatlantic travel, expected an explosive growth of private flying. In 1913, he forecast urban housetops converted into landing pads, and "a thousand aeroplanes flying to the opera."

The prediction of an explosive growth of private aviation was very popular with independent inventors. Peter Cooper Hewitt, a pioneer in fluorescent lighting and many other fields of invention, forecast in 1915 that the helicopter would be rapidly developed. The future airplane, he predicted, would be as easy to drive as a taxicab. Hewitt himself was actively working on an early version of the helicopter.³⁰ Thomas Edison had made only a few experiments with helicopter-like machines in 1885; but in 1924 he was confident that a practical and simple helicopter was imminent.³¹ Hudson Maxim also foresaw in 1924 that "travel by airplane will be as common as travel by automobile is to-day."³² Nikola Tesla, no longer a boy wonder of invention, but as active a predictor as ever, spoke of a civilization which would exchange "wheels for

30 Edward Marshall, "Manless Aeros May Now Bomb Distant Targets," New York Times Magazine, (Nov. 7, 1915), p. 10; George Galois, "Is the Practical Helicopter in Sight?" Scientific American, CXXIV(1921), 447.

31 George S. Bryan, Edison, the Man and His Work (London:Knopf, 1926), p. 249; Thomas A. Edison, "If the Answer's Easy...", p. 5.

32 Hudson Maxim, Reminiscences and Comments (New York: Doubleday, Page, & Co., 1924) p. 288.

wings," and in which private airplanes would be driven by power transmitted through radio waves.³³

This vision initiated by the independent inventors saw a light cheap private airplane making possible the same kind of transportation revolution in the skies that the Model T had created on the ground. It was popularized by magazine writers specializing in comment about the economic effect of modern technology. Floyd Parsons, who regularly surveyed the future of invention for the Saturday Evening Post, forecast in 1925 "aerial taxis," and the "\$150 airplane."³⁴ Roger W. Babson, a prominent stock market analyst and economic forecaster, was especially anxious to spread the idea of an inexpensive, readily available airplane. He viewed technology as without foreseeable limits. "Americans are becoming accustomed to magical inventions," he told a reporter in 1928.

Today you can't spring anything too wild for people to believe. If an inventor says he has a skyrocket that will carry passengers to the moon and return, there will be a waiting line for the first ride.³⁵

In another article, in 1929, Babson predicted that the "flivver airplane" (flivver being a nickname for the Ford Model T) would be the growth industry of the thirties. Each industry, he explained, needed to

33 Nikola Tesla, "When Woman is Boss," Collier's, LXXVII (Jan. 30, 1926), p. 17.

34 Floyd W. Parsons, "Inventions of the Future," Saturday Evening Post, CXCVII (March 14, 1925), pp. 26-27.

35 John T. Brady, "There's Magic in the Air," Collier's LXXXI (April 7, 1928), 8.

find its "master key" to become a "universal" industry (as the automobile had become by 1929). The master key to aviation was the helicopter principle - the ability to hover, or at least fly slowly and safely. Once the helicopter had come, a flurry of consequences would follow. "The automobile has created the suburbs," Babson wrote. "The airplane will create the countryside." For sporting purposes, a combination boat-plane-automobile would become popular. As aviation became widespread, a demand would begin to grow for weather control. Being a stern moralist (he was to make a run for the presidency on the Prohibitionist ticket); he cautioned that:

Without moral progress in pace with physical progress, the airplane will merely make dissipation more disastrous, immorality more widespread, and crime more efficient.

Nevertheless, he felt that there was a good possibility that the flivver airplane would carry on the prosperity which the flivver car had initiated.³⁶

The builder of the original flivver automobile (and of the Ford trimotor airplane) was much less enthusiastic about the aerial flivver idea. "There is too much transportation anyway," wrote Henry Ford (or his ghostwriter, Samuel Crowther) in 1926. Ford expressed yet another theme of the aviation prediction: aircraft principally as fast express carriers, dirigibles as heavy cargo carriers.³⁷

36 Roger W. Babson, "Air Flivvers and the Future," Forum, LXXXI (1929), 157-164.

37 Henry Ford (with Samuel Crowther), Today and Tomorrow, p. 20; 205-208.

To sum up the predictions regarding aviation, there was excessive optimism about the imminence of airline travel; excessive hope for such "safety" aids as the seaplane and the dirigible; and (particularly among aging inventors and magazine writers) as over-optimistic view of the possibilities of the "aerial flivver." Furthermore, there was a frequently expressed belief that because the airplane was a remarkable technical feat, its social impact must necessarily be correspondingly great. A view in this vein expressed by Richard Byrd was an extreme version of a common theme:

There are many of us who believe that the aeroplane, by speeding international communications, will speed understanding, gradually eliminate chauvinistic boundaries, and bring a broader knowledge to the isolated peoples of the world. If this is possible, then the aeroplane's contribution to civilization will be as great, perhaps, as that of language.³⁸

The vision of the aviation enthusiasts was the most evident, but not the only, theme of transportation prediction. Those who forecast a coming scarcity of energy resources also forecast that the long-delayed dream of an electric transportation system would finally come into its own. This vision centered on use of the electric locomotive for hauling long distance freight and passenger traffic.

Those who forecast electrification of the railroads felt that it would only take a slight improvement in the financial conditions of the

38 Richard E. Byrd, "Wings", p. 126.

railroads to make available the capital needed to switch from steam to electric operation. (This hoped-for improvement has, of course, not occurred by 1975) . Once the changeover had been accomplished, the annual savings of energy resources would be enormous.³⁹ One expert estimated that over 120 million tons of coal could have been saved in 1918 through electric operation of all the railroads of the country.⁴⁰ This was more than one-fifth of the nation's total coal consumption.

Of the fifty most frequent predictors, five definitely predicted the electrification of the railroads, while only one (Carl Hering, in 1915) predicted that electricity would not replace steam. A Scientific American forecasting panel of 1920 also predicted electrification. Looking backward from the 1970's, it is clear that the railroads of the 1920's lacked the vision-and the capital-to make such a change. Nor would fuel costs force them to it. But these developments were by no means obvious to contemporary experts.

If fuel shortages and the congestion of the existing transportation network were not enough to bring about railway electrification, they might at least cause some less expensive modifications in the transportation

39 A. H. Armstrong, "The Last Stand of the Reciprocating Steam Engine, " Journal of the A.I.E.E. , XXXIX (1920), 209-210.

40 Thomas C. Martin, "The Protean Power, " North American Review, CXXII (1923), 55; R. H. Fernald, "Fuel Wastes, " Annals of the American Academy of Political and Social Science, CXI (1924), 233; Armstrong, p. 211.

system. The transportation problems of the city were a point of deliberate focus.

Urban congestion was a continuing subject for admonitory articles and serious studies.⁴¹ Through them ran the warning that even the application of the best new technology -- such as subways, moving sidewalks, and streets placed above or below the level of pedestrian traffic -- could only slow the pace of urban overcrowding. The final answer to urban transportation problems, they unanimously agreed, was decentralization. But decentralization, they agreed, would be very difficult to achieve. Summing up, one of the writers noted that only a combination of

the spreading effect of the automobile and airplane, the rebuilding of transportation facilities to meet modern needs, a better understanding of the economics of industrial location, the effect of electricity and the stoppage of immigration could bring about a better type of city.⁴²

Amid so many predictions and recommendations for major transportation innovations, the conservatism of the transportation industries was overlooked. Occasional voices of caution pointed this

41 Harvey W. Corbett, "The City of the Future," Outlook, CXL (1925), 48; Lewis Mumford, "The Intolerable City," Harper's CLII (1926), 283-293; Albert A. Atwood, "The Future City," Saturday Evening Post, CCI (Sept. 8, 1928), 10-11; Harold M. Lewis, et. al., Transit and Transportation, (New York: City, 1928); Stuart Chase, "The Future of the Great City," Harper's, CLX (1929), 82-90.

42 Albert A. Atwood, "The Future CITY," p. 150.

out. One such voice was that of Charles Kettering, director of research for General Motors. He continually stressed throughout the twenties that the trend he expected in transportation was not a revolutionary advance, but rather a steady improvement along lines already laid down.⁴³ Kettering's conservative vision, the only one presented by any of the fifty most frequent predictors, was the one closest to the actual outcome. The revolutionary developments in all transportation fields predicted from 1914-1929 -- the rapid growth of airlines, the "aerial flivver," electrification of the railroads -- did not occur. And in fact, the next actual "revolutionary" development in transportation was to be an improvement hardly mentioned in the 1920's - the introduction of the diesel locomotive.

The Era of Superpower

An international crisis set off a chain of events resulting in sharply reduced availability of the fuel that supplied three-fourths of America's energy. In a few months, the cost of that fuel more than doubled. Energy experts responded with a flurry of energy conservation ideas: turn the thermostats down to 65 degrees; extend daylight savings time; tack a fuel adjustment onto electricity bills.

43 Charles F. Kettering, "Motor Design and Fuel Economy," Journal of Industrial and Engineering Chemistry, XVII (1923), 115; Edgar C. Wheeler, "Tomorrow's Motor Car," World's Work, XLIV (May, 1927), 77-8, 5.

These were some of the responses to the 'energy crisis' -
of 1917.⁴⁴ America's entry into World War I, and the energy demands set off by war production, were the immediate cause of the crisis. Labor shortages at the coal mines; excessive demand for the mined coal, and a tieup of the railroads combined to create a severe coal shortage. Only emergency allocation procedures and curtailment of nonessential power uses brought the nation through the immediate crisis.

But the possibility of a recurrence remained. Labor troubles after the war brought on another coal shortage to remind the public, and to set planners and predictors to work.

In 1920, the Federal government sponsored a major study of energy problems in the most severely affected part of the country, the Northeast. A group of engineers and economists headed by electrical engineer William S. Murray examined the expected future energy needs of the North Eastern seaboard from Maine to Washington, D. C. (more precisely, the region between 39 and 44 degrees of latitude, and extending 150 miles inland from the Atlantic Ocean.) The report concluded that the best way to meet these projected power needs was through a carefully

44 Lynn S. Goodman and William B. Jackson, "Effects of War Conditions on Cost and Quality of Electric Service," Journal of the American Institute of Electrical Engineers, XXXVII (1918), 1-17 and "Discussion," ibid., pp. 18-63; U. S., Congress, Emergency Power Bill, Sept. 19, 1918, Report to Accompany H. R. 12776 (Washington, D. C.: Government Printing Office, 1919); Ernest Greenwood, Aladdin, USA (New York: Harper & Brothers, 1928), p. 126.

planned set of hydroelectric power plants on the major rivers, and large steam-powered plants located near the major coalfields. These would supply electric power to all of the industries and railroads of the region by means of a unified system of interconnecting electric transmission lines.⁴⁵ This plan was given a name: superpower.

The novelty of the proposition was in the idea of planning for the overall power needs of the region. The practice in the electric utility industry to 1919 had been for each utility to separately plan for and meet its own local demand. Some interconnection among utilities with common ownership existed. But Murray proposed to greatly "coordinate and supplement" this rudimentary cooperation.⁴⁶

The Northeast Superpower system was to play the same role in energy supply that the Federal Reserve system played in banking.⁴⁷ It would be a means of applying the power supply capacity of the region to the areas of greatest demand -- of transferring kilowatt-hours of energy among local utility systems as the Federal Reserve transferred deposits among local banks. As the Federal Reserve was the "banker's bank," so the superpower system would be the power company's power supply.

45 W. S. Murray, et. al., "Economical Supply of Electric Power," Journal of the American Institute of Electrical Engineers, XXXIX (1922), 219-222+; "Advantages of Superpower System," Electrical World, LXXVIII (1921), 916-921.

46 Ibid., p. 916.

47 C. O. Ruggles, "Problems in the Development of a Super Power System," Harvard Business Review, II (1924), 160-173.

As one of its proponents put it, the system would be:

but a large power reservoir into which will be fed the output of the more efficient existing plants, the proposed new base load steam electric stations, and the hydroelectric stations; and from which the power to supply the industrial, the railroad, and the domestic requirements of the various load centers will be tapped where and when needed.⁴⁸

Technically, the program seemed to meet the most pressing needs of the electrical industry. The system recommended would effectively increase the generating capacity of each local utility. Under the plan the "load factor" (a measure expressing the energy actually used as a percentage of the maximum possible energy output of the system) would rise from 15% to 50%. This would mean a drop in the fixed cost of power production. Combining this with the use of efficient large generating plants instead of inefficient small ones, William Murray predicted a total saving of \$300,000,000 by 1930.⁴⁹ Coming technological improvements, such as the increase of electrical transmission voltages to 220,000 volts, increase of generating efficiency through use of mercury vapor turbines, and possibly even the use of high-power vacuum tube equipment to make efficient direct-current transmission possible, seemed to make a large planned power system even more attractive.⁵⁰

48 Henry Flood, Jr., "Superpower and its Relation to Industry," Journal of the A.I.E.E., XL (1921), 193.

49 Murray, et. al., "Economical Supply Electric Power," pp. 219-220.

50 Albert W. Hull, "The Magnetron," Journal of the A.I.E.E., XL (1921), 723; Edwin W. Rice, "Research and Power," Scientific American, CXXXI (1924), pp. 234-5+; "Mercury Vapor Turbine," Electrical World, LXXXII (1923), 950.

The superpower plan was the most ambitious attempt of the 1920's to combine technological forecasting with social planning. It was based on the best judgment of respected experts, not on utopian dreams. Reaction to the plan would provide a major test of the concept of an "age of efficiency" succeeding the age of competition.

Initial reaction to the superpower proposal was positive. Two of the outstanding power engineers of the major electrical manufacturing companies -- Charles F. Scott of Westinghouse, and W. L. R. Emmett of General Electric -- expressed their approval.⁵¹ The trade periodical of the electric power industry, Electrical World, added its blessing in a series of articles and editorials. "The old political economy based on the idea of free competition in somewhat self-supporting communities has long since gone by the board," one article noted; "Superpower Report Reveals Electrical Opportunities,"⁵² headlined another.

In the year after its inception, the year from mid-1920 to mid-1921, the concept of a planned electric power system seemed to sweep everything before it. A power engineer noted in 1920:

51 Murray et. al., "Economical Supply of Electric Power," p. 221.

52 Electrical World, LXXVII (1921), 18; 333; 910.

The general tendency towards the consolidation of existing power plants and transmission systems and the probability of the construction of super-power lines will undoubtedly result in the erection of large generating stations which can be operated at full load throughout the year. Whether such plants be located near coal mines where fuel is considerable, the fact that the load factor is high will justify the construction of the most economical plant.⁵³

The rush of enthusiasm for superpower posed a direct challenge to the established electric utility business. The concept posed two possible dangers: increasing government regulation of electric power supply; or an even more radical upsetting of established ways of doing business such as nationalization of the power industry. The first of these two possibilities might be seen in the endorsement of superpower by men identified with the progressive movement, such as Gifford Pinchot and Robert LaFollette. The second showed up in the views of two unconventional representatives of industry, Henry Ford and Charles Steinmetz.

Superpower combined in a politically attractive way engineering efficiency and social change. As columnist Charles Merz noted in 1923:

Now it will be observed that the men engaged in an engineering feat involving a vast distribution of cheap power are not approaching the problem from the point of view of the evangelist or the reformer. They are tackling a problem in the waste of energy.⁵⁴

53 H. Goodwin, Jr., "Design of a Superpower Station," GE Review, XXIII (1920), 399-418.

54 Charles Merz, "Twentieth Century Medievalism: the Machine Age on its Way to a New Order?" Century, LXXXIV (1923), 228.

But, as Merz noted, there was more to the story: decentralization of industries; shorter working days; birth of a "self-conscious localism" to replace the trend toward growth of central cities; and improvements in rural education and in the employment opportunities (due to the new rural factories) for those currently engaged in migratory labor.⁵⁵

The technical promise of superpower brought together prophets with many different social purposes. For Governor Gifford Pinchot of Pennsylvania, a veteran progressive, it represented a chance to achieve many of the aims of the progressive movement: breaking up the concentration of economic power in large corporations and the concentration of populations in cities; conserving natural resources; applying the rational, waste-eliminating principles of scientific management.

To achieve these aims, Pinchot created the Giant Power Survey Board in 1923.⁵⁶ The mission of this Board was to come up with a comprehensive plan for the future power system of the state. Its members were Morris L. Cooke, a disciple of Frederick W. Taylor in the field of industrial engineering; and Robert H. Fernald and Frederick K. Newell, two engineers and advocates of energy conservation.

55 Ibid., pp. 234-236.

56 New York Times, Sept. 30, 1923, III, 7:1.

For Cooke, the basic aim of superpower was the scientific management goal of greater efficiency through planning: "to substitute the look-ahead for regret after the event."⁵⁷

He began from technical imperatives: "we are now in the position to generate current either by water power or steam power wherever it can be manufactured with the least expenditure of effort and material, and then transmit it to the point of use. This one fact requires an absolutely new synthesis of our energy resources and our energy requirements."⁵⁸

The problem for the engineer was to combine efficient production of energy with socially valuable use of it. On the supply end this was to be established through the economies of scale: large power stations (500 megawatts or more) located at the coal fields or on the great rivers, and 220,000 volt transmission lines to carry power to high-demand areas. On the demand end, this would mean a radical reduction in the cost of electric power to the consumer. This would result in rural electrification, the revival of small industry, and the electrification of the railroads.⁵⁹ In the view of another member of the Giant Power Survey, Robert Fernald, the increased efficiency made

57 Morris L. Cooke, "Giant Power: Foreward," Annals of the American Academy of Political and Social Science, CXVIII (1925), v.

58 Morris L. Cooke, "Giant Power and Coal" Annals of the American Academy of Political and Social Science, CXI (1924), 212.

59 Ibid., pp. 213-216.

possible by superpower would enable the American people to both conserve fuel and use more power.⁶⁰

The progressive conception of superpower identified centralization with the steam engine, and decentralization with electricity. One electrical engineer predicted:

It would seem likely that with the dawn of the electrical age will come decentralization, with proximity to raw materials, less pressure of transport, new access to markets, small rents and taxes, and many other advantages, social and economical, just as with the steam engine came all the evils of the crowded city.⁶¹

Robert K. Bruere, editor of the magazine Survey, also predicted that superpower would bring a second industrial revolution free from the evils of the first. A member of Bruere's staff elaborated on this vision:

As far as power is concerned, the artisan may now go back to his cottage, assemble his family, set up machines for himself and for them there, to be driven by power from the common reservoir, and thus regain both his freedom and his family life.

He admitted, however, that "other influences operating against the cottage industry, will remain."⁶²

60 R. H. Fernald, "Fuel Wastes: Causes, Effects, Remedies," Annals of the American Academy of Political and Social Science, CXI (1924), pp. 219-223.

61 "Beama," "A Sociologic Aspect of Superpower," Journal of the AIEE, XLIII (1924), 16.

62 Philip A. Wells, "Our Federal Power Policy," Survey Graphic, LI (1924), 570.

As the decade progressed, the "second industrial revolution" theme became a staple of journalistic prediction. Evans Clark of the New York Times saw the abolition of steam power and the decentralization of industry in the coming "giant power age" (successor to the "age of interconnection, 1917-1925"). "As steam produced the city and the slum," he wrote, "they say electricity may resurrect the country and the small town."⁶³ This was in 1925. By 1929, the progressive vision had been elaborated by science writer Waldemar Kaempffert:

Watt and the individualistic steam engine gave us tenements, jungles of stone and steel, forests of chimneys, high rents, clogged street cars and subways, slums, diseases unknown among savages. And the electrical engineers of today? Thousands of small towns with plenty of garden space, low rents, breathing space, open-air sports for all, servantless houses in which electricity is the maid of all work, health, and a finer outlook on life.⁶⁴

Such a prospect deserved to be in a political platform. In 1924, superpower was a plank in two platforms -- one actual, and one abortive. Robert LaFollette's Progressives proposed "public ownership of the nation's water power, and creation of a public superpower system."⁶⁵ And a vaguer but more dramatic use was made of the superpower theme at the center of the presidential boom engineered by Henry Ford.

63 Evans Clark, "Giant Power Transforming America's Life," New York Times (Feb. 22, 1925), VIII, 1; "The Great Epic of Power," New York Times (March 29, 1925), IV, 7.

64 Waldemar Kaempffert, "The Age of Superpower is Here," New York Times (Sept. 22, 1929), VI, 23.

65 Preston J. Hubbard, Origins of the TVA (N. Y.: Norton, 1961), p. 136.

The year 1922 saw three major efforts by Henry Ford. He offered to purchase the government-built power production and fertilizer-making facilities at Muscle Shoals, Alabama; his newspaper intensified its anti-Semitic campaign; and he permitted or encouraged the launching of a Ford-for-president drive.⁶⁶

The Muscle Shoals issue, especially in its political aspects, gave Ford a platform for prediction. Muscle Shoals, in his view, was just a beginning. His long range aim was expressed in his 1926 book *Today and Tomorrow*: "we must have big business -- which does not, however, necessarily mean centralized business. We are decentralizing."⁶⁷ He proposed his own superpower system to make this decentralization possible. There were to be Ford water power plants on the Tennessee and other major rivers; and Ford fossil fuel power plants at the coal fields. One such plant, combining power production, motor fuel distillation, and coal gasification, was planned for Huntington, West Virginia.⁶⁸

The Ford power system would solve the farm problem as well. Ford saw as the key issue the fact that farming was not really a full time job, so it could not offer a full time living. The solution: rural industries that could offer employment in the slack seasons--made

66 Ibid., pp. 33-38; 106.

67 Henry Ford and Samuel Crowther, *Today and Tomorrow* (Garden City: Doubleday, Page & Co., 1926), p. 10.

68 *ibid.*, p. 6; New York Times (July 15, 1923), VII, 13.

possible by cheap electricity.⁶⁹

Some of the more extreme aspects of Ford's energy program had been revealed during a triumphal speaking tour of the Tennessee Valley in late 1921. Using the great energy resources at Muscle Shoals and other water powers, Ford asserted, the United States could replace the gold standard with an "energy dollar." Furthermore, in place of the industrial cities of the past, he proposed a seventy-five-mile-long decentralized industrial region along the Tennessee River.⁷⁰

Little came of all this. The Ford offer for Muscle Shoals came under congressional criticism and was withdrawn. The Ford-for-president boom collapsed. Ford had articulated the feelings of a significant minority in the nation, but was unable to follow through on his ideas.

Henry Ford represented the superpower idea viewed through the populist assumptions of a small-town Midwesterner. A second perspective on the concept was provided by Charles P. Steinmetz, the German born immigrant, socialist, and successful engineer. In the same year (1922) that Ford was launching his energy-dollar and presidential boom, Steinmetz was writing to Lenin offering his "advice, suggestions, or consultations," to the Bolshevik revolution.⁷¹

69 Ford and Crowther, p. 218.

70 Hubbard, pp. 36-39.

71 "Lenin and Steinmetz Correspond," Nation, CXV (July 19, 1922), p. 78.

Steinmetz's predictions about the future effects of electric power on society were somewhat less sweeping than Lenin's dictum, "Communism is Soviet power plus electrification of the whole country."⁷² For Steinmetz, electricity was only a first step toward socialism. Government control of electric power would be a transitional measure. In 1915, for example, he predicted that electricity would be "used so generally that it is very likely that the cost will be on the basis of a tax, like our water tax."⁷³

One of his biographers summed up Steinmetz's views on the relation of electrification and socialism.

For years he had preached electrification as one of the chief agents of Socialism. If a country was bound together closely by power lines in the inevitable control of some central agency, and if that agency drifted more and more toward government management, there was sure to be a parallel drift in other lines.⁷⁴

While not directly endorsing (or rejecting) the superpower Scheme, Steinmetz spoke of a "network of interconnected generating and conducting systems, " which would do "for the distribution of energy what the railroads in the last seventy-five years have done for the distribution of materials."⁷⁵

72 E. H. Carr, The Bolsheviki Revolution, II (London: Pelican, 1966), p. 370.

73 Charles P. Steinmetz, "You Will Think This a Dream," Ladies Home Journal, (1915), 12.

74 Jonathan Norton Leonard, Loki: the Life of Charles Proteus Steinmetz, (N. Y.: Garden City, 1929), p. 264.

75 New York Times, (Nov. 26, 1921), 10:2; (Nov. 27, 1921), II, 3:2.

Like Henry Ford, he saw the revolution wrought by electrification as only a beginning. In the last year of his life (he died in 1923) Steinmetz foresaw such future wonders as food production using nitrogen-fixing microorganisms; the four-hour day and two-hundred-day year for the worker; possible communication with Mars; and an epoch in which "collectivistic civilization will spread over Europe from the East, where the leaders of the future will be born."⁷⁶

Steinmetz was far from being a revolutionary. He thought that socialism would be gradually established, under the leadership of the existing industrial corporations. "Industrial cooperation," he wrote, "would be so near socialism, would so imperceptibly merge into it, that nobody would be able to see where 'capitalistic society' ended and the 'socialist commonwealth' began."⁷⁷

A development in 1923 seemed a step toward the type of industrial cooperation that Steinmetz had in mind. The Westinghouse Electric Company financed a study by the consulting engineer Frank G. Baum to draw up a superpower system for the entire country. It was presented at the 1923 convention of the National Electric Light Association (the electric utility trade organization) and was greeted as "a fascinating glimpse of the United States of the Future." Guy E. Tripp, chairman of

76 New York Times, (Aug. 20, 1923), p. 1:7.

77 Charles P. Steinmetz, America and the New Epoch, p. 222

Westinghouse, predicted that electricity will "lead industry to seek the country, where rents are low, and raw materials accessible." He added that "we can confidently expect that the people will spread out into the open, where they will find fresh air and health."⁷⁸

This language was similar to that of the progressives, Ford and Steinmetz. So were the technical means through which superpower was to be established: water power, power plants fueled by the wastes from gasoline production and coal carbonization, and power plants at the coal mines.

However, on one key point, the Baum-Westinghouse plan parted company with those of the reformers. The superpower system, Tripp stated, "must be a monopoly," and "it must be owned and operated by private interests, and not by any government agency."⁷⁹ Furthermore, it would develop through evolution of the existing network of electric utilities. It was not clear whether Tripp envisioned a voluntary national power grid, or a gigantic holding company.

The discussion of superpower thus passed from the technical to the political plane. The electric utility industry, seeing behind the superpower movement the threat of national control of electric power, sought to protect its interests. It did this by seeking to identify the

78 New York Times, (June 17, 1923), VIII, 1.

79 Ibid.; Guy E. Tripp, "The Electrification of North America," World's Work, XLVI (1923), 498-504.

superpower spirit with the already established practices of the electrical industry. The Baum-Westinghouse plan was one example. Another was the statement made by M. H. Aylesworth, Executive Manager of the National Electric Light Association, at the Spring, 1923, Convention of the American Institute of Electrical Engineers: "Superpower is merely an elaboration of the central station principle."⁸⁰

These responses were in line with the advice offered in an editorial of July, 1923, in the trade periodical Electrical World:

the industry must heed the movements for state and national development which have arisen frequently of late, and checkmate their further spread by actual installations and work.⁸¹

They also signalled the beginning of a campaign to play down the advantages of superpower. An editorial in August, 1923, complained that it had been "painted, often in colors too glowing, by the uninformed popular writer," and called it "one of those matters of public interest upon which politicians may appeal to popular prejudice."⁸² By November, 1923, the industry's attitude had turned sarcastic.

Superpower in the public mind is the monkey gland that will invigorate the country mechanically by making electricity available in such abundance and at such a price that even 'father' won't have to work any more. Like radio in its heyday, superpower appeals to the imagination of the

80 "Superpower -- A National Resource," Journal of the American Institute of Electrical Engineers, XLII (1923), 648.

81 Electrical World, LXXXII (1923), 1.

82 Electrical World, LXXXII (1923), 479.

public, and countless enthusiasts have begun to preach the popular gospel, and lead their converts to dazzling heights in the clouds of fantasy.⁸³

Superpower, which had originated as a technical proposal and had been at the center of many technological predictions, had become a mainly political issue by the mid-1920's. Like the Muscle Shoals issue and the St. Lawrence Power and Seaway Project, it was stalemated by blocking tactics initiated by both public power and private power advocates.

Both sides were guilty of making misleading statements. Representatives of the existing, privately owned, power companies tended to blur the distinction between superpower and interconnection. Superpower, said the president of Boston Edison, is already here: "instead of something to be sought for in the future it is already in large degree an accomplished fact."⁸⁴ On the other side, public power advocates tended to identify the technical advantages of superpower or Giant Power with the political or economic advantages of government ownership. Actually, mixtures of public and private ownership can capture the technical advantages of strong interconnection. In Sweden in the 1970's, for example, the state owns the integrated transmission network while power production is split almost equally between private and public organizations.⁸⁵

83 Electrical World, LXXXII (1923), 949.

84 New York Times (Sept. 25, 1924), p. 34.

85 A. Philip Sporn, The Social Organization of Electric Power Supply in Modern Societies (Cambridge, Mass.: M.I.T. Press, 1971), pp. 22-24.

Emergence of the holding company issue in the 1920's further complicated the superpower debate. A holding company serves to unify the financial operations of several companies whose individual activities remain otherwise separate. A capital-intensive business like electric power supply found such unification advantageous, even while resisting the technological unification involved in superpower. The progressive supporters of superpower expressed strong opposition to holding companies, condemning them as monopolistic.

The result was something of a standoff. The Murray and Baum superpower plans were shelved. The electric utility companies continued to develop on a basically feudal pattern. Extensive interconnections linked the company systems, but these interconnections were treaties between independent entities, rather than attempts to impose an overall plan or logic upon national or regional power supply.

The predictions about superpower and its effects proved incorrect. But would a unified power system be a good idea? This question has never been fully clarified. A bill proposing a national power grid is before the U. S. Congress in the 1970's. Electrical engineers continue to debate its merits. The Northeast Blackout of November, 1965, led to a strengthening of intersystem ties in the superpower zone. But practical considerations of business and politics, rather than economic theories or engineering plans, continue to shape the way electric power

is supplied in America.⁸⁶

⁸⁶ see, e.g., IEEE Spectrum, XI (1974), 28; Stephen G. Breyer and Paul W. MacAvoy Energy Regulation by the Federal Power Commission (Washington, D. C.: The Brookings Institution, 1974), pp. 89-121.

CHAPTER VI

WHEN THE OIL RUNS OUT: 1915-1929

The appetite of the United States for fossil fuels had alarmed many Americans even before 1914. It should have been much more alarming after two developments of the years 1915-1920. First, the war and immediate postwar period had revealed serious weaknesses in the structure of the United States coal industry. Second, the automobile had become (in words that were already a cliché by 1920) no longer a luxury, but a necessity.¹

Estimates frequently appeared from 1914 on concerning the reserves and probable resources of the major fuels. Unlike other types of technological predictions, these tended to cluster around a few estimates. There is a simple reason for this: all were based on a few comprehensive efforts at resource estimation (by the few groups with the time, interest, and money to make them). The individual predictor generally added only his own personal correction factors, and an expression of his optimism or pessimism. Most predictions dealt with future supply, only a few with future demand.

To sum up the underlying trend of these predictions:

1 "Symposium on Coal Supply," Outlook, CXXXIII (1923), 618-624; John R. Eustis, "The Future of Motor Travel," Independent, XCVV (1920), 174.

(1) Putting together some separate demand predictions for energy, it appears that the estimators in the years 1914-1929 came quite close (within about 10%) to predicting the actual figure for total energy use in 1970. Their estimates of United States and world energy supplies in 1970 were, however, far below those held by experts today. This leads to the question: why wasn't the energy situation of 1923 much more alarming to experts than the energy situation of the 1970's now is?

(2) The answer is that the experts also made a very bad guess about Americans' choice of fuels. In spite of the arrival of the automobile and pipeline age, energy predictors greatly underestimated future gasoline and natural gas demands. At the same time, they greatly overestimated future coal production. The net result was to assume that the U. S. energy demands circa 1970, while enormous, would be met by our most abundant fossil fuel - coal.

(3) Almost all of the exotic energy sources which are now being counted on to supply this nation with energy "after the oil gives out" -- nuclear fission and fusion, solar, geothermal, and synthetic liquid and gaseous fuels -- were at least mentioned by the predictors of the 1920's. However, the order of likelihood of success of these methods expected by past prophets is very different than the order expected by today's. To sum it up simply: in the twenties, the chemist was expected to supply tomorrow's energy technology; today (1974) the physicist plays a much bigger role in our energy plans.

Supply, industry structure, and the role of future technology were then - and are now - the main concerns of those dealing with the energy situation. It is worth looking at each one separately to get the full picture of the expected future of energy.

Supply and Demand for Energy, 1915-1929

To the technological forecaster in the period 1915-1929, only three energy resources were of immediate concern: coal, oil, and water power. Natural gas was not to be relied upon for any extended period of time. Shale oil and vegetable fuels were possible future supplements; other proposed sources were seen as little more than curiosities at that time.

The coal forecast was tied to an old estimate. The work of Marius R. Campbell, of the United States Geological Survey, has already been discussed. His map of the coal fields of the United States, completed in 1908, remained the nation's principal estimate of coal resources for the next forty years. It was generally taken as a starting point for prediction by those interested in the resource situation. There were many ways of making use of Campbell's data, however.

Campbell himself was careful to warn that predictions which took into account only the total tonnage of coal in the ground were nearly valueless. The word "coal" covered a great range of fuels, starting from the "high ranking" anthracite, valuable both as a source of coke and as a domestic fuel of high heat content and low pollution emission. At the other end were the "low ranking" coals -- mostly lignites and

sub-bituminous coals of a soft, crumbly consistency. These had little value as either coke or home fuel. Campbell prefaced his resource estimates with two warnings: "the great bulk of the coal in this country is low rank"; and "our best coal will be the first to be exhausted."²

Many people who used Campbell's statistics neglected these warnings in favor of a third, more cheerful estimate: "the really staggering fact presented ... is the immense, really inconceivable total quantity of the coal."³

Of the experts who looked at the nation's coal supply in the period 1915-1929, only one - the mechanical engineer Robert H. Fernald - could summon up any real alarm over the lifetime of our coal supply. Fernald's estimate, hinting at a lifetime possibly as short as "a few hundred years" was about one-tenth that of other predictors.⁴

A few examples of the more optimistic forecasts will suffice. Svante Arrhenius, the great chemist, estimated in 1920 that the U. S. had a 2000 year coal supply; Joseph E. Pogue, a geologist, gave the 1917 reserve as "several centuries." Industrial chemist Arthur D. Little, a proponent of more efficient energy use, still believed in 1922 that "we have enough coal to last six thousand years." Chemist Edwin

E. Slosson gave the lifetime as 5000 years in a 1923 article. Oil

2 Marius R. Campbell, "The Coal Fields of the United States," General Electric Review, XXI (1919), 618.

3 ibid.

4 R. H. Fernald, "Is Our Fuel Supply Nearing Exhaustion?" General Electric Review, XXI (1921), 551.

executive Henry L. Doherty, serving as an energy resources expert at a 1926 conference held that our coal was virtually inexhaustible.⁵

Notice that each of these estimates was for a coal resource lifetime. Each, therefore, implicitly contained an assumption about supply and demand. On supply, the pessimistic and optimistic estimators were in agreement: beneath the soil of the United States lay about 3000 billion tons of coal, of which about one-seventh was of high quality, and of which nine-tenths was within 3000 feet of the surface (that is, at depths potentially mineable).⁶

By 1920, this reserve was being used up at a rate of about 530 million tons per year. One simple estimate of demand assumed this figure would stay constant. Simply dividing this figure into the total resources figure given above yields a lifetime of over 5000 years. But, as Marius R. Campbell warned in 1918: "it is manifestly incorrect to base the calculation on the present rate of production or consumption, or on the rate for the last decade, as the rate will continue to increase

5 Svante Arrhenius, "The World's Supply of Energy," Scientific American Monthly, II (1921), 103-106; Joseph E. Pogue, "Mineral Resources in War," Scientific Monthly, V (1917), 120-134; Arthur D. Little, "Our Power Problem," Colliers, LXX (Aug. 19, 1922), pp. 5-6; Edwin E. Slosson, "An Inventory of Our Energy Supply," Scientific Monthly, XVI (1923), 217; Henry L. Doherty, "Our Future Sources of Energy," Journal of Industrial and Engineering Chemistry, XVIII (1926), 1063.

6 Fernald, pp. 549-551; Chester G. Gilbert and Joseph E. Pogue, America's Power Resources (New York: Century, 1921), p. 16.

for a long time."⁷

The most comprehensive effort to estimate of future demand for coal dated back to 1908. E. W. Parker, a coal geologist, drew the original of the curve which is reproduced in black as figure 1. Judging this in 1918, in the light of ten years more experience of resource estimation, Campbell found it to be a conservative prediction of future consumption. In a similar, but less comprehensive estimate, Charles P. Steinmetz found in 1918 that the amount of coal produced annually in the United States was doubling in each 25 year interval, with no visible signs of slackening.⁸

How well have these supply and demand estimates stood up over the half century since they were made? The prediction regarding coal supply is now regarded as too optimistic. The total recoverable coal resources of the United States are now placed at just over 1500 billion tons, or about half the value they were estimated at in the 1920's.⁹

The predictions of future coal production have fared much worse. United States coal production has never exceeded 630 million tons a year. This peak was reached in 1947. In 1970, the year for which E. W. Parker's "conservative" prediction forecast a coal production of about 1.8 billion tons, actual production was only about 590 million tons.¹⁰ The dashed line

7 Campbell, pp. 618-619.

8 Charles P. Steinmetz, "America's Energy Supply," Transactions of the American Institute of Electrical Engineers, XXXVII (1918), 985.

9 M. King Hubbert, "The Energy Resources of the Earth," Scientific American, CCXXIV (1971), 60-87; David J. Rose, "Energy Policy in the U. S." Scientific American, CCXXX (1974), 25.

10 Science News, XCIX (1971), 83.

in figure 1 shows actual coal production during the last 80 years.

Certainly any history of twentieth century technology (which this work is not) must explain this sudden levelling off of coal production after 1915.

A partial, but incomplete, explanation is the substitution of petroleum for coal. A look at predictions regarding petroleum's future use shows that most predictors missed this trend entirely. They regarded oil as a short-lived energy resource unable to meet the price competition of coal for very long. Again, a useful approach is through a look at estimates of supply of oil, estimates of demand, and predictions made in light of the two estimates.

The first official estimate made of the United States oil supply in the period 1914-1929 was considerably lower than previous official estimates. According to petroleum geologist Ralph Arnold, writing in 1915, the United States had used up nearly half of its original oil supply. Only about 5.8 billion barrels of potentially recoverable oil remained beneath the soil of the United States. (This is roughly the amount of oil consumed in the United States in the single year 1973.)¹¹

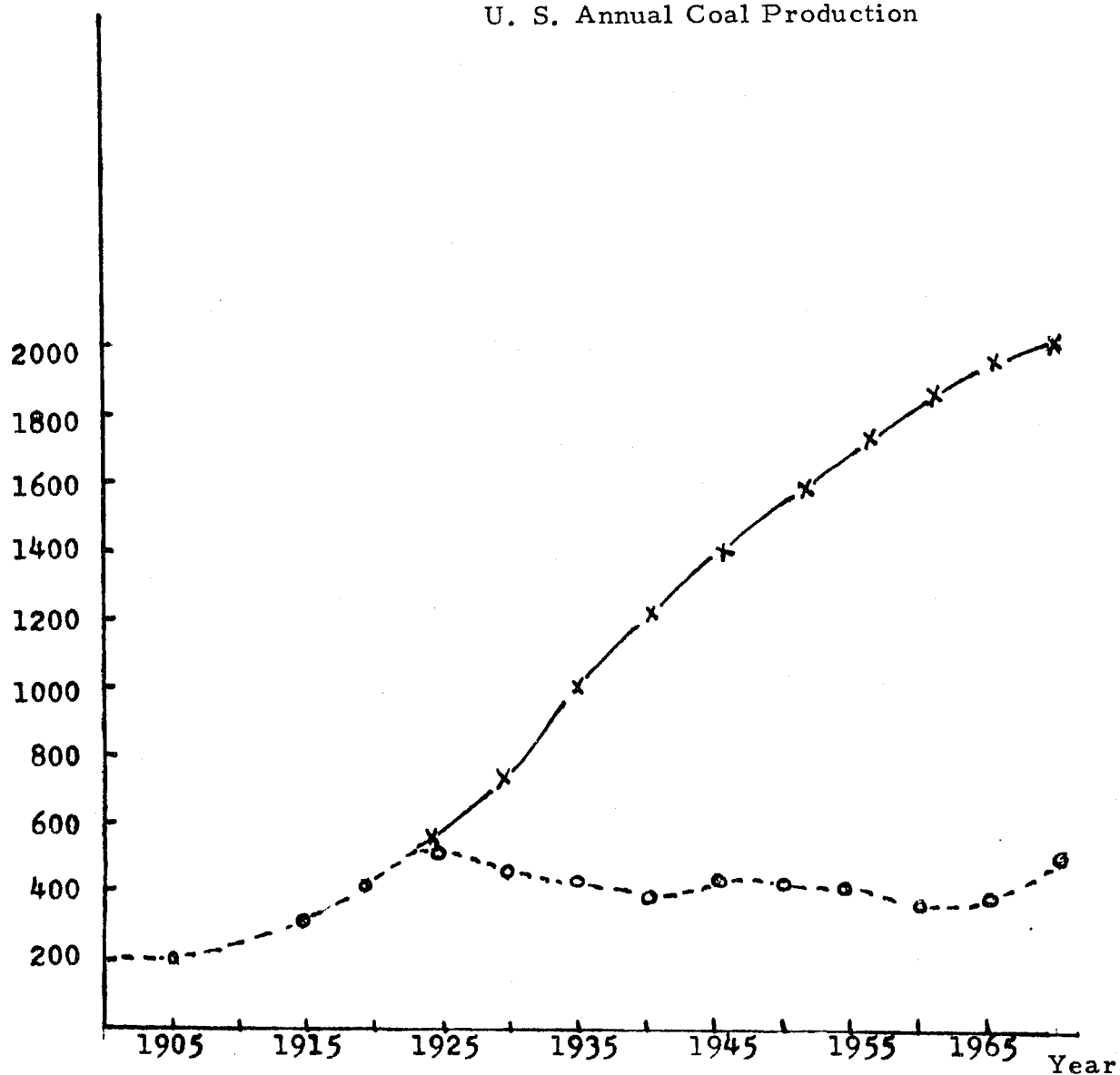
Until the mid-1920's, most forecasters agreed with this pessimistic estimate. Fuel executive W. A. Williams, placed the U. S. future

11 Ralph Arnold, "The Petroleum Resources of the United States," Annual Report of the Smithsonian Institution, 1916 (U. S. : GPO, 1917), pp. 273-275.

Figure 1:

Coal Production, U.S.
(Million Tons/Year)

Predicted and Actual
U. S. Annual Coal Production



predicted 1915 X—X—X

actual O---O---O

(Adapted from Marius R. Campbell, "Methods for More Effectively Utilizing our Fuel Resources," p. 619)

supplies -- "both known and prospective fields" -- at seven billion barrels (about enough to last present-day America 14 months). The widely quoted study by economist Chester Gilbert and geologist Joseph Pogue, America's Power Resources, put the figure at about 6.4 billion barrels in 1921. Arthur D. Little claimed in the same year that the nation's original oil resources were 40% exhausted.¹²

By 1927, large oil discoveries made in the far west and southwest made these estimates look hopelessly conservative. The application of scientific techniques to oil exploration -- as well as some lucky discoveries -- caused a doubling of known U.S. oil reserves (that is, the oil supply in fields available for exploitation) in the years 1925-1926 alone.¹³

Predictions had to be adjusted upward to follow known facts. But even with improved geological techniques it was impossible to make a survey of U.S. oil supplies that would be as authoritative as Marius Campbell's coal survey. Coal is deposited in large beds, which can be roughly mapped by drilling widely spaced holes to the earth to obtain samples. Oil, on the other hand, is concentrated in a few favored locations.¹⁴ Pre-

12 W. A. Williams, "Our Future Petroleum Industry," General Electric Review, XXI (1918), 70-72; Chester G. Gilbert and Joseph E. Pogue, America's Power Resources (New York: Century, 1921), p. 16; Arthur D. Little, "The Fuel Problem," Atlantic, CXXVII (1921), 194-195.

13 Leonard M. Fanning, "Technology--the Great Multiplier," in Our Oil Reserves (N. Y.: McGraw-Hill, 1945), pp. 74-75.

14 Hubbert, p. 64.

dictions of oil resources (defined as the amount of oil likely ever to be located) or recoverable resources (defined as the amount ever to be recovered) are at best educated guesses based on the record of past exploration.

The prediction which was most comprehensive, of all those made between 1914 and 1929, was one made under the auspices of the Federal Oil Conservation Board and released in 1926. The survey of reserves and estimation of probable future discoveries was actually done by a Committee of Eleven selected by the American Petroleum Institute (an oil industry group). This group set the oil reserves of the United States at 5.3 billion barrels (a figure nearly as great as Ralph Arnold's 1916 estimate of our oil resources). It further estimated that the known oil fields containing these reserves also contained 26 billion barrels of oil not recoverable by 1926 recovery methods. There were also 1.1 billion acres of favorable oil land, as yet unexplored, which should yield some undetermined amount of oil (measurable in many billions of barrels).¹⁵

Although some commentators, mistaking reserves for resources, saw this report as alarming,¹⁶ the main reaction between 1926 and 1929

15 K. G. Mackenzie, "Petroleum Motor Fuel," Industrial and Engineering Chemistry, XVII (1923), 1108-1113; A. C. Fieldner and R. L. Brown, "Future Trends in Automotive Fuels," Journal of Industrial and Engineering Chemistry, XVIII (1926), 1009-1014.

16 Jonathan N. Leonard, "When the Oil Gives Out," Nation CXXIII, (1926), 557-559.

was an increased optimism. However, the indefiniteness of the prediction, coupled with a wide variety of preconceptions on the part of individual predictors, left room for a wide range of judgments.

For example, Thomas Edison, the irrepressible optimist, refused to entertain the possibility of a rapid diminishing of petroleum supplies. "The oil shortage is exaggerated," he was quoted as saying in 1924. "Such exaggeration always keeps up the price. We haven't searched the earth for oil."¹⁷ (Incidentally, the record of oil discoveries and crude oil prices between 1916 and 1938 does not bear out the frequently made accusation that oil discoveries are conveniently withheld until the price has risen. Figures gathered by economist Joseph E. Pogue support that author's conclusion that there is an "all too imperfect conformance between rate of discovery and price of crude oil ... the volume of discovery has not been proportional to price.")¹⁸

A more pessimistic predictor viewed the oil situation with much more alarm. Writing in 1922, the industrial engineer Walter Polakov concluded that "we ourselves will have the privilege of writing in our memoirs the experiences of seeing this country going dry -- dry of oil." He viewed this fate as a warning to America:

The petroleum industry exhibits our national economic characteristics; it is a symbol and a

17 Thomas A. Edison, "If the Answer's Easy . . .", p. 6.

18 Joseph E. Pogue, Economics of the Petroleum Industry (Preprint, 1939), p. 12.

prophecy. It is based on gambling and speculation; it is carried on with ignorance and waste unsurpassed in any other field; it is specular, almost overtaking one's imagination; it is medieval administratively, progressive mechanically, socially criminal, financially modern. And it gallops to its fall.¹⁹

Neither Polakov nor Edison -- nor any of the other extreme optimists or pessimists of the 1920's -- backed up their beliefs with quantitative predictions of the future demand for oil. The most concrete estimate of future demand available in the 1920's was contained in the American Petroleum Institute's Committee of Eleven report. This group predicted that the maximum demand for automobile fuel in 1970 would be about 22 billion gallons of gasoline or its equivalent. Minimum demand could be as low as 12 billion gallons.²⁰

Even the higher of these two estimates was only one-fourth of the actual 1970 motor fuel usage, which was about 92 billion gallons. Why were the 1926 oil experts so far off? They had used a simple model for prediction: they multiplied the expected population of the United States in 1970 by the expected saturation ratio of cars to people; this product was then multiplied by the expected gasoline consumption of each car (trucks and buses were apparently neglected). The last two factors account for most of the error. The population estimate of 200 million people in 1970

19 Walter Polakov, "Oil," New Republic, XXXI (June 14, 1922), 69.

20 Fieldner and Brown, "Future Trends in Automobile Fuels," p.1009.

was close to correct; but the assumed ratio of cars to people was 1:4, compared to the actual ratio of 1:2 1/2. And the study saw each vehicle using only about 400 gallons of gasoline per year; the actual all-vehicle average was about 900 gallons, with autos using about 700 gallons each, on the average, and trucks and buses over 1300.²¹

Compounding the unrealistic view of the oil future was a vast underestimate of the prospects for natural gas. The consensus view held that the natural gas supply of the United States was nearly exhausted. For example, here are the views of three prominent chemists:

Arthur D. Little, in 1921: "A forced return to coal gas seems inevitable, if present standards of quality are to be maintained."²²

Robert T. Haslam, in 1924: "Owing to a decrease in the supply of natural gas, a number of American cities have been giving attention to the problems involved in the change to manufactured gas."²³

Otto Wilson, in 1926: "The use of natural gas in the United States is now probably at or near its peak ... the future of gas production lies obviously in the field of manufactured gases."²⁴

21 Information Please Almanac, (N. Y.: Golepaul, 1971), pp. 118-119.

22 Arthur D. Little, "The Fuel Problem," Atlantic Monthly, CXXVII, (1921), 197.

23 R. T. Haslam and E. W. Thiele, "Recent Progress in the Field of Fuels," Journal of Industrial and Engineering Chemistry, XVI (1924), 752.

24 Otto Wilson, "Gases in Commerce and Industry," Jour. Ind. Engr. Chem., XVIII (1926), 1273.

The natural gas supply which provided about 10^{15} Btu of energy in the U.S. in 1925 -- and was believed to be nearly exhausted -- was to be developed to provide over 20×10^{15} Btu of energy each year by the 1970's. This is more energy than was supplied by all U.S. energy sources put together in 1925. Gas proved sufficiently abundant not only to meet home-heating and industrial demands, but to invade the electric power supply market as well.

To summarize, only the predictions about the total coal supply bore a close relation to the actual situation as it is perceived in the 1970's. The oil and gas supply estimates were both too low by a multiple of ten or more. However, estimates about the future use patterns of these fuels were also incorrect -- and in a way which tended to alleviate concern about the nation's long range fuel supplies. Another source of confusion was the total ignorance about world oil resources. The staff of the World Power Conference concluded in 1929 that, on a worldwide scale, "any statistics that are published of oil resources are probably inaccurate, and have their real basis in propaganda."²⁵ One can conclude that while the energy use patterns developing in the 1920's showed little concern for expert opinion regarding fuel supplies, it is doubtful that expert opinion could have supplied sufficiently accurate estimates to have served as a reliable guide.

25 World Power Conference, Power Resources of the World (London: World Power Conference, 1929), p. 89.

The Future Structure of Energy Supply

Inaccurate estimates of the absolute demand for various types of fuel do not necessarily invalidate predictions about the future relative importance of various fuels. That is, predictors may have correctly estimated the future structure of U.S. energy supply.

No single prediction of the structure of U.S. energy supply exists. However, one can be created by putting together the predictions that qualified experts made regarding each of the components of the total. As indicated in the previous section, the most widely accepted predictions about coal's future were those made by Marius Campbell, and the most widely accepted oil predictions were those made by the American Petroleum Institute's Committee of Eleven. The most widely quoted predictions about the future of water power were those made by the Federal Power Commission and U.S. Geological Survey, and an independent estimate made by Charles P. Steinmetz.²⁶

These figures allow a calculation of the expected 1970 structure of U. S. energy supply, as visualized by the experts of the 1920's. To put the figures in context, three additional energy structures are included. The sources of U. S. energy in 1920 are taken from a

26 O. C. Merrill and N. C. Grover, "Potential Water Power Resources of the United States," in Transactions of the First World Power Conference (London: Percy Lund Humphries, 1925), pp. 641-643; Charles P. Steinmetz, "America's Energy Supply".

contemporary source, as are the sources of energy in 1925.²⁷ For consistency, the use of wood as fuel has been omitted. This may create an error as large as 5% in the 1920 and 1925 figures, for wood was then a significant, though no longer dominant, source of energy.

Results of the estimates of energy structures are given in table 1. For convenience, the results are given in three forms: percentage of total energy needs supplied by each type of fuel; amount of total energy supplied by each type of fuel as measured in natural units (barrels of oil, tons of coal, kw-hours of water power); and amount of energy supplied by each type of fuel in a common physical unit, the Btu (defined as the amount of energy needed to heat one pound of water by one degree Fahrenheit.) The main piece of information in the tables can be summed up in a sentence: the amount of energy expected to be supplied annually by coal in the late 20th century (according to the predictions of Campbell, Parker and Steinmetz) is quite close to the actual amount of energy supplied in 1970 by petroleum and natural gas. This helps explain why the total energy use expected for 1970 (58×10^{15} Btu) is only about 10% below the actual energy consumption in 1970 (65×10^{15} Btu).

27 Gilbert and Pogue, "America's Power Resources,"; R. T. Haslam, "The Relation of Chemistry to the Development of Power," Industrial and Engineering Chemistry, XVIII (1926), 1047-1050.

Table 1: Energy Supplied by Each of Four Principal Sources

a) Percentage of total energy supplied by each source

<u>Source</u>	<u>Year</u>			
	<u>1920</u>	<u>1925</u>	<u>Expected 1970</u>	<u>Actual 1970</u>
Coal	80%	72%	78%	20%
Petroleum	12%	18%	16%	42%
Natural Gas	4%	4%	*	33%
Hydroelectric	4%	5%	6%	5%

b) Supply from each source in physical or quantity units

<u>Source</u>	<u>Year</u>			
	<u>1920</u>	<u>1925</u>	<u>Expected 1970</u>	<u>Actual 1970</u>
Coal (10 tons)	6.5	6.4	18	5.2
Petroleum (10 ⁸ barrels)	4.4	7.3	15	50
Natural Gas (10 ¹¹ cu.ft.)	7.5	11.0	*	210
Hydro (10 ¹¹ kilowatt-hr.)	1	1	3.5	3.0

c) Supply from each source in units of 10¹⁵ btu (British thermal unit). For hydroelectric power, each kilowatt hour is assumed to be the equivalent of 10,000 btu's of thermal energy. This is roughly the efficiency with which thermal energy was turned into electrical energy in a 1770 power plant.

<u>Source</u>	<u>Year</u>			
	<u>1920</u>	<u>1925</u>	<u>Expected 1970</u>	<u>Actual 1970</u>
Coal	16	16	45	13
Petroleum	2.6	4	9	29
Natural Gas	.75	1	*	21
Hydroelectric	1	1	3.5	3
Total	20.4	22	57.5	66

* Natural gas was expected to be of negligible importance by 1970.

References: Chester G. Gilbert and Joseph E. Pogue, America's Power Resources, (New York: Century, 1921); Charles P. Steinmetz, "America's Energy Supply," Trans. American Institute of Electrical Engrs., XXXVII (1918), 211; Marius R. Campbell, "Methods for More Efficiently Utilizing Our Fuel Resources," General Electric Review, XXI (1918), 619; Chzuncey Starr, "Energy and Power," Scientific American, CCXV (1971), 37-49.

In order for coal to play the large role in 1970 that the predictors of the 1920's envisioned, both short-range applications of technology and longer-range technological developments were needed. The superpower plans which have been discussed earlier -- with their emphasis on power plants located in the coal fields, and on the electrification of the railroads -- played a big role in plans to expand coal use. Such plans saw all of the electric power in the United States of 1970 generated in coal-burning or hydroelectric plants.²⁸ Actually, those two sources today supply less than two-thirds of our electric power, most of the remainder coming from oil and natural gas. Thus electrification, which was expected to be a long-term saver of oil and gas has turned out to be a significant user of oil and gas.²⁹

The speed with which coal would virtually disappear as a fuel for domestic heating was also not foreseen by predictors of the 1920's. When predictors spoke of using gas in domestic heating, they were usually referring to gas manufactured from coal, rather than natural gas. (As early as 1896, Thomas Edison was touting manufactured gas of low heat content as "practically the only method for domestic heating.") Another popular prediction was that coked coal (which put forth much less

28 Robert H. Fernald, "Fuel Wastes: Causes, Effects, Remedies," Annals of the Amer. Acad. of Pol. & Soc. Sci., CXI (1924), pp. 219-234; C. P. Steinmetz, "America's Energy Supply."

29 Earl Cook, "The Flow of Energy in an Industrial Society," Scientific American, CCXXIV (1971), 138.

air pollution than raw coal) would become a major home fuel. Certainly many experts on fuel use were aware of what two of them termed the "phenomenal" increase in the use of fuel oil in home heating during the 1920's. But most of them did not deal with the possibility that U. S. oil reserves were vast enough for this trend to continue for long.³⁰ Similarly, the increased domestic use of natural gas (more than doubling in each of the two decades between 1902 and 1922) was treated as a temporary perturbation.³¹ In the long run, according to most analyses, coal would have to make a comeback as a domestic heating fuel -- whether in the form of clean solid fuel, manufactured gas, or coal fueled electricity.

In the field of transportation, the rapid expansion of demand for petroleum could not be ignored. Nevertheless, improvements in motor fuel technology lessened the pressure on fuel supplies. The most notable efforts in this area were the introduction of the Burton thermal cracking process in refining, and the work of Midgeley and his associates in developing an anti-knock motor fuel. To some extent, these advances tended to lessen the concern of the pessimists, and strengthen the case of the optimists. Charles Kettering, for example, could say in 1927:

Now and then people ask me "What is going to happen when gasoline runs out?" I never worried much about that. When the good Lord started this

30 Gilbert and Pogue, p. 158; 203; Floyd W. Parsons, "Gas v. Coal", World's Work, XLIII (1922), 596-602.

31 Samuel S. Wyer, "Natural Gas," in R. F. Bacon and W. A. Hamor, American Fuels (N. Y.: McGraw-Hill, 1922), p. 909.

thing off, he had it all planned, so I'm not going to worry about it. By the time we run out of gasoline it will be so worthless that we won't want it.³²

Of course, not even the most optimistic commentator expected U.S. oil reserves to last indefinitely. But the optimists believed that domestic and imported oil would last until the time, as one review article described it in 1926,

when science will limit the demand by development of a more efficient use of or substitute for oil, or will displace its use as a source of power by harnessing natural energy.³³

Both of these proposed directions -- more efficient utilization of fuels, and the development of new sources of energy -- were actively explored in the 1920's. The next section will examine expectations held by predictors in the two areas.

Expectations about the Future of Energy
Conversion Technologies, 1915-1929

Improvement in energy conversion technology was a constant theme of prediction throughout the 1920's. Unlike predictions made in other areas (such as communication), these were not confined to people in industries connected with the subject. For example, response to a New York Times reporter's 1922 query "What Invention Does the World

32 Edgar C. Wheeler, "Tomorrow's Motor Car," World's Work, XLIV (1927), 78.

33 K. G. Mackenzie, "Petroleum Motor Fuel," Ind. & Engr. Chem., XVII (1925), 1109.

Need Most?" drew similar answers from a wide spectrum of technical people. Said Frank B. Jewett of Western Electric: "a great, if not the greatest, present day need is the development of some new source of cheap, utilizable energy." Elmer Sperry, inventor of a broad range of electrical and mechanical devices, agreed: "the need of the hour is conservation of our irreplaceable fuel resources." Engineer William S. Murray, director of the superpower survey, asked for "economic power," while independent inventor Lee DeForest sought a "cheap and practical source of power, by means of which we will be able to draw practically unlimited energy from natural sources."³⁴

To the fifty most frequent predictors the development of new sources of energy was seen as primarily a problem for the chemist, with other technical people playing lesser roles. More precisely, of thirty-one affirmative predictions (made by nineteen frequent predictors) regarding future trends in energy conversion technology: twelve saw new chemical methods of making liquid fuels as a major hope for the future; six believed atomic energy had long-range promise; solar energy and geothermal power each had four adherents; while no other method was favored by more than two adherents.

The development of a gasoline substitute was seen as a technical problem of first importance, and the chemist was seen as the man to

34 New York Times, May 20, 1923, p. 43.

solve it. "It is quite certain," wrote popular science reporter Floyd Parsons in 1922, "that the destiny of America lies more in the hands of our chemists than in those of the members of any other profession or business fraternity. We must look to our chemists to make us free industrially."³⁵

Proposals for a gasoline substitute fell into two classes. One saw the use of vegetable matter as the raw material for the future fuel. The other saw abundant minerals - coal or shale - being used as the fuel source.

The use of grain or wood alcohol as a motor fuel has been mentioned earlier, as a favorite suggestion of the early automobile era. It never totally vanished from sight, and the fuel shortage fears of the 1918-1920 period brought it back into prominence. A longtime backer of the idea was Alexander Graham Bell, who put "cheap production of alcohol for power purposes" at the top of his 1922 list of needed inventions.³⁶

More comprehensive views of the problem recognized that economics would determine the usefulness of alcohol as a major fuel. Thomas Midgeley, the chemist who discovered the anti-knock properties of tetraethyl lead, saw alcohol and benzene as the most promising of the

35 Floyd W. Parsons, "Looking Ahead," World's Work, XLIV (1922), 144.

36 "SOS Calls by Noted Men," Popular Science Monthly, C (1922), 68-69.

proposed gasoline substitutes. He warned, however, that its use awaited a "cheapening and simplification of the process of converting cellulose to a liquid suitable for motor fuel."³⁷

An early suggestion for the source of cellulose was farm wastes.³⁸ However, the magnitude of the problem, estimated by one expert about five billion gallons of artificial motor fuel per year, made it necessary to look beyond the farm fields,

A 1922 survey examined both forest crops and agricultural crops, and mentioned cassava as a leading candidate.³⁹ Commenting on the use of tropical plants for fuel, chemist Edwin E. Slosson held that, "sooner or later at any rate, we must grow our fuel as we grow our food, from year to year," and quoted approvingly Rudolf Diesel's earlier prediction that "supremacy of the sea would go to that power which possessed the most tropical territory for growing vegetable oil."⁴⁰

Pursuing the same theme, chemist William Hale predicted that a mixture of alcohol and oil would be our future motor fuel. With this in mind, the U. S., he said, should accept from Britain and France some tropical islands in payment of the war debts, and use the islands to grow

37 Thomas Midgeley, Jr., "The Application of Chemistry to the Conservation of Motor Fuels," Ind. & Engr. Chem. XIV (1922), 849-851.

38 Floyd Parsons, "Looking Ahead," p. 147.

39 H. N. Whitford, "Possibilities of the Plant Growth of the Moist Tropics to Furnish Materials for Liquid Fuel," Ind. & Engr. Chem., XIV (1922), 191-192.

40 Edwin E. Slosson, "The Expansion of Chemistry," Industrial & Engineering Chemistry, XVI (1924), 447.

fuel crops.⁴¹ Others who believed that fuel crops, tropical or domestic, had promise for power included Frank Jewett, Lee DeForest, engineer R. H. Fernald, Charles Steinmetz, and Edwin W. Rice, president of the General Electric Company.⁴²

Far from developing inexpensive processes for synthesizing alcohol from vegetable materials, however, the organic chemicals industry took the opposite direction. Following on the commercial application of the Haber-Bosch methanol production process in 1923, the basis of the industrial alcohol industry gradually became more and more completely petroleum and natural gas. Organic chemistry became not a competitor to the petroleum industry, but a branch of it.⁴³

The other major option seen for chemical fuel production involved making a liquid or gaseous fuel from North America's abundant mineral fuels - coal, shale, and tar sands. The utilization of these fossil fuel resources became a favorite source of speculation in the 1920's, and by the end of that decade they had replaced alcohol as the leading candidates for a future fuel supplement. However, the choice of a process for making use of them was the subject of continually changing estimates.

41 William J. Hale, "Prophecy of a Chemist," Scientific Monthly, XXII (1926), 165-166.

42 New York Times, Feb. 15, 1923; May 20, 1923; R. H. Fernald, "Fuel Wastes: Causes, Effects, Remedies," p. 233; E. W. Rice, "Research and Power," Scientific American, CXXXI (1924), 234-235.

43 Chemistry in the Economy, (Washington: American Chemical Society, 1973), pp. 15; 31-32.

In the years immediately following the First World War, the favored scheme involved coal-processing plants at the coal mine mouth, producing a variety of products, including motor fuel, gas, ammonia, tars, and coke. Many analysts linked these plants to the superpower program; energy experts Chester G. Gilbert and Joseph E. Pogue, for example, writing in 1922, claimed that "multiple production (of coal products) and the principle of electricity are the two most important economic forces that have come into play during the current industrial order."⁴⁴

The central concept of the multiple production scheme was the ability to reclaim the coal by-products at a low enough cost to make their profitable sale possible. The first process introduced to achieve this end was low-temperature carbonization of coal, which first appeared in the U.S. in 1906. From 1919 through 1929, it was the focus of several major development efforts.⁴⁵ All these projects used processes in which coal was heated to a temperature of about 1000 degrees F. in an evacuated air-tight oven. Gaseous and liquid products of the chemical reactions occurring at this temperature were then collected and separated.

44 C. G. Gilbert and J. E. Pogue, "The Economics of American Power Practice," in R. F. Bacon and W. A. Hamor, American Fuels, II, 1150.

45 S. W. Parr, "Future Trends in Low Temperature Carbonization," Industrial and Engr. Chem., XVIII (1926), 1015-1016; F.H. Newell, "The Relation of By-Product Coke Ovens to Superpower Development," Ind. & Engr. Chem., XVIII, (Oct., 1926), pp. 1052-1054.

The remaining solid product was coke - long useful as a raw material for iron refining; perhaps about to become useful as a domestic fuel.

As evidence prepared by an advocate of coal carbonization showed, the increasing use of coke as a home heating fuel was the key to the economic success of low temperature carbonization.⁴⁶ Among organizations developing processes to tap this potential demand for coke and its liquid and gaseous by-products were the American Gas and Electric Company, the Old Ben Coal Company, and (as mentioned earlier) Henry Ford's organization.⁴⁷ None of them were able to achieve commercial success.

As early as 1924, chemists R. T. Haslam and E. W. Thiele could note that the emphasis on low temperature carbonization "seems to be misdirected."⁴⁸ The new emphasis in chemistry's solution to the coming fuel shortage, they thought, would be the synthesis of liquid and gaseous fuels. As Harrison Howe, editor of Industrial and Engineering Chemistry, summed it up in 1925:

Who shall say that synthesis shall not prove the key to our liquid fuel problem? Water gas may be produced cheaply, and it would seem that so long as we have coal it may be possible, thanks to chemistry, economically to transform the solid

46 Horace C. Porter, "Coal Carbonization and the World's Fuel," Ind. & Engr. Chem., XV (1923), 335-338.

47 S. W. Parr, "Future Trends in Low Temperature Carbonization;" New York Times, July 15, 1923, VII, 13.

48 Haslam and Thiele, "Recent Progress in the Field of Fuels and Fuel Technology," p. 750.

fuel by way of catalysis into the much desired liquid variety. The field is new, and the opportunities are correspondingly bright.⁴⁹

Among the artificial gaseous fuels, three types were main hopes of the 1920's. These were "coal gas" (the gaseous by-product of the low temperature carbonization process, which has about 60% as much heat content per cubic foot as does natural gas); "water gas" (a mixture of hydrogen and carbon monoxide, with a heat content per cubic foot about one-third that of natural gas); and "producer gas" (principally carbon monoxide, with a heat content per cubic foot less than one-sixth that of natural gas).⁵⁰ Producer gas has been mentioned earlier as the fuel for the gas engines which seemed such promising prime movers at the turn of the century.

In the area of artificial liquid fuels, the main front of technological advance was not the United States, but oil-short and coal-rich Germany. Two fuel production processes shared the spotlight. The one developed by Friedrich Bergius treated finely divided coal, suspended in oil, with hydrogen. When carried out at the proper temperature and pressure (about 900 degrees F. and 1800 pounds per square inch) the process converted almost all the coal into a liquid fuel. The second process, originated by Franz Fischer and his associates, involved making

49 "Liquid Fuels of the Future," Ind. & Engr. Chem., XVII (1925), 334.

50 F. W. Steere, "Producer Gas Technology," in Bacon and Hamor, American Fuels, II, p. 917.

water gas from coal and steam, then converting the water gas to liquid fuel. Again, with the proper choice of catalysts and operating conditions, the transformation of solid to liquid fuel could be made virtually complete.⁵¹

The further development of these two processes, or competing ones such as the Patart and Audibert processes, was predicted as a main theme of energy research in the second quarter of the twentieth century. A potential intermediate step in fuel technology, the use of oil shales as a source of liquid fuel, was also a subject for intensive research. Optimism in regard to these areas was high. Chemist Arthur D. Little predicted in 1928 that "within a short time," one or more of the gaseous or liquid fuel production processes discussed above "will take an assured and important place in fuel technology."⁵² Chemist Robert Haslam, in 1926, asserted that the development of a means of extracting oil from coal was imminent and would mean that "the possibility of wars as a result of the international struggle for oil will be eliminated."⁵³ Roger W. Babson claimed in 1928 that, because of the existence of oil shales, and the development of the Bergius process, "we need never fear for a fuel oil famine."⁵⁴

51 R. T. Haslam, "The Relation of Chemistry to the Development of Power," p. 1047.

52 Arthur D. Little, The Handwriting on the Wall, p. 137.

53 New York Times, Aug. 5, 1926, p. 5.

54 Roger W. Babson, "There's Magic in the Air," Collier's LXXXI (April 7, 1928), 8-9.

The high hopes so widely held for "artificial fuels" technology were not fulfilled in the lifetime of the predictors who held them. As late as 1973, a survey commissioned by the American Chemical Society concluded that "the technology for the conversion of coal to liquid products still requires a major step forward before it can generally be applied economically without special incentives."⁵⁵

The same 1973 survey devoted a full chapter to nuclear energy, which had grown to nearly a billion-dollar industry by 1973. Yet the predictors of the period 1915-1929 saw nuclear power as a far less promising hope than artificial liquid fuel production. It was a subject of frequent speculation. Of nine experts who mentioned it, six gave favorable verdicts - but all of them put it in the same far distant future as solar power, geothermal power, and other exotic energy sources.

Because the pioneering work occurred in Great Britain, that nation was the source of the first predictions by leading scientists about the ultimate use of atomic energy. From 1915 to 1920, chemist Frederick Soddy and physicist Oliver Lodge gave popular addresses on the atom's potential. (Lodge, with fine British understatement, warned that "there might occasionally be explosions due to the liberation of power more quickly than it was wanted.")⁵⁶

55 A. C. S., Chemistry in the Economy, pp. 296-297.

56 Frederick Soddy, Science and Life, (London: Murray, 1920), pp. 35-38; Science, n. s. L (1919), 388.

In the United States, the subject of atomic energy was picked up most readily by independent inventors whose best years were behind them. Thus Hudson Maxim, writing in 1923, placed "a method of utilizing interatomic energy" second on his list of needed inventions; Lee DeForest, in the same year placed "atomic or inter-atomic energy" among the three most promising solutions to the world's energy problems; and Thomas Edison, while admitting that he did not see the way to develop atomic energy, suggested in 1922 that "some fellow may come along and do it tomorrow."⁵⁷

Indeed, atomic energy became a favorite of popular science writers in the years 1920-1925. Thomas C. Martin spoke of it in 1923 as the presently favored speculation, while Haviland Hull Platt, a writer and independent inventor, complained that it was being overemphasized. "Atomic energy is the phrase of the hour," he complained:

No prophetic book or lecture is complete without speculation on the possibility of turning to account the vast store of energy contained in the atoms of all matter.⁵⁸

Optimists who helped popularize the theme included General

-
- 57 Hudson Maxim, "Plenty Left to Invent," Literary Digest, LXXVI (March 17, 1923), 28; New York Times, May 20, 1923; "Look Fifty Years Ahead With Edison," Popular Science Monthly, C (May, 1922), 22.
- 58 Thomas C. Martin, "The Protean Power,"; Haviland Hull Platt, "A Molecular Engine," Scientific American, CXXXI (1924), 120.

Electric research director Willis R. Whitney (one of the few early prophets to see the military potential of atomic energy.),⁵⁹ and Roger Babson, who predicted that:

Instead of shoveling coal into the furnace, all (the homeowner) will have to do is to take a medicine dropper, and with a drop or two of atomic energy derived from water, he will be able to 'fire up' for a week.

In practice, however, he won't even do this, for when power can be developed so easily and cheaply, it will be broadcast free of charge for heating and lighting purposes from atomic energy plants.⁶⁰

Atomic power became so popular a subject in the 1920's that leading members of the scientific and technical communities felt it necessary to deflate premature hopes. Among the chemists, Edwin E. Slosson, in 1925, labeled speculation about atomic energy "premature," and F. M. Jaeger claimed that atomic energy could be neglected as a solution to world energy problems because:

In the opinion of our ablest scientists the practical accomplishment of this objective will be achieved only in the far distant future, if ever.⁶¹

59 Boston Sunday Post, Oct. 4, 1925.

60 John T. Brady, "The Inventions of the Future," p. 541.

61 Edwin E. Slosson, "The Progress of Science," Scientific Monthly, XX (1925), 111; F. M. Jaeger, "The Present and Future State of Our Natural Resources," Science, n. s., LXIX, (1929), 442.

One of the experts Jaeger was referring to may have been Robert A. Millikan. Although more a scientific administrator than a physicist by the late 1920's, Millikan was widely regarded as a leading U. S. expert on atomic phenomena. He was also scornful of atomic energy's possibilities. He put it this way, in 1928:

The energy available ... through the disintegration of radioactive, or any other, atoms may perhaps be sufficient to keep the corner peanut and popcorn man going on a few street corners in our larger towns, for a long time to come, but that is all.⁶²

On the whole, atomic energy was seen as far less likely to play a role in the future energy picture than were the "artificial" (i. e., non-petroleum) fuels. The other long-range hopes also had some backers, but were seen as far off. Examples included utilization of solar power through artificial photosynthesis (favored by chemists Colin G. Fink and Hermann Spoehr); nuclear fusion (mentioned by physician Henry Smyth Williams in a popular article in 1927); the use of manufactured hydrogen as a fuel (A. T. Stuart, 1927);⁶³ the suggestion by chemist James F. Norris (inspired by experiments performed by W. D. Coolidge and S. C. Lind) that liquid fuels could be produced by irradiating methane

62 R. A. Millikan, "Available Energy," Science, LXVIII, 1761 (Sept. 28, 1928), p. 284.

63 Hermann A. Spoehr, Photosynthesis, (New York: Chemical Catalog Co., 1926); Henry Smyth Williams, "Six Ways to make a Billion Dollars," American Magazine, CX (July, 1927) 14; A. T. Stuart, "Hydroelectric Fuel," Ind. & Engr. Chem., XIX (1927) 1321-1324.

or other chemicals with electron beams or X-rays;⁶⁴ and Henry Smyth Williams' suggestion that the world's energy problems could be solved if someone would invent a material that would conduct heat in only one direction.⁶⁵

In all, the position of most predictors regarding energy supplies in 1929 was far more optimistic than it had been in 1920. Oil reserves had been developed to a much greater extent than had previously been believed possible. Chemistry was waiting in the wings to supply an artificial liquid fuel - vegetable or mineral - when the oil ran out. Most likely the day would come when man would have to rely on some other source of power. But mankind had plenty of time to explore the still hazy possibilities inherent in solar power, artificial photosynthesis, or perhaps even atomic energy.⁶⁶

With all these possibilities, the "energy crisis" fears had nearly vanished by 1929. A serious assertion of a coming "energy crisis" would not revive until the early 1950's.

64 James F. Norris, "A Look Ahead," Ind. & Engr. Chem., XVII (1926), 996.

65 Henry Smith Williams, p. 14.

66 Hermann A. Spoehr, "Civilization Must Fail Unless Solar Energy is Utilized," Science, n. s. LVI, (Dec. 8, 1922), x; F. M. Jaeger, "The Present and Future State of Our Natural Resources," pp. 438-442.

CHAPTER VII

THE DESTRUCTIVE POTENTIAL OF TECHNOLOGY: 1915-1929

A side effect of the First World War was to transform the airplane and submarine into full members of the world's land and naval forces. But these were only the latest, not the last words in warfare. The development of electronic devices made new "remote control" devices for both war and peace appear imminent. Advances in physics and biology brought even more terrible weapons within the range of possibility. Yet little apprehension was voiced by those who made predictions about the future of technology during this period. Of the fifty most frequent predictors, eighteen made predictions between 1914 and 1929 dealing with aspects of technology which might prove potentially destructive. But only one, Stuart Chase, seemed alarmed about the possible consequences. The comments of the others seemed designed more to explain the new devices, to allay fears about them, or even to acclaim them.

In military weaponry, the airplane and submarine remained the most popular subjects for predictions. They were joined by two products of World War I: remotely-controlled projectiles and military use of gases and chemicals; and by two new subjects of speculation: the "death ray" and the atomic bomb. In predicting for each of these areas, there was a tendency to take one of three positions. First, one might argue that the prospective invention would make all past experience

obsolete. General William Mitchell's views on aviation are the best example of this. Second was the counter-argument: that the glamor of the new weapon ought not to make us forget that the established one (gun, battleship, or fighting man) was still the backbone of our defenses. Third, there was the "silver lining" position: that the new weapon was not a threat, but rather held great promise for the future. It might make war so terrible as to make everyone realize its futility; or it might guarantee the safety of the United States from foreign attack. Missing in predictions in all three groups was an attitude of realism. None of the experts sought to fully accept the devices, recognize their potentially destructive nature, and seek to limit their effects. The idea that submarines and airplanes might prove capable of causing enormous destruction in future wars, yet not prove decisive, was one which predictors did not entertain.

Similarly, as to applications or limitations of technology of a non-military nature, extreme predictions prevailed. Machines might "enslave" man; the technology serving cities (sewers, transportation) might suffer a catastrophic breakdown. But the possibility of chronic problems of an undramatic yet significant nature was one which predictors were reluctant to face.

The Submarine and World Peace

In light of the importance of the submarine in the First World War, and the narrow margin by which its threat was overcome, one might expect the submarine to have been a major concern of technology predictors during the period 1914 - 1929. Yet little was said to accurately foreshadow its future military development. Predictions served more to protect debating positions than to present new possibilities.

The submarine became a target for moral outrage by 1917. At Versailles, Woodrow Wilson apparently made some effort to outlaw the submarine; Ray Stannard Baker claimed that Wilson had supported international control of invention (especially developments like the submarine and airplane). But American and British proposals to "sink the pests" were torpedoed by the French, who saw the submarine as the ideal weapon for weak naval powers.¹

A similar exercise occurred at the 1922 Washington Naval Conference. In this case, the impetus for outlawing undersea craft came not from the official U. S. representatives as from outside: from Senator William Borah, Colonel Edward House, and the New York Herald. Again, the French blocked even constructive discussion of the topic.² By 1925, a commentator could write that the submarine "will disappear only with

1 New York Times, Feb. 19, 1922, VII, 1:1.

2 Mark Sullivan, The Great Adventure at Washington (N. Y.: Doubleday Page & Co., 1922), pp. 168-173.

general disarmament, or by becoming obsolete."³

To those who tried to predict the future of technology, outlawing the submarine held little appeal. None of the fifty frequent predictors either predicted it would happen, or recommend it. Some saw it as a typical intrusion of the ignorant and the idealist upon technical matters. For example, the inventor John Hays Hammond, Jr., discussing submarine warfare in 1916, remarked:

It is a curious thing that such an ultratechnical question as defense should be in the hands of the people, and as long as it remains in the hands of the people, programmes of defense will be merely a matter of political compromise, and will never fulfill the scientific requirements that are imposed upon us through the organization of enemy forces.⁴

Yet the view of the technical expert was not necessarily more realistic than that of the ordinary citizen. If the layman could be turned against the submarine by exaggeration of its unique immorality, the technical expert could be attracted to it merely by the technical challenges it presented. Even Henry Ford, sponsor of the "Peace Ship," showed an active interest in greatly reducing the cost of submarine construction, perhaps by the techniques he had applied to the automobile.⁵

3 New York Times, Nov. 22, 1925, IX, 3.

4 John Hays Hammond, "The Future Mechanism of Warfare," North American Review, CCIV (1916), 373.

5 Boston Herald, Sept. 21, 1915.

After 1918, predictions regarding the future of the submarine emphasized the craft's utility (or futility) rather than the morality of its use. Themes of prediction tended to be of two main types: first, that the First World War had proved that the threat of the submarine could be mastered; and, second, that the submarine would revert to its originally intended use as a defensive weapon, protecting the coasts of the United States against enemy attack.

Statements aimed at allaying the "submarine menace" were based on wartime experience. The World War I submarine had not proved decisive in battles between naval fleets. As leading submarine inventor Simon Lake admitted, the battleship was still able to run away from the submarine. The battleship would have the speed advantage for some time to come, Lake wrote in 1918. "My own personal opinion is that we shall not see satisfactory twenty-knot submarines, let alone twenty-five-knot submarines, for a matter of several years."⁶ In 1916, John Hays Hammond, Jr., also viewed the gun, not the torpedo, as the dominant naval weapon for the near future.⁷ In a post-war review, the admiral who had commanded U. S. naval forces in the Atlantic, Henry T. Mayo, called the battleship's superiority to the submarine one of the key lessons of the naval portion of the war. In the next war, Mayo predicted, the battleship would still be more important than the submarine.

⁶ Simon Lake, The Submarine in War and Peace, (Philadelphia: Lippincott & Sons, 1918), p. 201.

⁷ Hammond, "The Future Mechanism of Warfare," p. 377.

The submarine he concluded, should be placed on the list of weapons which had failed to make the battleship obsolete.⁸

Furthermore, as a commerce destroyer, the submarine had been defeated by the end of the War. A Literary Digest article in 1919 article in 1919 proclaimed "U-Boat Peril Ended Forever," and stated:

the fear that Germany may secretly build a big submarine fleet and launch her 'next war' by a wholesale destruction of allied shipping loses much of its terror when we learn that the dreaded U-boat was pretty near its last gasp when the armistice was signed.⁹

More than wishful thinking was behind this confident prediction. The "U-boat peril" had been the target of technical efforts by outstanding scientists on both sides of the Atlantic. In the United States, the moribund National Academy of Science had mobilized a National Research Council to attack the problem; and a Naval Consulting Board had been formed to enlist inventors (including the septuagenarian Thomas Edison) and engineers in the effort. Leading scientists, such as future Nobel laureates Robert Millikan and Irving Langmuir, undertook antisubmarine research. The General Electric and Western Electric companies temporarily put aside their rivalry in the new field of electronics to collaborate on submarine detection. U. S. and British efforts did lead to two important antisubmarine concepts: the use of sound to detect subs;

8 New York Times, May 30, 1920, VI, 4:1.

9 "U-Boat Peril Ended Forever," Literary Digest, LXII (July 19, 1919), pp. 23-24.

and the convoy system.¹⁰ Against the First World War U-boat, these proved decisive. But, for the future, they bred an overconfidence that would prove a handicap. Through the 1920's the argument recurred that the problem of the submarine was solved. Memoirs of key administrators of the World War II antisubmarine warfare campaign note having been hampered by the ingrained belief, due to the First World War experience, in the "conquest" of the submarine by sonar and the convoy.¹¹

The second type of prediction regarding the submarine took a different, but equally extreme, position. It will be remembered that when in the late 1890's the undersea torpedo boat first became a major topic for speculation, its justification was mainly defensive. The submarine would protect United States harbors and sea lanes from invading fleets. The emergence of the submarine as almost exclusively a commerce destroyer in World War I did not eliminate this prediction. Simon Lake, writing in 1915, reiterated his earlier claims:

10 Ibid.; Lloyd N. Scott, The Naval Consulting Board of the United States, (Washington: G. P. O., 1920), pp. 160-205; Hudson Maxim, Reminiscences and Comments, p. 192; C. G. Suits, ed. The Collected Works of Irving Langmuir, (N. Y.: Pergamon, 1960), XII, 103-106; Scientific American Monthly, (1920), 88.

11 New York Times May 20, 1920, VI, 4; Nov. 22, 1925, IX, 3; L. V. Spear, "Battleships or Submarines," Foreign Affairs, VI (Oct., 1927) pp. 106-115 (a refutation); Vannevar Bush, Pieces of the Action, (N. Y.: Morrow, 1970) pp. 75-78; Henry L. Stimson and McGeorge Bundy, On Active Service In Peace and War, (N. Y.: Harper & Brothers, 1948), pp. 514-516.

They (submarines) will be the most potent influence that has yet been conceived to bring about a permanent peace between maritime nations ... the submarine is unique in that it is the first weapon which has the potential power to destroy an invading force ... but which is itself useless for invading purposes.¹²

Charles Steinmetz, writing in the same year, also held that the submarine was basically a defensive weapon. He took the politically unpopular position that the present right of the submarine to destroy munitions-carrying merchant ships ought not to be restricted; for he saw, in the long run, submarine defense as the best way for the U.S. to protect its interests against militarily stronger powers. He claimed that Edison was also a defender of submarine warfare.¹³ Through the 1920's the argument of the submarine as "intrinsically a defensive weapon" got the continued support of Simon Lake.¹⁴

Opinion solidified around these two extreme views. "The submarine is the only warship with a future" concluded one 1925 article. "Submarines to the Scrap Heap?" another asked rhetorically in the same year.¹⁵ Between support of the submarine as a vital defensive weapon,

12 Simon Lake, "The Art of Submarine Defense," Century, LXXIX (1915), 732.

13 Charles Steinmetz, "The Submarine," and "Comments on Edison," Charles Proteus Steinmetz Papers (Alger Book Material, and Caldecott 52), Union College, Schenectady, New York.

14 Simon Lake, "The Future of the Submarine," World's Work, LV, (1928), p. 611.

15 Willard Cooper, "The Navy and the Next War," Independent, CXIV (1925), 640; "Submarines to the Scrap Heap?" Independent, CXV (1925), 602-603.

and an overconfidence in the antisubmarine measures of 1918, lay the middle ground that the sub was a limited weapon of great destructive power but not of decisive military significance. None of the expert predictors took this sensible middle ground.

The Future of Military Aviation

The airplane, not the submarine, was the center of most military and naval controversy during the 1920's. It is natural today to view the prophets of future air power, such as William Mitchell, in a favorable light. After all, the airplane did become a major weapon of World War II. Yet one may ask: did the pro-aviation prophets predict the direction of aviation development? Were they right for the right reasons?

The conservatism of entrenched military bureaucrats delayed technological development - but so did the overstatements of aviation's friends. Prophecy seemed to present only two alternatives: aviation as a revolution in warfare; or aviation as a relatively unimportant supplement to existing weapons. The possibility that aviation was a very potent weapon, whose effects on civilian populations could be drastically limited through intelligent application of technology, was not actively explored in the 1920's. In journalistic prediction, the sweeping simplification, as always, overcame the balanced assessment. By the end of the 1920's, the airplane had become, in the popular mind, a superweapon.

"It hardly pays to discuss any mechanism of war except the airplane," wrote Stuart Chase in 1929.¹⁶

Five key areas of prediction as to aviation's military possibilities emerged: airplanes and naval warfare; airplanes and land warfare; the relation of military to civilian aviation; the possibility of defense against air attack; and the prediction of the next major weapons development in warfare's "air age."

In considering the effect of aviation on naval warfare, the role of prediction was unfortunately to turn most discussion on a limited question: does the airplane make the battleship obsolete? As in the submarine debates, defense of the battleship became a test of orthodoxy for naval officers. The old guard fell back on old arguments, as exemplified by a remark of Secretary of the Navy Edward Denby in 1923:

Enthusiasts for each new weapon of sea warfare predict that the heavy-armored, heavy-gunned ship is doomed by that particular weapon. It was so with the submarine, but nobody now claims that the submarine made the battleship obsolete. It is so now with the aeroplane -- but the battleship is still the strongest element in the nation's sea defense.¹⁷

The occasion for this particular statement was the release of the conclusions of the General Board of the U. S. Navy of the airplane vs. battleship question. But the same view was expressed by official Navy spokesmen on numerous other occasions: to the Senate

16 Stuart Chase, "The Two Hour War," New Republic, LVIII (1929), 326.

17 New York Times, May 27, 1923, II, 1.

Naval Affairs Committee in 1921; by President Coolidge's Naval Aide in 1924; in debates over the "Big Navy" bill of 1929.¹⁸

Prediction of the future of naval aviation was not aided by performing experiments in which bombers tried to sink a battleships. As is well known, many such experiments were made in the 1920's, most notably the sinking of the battleship Ostfriesland in 1921 by U. S. Army planes under the command of William Mitchell. But to committed partisans such tests were only ammunition for defending previously taken positions. For example, battleship partisans argued that the Ostfriesland test showed only the difficulty Army pilots had in hitting a stationary, undefended ship. They could never hit a maneuvering one; and the random hits which did occur would not stop a new battleship, protected by new types of armor.¹⁹

Pro-aviation prophets responded in a similarly one-sided manner. Aircraft, they claimed, were capable of driving all surface vessels from the seas. Even the submarine would soon become vulnerable to the depth-charge-carrying airplane. The once mighty battleship, one writer argued, could be sunk by a single six hundred pound bomb.²⁰

18 Scientific American, CXXV (April 23, 1921), p. 322; New York Times, Sept. 21, 1924, p. 1; Frank A. Tichenor, "Wings for the Future," North American Review, CCXXVII (1929) 521-528.

19 "The Bombing Tests and our Naval Policy," Scientific American, CXXV (1921), 40; New York Times, May 27, 1923, II, 8; Joseph Straus, "Air Power--the Myth and the Reality," Outlook, CXL (1925), 290-291; Barrett Studley, "Bombing Planes or Battleships?" North American Review, CCXXVII (1929), 727-736.

20 Frank Tichenor, "Wings for the Nation," North American Review, CCXXVII (1929), 521-528; "Bombing the Battleship," Scientific American, CXXX (1924), 252.

William Mitchell is remembered principally for his insistence on the airplane's superiority to the battleship. He was right. But it is also well to remember that of five specific major predictions he made about the effect of aviation on naval warfare, four have been proven wrong. As stated in his book, Winged Defense, and in a series of articles published from 1925 through 1927. these were:

1) That airplanes were then (1925) capable of destroying battleships with one bomb: this was not true until the development of atomic weapons.²¹

2) That the surface ship will disappear, being replaced by submarine commerce destroyers and submarine transports.²² This had not happened by 1975.

3) That the best use of aircraft against submarines was to bomb submarine bases and fueling stations.²³ This was tried unsuccessfully in World War II. A better answer was to use planes as sub hunters.

4) "Airplane carriers are useless instruments of defense against first class powers."²⁴ This incorrectly assumed carriers to be too vulnerable to submarines and bombers to be of use.

This left him with one correct major prediction:

5) That "strings of island bases" would be a key in the next war,

21 William Mitchell, Winged Defense, (Reprint; Port Washington, N. Y., and London: Kenniket Press, 1971, p. 16.

22 Ibid., p. 18.

23 Ibid., p. 99.

24 William Mitchell, "Building a Futile Navy," Atlantic, CXLII (1928), 412.

because of the importance of strategic aviation.²⁵

If his sweeping claims about aviation in naval warfare had been accepted, Mitchell would have delayed development of the naval air arm. Certainly the statements of less dogmatic prophets of naval aviation, such as retired Admirals Bradley Fiske and William S. Sims, look more prescient from today's vantage point. These experts recognized that the 1920 military picture was clouded by a number of potentially effective weapons -- air-launched torpedoes, gases, carrier-based bombers -- which had not yet been evaluated.²⁶ They saw a development period needed before the full potential of aviation could be evaluated. Sims, in particular, saw that the key comparison from the point of view of naval warfare was not "airplane vs. battleship," but "aircraft carrier vs. battleship." Such a question, however, attracted less public attention than did Mitchell's pet issues: a unified defense department and the alleged incompetence of Army and Navy aviation officers.²⁷ Prediction of the future of naval aviation had tended by the mid-1920's toward the two extremes of a blind reaction and a shallow defiance. Reaction was symbolized by Mitchell's superiors; defiance by the air mail pilot who,

25 William Mitchell, Winged Defense, p. 12.

26 New York Times, July 11, 1920, III, 20; July 15, 1923, VII, 3; William S. Sims, "The Battleship and the Airplane," World's Work, XLII (1921), 25-28.

27 U.S., Hearings of the President's Aircraft Board, Sept. 21-Oct. 15, 1925, (Washington: Gov't. Printing Office, 1925), II, 497-588; Samuel Taylor Moore, "Airplanes Land in the Field of Politics," Independent, CXV (1925), 700-702.

spotting a portion of the U.S. fleet approaching Panama for "secret" maneuvers, defiantly and accurately bombed it with ripe tomatoes.²⁸

Predictions in a second area - airplanes and land warfare - were complicated by one consideration. Many experts doubted that a practical bombing airplane could be built that could cross either the Atlantic or the Pacific and return. Indeed, a 1925 Navy study concluded that "no airplane could be designed" with sufficient capacity and endurance to carry a decent bomb load across the Atlantic.²⁹ Since the U. S. admitted to fighting only defensive wars, this left a very limited role for airplanes in land warfare (unless the prospective enemy landed in our hemisphere). Some dissenters did feel that foreign bombers might cross the ocean. Major Leslie MacDill of the Army Air Service predicted in 1925 that transatlantic bombers would be possible by 1930. In 1925, airplane builder Igor Sikorski suggested that bombers could clear the Atlantic with two refuelings, and sketched a hypothetical raid on New York.³⁰

Most prophets of overland air warfare avoided such technical details and concentrated on the consequences of the appearance of a hostile air fleet over a defenseless city. All of the frequent predictors

28 "Tomato Bombing Delays Game of War," New York Times, Jan. 16, 1924, p. 1.

29 Hearings of the President's Aircraft Board, IV, 635; quote by Maj. Leslie MacDill, Chief Engineer, Engineering Division, Air Service, U. S. Army.

30 Ibid., I, 739.

who commented on the use of aviation against cities - William Mitchell, Stuart Chase, Waldemar Kaempffert, and T.J.C. Martyn - accepted the premise that one air attack of modest size could cripple a major city. Chase held that 200 planes could spray enough poison gas (50 tons) to kill every living thing in London;³¹ Kaempffert and Martyn disagreed only in claiming that high explosives, not gas, would be the principal means of slaughter.³² Mitchell saw the United States potentially endangered by attacks from Great Britain (operating from bases along the St. Lawrence River) or from Japan (via Alaska). He predicted that "a few shells, gas, explosive, or incendiary, landed in Manhattan, would cause a complete evacuation."³³

A more controversial aspect of use of aviation in land warfare was in fighting limited wars and curbing domestic disturbances. William Mitchell not only saw the British "aerial occupation" of Iraq as a clue to aviation's future. He also called attention to the use of bombers to carry "medicines, ammunition for the machine guns, tear gas bombs, and explosive bombs" to West Virginia to deal with "domestic disturbances."³⁴

The third of the five areas of aviation prediction, the relation of civil to military aviation, was marked by general acceptance of a single

31 Stuart Chase, "The Two-Hour War," p. 326.

32 New York Times, June 30, 1929, V, 4; Feb. 20, 1927, VIII, 15.

33 U. S., Hearing of the President's Aircraft Board, II, 499-501; William Mitchell, "Airplanes in National Defense," Annals of the American Academy of Political and Social Science, CXXXI (1927), 40.

34 Ibid., p. 56.

assumption. This assumption, as phrased by T. J. C. Martyn, was that "all commercial planes are easily convertible to military or war uses."³⁵ This conclusion was endorsed by such varied figures as William Mitchell, Henry Ford, and aeronautical engineer Edward F. Warner.³⁶ Each of them predicted that commercial aviation would be rapidly developed, and that commercial airliners could be rapidly converted to bombers in time of war. None of them foresaw that the actual sequence would see military aircraft take the technological lead and contribute to the development of civilian aircraft.

The dirigible, which had been a dismal failure as a strategic bombing vehicle in the First World War, appeared close to commercial success in the late twenties. It too was seen as having possible military use. One widely discussed potential use of the dirigible was as an aircraft carrier. About 1925 some tests were apparently carried out on this concept, indicating that an airship could transport and launch airplanes.³⁷ In the case of the airship, as with the airplane, it was thus argued that development of military technology was tied to commercial developments.

35 New York Times, June 30, 1929, V, 4.

36 William Mitchell, Winged Defense, p. 120; Henry Ford and Samuel Crowther, Today and Tomorrow, p. 205; New York Times, May 12, 1926, p. 20.

37 William Mitchell, Winged Defense, p. 39; Hearings of the President's Aircraft Board, I, 213; Mason M. Patrick, "Military Aircraft and their Use in Warfare," Journal of the Franklin Institute, CLXXXIX (1925), 53.

This was one more argument against international control of military aviation. At the Washington Conference of 1921-22 this issue came up, but as a writer for the Carnegie Endowment for International Peace has noted:

military aviation was closely linked with commercial aviation; it was felt that the latter would be greatly hindered by any restrictions placed on the former.³⁸

Whether or not this argument was decisive in the debate over aviation limitations, it is clear that the argument of an unbreakable connection between military and civilian aeronautical technology was well established by the 1920's. Effective defense against aerial attack seemed hopeless. Those frequent predictors who commented on air defense took this position. William Mitchell foresaw no long war of attrition between attacking and defending forces. "Aircraft operating in the heart of an enemy's country," he wrote

will accomplish (their) object in an incredibly short space of time, once the control of the air has been obtained, and the months and even years of contest of ground armies with a loss of millions of lives will be eliminated in the future.³⁹

T. J. C. Martyn echoes Mitchell's doctrine of the dominance of the offense, and the futility of anti-aircraft guns.⁴⁰ Stuart Chase went

38 John C. Shillock, "The Post War Movement to Reduce Armaments," International Conciliation: Documents for the Year 1928, Carnegie Endowment for International Peace, (New York: Carnegie Endowment, 1929), p. 11.

39 William Mitchell, Winged Defense, pp. 126-127.

40 New York Times, June 30, 1929, V, 4.

even further. Ignoring, as did many others, the differences in speed and maneuverability between fighters and bombers, he held that "defense by home aeroplanes is almost equally futile (as anti-aircraft fire). There is too much space through which the attacker can slip."⁴¹

Two further excerpts show that similar views on the futility of air defense were held worldwide. A 1928 commission of experts sponsored by the International Red Cross found the cost of air defense to be very high; and it went on to predict that if weaponry made any significant advance beyond the technology levels of the First World War, protection of cities against chemical attack from the air would be impossible.⁴² The obvious conclusion following from the futility of defense, in the minds of some, was the necessity for deterrence or revenge. As Lord Thomson of Great Britain put it in 1925:

Although it will always be difficult to persuade public opinion of its truth, it is none the less a true statement to say that the only effective defense against attacks of this nature (i. e., aerial attacks) is in the nature of a counter-attack.⁴³

In reality, of course, Britain was to find air defense efforts far from futile. Counterattacks, on the other hand, while popular with the

41 Stuart Chase, "The Two Hour War," p. 326.

42 Frederic J. Brown, Chemical Warfare: a Study in Restraints, (Princeton, N. J.: Princeton University Press, 1968), pp. 169-170.

43 Lord Thomson, "Aerial Warfare and Disarmament," Survey Graphic, LIII (1925), 504.

public, proved of questionable military value.

The superiority of the offensive was expected to be enhanced by the next major weapon. There were three major candidates suggested for this role by predictors during the period 1914-1929. In order of ascending likelihood, they were: atomic energy; an electrical or electromagnetic "death ray"; and the remotely controlled (or "teleautomatic") airplane. Only this last one seemed certain to be developed, and certain to be of major military significance.

Atomic energy for peaceful purposes was a fairly frequent subject for predictions during the years 1914-1929. Atomic energy for military purposes was not. As previously noted, Wills R. Whitney was the only frequent predictor to suggest that atomic energy would become a weapon.⁴⁴ At least two others - Robert A. Millikan and T. J. C. Martyn - rejected the military use of atomic energy. Millikan was as sure that atomic energy could not be used in a bomb as he was that it could not be used for peaceful purposes. He believed that science had shown the idea of "dangerous quantities of subatomic energies" to be a myth, and suggested that those people

who are now living in fear lest some bad boy among the scientists may some day touch off the fuse and blow this comfortable earth of ours to star dust may go home and henceforth sleep in peace with the consciousness that the creator has put some fool-proof elements into his handiwork and that man is

⁴⁴ Boston Sunday Post, October 4, 1925.

powerless to do any titanic physical damage, anyway.⁴⁵

Martyn presented a different argument. Without ruling out the possibility of atomic weapons, he concluded that

the utilization of such power, if it were possible, would, of course, be of no military advantage -- it is too vast. But the knowledge that such enormous untapped energy exists carries a sharp moral warning.⁴⁶

A second rumored superweapon, the "death ray," got a brief burst of publicity, which peaked in the years 1924-1925. At this peak, the death-ray controversy elicited opinions from a large number of technical experts. The question involved the possibility of using a "ray" or "bolt" of electricity, instantaneously propagated through space, to kill men or disable airplanes. Only one frequent predictor, Nikola Tesla, predicted that "electrical rays" would become an important weapon. Another, T. J. C. Martyn, made no prediction, but mentioned that experiments were underway by a scientist at the Westinghouse Electric Company to test the practicality of the death-ray concept. In 1925, a third, Michael I. Pupin, rejected a claim that a death-ray had been built, and added:

I notice the prediction that such a device may stop all wars by making them too horrible. That's nonsense. . . The only way to stop war is by education.⁴⁷

45 Robert A. Millikan, Science and the New Civilization (New York: Charles Scribner's Sons, 1930), p. 59.

46 New York Times, June 30, 1929, V, 4.

47 New York Times, June 1, 1924, VIII, 8.

Besides Pupin, such physicists as Robert Severinghaus and Robert W. Wood of the United States, Paul Langevin and Edouard Branly of France, and Max von Laue of Germany⁴⁸ also rejected the death-ray idea. Nevertheless, predictions continued to be made on this subject throughout the 1920's, and beyond. These predictions took three forms. The first, was an electromagnetic ray carrying enough energy to knock down an airplane. This idea was clearly beyond the technology of the period; only the laser, invented in 1960, brought this idea into the realm of the possible. The second suggestion, most prominently proclaimed by British inventor A. M. Low, was that small electrified droplets of water would be used to deliver the fatal jolt; Low expected this electric weapon to be ready by 2023 A. D. at the latest. The third and most popular scheme was the use of very high frequency electromagnetic waves to ionize the air, making it a conductor of powerful electric current.

The death-ray was most popular as an antiaircraft weapon. The physicist E. E. Fournier D'Albe suggested in 1924 that the popularity of the death ray might be a reflection of public fears. The public, particularly in Britain, was eager to seize on any means of countering aerial warfare.⁴⁹

48 Ibid., New York Times, May 19, 1924, p. 4.

49 "A New Death-Dealing Ray," Literary Digest, LXXXI (June 7, 1924), 27-28; E. E. Fournier D'Albe, "The Myth of the Death Ray," New Republic, XXXIX, (1924), pp. 207-208.

However, the weapon which most predictors believed would bring the next revolution in warfare was neither atomic energy, nor the death ray; it was the remotely controlled airplane. One frequent predictor after another confidently predicted the successful development of a pilotless bomber, guided accurately to its target by radio waves. "Any skillful mechanic could rig up an automatic airplane capable of dropping fire, poisons, and explosives on an enemy area," warned chemist Edwin E. Slosson in 1926.⁵⁰ Indeed, some of the more mechanically skilled of the experts had tried to make such an invention. John Hays Hammond, Jr., for example, had developed a radio-controlled torpedo during the First World War and sold it to the U.S. government in 1918 for \$750,000.⁵¹ One of the major military development projects undertaken by the United States after entering the war was an attempt to develop a remotely controlled bomber. Among the participants in this effort were the inventor Charles Kettering and the chemist Thomas Midgeley, while Robert A. Millikan was on the project's advisory board. Peter Cooper Hewitt also confidently predicted in 1915 that "an automatic fleet... might conceivably utterly destroy cities."⁵²

In all, eight frequent predictors foresaw early development of

50 New York Times, May 12, 1926, p. 20.

51 Boston Herald, July 1, 1918.

52 T. A. Boyd, Professional Amateur, (N. Y.: E. P. Dutton and Co., 1957), p. 107; Peter Cooper Hewitt, New York Times, Nov. 7, 1915, (Magazine), p. 10.

such a weapon, while none denied the possibility. Stuart Chase and William Mitchell claimed that the invention was virtually perfected by the late 1920's. Indeed, Mitchell told the President's Aircraft Board that the U. S. Army already had radio-controlled "gliding bombs" or aerial "torpedoes" which could be directed accurately to targets up to 136 miles from the weapon's point of release. (This claim was denied by a Navy expert who testified subsequently at the same hearing).⁵³

Confidence in the development of a remotely controlled airplane was not, however, confined to air-power zealots like Mitchell. General Mason Patrick, head of the Army Air Service and usually a moderate counterweight to Mitchell's extremism, stated in 1925 that

it is not at all improbable that in the near future a number of such planes, none of them containing a human being, may be directed and guided by a man in another plane several miles away, steering them over his objective and causing them to drop their bombs at his will.⁵⁴

General George Squier, an outstanding inventor, presented in 1924 the even more frightening possibility that "a whole nation will be put to sleep for twenty-four hours by gases distributed by radio-controlled airplanes."⁵⁵

53 U. S. Hearings of the President's Aircraft Board, II, 516; 823.

54 Mason M. Patrick, "Military Aircraft and their Use in Warfare," Journal of the Franklin Institute, CLXXXIX (1925), 62.

55 "Science to End War or End the Race," Literary Digest, LXXXIII (October 4, 1924), 13.

This confidence in the quick development of the 1920's version of the "guided missile" was part of a general overestimate of the effectiveness of strategic air warfare. Most predictors of the 1920's saw aviation as already a powerful offensive weapon, on the verge of becoming an unstoppable weapon.

The most serious factual error in such predictions was an undervaluing of the potential value of air defense. The potential of a weapon like radar, which would throw the advantage to the defense, was hardly mentioned, even though the technical possibility of a radar-type system did enter into the predictions of a few (such as Nikola Tesla, and the French General Eugene Debeney).⁵⁶ Almost as serious were the errors of overestimating the catastrophic effects of conventional explosives and gases upon cities; and overestimating the strategic, as opposed to the tactical, value of aviation.

Perhaps as interesting as the factual errors in prediction, however, were the attitudes expressed by the predictors. Few were alarmed by the apparent growth of destructive technology; many were fascinated by the gadgetry involved. And most would have agreed with the philosophy expressed in an article in the New York Evening Post. Discussing the view that advancing technology made a solution to the problem of international violence necessary, the article concluded: "scientists are doing more for the cause of peace and a warless world than all of

⁵⁶ New York Times, Nov. 7, 1915, II, 17; Sept. 25, 1921, VII, 1.

our statesmen, leagues, and peace societies. The threat raised by science has become so great that it may be on the eve of forcing the world to solve it or perish."⁵⁷

Potentially Harmful Non-Military Aspects of Technology

To some predictors, expected developments in military technology held lessons for times of peace. Two particular issues emerged. First, the supposed vulnerability of the large city to a few well-placed bombs suggested that the modern city was also vulnerable to the accidents of peacetime. Second, the expected early realization of the remotely controlled airplane seemed to bring closer an old dream -- the automaton, or, as it was renamed in the 1920's, the robot.

Stuart Chase, who predicted that bombs would be dropped on cities in the next war, generalized that argument into a general condemnation of the vulnerable large city.⁵⁸ In his view, a modern city had ten principal "underground nerves" (such as water mains and pneumatic mail tubes) and fourteen principal "surface nerves" (such as roads, bridges, and airports). "If one prime nerve is cut for any length of time," he concluded, "the urban environment starts rapidly to disintegrate." This vulnerability, he predicted, left only three possibilities for the future of

57 Editorial, New York Evening Post, quoted in "Science to End War or End the Race," Literary Digest, LXXXIII (October 4, 1924), 13.

58 Stuart Chase, "The Future of the Great City," Harper's, CLX (Dec., 1929), 82-90.

the modern city: a "sudden and disastrous technical breakdown"; a "less dramatic surfeit of citizens with their environment, resulting in steady emigration"; or the imposition of "drastic measures of coordination and preplanning." Chase saw the second of these as the most likely outcome.

A second critic of the city, Lewis Mumford, also saw the dependence of the modern city on technology as one of its weaknesses. He held that this dependence as a consequence of the use of old technology to make further growth unnecessary. Because urban growth was accepted as "given," Mumford argued, engineering improvements such as double-decked streets and subways could not improve the quality of urban life. The answer lay elsewhere, in planned decentralization, based on the automobile and on Giant Power. "Shall we make the attempt?" he asked. "Perhaps not... The likelihood is that we shall go a little further along the road of super-congestion before our disillusionment becomes complete."⁵⁹

In their prophecies of the collapse of the city, Chase and Mumford expressed distinctly pessimistic views regarding the effects of technology on society. Yet not even these two critics of established institutions were without hope. Each had his own solution to the problems he had uncovered. Mumford's, as has been discussed, was decentralization.

59 Lewis Mumford, "The Intolerable City," Harper's, CLII (1926), 283-293.

Chase favored another solution: the elimination of waste in industrial production. "It is more than time," he wrote in 1921, "that the challenge be taken up of at least completing a rough engineering draft of a wasteless society."⁶⁰

One path to a wasteless society - automation - offered a threat of its own. In the years 1920-1930 an intelligent automaton seemed possible and imminent. Karel Capek's play R.U.R., which had its first American performance in 1922, introduced to Americans the word "robot."⁶¹ Capek's robots were products of the biologist and chemist--creatures of artificial flesh and nerves, rather than of metal and electrical circuits. This type of robot was not ignored by predictors. For example, the chemist Edwin Slosson said in 1927 that: "living beings may be artificially produced in a chemical laboratory."⁶²

The "mechanical man," however, soon became the most popular form of proposed robot. And the most widely publicized of the mechanical men was the "Televox," developed by R. J. Wensley, an engineer for the Westinghouse Electric Company. The technological advances embodied in this invention were significant, but not revolutionary. The principal one was the use of musical tones, converted into electrical signals, to

60 Stuart Chase, "The Challenge of Waste to Existing Industrial Creeds," Nation, CXII (1921), 284-287.

61 Karel Capek, R. U. R., (New York: Washington Square Press, 1969), "Reader's Supplement," p. 37.

62 New York Times, Oct. 22, 1927, p. 7.

turn on and off the switches controlling various mechanisms. At the time, the Televox was most useful for controlling automatic substations in the electric power industry. But a series of popular articles attached a larger significance to Wensley's work, as is shown by the articles' titles: "Making the Televox do Your Work"; "Science Produces the 'Electrical Man'"; "Robots -- the New Race of Men."⁶³ The last of these three articles contained the prediction that

One hundred years hence, humans may look back on the third decade of this century as the birth years of a new race of men -- mechanical men, who, even now, are learning to do the work of the world.⁶⁴

Among the frequent predictors, however, a much different tone prevailed. To them, the Televox and its mechanical brothers (such as the radio-controlled airplanes previously mentioned, and Elmer Sperry's ship-controlling system "Iron Mike") were in no sense rivals or imitations of man. "There will never be a Robot," wrote Waldemar Kaempffert. "Even the most ingenious technologist cannot make a collection of wheels, shafts, magnets and wires think."⁶⁵ John Hayes Hammond, Jr., an inventor of many remotely controlled devices, agreed that the threat of the robot was greatly exaggerated. True, he admitted, the industrial progress of the United States sometimes appeared to menace society. But this was merely a sign of the failure of "social intelligence" to keep up

63 "Making the Televox do Your Work," Literary Digest, XCV, (Nov. 19, 1927), pp. 21-22; New York Times, Oct. 10, 1927, IX, 1; "Robots -- the New Race of Men," Review of Reviews, LXXIX (1929) pp. 126-129.

64 "Robots -- the New Race of Men," p. 126.

65 New York Times, Oct. 23, 1927, IX, 1.

with technology. The obvious solution was not to slow down technology, but to speed up social intelligence.⁶⁶

Behind such vaguely expressed evaluations as Hammond's, and such clear predictions as Kaempffert's, can be seen two underlying themes for the prediction of advances in automation. First, the robot, as a perennially popular subject for discussion, blinded predictors to advances making possible a more realizable "intelligent machine" - the computer. Of the frequent predictors, only Roger Babson foresaw a "thinking machine" as one of the significant inventions of the future.⁶⁷ In considering automation, social implications, rather than technological logic, inspired - and misled - prediction.

Second, while recognizing the possible destructive effects of a new technology, the experts were confident that such effect could, in some way, be avoided -- just as the effects of the submarine, air warfare, and the increasing vulnerability of the city could be avoided. "Have you joined the Frankenstein chorus?" Stuart Chase asked in a 1929 article.

It is quite the thing to do nowadays. From pulpit, rostrum, editorial chair, the cadence comes, in swelling volume; and the burden of the song is that man has become the slave of his machines, even as Doctor Frankenstein was overwhelmed by the monster he created.

Were such fears justified? Chase considered them carefully, and

⁶⁶ Boston Herald, June 26, 1926 (from Herald files; no page number).

⁶⁷ R. W. Babson, "There's Magic in the Air" Collier's, LXXXI (April 7, 1928), 52.

answered with an unqualified "no." The machine would free man from drudgery, not enslave him. "Talk about machinery enslaving the whole body of the industrial workers," he concluded, "is nonsense."⁶⁸

In a time of prosperity, like March, 1929, it seemed clear that advancing technology brought the promise of progress rather than the danger of destruction. Within a few years, however, the promise was less clear, the danger more apparent. The depression which began in 1929 would make it much more difficult for predictors to assume that technology was an automatic source of social progress.

⁶⁸ Stuart Chase, "Slaves of the Machine," Harper's, CLVIII (1929), 480; 489.

CHAPTER VIII

THE NEXT BIG INDUSTRY: 1930-1940

In the spring of 1904, two men set out to form an automobile company. One of the men had recently failed in a similar business venture; the other was well-known as an "impulsive plunger." Nevertheless, the two were able to pull together \$28,000 from ten friends and business associates, and start the company. The enterprise was the Ford Motor Company; the eight original stockholders who stuck with it all became millionaires.¹

In 1947, Margaret Harris, an employee of a small photographic equipment company, asked the company's president for some advice. Should she buy some company stock on the strength of a rumor she had just heard about an invention the company had recently licensed? "Confidentially, Margaret," the president replied, "I think it's damfoolishness ... Put your money into Kodak." Fortunately, Margaret Harris ignored this advice, and invested in her own company. Its name was the Haloid Corporation; the invention it had licensed was the Xerox machine.²

On March 20, 1975, Robert W. Sarnoff, then chairman of RCA, made a speech at Indianapolis. In that speech he announced that the

1 Allan Nevins, Ford: the Times, the Man, the Company (New York: Charles Scribners' Sons, 1954), pp. 236-239.

2 John Dessauer, My Years With Xerox (Garden City, N. Y.: Doubleday, 1971), p. 49.

company had developed a "microprocessor" (miniature computer) capable of controlling an automobile's engine and transmission in a way that would improve gasoline mileage by "up to 40 percent in standard and large size cars." Would this invention cause RCA to take off, in the manner of Ford and Xerox? Apparently several people thought so. Within five hours of Sarnoff's speech, the value of RCA stock had jumped by 3-3/8 points (more than it usually changes in a week), and trading in the stock on Wall Street was suspended.³

These stories suggest one major motive for trying to predict the future of technology: the wish to get rich. Of course, picking the right invention is only a beginning: you have to pick the right company also. In 1904, 56 companies beside Henry Ford's entered the automobile business; in the 1940's and 1950's several large companies, including Kodak and 3M, tried to beat Haloid to the instant dry copy duplicator market; in 1975, perhaps twenty electronics companies stood a chance of beating RCA in the microprocessor race. Still, if picking the right invention is not sufficient to insure the success of the speculator, it would certainly be helpful to him.⁴

That leads to the question which is the theme of this chapter: is it possible to predict the success or failure of new technology-based industries which seek wide public acceptance - the kind enjoyed by the

3 New York Times, March 21, 1975, p. 1, 56.

4 Ibid.; Nevins, p. 234; Dessauer, p. 80.

automobile and Xerox machine?

In the 1930's, this question possessed greater than usual urgency. The nation's economy seemed stuck in a depression. In the view of several commentators,⁵ an impetus that could bring the economy out of this depression would come from the founding of a new technology-based, mass-consumption industry.

which, like the auto industry of twenty-five years ago, will grow swiftly into large scale production, with direct beneficial effects on wages, investment values and living conditions.⁶

The quote is from a 1934 magazine article by Alfred Sloan, chairman of the General Motors Corporation. In that year, Sloan organized a "Jules Verne Symposium" aimed at picking the technological developments which gave most promise of generating such an industry.⁷

A parallel forecasting effort, under federal government sponsorship, led to publication of the 1937 report Technological Trends and National Policy. In a foreward, the reporting group's staff director, sociologist William F. Ogburn, summed up the premises on which the

-
- 5 Stuart Chase, Out of the Depression (John Day Pamphlet No. 2, 1931), p. 7; William J. Hale, "When Agriculture Enters the Chemical Industry," Ind. & Engr. Chem. XXII, (1930), 1311-1315; New York Times, July 25, 1937, VI, 5; Robert K. Leavitt, "What Shall We Sell When the Upturn Comes," Forum LXXXIX, (1932) 341-347; Wayne W. Parrish, "Technocracy's Question," New Outlook (Dec., 1932) CLXI, 13-16.
- 6 Alfred Sloan, "The Forward View," Atlantic CLIV (1934), 257-262.
- 7 General Motors Corporation, Preview of Industrial Progress, (1934).

report was based:

anticipation of the future is the key to adequate planning for the best use of our national resources

and:

it is fair to say that the greatest general cause of change in our modern civilization is invention.⁸

Sloan sought to encourage private investment that would bring the nation out of the depression with the free enterprise system intact; Ogburn and his associates sought to secure public control over the process of technological and economic change. But both acted from the assumption that it was possible to identify in advance technological changes with major economic impact. Were the two efforts, and other smaller-scale tries, able to deliver accurate predictions?

Candidates put forward as the next mass consumption industry ranged widely, but twelve types of new products emerged as the most popular for prediction.

In the area of transportation and communication:

- the aerial flivver was predicted to come into its own at last.

- what we would today call a sub-compact car - a small, lightweight automobile with a low-powered, efficient engine - was predicted to become the general public's main passenger vehicle.

8 U.S., National Resources Committee, Technological Trends and National Policy (Washington, D. C.: Government Printing Office, 1937), viii.

- a network of automobile superhighways was predicted, for carrying the products of a revived auto industry.

- for long-distance transportation, long-range air travel was predicted, including transatlantic air service.

- television was predicted as the principal coming change in the communications area.

In the area of automation

- new electronic control devices were predicted for both industry and the home.

- in agriculture, mechanical farm equipment was predicted as taking over many tasks then done by hand, especially cotton-picking.

In the area of materials:

- new synthetic fibers were expected to find wider uses than rayon and other early synthetics.

- non-agricultural foodstuffs - either foods produced in factories from coal, oil, and similar chemical raw materials, or foods from crops grown by such methods as hydroponics (popularly known as "soilless agriculture") - were predicted to supplement foods made from traditional farm crops.

- to supplement the farmer's income, the practice of

farm chemurgics was predicted to vastly increase in scale; this practice involved the use of various farm products as raw materials for the chemical industry.

In the area of home environment:

- Mass-produced houses, assembled on the homeowner's property from factory-made components, were predicted to partly replace traditional "stick-built" houses.

- Air-conditioning was predicted to become a widely adopted home convenience.

In retrospect, seven of these predictions must be regarded as correct. Superhighways, long-range air travel, television, electronic control devices, mechanical farm equipment, synthetic fibers, and air conditioning, have more than fulfilled the hopes of optimistic predictors. On the other side, predictions of the coming of the aerial flivver, the sub-compact car (as the principal passenger auto in America), non-agricultural foodstuffs, farm chemurgics, and mass-produced houses, must be judged vastly overstated or just plain wrong.

Could this record of prediction have improved upon by the forecasters of the 1930's? Were the arguments put forward in support of the seven "new industries" which succeeded demonstrably sounder than the arguments put forward for the five which did not? It is worth while to look for such differences not only in the "reasons why" presented as

the basis for predictions of success, but also in the "reasons why not" presented as the basis for predictions of failure.

The "reasons why" can be divided into four categories. A prediction may be based on similarity between the current status of an innovation and the early history of an established product or process. It may be based on the predictor's identification of a trend, of which the innovation seems to be an extension. Or perhaps a breakthrough in science or invention may give rise to a prediction of the success of an innovation using that breakthrough. Finally, an innovation may appear to be the answer to a current social or economic problem.

Do any of these four sources of positive prediction give a reliable guide to the future? Let us examine them one at a time, using the twelve predictions of the 1930's as examples.

Similarity gave rise to some accurate predictions. The wide use of electronics in industry was predicted to be similar to with two previous "industrial revolutions": the introduction of the steam engine in the factory during the nineteenth century, and the replacement of mechanical drive by electrical drive in twentieth-century factories. In each of these cases, inventions made outside the industrial system greatly modified the organization of industries. Electronic devices were seen by many predictors as capable of doing the same. A typical expression of the similarity idea was given by physicist George R. Harrison in 1939:

as the steam engine introduced an industrial revolution, so the electronic vacuum tube seems to be inaugurating an equally far-reaching change in our habits of living.⁹

A number of other predictions contained the same general thought.¹⁰ In 1939 an entire book was constructed by taking the new industrial revolution concept, fitting to it examples chosen from work in electronics then being carried out by several industrial and university laboratories, and applying to the result the ominous title Machines Over Men.¹¹

The parallel between the status of radio in the years 1910-1920 and the status of television in the 1930's inspired another correct prediction. Television, predictors argued, was destined for mass popular success of the kind radio had gained in the 1920's. The most explicit expression of this similarity came from electrical engineer Ernst F. W. Alexanderson in about 1930:

Television today is in the same state as radio telephony was in 1915. We may take some comfort from this.¹²

-
- 9 George Russell Harrison, Atoms in Action (New York: William Morrow & Company, 1939), p. 109.
- 10 L. W. Chubb, "Research in the Future," Scientific American, CXLVI (July, 1932), 12; Claude C. Furnas, The Next Hundred Years, (New York: Reynal & Hitchcock, 1936), p. 208; Floyd W. Parsons, "A Look Ahead," Saturday Evening Post CXCI (April 3, 1931) 1; "The Expanding Decade," III Fortune (June, 1931), 146.
- 11 Raymond W. Yates, Machines Over Men (New York: Frederick A. Stokes & Co., 1939).
- 12 Ernst F. W. Alexanderson, "Development and Future of Television," Alexanderson Collection, Union College, Schenectady, N. Y. (undated).

Indeed, the parallel between television and radio (and also that between television and "talking movies") had, as mentioned earlier, led to over-optimism about television's prospects. By the early 1930's, advocates of television were already forced into a slightly defensive position, explaining why television, like prosperity, was taking so long to come around the corner.¹³

A third successful use of similarity, by regional planner Benton MacKaye, appeared in a series of magazine articles in the early 1930's. It can be summed up by the title of one of those articles: "Cement Railroads." The point was that the future of automobile roads would be similar to the history of railroads. After a period of opening rail lines to all vehicles, railroads limited access to company locomotives and their trains. Similarly, MacKaye argued, road-builders will have to limit access to the next generation of main highways, allowing automobiles and trucks only.

Other railroad concepts MacKaye saw as being carried over to automobile superhighways were: double-tracking (divided highways); grade-crossing elimination (over- and underpasses); and stations at regular intervals (food-fuel stops). All of these parallels yielded correct predictions; MacKaye was wrong only when he took the comparison too literally and suggested that superhighways be built by pouring concrete

13 Warren J. Horton, "Looking 'Round the Corner," Technology Review XXXV, (1932), 30.

in abandoned railroad rights-of-way.¹⁴

While similarity could lead to successful predictions, such as the three mentioned above, it could also lead to errors. One of the most often repeated predictions of the 1930's compared the mass production of automobiles and the mass production of houses. This similarity was often made explicit: one construction company called itself General Houses, Inc. (imitating General Motors); another advocate of the concept called for "houses like Fords."¹⁵ The comparison proved false; mass production methods have had far less impact on housing than they have had on automobile construction. (although both house-trailers and tract construction show some successful applications of mass-production).

The comparison between Henry Ford's flivver and the hoped-for "aerial flivver" has already been discussed. Another hoped-for interchange between automobiles and airplanes moved in the opposite direction. Streamlining had played a major part in transforming aircraft from the clumsy-looking biplanes of the First World War to the sleek, efficient metal monoplanes of the 1930's. Would application of such principles improve the fuel efficiency of automobiles? Some predictors

14 Benton MacKaye, "Cement Railroads," Survey LXVIII, (1932), 541-542; "Townless Highway," New Republic LXII, (March 12, 1930), 93-95.

15 Alfred Sloan, "A Forward View;" Douglas Haskell, "Houses Like Fords," Harper's CLXVIII, (1933), 286-296.

thought that it would.¹⁶ But automobile "streamlining" followed a completely different course from airplane streamlining, becoming a styling artifice, rather than a utilitarian aspect of sound design. In 1975, critics of Detroit's designs were still asking for truly scientific streamlining.¹⁷

To avoid the pitfalls of similarity, many predictors used the method of trend extrapolation. The idea here was to identify key variables of technology: speed, efficiency, maximum size, and so on. By determining the trend one or more such variables had followed in the past, and assuming continuation of that trend, predictions were made. The most comprehensive technology prediction effort of the 1930's relied on this method, as is apparent from its title, Technological Trends and National Policy.

But in practice, trend extrapolation was little more scientific than was reliance on similarity. Some predictors did identify trends that were to continue. Willis R. Whitney correctly forecast in 1934 that the trend in aviation was toward higher altitudes, and greater use of automatic controls.¹⁸ Waldemar Kaempffert correctly extrapolated

16 Stuart Chase, The Economy of Abundance (New York: MacMillan, (1934), p. 111; Joseph Ledwinka, "The Automobile Will Come Back," North American Review CCXXXIII, (1932), 61; Bruce Bliven, "Metropolis, 1960 Style," New Republic LXXXII, (1935) 211-212; Douglas Haskell, "From Automobile to Road Plane," Harper's CLXIX, (July, 1934), 171-181.

17 John R. Pierce, "Fuel Consumption of Automobiles," Scientific American CCXXXII, (1975), 39-40.

18 "Science and Industry in the Coming Century," Scientific Monthly, XXXIX (1934), 68.

the trend of falling electricity prices, and predicted that it would bring ever wider use of home air conditioning.¹⁹ And construction experts correctly predicted a trend toward an increased variety in building materials.²⁰

But mere extrapolation gave no hint of an impending reversal of a trend. Extrapolating from recent developments in automobile design and manufacture, predictors of the 1930's thought they observed the following trends: toward smaller, lighter autos; toward a de-emphasis on power and speed; and toward more efficient overall performance (on a miles-per-gallon basis).²¹ All of these apparent trends had been clearly reversed by 1950.

To avoid blind trend extrapolation, some predictors deliberately looked for turning points. In some cases, such a turning point was marked by a significant invention. For example, a few predictors realized that the practical application of the cathode ray tube to television by Zworykin and Farnsworth was the breakthrough which would make television practical.²²

19 Waldemar Kaempffert, "Boundless Frontiers of Science," New York Times Magazine, May 19, 1940, pp. 10-11.

20 New York Times, May 12, 1936, p. 12.

21 Technological Trends and National Policy, p. 267; Ledwinka, pp. 59-64; U.S., National Resources Committee, Technology and Planning (Washington, D.C.: Government Printing Office, 1937), p. 20; Furnas, p. 256.

22 Harrison, p. 128.

In other cases, the key breakthrough was not a specific invention, but rather an advance at many places along a key scientific front. For example, the chemist Claude C. Furnas was able to predict, in 1936, that synthetic rubber was close to being practical. His reason was that there were so many approaches being taken that at least one was bound to succeed.²³

But even the existence of a breakthrough did not guarantee the success of an invention. One of the outstanding breakthroughs of the 1920's was the invention of the autorotation principle by the Spanish inventor Juan de la Cievra. The concept was to mount a freely-rotating long-bladed propellor above an airplane's cockpit. (Unlike the helicopter's rotor, this propellor was not driven by the engine). This "autorotating" propellor replaced the wing; it also acted as a parachute, virtually eliminating the danger of stalling in midair. Technically, it was a major invention. Publicly, it was hailed as the breakthrough that would make the aerial flivver practical.²⁴ However, the autogyro, never achieved commercial success.

An even more extreme example of an illusory breakthrough was the invention of the photoelectric cell. Predictions by popularizers, social scientists, and technical experts all picked this device as the key to the coming electronics revolution. In nearly all these accounts, its

23 C. C. Furnas, The Next Hundred Years, pp. 177-178.

24 D. S. Ingalls, "Autogyros," Fortune III, (1931), 78; Malcolm B. Ronald, "Autogyro," Atlantic CLIX, (1937), 20-27.

ability to use a light signal for control purposes was considered far more useful than the possibilities offered by the electron tube. In reality, of course, electron devices achieved widespread use, while photoelectric cells remained special-purpose devices with only a few applications. The tone of most predictions concerning the photoelectric cell indicates that the glamor and seemingly miraculous operation of this device led predictors to overestimate its importance.²⁵

A criticism which applies to each of three "reasons why" - similarity, trends, and breakthrough - which have been discussed so far is that each treats technology in isolation from its social and economic surroundings. Predictors with a broader outlook saw technology as responding to, as well as causing, social and economic changes.

The social and economic problems of the 1930's presented many opportunities for and demands upon technology. New inventions were needed to make jobs for the unemployed; to help solve the problems of the railroad and coal industries; and to solve the problems of the most depressed sector of the entire American economy: agriculture.

In retrospect, it may be possible to trace the influences of

25 S. Chase, The Economy of Abundance, pp. 105-107; R. W. Yates, Machines Over Men, pp. 94-105; Technological Trends and National Policy, p. 19; W. F. Ogburn, "A Sociologist's Forecast," NY Times Magazine (Dec. 10, 1939) VII, 14-15; Harvey C. Rentschler, "How Shall We Live in the Future?" Scientific American CXLVI (1932), 73.

these social and economic problems upon the development of technology. But attempts made in the 1930's to predict such effects were almost completely unsuccessful.

The best example is the farm chemurgic movement. Its purpose was succinctly expressed by a proponent as "freeing the farm market from the inelastic stomach market."²⁶ The purpose, in other words, was to convert persistent agricultural surpluses into profitable products. These products were to include paper made from cornstalks, plastics made from soybeans, and, reviving an old hope, fuel alcohol made from grain.²⁷

Initiated as a formal movement in 1926, chemurgics gained momentum during the depression. By 1935, Karl Compton, president of the Massachusetts Institute of Technology, could predict that:

Experience justifies reasonable hope that a large fund reasonably expended on research along this line will contribute toward a positive and permanent solution of the problem of agricultural overproduction.²⁸

However, chemurgics was never able to develop products that were economically viable. As a result, the main emphasis of the farm

26 Wheeler McMillan, "Chemurgy," Industrial and Engineering Chemistry XXXI (1939), 540.

27 William J. Hale, "When Agriculture Enters the Chemical Industry," Industrial and Engineering Chemistry XXII, (1930) 1311-1315.

28 Karl T. Compton, "Put Science to Work," Technology Review XXXVIII, (1935) 152.

movement remained on a successful effort to solve the farm problem through subsidies and acreage allotments instead of turning farming into a supplier of the chemical industry.

Other suggested technological responses to society's problems met the same fate. Among predicted "technological fixes" for the depression were: a major program in construction technology, designed to aid the housing industry; revival of the "old New England village" by placing new towns along automobile superhighways; and revival of the railroad industry by electrifying the railroads, and then combining a modernized rail system with the infant airline industry. None of these programs was ever carried out.²⁹

In one case, however, a major new industry was correctly predicted on the basis of social and economic needs. In the 1920's the growth of the automobile industry established rubber as an essential American need. At the same time, the British government, as part of its colonial policy, established effective control over the price and supply of natural rubber. This action stimulated some Americans to predict that it would become necessary for the U.S. government to encourage the development of synthetic rubber, in order to establish national self-sufficiency.³⁰ This prediction was eventually fulfilled

29 New York Times, Dec. 16, 1934, VI, 6: B. MacKaye, "Townless Highways," pp. 93-95; F. W. Parsons, "A Look Ahead," p. 246.

30 Edwin E. Slosson, Snapshots of Science (N. Y.: Century, 1928), pp. 255-258; Bert H. White, "They've Got Your Future All Planned," Saturday Evening Post CCXI, (June 10, 1930) 11.

through the government's World War II synthetic rubber development program, which made possible (after some postwar adjustments) a major synthetic rubber industry.

In all, neither the technical nor the non-technical "reasons why" proved reliable guides to prediction. They led to the prediction of about twice as many new industries as actually materialized. This suggests that to improve the accuracy of prediction, it would help to consider "reasons why not" to help filter out the overoptimistic predictions.

Four principal such reasons were advanced by forecasters. Technical roadblocks might prevent development of a practical product. Technical competition might prove, too stiff for an innovation -- that is, another product might do the job better at no higher cost. Economic competition might prove too stiff -- that is, another product might do the job cheaper. Finally, social inhibitions against the product might prove insurmountable. Let us look at each of these "reasons why not" to see if it gave reliable clues to predictors.

Technical roadblocks were correctly recognized as blocking at least one of the popular "new industries" of the future, non-agricultural foodstuffs. Enthusiasm for this idea had been quickened by the successful syntheses of carbohydrates from mineral oil and wood pulp, achieved by German chemists in the 1920's. But some predictors clearly realized that even more severe technical problems had to be solved before

synthesis of more complicated foods, like proteins and vitamins, would be possible.³¹

But very serious technical roadblocks were also cited as an argument against an innovation that did succeed -- television. The cathode-ray tube breakthrough previously mentioned had removed one such roadblock, but others remained. For example, frequency bands used in radio transmission were estimated by a 1932 predictor to be too narrow (by a factor of 1000) to carry television signals.³² To make enough frequencies accessible for broadcasting, large advances in high-frequency electronics would be needed. Another roadblock was the need for very bright lighting to allow a camera to pick up television pictures. One 1939 forecaster expressed doubt that television would ever carry sporting events because of the lighting limitations of stadiums and arenas.³³

As the television example suggests, technical problems do not necessarily form a good basis for prediction, because they often can be overcome if enough money and effort are applied to them. Four of the seven successful innovations being examined in this chapter (television, synthetic fibers, long-range air travel, and electronics) overcame

31 E. E. Slosson, Snapshots of Science, pp. 224-227; George W. Gray, The Advancing Front of Science (N. Y. : Whittlesey House, 1937), p. 162.

32 Keith Henney, "When Will Television Come," Review of Reviews LXXXV (1932), 44-48.

33 "Television," Fortune XIX (April, 1939), 154.

enormous technical roadblocks, while three of the five which did not succeed (economy cars, mass-produced houses, and farm chemurgics) failed in spite of the fact that no major technical roadblocks prevented their realization.

Even assuming technical problems could be solved, new devices had to compete technically and economically with old ways of doing the same job. In the case of television, a 1931 predictor felt that "the chances that the picture will ever approximate in quality those of the common movie is negligible," and that as a result television would be a gadget for a few hobbyists, rather than a widely used product.³⁴ In contemplating the possibilities for automatic computing machinery (today the most versatile product of the electronics industry) a writer for M.I.T.'s Technology Review suggested in 1931 that improvements in mechanical calculators made such devices unnecessary for most mathematical problems.³⁵

Economic competition provided another roadblock. Even those who believed television could be made practical doubted that it could ever penetrate the low-income market to the same extent that radio had done. A 1939 estimate was that ultimately some eight million U.S.

34 S. McClatchie, "Industrialism Near Journey's End," North American Review CCXXXII (1931), 333.

35 Harold L. Hazen, "Working Mathematics By Machinery," Technology Review XXXIV (1931), 323-327.

homes would have television. The actual 1973 figure was nearly
seventy million U.S. homes.³⁶

The economics of innovation are difficult to predict because economic considerations form a circle. Establishment of a mass market depends largely on lowering the product price, which depends largely on achieving economies of scale in manufacturing, which, in turn depends on the assurance of having a mass market. In the case of air conditioning, for example, one predictor recognized that the existence of such a circle made it impossible to predict the timing of the development of a large market for home air conditioners.³⁷

Air-conditioning predictions also had to deal with the final type of "reason why not": the matter of public tastes and preferences. "So far," noted one observer of the air-conditioning business, "the chief difficulty has been to make people purchase intangible benefits with tangible expenditures."³⁸ Had the public not made such a choice, no purely technical considerations could have insured the success of the air-conditioning industry.

In two cases, judgments that the public taste would not accept

36 Claude C. Furnas, "A Chemist's Forecast," New York Times, Dec. 10 1939, VII, 14-15; "Television," p. 162; U.S. Fact Book, (N. Y.: Grosset & Dunlap, 1975), p. 705.

37 Vannevar Bush, "Significant Trends in the Development and Utilization of Power Resources," Transactions of the Third World Power Conference (Washington, D. C.: Government Printing Office, 1938), pp. 670-671.

38 "In Debatable Air," Fortune III (1931), 53-55.

certain innovations led to correct predictions that the innovations would not be commercially successful. Author Bernard de Voto correctly forecast that most American drivers would not accept sub-compact cars, in spite of the fuel savings that could be obtained. He asserted that the choice of an automobile was an irrational decision, not an engineering exercise. As another predictor put it, Americans wanted to go on bragging about horsepower, which was "equivalent to a convict bragging about the weight of his chain and ball."³⁹ The other innovation that failed to satisfy public preferences was the mass-produced house. As a minority of predictors dealing with that idea said, the money saved by mass production would not be enough to overcome the public's preference for a traditional house, or the influence of the traditional system of home building and financing in supporting such a preference.⁴⁰

In other cases, however, assessment of future public preference produced erroneous predictions. The U.S. National Resources Committee felt that public fear of technological unemployment would lead to serious troubles in connection with the invention of the mechanical cotton picker. Bernard de Voto, seen above correctly predicting the limited appeal of economy cars, felt that the motoring public would also not

39 Bernard de Voto, "The Absolute in the Machine Shop," Harper's CLXXVIII (1935), 125; D. Haskell, "From Automobile to Road Plane, p. 172.

40 Arthur Train, Jr., "Catching Up With the Inventors," Atlantic CLXIII, (1939) 371; Lewis Mumford, "The Flaw in the Mechanical House," New Republic LXVII, (1933) 65-66.

tolerate superhighways. And the feeling that safety considerations would limit the popularity of air travel is reflected in a remark attributed to "one of Wall Street's leading aviation financiers" in 1935: "I'll do anything for aviation, except fly."⁴¹

Even when considering an invention as eagerly sought as television, predictors could still come up with possible public concerns which might block commercial success. Critic Gilbert Seldes (later a television program planner) felt in 1937 that the experience of the movies proved that a visual medium was not suitable for advertising specific products. A second objection concerned television's possibly excessive demands on the viewer. "If you are a workingman, tired after a hard day," went the argument, "would you rather lie down and listen to a radio program of your favorite music, or sit up straight and watch a television performance?"⁴²

These objections to television seem far-fetched today. But there was no way to determine this without going through the actual process of innovation and commercial development. The same can be said of all eight types of arguments used as the basis for predicting the success or

41 U.S. National Resources Committee, Technological Trends and National Policy, p. 23; B. de Voto, "The Absolute in the Machine Shop," p. 125; Bruce Gould, "Aviation Blues," New Republic LXV (1935), 65.

42 Gilbert Seldes, "The 'Errors' of Television," Atlantic CLIX, (1937) 536; Daniel Lang, "Ike and Mike on the Air," New Republic XCIX (1939), 47.

failure of new industries. Each has been shown to have yielded both correct and incorrect predictions. None seems to have been a consistently successful means of improving predictors' accuracies.

In fact, a survey of predictions concerning the twelve hoped-for major new industries of the 1930's leads to a very different conclusion. Each of the twelve had logical reasons for success; each had logical reasons for failure. It was the entire environment of the innovation -- the economic and social conditions surrounding it, even events in national and international politics -- which determined which of the logical "reasons why" or "reasons why not" would prove dominant.

Just as an example, consider the effect that a unique sequence of events - World War II - had on the dozen innovations being studied. Most obviously, it greatly accelerated the development of long-distance air travel, synthetic fibers, and electronics through direct wartime research and development. The first American jet engine, mass-produced synthetic rubber and the first electronic computer were all products of military research and development.

Less obvious, but also important, was the effect of the war upon other new industries. Migration of Southerners to Northern cities, stimulated by wartime labor needs, lessened the unemployment-creating impact of the mechanical cotton picker. The technology of television benefitted greatly from wartime advances in radar and radio. And, of course, to the extent that wartime deficit spending helped stimulate the

economy, it aided all industries catering to increased affluence (such as television and air conditioning) while making those based on energy or resource conservation (like sub-compact autos, mass-produced housing, and farm chemurgics) look less attractive.

This is not to say that the war was the only cause of success or failure of innovations. Rather, the war was just one of many singular disturbances since 1940 whose overall effect upon the success of new industries may have been much greater than the effect of the eight general causes used as bases for the predictions discussed earlier.

The attempt to predict success or failure for the new industries of the 1930's, then, could not have been successful without also predicting the total context of future events. Indeed, the whole premise on which it was based, like the premise of those who look at invention for a clue to the future of the stock market, is incorrect. Technology is both a determiner and a consequence of national economics and politics. The complexity of the connection has, so far, made accurate prediction of innovation impossible.

CHAPTER IX

TECHNOLOGY'S EARLY WARNINGS: 1930-1940

I don't believe in aeroplanes, science and progress, in railway timetables or in economic laws. I cannot think of them as real, and there will be none of them in my future. There is no room for them. I freely give the lot of them to Messrs. Shaw, Wells, Stalin, Sinclair Lewis, Mussolini, and the rest.¹

So wrote French philosopher Bernard Fay in 1933. The occasion for this outburst was his participation in a series of forecasting efforts commissioned by the magazine Forum under the general title "In Our Stars." The series included articles by predictors optimistic about technological possibilities. But the most cogent articles were those written by people who approached technological change warily and critically - in particular Fay, Lewis Mumford, and Julian Huxley. None of them was an opponent of technological progress. But each felt that technology needed to be redirected to avoid potential dangers. "Sheer fright," in Huxley's opinion, would put a stop to the arms race.² Technology, Mumford suggested, would become "more refined, more efficient, more delicate."³ In the future, he suggested, men would seek "an integrated solution for problems that people still seek to solve in 1932 by purely mechanical methods."⁴

1 Bernard Fay, "In Our Stars-IV," Forum LXXXIX, (1933) 13.

2 Julian Huxley, "In Our Stars-IV," Forum LXXXIX, (1933) 242.

3 Lewis Mumford, "In Our Stars-II," Forum LXXXVIII, (1933) 341.

4 Ibid.

This type of critic sought to preserve the benefits of technological progress while suppressing dangerous or dehumanizing technology. This required an advance assessment of potentially harmful new technologies, as well as an effort to replace harmful old technologies by more beneficial ones.

Of course, the advance assessment of technology was (and is) difficult. Even apparently destructive technologies had their positive side. This was as true in the 1930's as it is now. Military technology could bring unprecedented death and destruction; but could also provide a shield against European or Asian strife. Atomic energy could lead to bombs, but could also provide virtually limitless energy. Biological advances could lead to such dehumanizing developments as 'artificial life' or biological warfare, but could also ensure for the world an adequate food supply.

How well could predictors detect legitimate signals within the 'noise' of these ambiguous warnings? Let us look for an answer in two areas. First, the most clearly threatening area of technology, military technology, will be considered. Then two non-military technologies - biological technology and atomic energy - with potentially beneficial and harmful aspects will be looked at.

Technology for the Next War: 1930-1939

"General 'Billy' Mitchell's ghost will walk the halls of Congress again this week."⁵

With these words, New York Times military analyst Hanson Baldwin previewed the April, 1938, hearings of the Senate Naval Affairs Committee. The hearings were on the composition of the U.S. Navy. It was a tribute to 'Billy' Mitchell, who had died in 1936, that the issue he had raised fifteen years earlier - the proper relation of military policy and changing technology - was beginning to get a hearing. Unfortunately, those who tried to predict the future of military technology in the late 1930's became embroiled in the same squabbles that Mitchell and his critics had fought in the 1920's.

As in Mitchell's day, the main focus of predictors was on the expected conflict between two types of weapons: airplanes and battleships. The great "airplane vs. battleship debate" tended to distract attention from other potentially important technological developments, such as submarines, electronic systems, tanks, and aircraft carriers. When the question that had been stalling debate for nearly twenty years sank from sight along with American battleships at Pearl Harbor, a policy for integrating the full range of technology into the war effort had to be improvised virtually from scratch.

5 New York Times, March 14, 1938, p. 6.

One difference between 1920's predictions and 1930's predictions about military technology was the number of points of view involved. The 1920's discussion mainly involved a military establishment defending itself against a rebellious minority. In the 1930's, three distinct points of view had emerged. These might be labeled the "strategic," the "traditional," and the "defensive."

The strategic school argued for a complete overhaul of U.S. military strategy. Its views were based on an axiom put forward by Italian military strategist Giulio Douhet: "The form of any war depends on the technical means of war available."⁶ For this group of forecasters, prediction of future technological developments was essential for properly formulating a military strategy.

The traditional position saw continuity, not change, as the key to an intelligent military policy. For any new weapon, a counter-weapon was nearly certain to be developed. This had happened in regard to the supposed revolutionary weapons of the past, such as the torpedo boat and submarine.

The traditional group believed in geographical determinism, rather than technological determinism. The principal axiom of traditionalists was expressed by military analyst George Fielding Eliot

⁶ Quoted in Benjamin D. Foulois and C. V. Glines, From the Wright Brothers to the Astronauts (New York: McGraw Hill, 1968), p. 225.

in 1938:

the gifts of her geographical and (in the military sense) insular position enable the United States to depend upon her Navy, primarily, for her defense and for the maintenance of her rights and vital interests.⁷

Dependence on the Navy meant, in 1938, dependence on the battleships of the Navy. In the eyes of the traditionalists, the battleship still ruled the seas, supplemented but not made obsolete by the airplane.

The third point of view, the defensive viewpoint, held that ethical principle ought to guide national military policy. A nation ought not to possess more military or naval forces than were absolutely needed for self-defense. In the views of the proponents of this principle, the U.S. had already, by 1938, overbuilt her Navy. As Bruce Bliven, editor of the New Republic, put it in 1938:

I submit that the United States now possesses a Navy not intended for defense of our own shores, but for aggressive action in all parts of the world. I submit that if we intended only to defend the United States, we should have a very different type of military equipment.⁸

In attempting to predict the future of military technology, each of these groups shaped forecasts to meet one of the above mentioned axioms. Principles tended to narrow prediction, and block a broad

7 George Fielding Eliot, The Ramparts We Watch, (N. Y., Reynal & Hitchcock, 1938), p. 46.

8 U. S., Congress, House of Representatives, Hearings on HR 9218 to Establish the Composition of the United States Navy (Washington: Government Printing Office, 1938), p. 2147.

view of future possibilities.

What were the main technical possibilities being considered? Most of the "new" ideas put forward in the 1930's dated back at least to 1919. Remotely controlled aircraft, for example, still had their advocates. "The robot plane with a selenium eye," testified aircraft manufacturer Edwin L. Rice to a Senate Committee in 1938, "will become the great future weapon."⁹

The "death ray" -- an electromagnetic ray capable of shooting down airplanes -- was still discussed. "The now familiar death ray,"

MIT's Technology Review labeled it in 1934. Surveys shortly after the outbreak of the Second World War labeled such a device unlikely. But, as late as 1940, a writer could still ask "Has Germany a Death Ray?"¹⁰ (His answer: probably not, but we can't be sure).

While remotely controlled airplanes and death rays were considered very real possibilities, lack of technical progress in both areas caused interest to diminish. In areas where technical progress was being made, discussion of pros and cons was more lively. This discussion brought out very clearly the preconceptions of the three schools

9 U.S., Congress, Senate, Hearings before the Committee on Naval Affairs on H.R. 9218 (Washington: Government Printing Office, 1938), p. 247.

10 "Trends," Technology Review XXXVII, (1934) 91; Waldemar Kaempffert, "Will a New Weapon Win the War?" New York Times Magazine, Feb. 18, 1940, p. 20; William H. Wenstrom, "Inventions Win Wars," Scientific American CLXII, (1940), 324. Alfred Brandt, "Has Germany a 'Death Ray'?" Forum CII, (1940) 64-65.

of thought about defense policy, and showed how these preconceptions shaped policy recommendations.

The principal areas of technical progress were: submarines, tanks, air defense equipment, aircraft, battleships, and aircraft carriers. Let us see how each of the three schools of thought evaluated the future of each of these areas.

Submarines were definitely out of favor with both the traditional and strategic schools. The traditional school's attitude was summed up by Secretary of State Henry L. Stimson in 1930: "the lower the total number of submarines, the better for the naval power of America."¹¹ Stimson's opposition to subs was not based on pacifism; in the same hearing at which he made this statement he vigorously defended the role of the battleship in naval policy. Distrust of the submarine was one place where 'Billy' Mitchell, the chief inspiration of the strategic school, had agreed with his more conservative superiors.

This left the defensive school as the main defender of submarine warfare. Both Bruce Bliven and historian Charles Beard, a strong advocate of the defensive point of view, labeled the submarine one of the most useful of defensive weapons.¹² In doing so, they were unwittingly following a tradition, which, as we have seen, had initially

11 U. S. Congress, Senate, Hearings on the Treaty on the Limitation of Naval Armaments (Washington: Government Printing Office, 1930), p. 270.

12 Hearings on H. R. 9218, p. 2142; 2147.

viewed the sub as an anti-blockade weapon. Such a view had been put forth by individuals as different in attitude and background as Admiral George Dewey, Simon Lake, and Charles Steinmetz.

Another weapon which, surprisingly, was labeled "defensive" was the tank. Since 1939, the use of tanks on the offensive (as in Poland in 1939, in France in 1940, in South Korea in 1950, and in Budapest in 1956) has fixed the popular view of the tank as the weapon of the attacker. Yet in 1938, individuals arguing from the defensive point of view advocated stronger tank forces.¹³

Traditional military analysts had less use for the tank. George Fielding Eliot stated the orthodox view in 1938: "Four cavalry divisions of the Regular Army -- two horse and two mechanized -- would be sufficient."¹⁴ Another traditionalist held that the tank would not succeed in tactical warfare because defensive tanks capable of defeating offensive tanks could always be constructed. "Future war," concluded this analyst, "appears to hold no escape from stalemate in the field."¹⁵

The defensive school, trying to limit U.S. weaponry to a minimum necessary for defense, thus endorsed two weapons later used primarily in World War II for offensive purposes. At the same time, the

13 G.F. Eliot, The Ramparts We Watch, p. 17 (Eliot describes the pro-tank views of Congressman Maury Maverick, a principal spokesman of the defensive view).

14 Ibid., p. 299

15 A. W. Smith, "The Nature of the Next War," Harper's, CLXIX, (1934) 195; 201.

traditionalist school became the principal advocate of air defense.

The U. S. Navy was hampered in its public predictions about air defense by the need to keep secret the most promising possibility. Radar (as yet unnamed) made occasional appearances in the public press.¹⁶ But, under official questioning, Naval officers were vague. An example is the following exchange between a congressman and the chief of the Navy's Bureau of Aeronautics in 1938:

Mr. CHURCH: Are you familiar with the radio beam's use in locating articles other than directly through sight.

Admiral COOK: I am vaguely familiar with certain methods of directing some radio energy toward an object and getting an echo back.¹⁷

At the time that this statement was made, the Navy had finished the successful development of radar, and was equipping surface ships with it.¹⁸ The initial purpose of naval radar was for anti-aircraft use. Perhaps the sensitivity of naval officers toward the arguments of aviation advocates, and their desire to insure the survival of the surface ship, accounts for this unusual case of a brand-new technology being embraced by the 1930's U.S. Navy.

In public arguments, however, members of the traditional school

16 Ibid., p. 198.

17 Hearings on H. R. 9218, p. 2704.

18 Robert Morris Page, The Origin of Radar, (N. Y.: Doubleday, 1962), p. 34; 168.

did not refer to radar. Instead, in bolstering their case that even aviation had a counter-weapon, they spoke of alleged improvements in anti-aircraft guns. Those, along with improved armor and maneuverability, were counted on to protect surface ships from aerial attack.¹⁹

The strategic school, thoroughly committed to Billy Mitchell's vision of offensive air power, did not believe an effective air defense was possible. This school's public view of air defense was summed up by the title of a 1931 article: "The Anti-Aircraft Fable."²⁰

Unlike the Navy, the Army Air Service's public views on air defense fully matched its inside technical decisions. The Air Service's opposition to expenditures on air defense was based on an official technical assessment, made in the mid 1930's, that it was "doubtful whether pursuit(i.e., defensive) aircraft can be efficiently or safely operated" at the speeds modern bombers could attain.²¹ Based on this conclusion, the Army's meagre development funds were concentrated on bombers, and pursuit planes were deemphasized.

Spokesmen of the defensive school named the airplane, along with the submarine and tank, as the third of the purely defensive weapons.²²

19 Hearings on H.R. 9218, p. 2113; 2510; John Edwin Hogg, "The Bogey of War in the Air," Forum XCII, (1934) 344-348.

20 A. G. West, "The Anti-Aircraft Fable," North American Review CCXXXII, (1931) 504-511.

21 Foulois and Glines, From the Wright Brothers to the Astronauts, p. 229.

22 Hearings on H.R. 9218, 2133-2147; Eliot, The Ramparts We Watch, p. 17.

Airplane builders and Air Service leaders were willing to go along with this interpretation in order to build support for a stronger air force. Aviation's "characteristic is more for defense than offense," testified Glenn L. Martin in 1938.²³ Martin's company was a leading supplier of military airplanes. Chief of the Army Air Service Benjamin Foulois advised his subordinates in the mid-1930's to "stress defense not offense." As he later explained this position: "if we could get bombers that could carry bigger bomb loads and fly greater distances this way, what difference did it make what words we used?"²⁴ With the consent of the defensive school (which saw bombers as a defense against enemy fleets) and with the encouragement of the strategic school, which saw the bomber as the only type of airplane worth considering, the discussion of air power narrowed down to a discussion of a single type of airplane.

What were the capabilities of the bomber? At the beginning of the decade, the assumption of air supremacy had been widespread. "Some military men and a vast number of civilians," wrote aeronautical engineer Edward Warner in 1932,

have come to take it for granted that the next war will be fought almost entirely in the air, and that it will be ended within a few hours or a few days.²⁵

23 Hearings on H.R. 9218, p. 2827.

24 Foulois and Glines, From the Wright Brothers to the Astronauts, p. 227; see also James Lee Cate and Wesley Frank Craven, eds. The Army Air Force in World War II (7 Vol.; Chicago: University of Chicago Press, 1948), I, 56-70.

25 Edward P. Warner, "Can Aircraft Be Limited?" Foreign Affairs X, (1932) 431.

However, Warner himself did not agree with this popular view. Neither did other members of the traditionalist school. Military use of aviation in the 1930's had tended to bear out this conservative assessment of air power's potential. In the Spanish Civil War, Madrid held out against Rebel bombing raids. In the Far East, Japanese use of air power was unable to force the quick surrender of China. Even the sinking of the U. S. gunboat Panay by Japanese planes was held up by traditionalists to show the difficulty of sinking even an obsolete and trapped navel vessel from the air.²⁶

These negative indications spoke against the air power concept. They were reinforced by a government policy decision to restrict flights of the new B-17 bomber to within 100 miles of shore. This policy limitation, effective through 1939, was mistakenly interpreted by some as a technological limitation. George Fielding Eliot, for example, wrote in 1939 that U. S. air strategy was based on the technological assumption that no bomber could cross either the Atlantic or the Pacific.²⁷

Such an assumption no longer fit the facts. The Army Air Service was already testing long-range bombers based on the concept

26 H. E. Howe, "Chemicals in Warfare," Industrial and Engineering Chemistry, XXX, (1938) 366; A. W. Smith, "The Nature of the Next War," p. 196; 201; George Fielding Eliot, The Ramparts We Watch, p. 42; "Three Thousand More Airplanes?" New Republic, XCVII, (1939) 335.

27 Craven and Cate, The Army Air Force in World War II, I, 68-69; George Fielding Eliot, Bombs Bursting in Air, (N. Y.: Reynal and Hitchcock, 1939), p. 98.

which had, as early as 1934, been named the "flying fortress." Considering the new B-17 bombers in 1938, Hanson Baldwin noted that their range

is becoming so great, and their size so tremendous, that some naval opinion is wondering where the Army Air Corps technical policy will lead; in other words, there is a feeling that the Army fliers have expanded their function beyond mere defense of our coasts, and are now building or planning ships which will be able to span the seas.²⁸

At the 1938 hearings on defense policy, however, the question asked about these new bombers was not "what is their proper military role?" Instead, the question was "could they sink battleships?"

The airplane-vs.-battleship debate had advanced remarkably little since Billy Mitchell's 1925 congressional appearances. Speaking in 1938, Captain David I. Hendrick of the U. S. Navy Ordnance Department listed eight major experiments in the aerial bombing of ships conducted since World War I, but labeled the results confidential. Admiral Arthur B. Cook, Chief of the Bureau of Aeronautics, added that the Navy had as yet reached no official conclusions about the effect of bombing on capital ships. Bomber-builder Glenn Martin, asked if the bomber made the battleship obsolete, replied: "I do not believe that is a question that can be answered."²⁹

28 New York Times, June 3, 1934, VIII, 3; New York Times, March 14, 1938, p. 6.

29 Hearings on H. R. 9218, p. 2717; 2726; 2814.

While the airplane-vs.-battleship debate ground on inconclusively, the battleship came under fire from another direction. To members of the defensive school, the battleship was a patently aggressive weapon. It symbolized an expansive view of protection of American rights overseas that might serve as a cause of war. Joined in this denunciation of the battleship were such unlikely allies as arch-conservative representative Hamilton Fish of New York, and liberals Jeanette Rankin, Stephen Rausenbush, and Charles A. Beard of the National Council for Prevention of War.³⁰

The defensive school coupled its objections to use of battleships with ridicule of battleships' military value. Beard, for example, quoted approvingly the devastating (and, in the event, highly prophetic) advice of Admiral William S. Sims:

the best thing to do with our battleships in case of attack on our coast would be to send them as far as possible up the Mississippi River.³¹

Such criticism does not seem to have shaken faith in the battleship. Following the hearings at which the criticism was given, the New York Times editorially summed up the consensus conclusion: "the plane and the battleship are, and must continue to be, complementary weapons."³²

30 Ibid., pp. 2133-2172.

31 Ibid., p. 2133.

32 New York Times, March 7, 1938, p. 16.

While faith in the battleship was reaffirmed at the 1938 hearings, another type of naval vessel came under nearly unanimous attack. The aircraft carrier received a negative verdict from each of the three schools of thought. Hamilton Fish, giving the defensive view, condemned it as an aggressive weapon. Speaking from the strategic viewpoint, Aero Digest editor Cyril Caldwell declared that it would be "impossible" to defend carriers against strategic bombing. Members of the traditional school concurred, dismissing the carrier as "vulnerable."³³

Rejection of the aircraft carrier was the worst error of public predictors of military technology during the 1930's. But such a rejection was typical of the partisan, unbalanced viewpoints exhibited by all predictors during the period. The final years of the decade saw opinion divided among a defensive school which urged reliance on those pre-eminently "defensive" weapons, the submarine, the airplane, and the tank; a strategic school, whose purported technological determinism actually meant an advocacy of strategic air power at the expense of all other weapons; and a traditionalist school which sometimes appeared more interested in defending the battleship than in defending the country.

In light of these contradictory predictions, the remarkable thing

33 Hearings on H. R. 9218, p. 2259; Hearings Before the Committee on Naval Affairs, p. 335; Ralph C. Parker, "Nothing But Airplanes?" North American Review CCXXXIII, (1932) 259; George F. Eliot, The Ramparts We Watch, p. 217.

is not that the U. S. lacked a coherent defense policy on the eve of World War II; rather, it is that any steps at all were taken toward preparedness. The Roosevelt program of 1938-39, inadequate as it was, was at least a step forward. In spite of the prophets, aircraft carriers got the major emphasis (over one-third of the total tonnage requested in the 1938 "Vinson Bill" outlining the naval program), although the fleet remained heavily weighted toward the battleship.³⁴ The president's aviation program in the following year called for 3032 additional airplanes. This number, small by the standards to be established after Pearl Harbor, was large enough to cause traditionalist George Fielding Eliot to oppose it as wasteful.³⁵

Indeed, the hearings on the 1939 aircraft program drew from military officers some clues that pointed beyond World War II and toward military-technological problems of the 1950's and later. One such problem was pointed out by General Henry H. Arnold of the Army Air Service: the increasingly symbiotic relation between the military and big industry. As Arnold put it:

There was a time when airplanes only cost \$6000 or \$8000 or \$10,000 and the companies did not hesitate to go to that expense, and they absorbed their loss because it did not amount to anything.

34 Hearings on H.R. 9218, p. 1937.

35 U.S., Congress, Senate, An Act to Provide More Effectively For the National Defense, (Washington: Government Printing Office, 1939), p. 3; George Fielding Eliot, "Three Thousand More Airplanes?" New Republic, XLVII (1939), 335.

But now airplanes have jumped to \$200,000 and \$300,000 and \$400,000, and when we have bids on six articles we take one of them. Now those six competitors have gone to that expense, and we can only take one, and each of those six competitors have spent \$300,000 or \$400,000. Now, we figure the best way to handle that would be to get an additional appropriation in our research money to pay also for the second and third articles, so that all unsuccessful competitors do not sustain a loss and thereby lose all interest in future competition.³⁶

Such institutional arrangements would prove at least as important to future military policy as all the issues so earnestly debated in the 1920's and 1930's. Summing up the situation as it stood in 1939, Secretary of War Harry Woodring prophetically indicated that large defense budgets would no longer be a matter for wartime only. His words, unappreciated then, serve as a good conclusion to predictions of military technology during the 1930's:

Technical developments in means of warfare during the past 5 years now compel a readjustment and reorientation of our plans and preparations for adequate national defense, regardless of our international tensions.³⁷

The Two Faces of Technology

Up until recent times the production of food has been the prime struggle of man. That war is won.

With these words, a lecturer addressing the subject 'Fifty Years

36 An Act to Provide More Effectively for the National Defense, p. 35.

37 Ibid., p. 3.

Hence" in 1932 presented the bright side of technology's impact on man's non-military pursuits.

But there was another side. "A being might be produced," the lecturer continued:

capable of tending a machine, but without other ambitions. Our minds recoil from such fearful eventualities, and the laws of a Christian civilization will prevent them. But might not lopsided creatures of this type fit in well with the Communist doctrines of Russia? 38

The man asking this rhetorical question was Winston Churchill, then on a lecture tour of North America. The conflicting emotions he expressed regarding technology were already standard fare for lectures and articles. The statement that uncontrolled technology posed threats to society was already familiar theme.

Vague indications of technological threats and promises were useless. Warnings of the direction from which the threat was to come were needed. Winston Churchill indicated one such direction: technology based on the emerging biological sciences. The other principal direction from which a threat was expected was a technology that might grow out of an already well-established scientific effort: atomic energy. Today we know that atomic energy was the more immediate problem. But in the 1930's that was not apparent.

If anything, biology was considered the field which was to have

38 Winston Churchill, "Fifty Years Hence," Review of Reviews, LXXXV (1932), 58.

immediate effects. This was part of a larger concern about the role of human skill and intelligence in an increasingly mechanized industrial society. Three of the most comprehensive attempts at technology prediction of the 1930's devoted much space to this problem. The 1937 report Technological Trends and National Policy took a short-range view, focusing on the questions of technological unemployment and automation. Clifford C. Furnas, in his 1936 book The Next Hundred Years, took a longer view. His first two chapters convey their emphasis by their titles: "The Battle of Eugenics," and "What is Life?" Waldemar Kaempffert's 1939 book Science, Today and Tomorrow contained a large section on the potential of biological technology; this marked a considerable change in emphasis from his previous concentration, in earlier writings, upon purely mechanical and electrical advances, such as aviation and radio.³⁹

Part of this upsurge of interest in the life sciences was caused by actual scientific activity. Great strides were made in genetics, particularly in achieving theoretical formulations covering a great deal of empirical information. At the same time, physical scientists, following the example of Louis Pasteur, showed increased interest in applying the methods of physical science to the problems of biology.

39 U. S., National Resources Committee, Technological Trends and National Policy (Washington: Government Printing Office, 1937); Clifford C. Furnas, The Next Hundred Years (New York: Reynal and Hitchcock, 1936), pp. 7-40; Waldemar Kaempffert, Science Today and Tomorrow (N. Y.: Viking, 1939) pp. 142-218.

One such method was to construct a highly simplified model of a physical system, in order to isolate a single characteristic of that system. In biology, such a technique created a unique problem. The public, and some science writers, tended to ignore the idealized and simplified nature of such models. Instead, such models were dramatically referred to as "imitations of life."

It seems likely that the obvious human-interest impact of progress in genetics and of "imitations of life" led to an overestimate of the rate of progress toward a biological technology. At the same time, progress in atomic physics was too irregular and esoteric to fuel similar hopes.

"The people who are genetically conscious have thought of heredity as being like a fixed star," wrote Clifford Furnas in 1936. "But the fixed stars really move at tremendous velocities, and genes may not be as unchangeable as we have thought."⁴⁰ A principal source of this belief was the work of many scientists on inducing mutations in the genes of plants and animals. Experiments by Herman J. Muller in 1927 had confirmed that bombardment of fruit flies with x-rays increased the rate of mutation to many times the spontaneous rate occurring in nature.⁴¹

The implications of this work seemed enormous. The scientist,

40 Clifford C. Furnas, The Next Hundred Years, p. 21.

41 George W. Gray, The Advancing Front of Science (N. Y.: Whittlesey House, 1937), p. 209.

Waldemar Kaempffert wrote in 1935, will "tinker with us as he is already tinkering in a blundering way with plants, fruit-flies, rats, and animals."⁴² However, the experiments of the thirties proved less conclusive than had been hoped. Research on the chemical basis of genetics proved necessary. It was not until the mid-1970's that science again seemed close enough to 'genetic engineering' that an effort to warn the public of the consequences was needed.⁴³

Another attack on the problem of life involved a behavioristic, rather than a genetic approach. Scientists sought to simulate the action of life processes, rather than unravel their origins. Like the genetic research of the 1930's, this approach was more productive of public speculation than it was of biological technology.

The increasing availability and precision of mechanical parts and electrical circuit elements helped make possible highly publicized experiments in the simulation of logical processes. A series of increasingly sophisticated analog computers drew an increasing amount of attention. Their developers did not characterize them as "thinking machines," preferring to concentrate on using them to solve complicated but straightforward problems in electrical and civil engineering.⁴⁴ The

42 Waldemar Kaempffert, "When Science Dictates," Current History, (Oct., 1935), 48.

43 "Decision at Asilomar," Science News, CVII, (1975) 194-196.

44 "To Nine Unknowns," Technology Review XXXIX, (1937); Harold L. Hazen, "Working Mathematics by Machine," Technology Review, XXXIV, (1931) 323-327; Raymond F. Yates, Machines Over Men (N. Y.: Frederick A. Stokes Co., 1939), p. 70.

press, however, was not always so cautious.

Less useful, but more stimulating to the imagination, were attempts to use mechanical models of the thought process in the study of psychology. Ingenious analog circuits were used to demonstrate the concept of a conditioned reflex. One circuit became "conditioned" by storing electric charges in a rechargeable battery; another by the expansion of an enclosed volume of gas under the "stimulus" of applied heat. By 1934, an MIT bachelor's thesis could detail 14 such "thinking" circuits. The appeal of these modest devices inspired some exaggeration. By 1937, biophysicist Nicholas Rashevsky was quoted by a science writer as claiming to have developed a machine which "will exhibit 'purpose,' and in particular will 'tell a lie,' which 'may be described as purposeful'."⁴⁵

Such models and claims did little to advance either technology or psychology; if anything, they tended to distract attention from the emergence of the digital computer, which would use circuitry derived from mathematical logic rather than from psychology. Whatever their scientific value, however, they were sure-fire sources for speculation about the future.

Even more appealing to the public was a line of experiments with intimations of immortality. Dr. Alexis Carrel had been carrying

45 George W. Gray, The Advancing Front of Science, p. 270; 282-3; Clifford C. Furnas, The Next Hundred Years, pp. 82-83.

out experiments since 1912 aimed at keeping cells alive outside of the body. In the 1930's, Charles Lindbergh joined in the research, adding his American ingenuity to Carrel's medical knowledge. The combination was irresistible to reporters. The culminating experiment of the Carrel-Lindbergh collaboration came with the keeping a chicken's pancreas alive outside a chicken's body in 1935.⁴⁶ Today, in the era of heart transplant, such an achievement seems small. But the suggestion of "life in the laboratory" was hard for popularizers to resist. So was the combination of America's greatest aviation hero with the charismatic, Nobel-prize winning "high priest of biology," of whom it was said:

We behold Carrel plunging into sociology as well as a study of tissues, organs, and environments. Nothing short of a superman with a supersoul will do for him.⁴⁷

Similar enthusiasm was reflected in statements by highly respected scientists. It might be expected that biologists would make statements like the one made by Raymond Pearl in 1934: "progress in biology in the next decade, comparable in significance to that in physics in the last decade may confidently be expected."⁴⁸

Somewhat more surprisingly, two of America's top physicists gave assessments of the future application of biology that were just as

46 Alexis Carrel and Charles Lindbergh, "The Culture of Whole Organs," Science LXXXI, (1935) 621-623.

47 Waldemar Kaempffert, Science Today and Tomorrow, p. 193.

48 "Science and Industry in the Coming Century," Scientific Monthly XXXIX (July, 1934), p. 76.

enthusiastic. "It would seem highly probable," said Arthur H. Compton in 1934, "that physical and chemical methods of making artificial cells will be developed." Biology, wrote Robert A. Millikan in 1939, is the science that gives most promise of "big new things."⁴⁹

Millikan, like many physicists, was far less optimistic about the most utopian possibility then offered by physics: the tapping of the energy of the atom. The publicly available predictions about atomic energy (and, until 1939, virtually all discussion was publicly available to anyone with the interest and education to participate in it) swung back and forth between pessimism and optimism.

As the decade began, the tone was mainly pessimistic. In 1930, for example, Millikan opened the decade with another of his attempts to deflate overstatements about the imminence of atomic energy -- or even about its eventual possibility. "It is highly improbable," he concluded, "that there is any appreciable amount of available subatomic energy for man to tap."⁵⁰ Engineer-journalist Floyd Parsons added in 1931 that "we need not worry over the consequences of breaking up the atom."⁵¹

But two spectacular scientific discoveries rekindled hopes. First, British physicist James Chadwick experimentally proved the

49 General Motors Corporation, Previews of Industrial Progress in the Next Century (1934), p. 10.

50 Robert A. Millikan, "Alleged Sins of Science," Scribner's, LXXXVII (1930) p. 121.

51 Floyd W. Parsons, "A Look Ahead," Saturday Evening Post, CXCI, (April 3, 1931) 150.

existence of the neutron, a particle whose lack of charge made it a valuable new 'bullet' to shoot at the atom. Then J. D. Cockcroft and E. T. S. Walton bombarded a lithium target with protons and succeeded, for the first time ever, in producing changes in an atomic nucleus. Interpreting these advances (as well as the earlier work of Lord Rutherford) for an American audience, MIT president Karl Compton concluded:

mostly within the last two years, it has begun to look as if the atom may succumb all along the battle front.⁵²

Commenting on Compton's remarks, the New York Times editorialized that practical application of atomic power could be as little as a century away.⁵³ Norbert Wiener, a mathematician on Compton's MIT faculty, saw the advent of practical energy from the atom as much closer. He felt that a technology assessment was needed to cushion the shock of such a revolutionary advance. Wiener's own assessment proved very inaccurate (for example, he saw atomic power being used in artificial food production and aviation and as greatly increasing technological unemployment). But the fact that he felt such an assessment was needed in 1933 gives an indication that, at least in some quarters, optimism

52 Karl T. Compton, "The Battle of the Alchemists," Electrical Engineering LII, (1935) 75 (a reprint of a speech delivered in 1933 at Schenectady, New York).

53 New York Times, Jan. 30, 1933, p. 15.

about the technological achievement of atomic energy was on the up-swing.⁵⁴

The over-inflated hopes of 1933 drew a rebuttal from the man whose ideas had inspired Chadwick, Cockcroft, and Walton-Lord Rutherford himself. "Anyone who says that, with the means presently at our disposal, and with our present knowledge, we can utilize atomic energy," said Rutherford in 1933, "is talking moonshine."⁵⁵

In later discussions of the subject, this statement has been shortened to the simple equation atomic energy is moonshine. Actually, as the full quote indicates, Rutherford's careful qualifications make his statement an assertion about the present, not about the future.

Most predictors in the mid-1930's adopted the caution which Rutherford had called for. Stuart Chase, not himself a scientist, followed Rutherford's lead and dismissed atomic energy in 1934 as a "remote and dangerous source" of energy. In 1935, geneticist Hermann J. Muller labeled it the most problematical of all proposed energy sources (including geothermal energy, solar energy, and tidal energy). Claude C. Furnas wrote in 1936: "do not buy any stock in an Atomic Energy Development Company. You will certainly lose." (Taken literally, this was good advice;

54 Norbert Wiener, "Putting Matter to Work," Technology Review XXXVI, (1933) 47-49 (Incidentally, after World War II, Wiener again took up the role of technological Cassandra, in his two highly publicized books on automation, Cybernetics and God and Golem, Inc.).

55 "Talking Moonshine," Scientific American CXLIX, (1933) 201.

it will be the 1980's before the peaceful atom will become the profitable atom for the American companies which build nuclear reactors. And there is still some doubt that the presently planned U. S. nuclear power program will ever be fully carried out.)⁵⁶

There were, of course, optimists whose hopes for practical atomic power remained high through the 1930's. Among them were chemist Thomas Midgeley, and experimental physicist Ernest O. Lawrence.⁵⁷ But the collection of predictions I have gathered indicates that the following quote, from a 1938 article in Fortune, accurately expresses the consensus by 1938:

at present few scientists foresee any serious or practical use for atomic energy. They regard the atom-splitting experiments as useful steps in the attempt to describe the atom more accurately, not as the key to unlocking any new power.⁵⁸

However, it was a purely scientific experiment, in late 1938, which in fact provided the clue to "unlocking any new power." Otto Hahn and Fritz Strassman of Germany determined that neutrons could split uranium nuclei, and other scientists quickly inferred that this nuclear

56 Stuart Chase, The Economy of Abundance (New York: MacMillan, 1934), p. 103; Hermann J. Muller, Out of the Night (New York: Vanguard, 1935), p. 61; Claude C. Furnas, The Next Hundred Years, p. 190.

57 Thomas Midgeley, "Chemistry in the Next Century," Industrial and Engineering Chemistry XXVII (May, 1935), 496; New York Times, July 18, 1937, XI, 6.

58 "9000 Billion Horsepower of Solar Energy," Fortune, XVIII, (1938) 88.

fission was the long-sought key to atomic energy. But the Hahn-Strassmann result, while published in the open scientific literature in January, 1939, can hardly be considered a public warning about atomic energy, as the public does not read scientific journals. To warn the public, interpretation was needed.

In the United States, interpretation of the event was provided by the Danish physicist Niels Bohr at the 1939 meeting of the American Physical Society in New York. The occasion was a dramatic one.

"Tempers and temperatures increased visibly today among members of the American Physical Society," one report began,

as they closed their Spring meeting with arguments over the probability of some scientist blowing up a sizeable portion of the earth with a tiny amount of uranium ... Dr. Niels Bohr ... declared that bombardment of a small amount of the pure isotope 235 of uranium with slow neutron particles of atoms would start a 'chain reaction' or atomic explosion sufficiently great to blow up a laboratory and the surrounding country for many miles.⁵⁹

This remarkable announcement was worth no more than six column-inches on page 35 of the New York Times. But within a year, after uranium 235 had been successfully isolated, and a very small scale fission reaction had been carried out, the story advanced to page 1. Science writer William L. Laurence prophetically summed up both the prospects (atomic bombs; uranium fueled electric power stations; nuclear submarines) and the problems (would Germany beat the U. S. to atomic

⁵⁹ New York Times, April 30, 1939, p. 35.

power? would uranium enrichment be practical?). A subsequent article, written by science writer John J. O'Neill for Harper's, repeated these possibilities (although with considerably less emphasis on the atomic bomb) and even added the possibility of power from nuclear fusion.⁶⁰

With these prominent warnings, why did the atomic age take Americans by surprise in 1945? There were three main reasons. First, the revelations of 1939 and 1940 left severe technical problems still to be solved. In particular, the enriching of uranium -- this is, the separation of the fissionable isotope of uranium from the vastly more plentiful non-fissionable isotope -- was an extremely difficult task. Contemporaries doubted it could be done economically. Even as late as the 1970's, American private industry was unwilling to finance construction of the vast, energy-intensive enrichment plants needed. Had the Second World War (and the ensuing cold war) not created a large military market for enriched uranium, it is possible the government might have avoided taking on this job, and atomic power would have been greatly delayed.⁶¹

60 New York Times, May 5, 1940, p. 1; John J. O'Neill, "Enter Atomic Power," Harper's CLXXI, (1940), 1-10.

61 Waldemar Kaempffert, Science Today and Tomorrow, p. 123; K. H. Kingdon, "Another Step Toward Atomic Power," GE Review, XLIII, (1940) 229. Of course, in this event, the U. S. might have developed natural uranium reactors (such as those now used in Canada) which do not require enriched uranium.

The second reason why atomic power remained an unappreciated possibility was that the headlines about the breakthroughs of 1939 and 1940 coincided with much more dramatic headlines -- the German blitzkriegs in Poland and France, and the domestic debate about a proper American role in the conflict. An as yet problematic scientific story had a hard time competing for attention.

A third cause of surprise was the fact that a unique scientific publication ban dried up the sources of scientific information on the subject. In April, 1940, the Division of Physical Sciences of the National Research Council established a system of self-censorship on papers about uranium. This ban, while voluntary, was very effective. It had its intended effect of preventing further alarms about the atomic bomb from reaching the ears of German intelligence; in doing so, it was necessary to keep the American public in the dark.

By the late 1930's, then , it was very difficult for an informed citizen to weight the relative seriousness of two main technological threats: biological technology and atomic energy. Both were centers of purely scientific activity. Both had fairly obvious technological implications. If anything, the issues raised by biological technology were more pertinent to the concerns of the 1930's than were those raised by atomic energy. The rise of racist ideologies in Europe highlighted the fields of genetics and eugenics. The concerns about technological unemployment and mechanization made the possibility of artificial life a threat rather than a promise.

On the side of atomic energy, the warnings were less urgent. The continued belief that two oceans isolated America defused the threat of an atomic bomb. With the nation's energy situation apparently very secure,⁶² a new source of energy did not arouse intense interest.

In retrospect, it is very easy to pick out the significant clues to the future. General Henry Arnold's testimony in 1938 foreshadowed the 'military-industrial complex' of a later day; Niels Bohr's speech to the American Physical Society in 1939 revealed the military side of atomic power; the material gathered by reporters William L. Laurence and John J. O'Neill filled in the details of the atomic power story.

But, in context, these clues were no more salient than many other indications. The atomic bomb was only one of a number of super-weapons, and seemed no nearer to military observers in the mid-1930's than did the death ray or remote-controlled airplane. And all these exotic possibilities seemed hardly worth discussing when even the previous generation of inventions -- airplanes, aircraft carriers, and electronic circuitry -- had not yet been absorbed into the military's doctrines.

In her book examining why the United States was surprised at Pearl Harbor, Roberta Wohlstetter has written:

62 See e.g., L.W.W. Morrow, "Economics of Power," Transactions of the American Electrochemical Society LXX, (1936), 167; "The Expanding Decade," Fortune III, (June, 1931), 73; "9000 Billion Horsepower of Solar Energy," pp. 87-88.

Signals announcing the Pearl Harbor attack were always accompanied by competing or contradictory signals, by all sorts of information useless for anticipating this particular disaster. We refer to these competing signals as 'noise.' To understand the fact of surprise it is necessary to examine the characteristics of the noise as well as the signals that after the event are so clearly seen to herald the attack.⁶³

A succession of technological surprises have confronted Americans since 1940: the atomic bomb; the development of a strategic military policy based on long-range bombers and missiles; and, more recently, the need to choose courses of action that will insure sufficient energy supplies. None of these came as suddenly as the attack on Pearl Harbor. But, as in the case of that attack, warning of each was obscured by the "noise" of competing signals.

Part of the noise was deliberately created. For example, the truth about radar was downplayed for very good national security reasons. The value of aircraft carriers was belittled, for less defensible reasons. The imminence of atomic energy was overlooked, for reasons that are related to the intrinsic unpredictability of pure science.

Other noise was caused by events that proved later to be distractions. Biological technology was not as close as some dramatic experiments had seemed to suggest. Technical improvements made on battleships did not help them maintain their crucial place in American

⁶³ Roberta Wohlstetter, Pearl Harbor: Warning and Decision (Stanford, California: Stanford University Press, 1962), p. 3.

defense. Threats like death rays and remote- controlled airplanes were not within the grasp of the technology of the 1930's.

Today, the ordering of these past technological threats seems obvious -- just as the threat to Pearl Harbor in December, 1941, seems clearly implied by preceding events. But only in retrospect is this feat of separating the genuine threats from the noise an easy one.

CHAPTER X

CONCLUSIONS: FROM PREDICTION TO FORECASTING

There do not exist today any reliable methods of prediction or forecasting (even in technology), but some spectacular predictions are often encouraged or demanded in order to enhance the game and attract attention ... the serious effort is devoted not to making predictions but to the more complicated and subtle art of defining alternatives.¹

This 1968 statement by sociologist Daniel Bell sums up the aim of his contemporaries working in the new field of "futures research." This would-be discipline has hovered at the boundary of academic respectability for over a decade. It has shown no signs of being absorbed by the conventional social sciences.

Early landmarks in futures research included the 1965 formation of a Commission on the Year 2000, and the turning of some previously national-defense-oriented "think tanks" toward the futures field. For example, Herman Kahn, physicist turned nuclear strategist, took on yet a third role - that of secular prophet - with his 1967 book The Year 2000. Attention focused on the growing field during the controversy surrounding the 1972 release of the study The Limits to Growth, sponsored by the Club of Rome. Views about the future presented by

1 Toward the Year 2000, Daniel Bell, ed. (Boston: Houghton Mifflin Co., 1968), p. 3.

Daniel Bell in his 1973 book The Coming of Post-Industrial Society also attracted wide interest.²

There is great diversity in the methods used in futures research. But most "futurologists" follow Daniel Bell in preferring to be forecasters, rather than predictors. By this, Bell means that they try to estimate future trends and rates of change (forecasting), not to foretell particular events (prediction).³ The modern futures researcher, or forecaster, wants to be like Dickens' spirit of Christmas-Yet-to-Come: capable of telling us what may be if we do not mend our ways, not what necessarily will be.

Today's forecasting studies range over many subjects, including economics, politics, and social change. But technology remains a central concern of forecasters, and technological forecasting remains the most highly developed part of futures research.

The examples of pre-1940 prediction detailed in the first nine chapters of this study contain information potentially useful to today's forecasters. More importantly, this information can help the general

-
- 2 Ibid., pp. 1-10; Herman Kahn and Anthony J. Wiener, The Year 2000 (New York: MacMillan, 1967); Donella H. Meadows, Dennis L. Meadows, Randers, and William W. Behrens III, The Limits to Growth (New York: MacMillan, 1972); Daniel Bell, The Coming of Post-Industrial Society (New York: Basic Books, 1973).
- 3 Daniel Bell, The Coming of Post-Industrial Society, pp. 1-5; 196-212.

public evaluate the claims of today's forecasters, who have been at the game for too short a time to have accumulated a record for either accuracy or inaccuracy. The concluding chapter will aim to perform these tasks by considering two questions: first, what general methods did the predictors of the period 1890-1940 use to produce the record for accuracy described in Chapter I? And, second, should today's forecasters be able to present a noticeably more accurate picture of the future than did their predecessors of the pre-1940 period?

Looking Backward: Methods of Prediction, 1890-1940

Modern forecasters are usually quite concerned about specifying the methods used in forecasting.⁴ The pre-1940 predictors usually were not. But they usually did have implicit bases for their predictions. While not formal methods, these bases were made sufficiently evident to allow the over 1500 predictions considered in the first nine chapters to be grouped into six categories. These are: intuition, analogy, extrapolation, leading indication, scenario writing, and deduction.

Each of these (except perhaps the first) can claim sound and specifiable reasons for its use. Each has one or more equally evident

⁴ See, e.g., Avrom J. Goldfarb, "Technological Forecasting: What and Whither?" Technological Forecasting and Social Change, III (1971), 51-64; Roy C. Amara and Gerald R. Salancik "Forecasting: From Conjectural Art Toward Science," Technological Forecasting and Social Change, III (1972), 415-426.

defects. It is worth examining the virtues and defects of each method in turn, in order to come to a preliminary understanding of the limits of predictive accuracy.

Intuition means, in the predictive context, "direct or immediate insight" - that is, it implies the lack of a method.⁵ It may well be that certain individuals have an inborn ability to predict better than others. But the statistics presented in Chapter I imply no need to rely on that hypothesis. The modest superiority of technically-trained predictors over others in the accuracy of their predictions about technology seems explainable on less mystical grounds. Other differences among individuals could plausibly be the result of chance variations alone.

Analogies cannot prove relationships, but they can suggest them. In this lies the strength of the method of analogy, a favorite of many past predictors and of some of today's forecasters as well.⁶ The method is a simple extension of the thought process which allows a person to make some sense out of the world around him. Without assuming that roughly similar effects will result from roughly similar causes, every new situation would seem unique and baffling.

Some analogies have proved prophetic. Benton MacKaye's analogy between railroads and what he called "cement railroads" enabled

5 The Compact Edition of the Oxford English Dictionary, (Glasgow: Oxford University Press, 1971), p. 444.

6 Herman Kahn and B. Bruce Briggs, Things to Come (New York: MacMillan, 1972), p. 31.

him to predict accurately many of the features of today's interstate highway system. Television, as predicted, followed a course of public acceptance analagous to that of radio. And both electricity and electronics had social effects analagous to those caused by the steam engine (although, in this case, the concept of the social effects of invention used by predictors was so vague as to diminish the predictive value of the analogy).

However, past predictions also indicate clearly the two main defects of analogy as a predictive technique. Frequently, the items chosen for comparison are inappropriate; and frequently an analogy is carried too far.

An example of the first type of error is the comparison frequently made between the submarine and other naval vessels. Defenders of traditional naval strategy drew the analogy between the submarine and other innovative fleet vessels, such as the surface torpedo boat. They consequently predicted that the submarine would have a usefulness as limited as the previous innovations had. A more appropriate analogy, however, would have been between the submarine and past commerce destroyers acting independently of the fleet (for example, the privateers of the War of 1812). Like most correct analogies, this one is more obvious in retrospect than in prospect.

A case of carrying an analogy too far is provided by the concept of the factory-made house. Many predictors drew the analogy between

the mass production of automobiles and the mass production of houses. Those who simply used the analogy to predict the success of the mobile home proved correct. But many extended the analogy to predict that just as the automobile had proved far superior to other means of personal transportation, the modularized, factory-produced house would prove superior to low and medium priced houses built by traditional methods. A variety of reasons, including customer tastes, land costs, and financing considerations, caused the analogy to break down, and the prediction to prove incorrect.

The defect of analogy, then, is its misleading simplicity. And this defect is made worse by the tendency of people to select the analogy which comes first to mind. Psychologists Amos Tversky and Daniel Kahneman, who have verified the existence of this tendency through a series of ingenious experiments, call it a "bias due to the retrieveability of instances."⁷

Extrapolation seems a more objective method than analogy, in that it consists of projecting forward past data according to a specified method. However, the use of numbers and graphs does not insure objectivity, much less predictive accuracy. Applied over short time periods, extrapolation is often useful. One can usually assume, for

7 Amos Tversky and Daniel Kahneman, "Judgments Under Uncertainty: Heuristics and Biases," Science, CLXXXV (17 Sept. 1975), 1127.

example, that tomorrow's temperature will be close to today's. But extrapolating over longer time periods is frequently dangerous.

To illustrate this, one need only look at the number of trend lines which suddenly leveled off or reversed direction without warning. Such apparently solidly based trends as the increase in coal usage, the increase in U.S. electrified railway mileage (including interurbans) and the increase in maximum electricity transmission voltage slackened suddenly during the first quarter of the present century. And such trends as the decrease in projected American natural gas supplies and the decrease in automobile fuel consumption per mile turned upward in the second quarter of the century. (Incidentally, both of these trends have again turned downward since 1970 - again without much advance warning).

To complement trend extrapolation, many predictors turned to the method of leading indication. As a present technological forecaster has put it:

Coming technology casts shadows ahead and becomes visible to society long before it has significant impact. Therefore we should be able to detect signs of coming technological change and monitor this change in a systematic way.⁸

⁸ James R. Bright, "Forecasting by Monitoring Signals of Technological Change," in A Guide to Practical Technological Forecasting, ed. by James R. Bright (Engelwood Cliffs, N.J.: Prentice Hall, 1973), p. 238.

The "therefore" in the above quote is somewhat misleading. Coming events may cast shadows ahead, but so do possibilities that are never to happen. The problem is to avoid missing legitimate signals while not generating an unacceptable number of false alarms.

When a technological development embodies a large number of inventions or process improvements the earliest of these inventions and improvements often provide accurate leading indication of coming change. Such indicators allowed accurate prediction of the revolution in prime movers that occurred at the turn of the century, the development of long range bombers in the 1930's, and the development of synthetic rubber before and during World War II.

However, the perceived possible commercial value of an idea often causes the generation of leading indicators in spite of the remoteness of practical success. The publicity surrounding work on fuel cells and liquid air motors in the 1890's provides two such cases of misleading indicators.

Indeed, as noted in Chapter I , the overall record of prediction suggests the following relation of leading indicators to actual outcome: about 85% of the major technological developments cast shadows ahead; about 50% of the shadows perceived by a predictor of technology were cast by possibilities that are not going to be realized.

When should one extrapolate, and when should one look for a turning point? To solve this problem, some modern forecasters have

adopted the method of scenario writing. This means sketching in outline or story form the description of a possible future.

The great merit of the scenario is that it tells how to get there from here. It explicitly details the intermediate steps leading from the present to the forecast future, allowing considerations of their plausibility. A pioneer in the scenario method was Edward Bellamy, whose books Looking Backward and Equality tell not only what utopia is like, but also how the U.S. of 1890 managed to get there by the year 2000.

But even in writing deliberately imaginative scenarios, predictors find it very difficult to rid themselves of unstated assumptions. Bellamy could not imagine his highly-centralized bureaucratic state as anything but benevolent in intent and results. Less comprehensive scenarios also include crippling stated or unstated assumptions. Thus, some predictors thought that soundwave detection methods had rendered the submarine obsolete by the 1930's; others thought that the years 1915-1920 marked a change from a growth economy in the United States to an "age of efficiency"; still others in the 1930's thought the automobile industry would never again reach its 1929 sales levels.

In short, the problem with scenarios is often not their fantastic details, but rather their narrow assumptions. Even producing a whole cluster of scenarios, or alternate futures, does not help if all contain the same unstated assumption.

To give more rigor to the process of forecasting, many of

today's forecasters are turning to the method of deduction. This is sometimes called model building, and often carried out with the aid of a computer. The procedure is to begin from clearly stated assumptions, and to use logic to deduce the consequences of these assumptions.

Lacking a computer (indeed, lacking even the vision to predict the invention of the digital computer) pre-1940 predictors could only make rudimentary efforts at deductive prediction.

One such simple model was used by the American Petroleum Institute's 1926 Committee of Eleven to predict future gasoline consumption. Its builders used assumptions about future car ownership and future population to deduce the number of future motor vehicles, and then used assumptions about future driving habits to deduce the demand for gasoline. Errors in each assumption were combined by the model to produce a prediction that proved far too low. The same fate befell predictors from the General Electric Company in 1939, when they tried to deduce the future demand for television sets.

It may be argued that the failure of these simple models casts no light on the success to be expected from today's more sophisticated efforts. This may be true. But the simple examples cited show that deduction can magnify the errors inherent in faulty assumptions.

To sum up, the predictive methods of the past have relied on

judgment, not on science. Are today's forecasters likely to develop scientific techniques that will lead to a major improvement in accuracy? That is the subject of the next section.

Looking Forward: Forecasting's Prospects

Accuracy is not the only criterion of the value of a forecast. Some forecasts are self-fulfilling, and help to foster the very trends they foresee; others are self-defeating, and help to head off those trends.⁹ But accuracy is certainly one of the most important criteria by which to judge most forecasts. The main emphasis in this section, therefore, is on the possibility of today's forecasters improving on the record for accuracy registered by the predictors of the period 1890-1940.

Most of this study has dealt with a simple question: what was predicted? This often led to related questions: why were certain developments that now appear obvious (such as radio broadcasting) so widely overlooked? Why were other ideas which now seem impractical (such as the aerial flivver) so generally expected to become realities?

Such omissions and unrealistic expectations were common. But much more common were predictions of items that were realistic and technically feasible, but not destined to happen within the predictor's time limit. Some, such as railroad electrification, were widely adopted in

⁹ Joseph P. Martino, "Evaluating Forecast Validity," in A Guide to Practical Technological Forecasting, pp. 26-52, discusses this and other forecast criteria.

nations with a different mix of resources and technical capabilities than those possessed by the United States of 1900-1970. Others, such as fluorescent lights, were unsuccessful in an early period when they were widely predicted, but succeeded later.

Certainly the record of predictors suggests that if American technological development was predetermined, the nature of that predetermination was not obvious to those who tried to predict the future from 1890-1940. No doubt this was partly due to the deficiencies in the methods used. But might not much of the error in prediction be due to genuine uncertainty?

Far from being due to broad general causes, the development of technology is often due to specific historic particulars. The laws of science provide limits within which technology can develop, but do not indicate which technical choices will be made within those limits. For example, the techniques used to supply electric power must satisfy the scientific laws of electricity, magnetism, and thermodynamics. But the particular choice of generation, transmission, and distribution methods has historically depended on such things as the debates between publicly and privately owned power companies; the legal leeway given (or denied) to holding companies; the interest rates of the Rural Electrification Agency; the oligopolistic organization of the electrical machinery industry; and the costs of various fuels. And these features were effects of the organization of electric power supply, as well as its causes.

Predictions of innovation in the power industry, from superpower to nuclear power, have not always successfully taken this complex web of causation into account.

Today's forecasters have two main hopes for dealing with this kind of complexity. One is to avoid the systematic biases that caused past predictors to consistently err in certain directions. The other is to rely on new forecasting methods. I will discuss both of these tactics in turn, and conclude with my assessment of their probable success.

The main avoidable biases of past predictors were contained in two theories of invention. Necessity is the mother of invention, sums up one of these theories. New technology has vast and identifiable social effects, states the other. When not mere platitudes, these two can be useful for exposition. But they are useless for accurate prediction.

Some of the seeming necessities which failed to give rise to invention were: the 1920 need for efficiency in industry and transportation, which was expected to cause the adoption of the superpower plans and the electrication of the railroads; the need for a new industry in the 1930's, which was supposed to introduce mass-production into the construction industry; and the needs for solutions of the economic problems of coal mine operators and farmers, which were supposed to lead to coal carbonization and farm chemurgic industries. No doubt most inventions are intended to meet perceived market needs; but this fact does not predict which inventions will in fact meet such needs.

"Effects of technology" predictions tended to load single inventions with unduly large responsibilities for changing the world. Electric railroads were to cure the ills of the cities; airplanes were expected first to shorten wars, then to end war altogether, and finally to insure international harmony. The photocell was sometimes seen as a one-device industrial revolution.

Another bias of pre-1940 predictors was to place too much faith in old ideas. Every time the prospect of a fuel shortage emerged, ideas like tidal power, alcohol fuel, and shale oil were optimistically revived. When transportation problems seemed acute, the aerial flivver or the use of electric mass transportation methods attracted more attention than they warranted. This is not to say that long-time dreams never come true. Witness the steam turbine, realized after a century of efforts, or television, making a commercial success after more than half a century of predictions. But such long delays between prediction and realization did not happen as often as predictors thought they would.

A final source of avoidable error was the tendency of people not trained in technical subjects to try to judge the validity of technical ideas. The possibilities of such devices as the liquid air motor, the death ray, and the aerial flivver were oversold in this way to some highly respected journalists. Statistically, this bias helped keep the batting average of predictors without technical training .010 below that of the technically trained predictors.

The ability to avoid these systematic errors gives today's forecasters an advantage over yesterday's predictors. The existence of new methods of carrying out the forecasting process provides further advantages of as yet uncertain value.

The most widely publicized of the new methods have the impressive names "Delphi" and "world dynamics." The first of these uses an iterative method of polling a panel of experts. The second uses a digital computer to "run" a mathematical model of the world for a century or more, to see what certain assumptions about resources, technology, and policy imply about man's fate. Both of these are controversial, and not fully tested. But they certainly represent new departures. An evaluation of their possibilities is beyond the scope of the present study.¹⁰

However, the material presented in this study gives a preliminary basis for an assessment of the prospects for today's forecasters to move, as two of them put it "from conjectural art toward science."¹¹

The prospects do not appear to me to be good. The use of a sophisticated method is neither necessary nor sufficient for a field to

10 For an introduction to and appraisal of these methods, see, e.g., Donella Meadows et. al, The Limits to Growth (for world dynamics) and Kim Quaile Hill and Jib Fowles, "The Methodological Worth of the Delphi Forecasting Technique," Technological Forecasting and Social Change, VII (1975), 179-192.

11 Roy C. Amara and Gerald R. Salancik, "Forecasting: from Conjectural Art toward Science," p. 415.

become scientific.

Rather, it is the appearance of empirical regularities which has heralded the advance of science. These regularities tell a scientist what facts are worth looking at. The scientist then uses these facts to describe and to predict. This is quite different from the procedure of today's forecasters, who first develop methods, and then look for facts to use the methods on.

This does not mean that the efforts of today's forecasters are bound to fail. It merely means that these efforts are not science. They ought not to be allowed to share the prestige of the proven physical sciences, even though many of the people who now call themselves "futurologists" were once scientists or engineers.

As just one example, the former physicist Herman Kahn has based much of his forecasting on the assumption that there is a "multifold trend" in world history. This assumption places Kahn's work in the tradition of system-builders like Oswald Spengler, Arnold J. Toynbee, and Pitrim Sorokin. This tradition describes history as an unfolding of a master plan. It is a tradition based on metaphor, not science.¹²

This is not intended as a criticism of Kahn's work; rather it is an attempt to categorize it. He is to be commended for making so clear

¹² Herman Kahn and B. Bruce-Briggs, Things to Come, pp. 6-9.

the underlying assumptions from which he is working.

Possibly, by making a continuing effort at forecasting, Kahn and his fellow workers will stumble upon empirical regularities from which a science can be constructed. But it is also possible that speculations about the future just will not provide the stuff from which science is made.

The situation of future studies today is much like the situation of sociology in 1900. As the mathematician Henri Poincare described that situation:

the sociologist is more embarrassed (than the physicist); the elements, which for him are men, are too unlike, too variable, too capricious, in a word, too complex; besides, history never begins over again. How then choose the interesting fact, which is that which begins again? Method is precisely the choice of facts; it is needful, then, to be occupied first with creating a method, and many have been imagined since none imposes itself, so that sociology is the science which has the most methods and the fewest results.¹³

Leaving aside the fairness of this description as applied to sociology, it certainly seems to me a fair statement if the word "sociology" is replaced by "future studies." The proliferation of forecasting methods in current future studies is not a sign that the field is becoming scientific. Rather, many methods have been imagined, since none imposes itself.

As long as forecasting remains highly fallible, the forecaster

¹³ Henri Poincare, The Foundations of Science (Lancaster, Pennsylvania: Science Press, 1946), first published 1913.

cannot expect to play a major role in the making of national decisions regarding technology. Rather, the principal types of technological advice will be given from the two points of view that have been labeled "technological fixes" and "technology assessment."

Those who advocate technological fixes hold that many social problems can be ameliorated by the use of technology. New technology, they argue, is likely to be more effective at improving the quality of life than are massive social programs that try to change human nature.¹⁴

On the other side, advocates of technology assessment present a view which can be summed up in the words "not so fast." They suggest that before a commitment to a new technology be made, a study should be performed to assess its consequences (intended and unintended) as well as the advantages and disadvantages of alternative methods of doing the same job. This view was enacted into Federal law in 1972, with the creation of the Office of Technology Assessment, a Federally-funded organization which supervises the performance of technology assessment studies. A joint congressional committee and an advisory board share responsibility for choosing the subjects to be studied; contractors are

¹⁴ Alvin M. Weinberg, "Social Problems and National Socio-Technical Institutes," U.S. Congress, House of Representatives, Committee on Science and Astronautics Applied Science and Technical Progress, (Washington, D.C.: Government Printing Office, 1967), pp. 415-434.

selected to actually carry out the studies.¹⁵

To the forecaster, the case-by-case approach of both of these groups seems hopelessly shortsighted. The technological fix risks ignoring the subtle secondary consequences of technological change, whose effects may ultimately outweigh the intended primary consequences. Technology assessment runs the risk of becoming technology harassment, bogging down needed changes. To the forecaster, neither of these approaches is a substitute for a comprehensive look ahead.

But anyone urging value-free, scientific, and accurate forecasts to aid in the planning and control of change must first prove that such things are possible. The evidence from predictions of technology made from 1890 through 1940 suggests that they are not. The failure of these predictions seem to me to be due less to avoidable errors than to genuine uncertainty.

For the present, the claims of the forecasters ought to be put into the category "not proven." Nor should the present lack of a science of social or technological forecasting be greatly regretted. Recognizing the limitations of what can be known about the future does not absolve

15 U.S. Congress, An Act to Establish an Office of Technology Assessment for the Congress as an Aid in the Identification and Consideration of Existing and Probable Impacts of Technological Applications; to Amend the National Science Foundation Act of 1950; and for Other Purposes, Public Law 92-484 92d Congress, 2d Session, 1972.

decision makers of responsibility for the consequences of their decisions. But it should lead to both increased realism about what proposed technological or social changes can be expected to accomplish, and to more generosity on the part of historians carrying out their exercises in hindsight.

Appendix: Statistics and Data on the Climate of Prediction

This appendix contains a summary of the data on which Chapter One is based. As frequent reference is made in Chapter One to the significance of the relation between two properties of predictions, let me explain how I am using the word "significance."

Statistical significance (or simply significance) as used in this study refers to the association between two attributes of a set of observations. I have measured significance by the chi-squared tests, where

chi-squared tests essentially whether the observed frequencies in a distribution differ significantly from the frequencies which might be expected according to some assumed hypothesis.¹

Symbolically

$$\text{chi-squared} = \sum \frac{(O-E)^2}{E}$$

all attributes or combination
of attributes

where:

O= number of observations having a specified attribute or combination of attributes

E= number of observations expected to have that attribute

In the sections that follow, the "observations" are predictions, and the "attributes" are such things as the goodness of the prediction, or whether it was made by a technically trained predictor. To determine E, the hypothesis used in each case has been that the proportion of predictions having a given pair of attributes is the product of the proportion

¹ M. J. Moroney, Facts From Figures (Baltimore: Penguin, 1951), p. 249.

having each attribute separately.

Thus, for example, if half of a given set of predictions are good, and half are made by technically trained predictors, I have hypothesized that, if the two attributes are unrelated, one-fourth of the predictions will be both good and made by technically trained predictors. The statistic chi-squared then is computed, using the formula above, to compare this "no association" hypothesis with actual observations.

Standard tables relate the resulting value of chi-squared, and the number of frequency classes that can be independently specified (the number of degrees of freedom), to a significance level.² This significance level tells how likely the observed chi-squared value is to be exceeded by chance alone. For example, a significance level of .05 is likely to be exceeded by chance alone once in twenty times. In Chapter One, I have called associations significant if they show a significance level less than or equal to .05, and not significant if they show a level greater than .05. A significance level of .05 or lower does not prove association between two variables, but it does help identify potential associations which ought to be more closely studied.

² e.g., Ibid., p. 253.

1) The Fifty Most Frequent Predictors.

<u>Name</u>	<u>Occupation</u>	<u>Number of Predictions</u>	<u>Batting Average</u>
Abbot, Charles G.	Astomer	7	.286
Babson, Rober W.	Business Analyst	25	.360
Baxter, William, Jr.	Writer	9	.445
Bell, Louis	Electrical Engr.	14	.642
Bellamy, Edward	Writer	14	.358
Chase, Stuart	Writer	24	.418
Chubb, L. Warrington	Electrical Engr. / Research Director	9	.556
Compton, Karl T.	Physicist	9	.333
Duncan, Louis D.	Electrical Engr.	11	.454
East, Edward M.	Biologist	11	.454
Edison, Thomas A.	Inventor	34	.588
Egloff, Gustav	Chemist	12	.417
Eliot, George F.	Writer	5	.400
Fernald, Robert H.	Mechanical Engr.	11	.182
Fessenden, Reginald A.	Inventor	9	.222
Fieldner, Arthur C.	Mechanical Engr.	13	.384
Ford, Henry	Inventor	6	.000
Furnas, Clifford C.	Chemist	37	.568
Hale, William J.	Chemist	10	.200
Hammond, John Hays, Jr.	Inventor	10	.300
Harrison, George R.	Physicist	<u>17</u>	.471
		297	

<u>Name</u>	<u>Occupation</u>	<u>Number of Predictions</u>	<u>Batting Average</u>
Haupt, Lewis	Civil Engr.	6	.166
Hering, Carl	Electrical Engr.	14	.572
Kaempffert, Waldemar	Writer	48	.333
Kettering, Charles F.	Inventor	5	.800
Lake, Simon	Inventor	14	.357
Lincoln, Paul M.	Electrical Engr.	9	.667
Little, Arthur D.	Chemist/ Research Director	32	.532
Martin, Thomas C.	Writer	14	.276
Martyn, T.J.C.	Writer	7	.428
Maxim, Hudson	Inventor	21	.477
Midgeley, Thomas, Jr.	Chemist	9	.444
Millikan, Robert A.	Physicist	9	.333
Mitchell, William A.	Soldier	19	.368
Muller, Hermann J.	Biologist	11	.263
Ogburn, William F.	Sociologist	18	.500
Parsons, Floyd W.	Writer	42	.214
Pupin, Michael I.	Physicist	8	.625
Rentschler, Harvey C.	Electrical Engr. / Research Director	9	.333
Shaler, Nathaniel	Geologist	10	.500
Slosson, Edwin E.	Writer	10	.500
Steinmetz, Charles P.	Electrical Engr.	<u>25</u> 340	.360

<u>Name</u>	<u>Occupation</u>	<u>Number of Predictions</u>	<u>Batting Average</u>
Suplee, Henry H.	Writer	14	.428
Tesla, Nikola	Inventor	52	.404
Thomson, Elihu	Inventor	14	.787
Thurston, Robert H.	Mechanical Engr.	15	.266
Walker, John B.	Writer	17	.412
Whitney, Willis R.	Chemist/ Research Director	15	.333
Wiener, Norbert	Mathematician	7	.143
Williams, Henry S.	Physician	<u>6</u> 140	.333

Totals: Right: 236 predictions

Established: 85

Not proven: 197

Wrong: 269

Total: 777

Overall batting average: .414

- 2) Predictions by predictors in occupations requiring technical training compared with predictions by predictors in other occupations.

Predictors in occupations
requiring technical training
(TP)

Abbot, CG
Bell, L
Chubb, LW
Compton, KT
Duncan, LD
Edison, TA
Egloff, G
Fernald, RH
Fessenden, RA
Fieldner, AC
Ford, H
Furnas, CC
Hale, WJ
Hammond, JH
Harrison, GR
Haupt, L
Hering, C
Kettering, CF
Lake, S.
Lincoln, PM
Little, AD
Maxim, H
Midgeley, T
Millikan, RA
Pupin, MI
Rentschler, HC
Steinmetz, CP
Tesla, N
Thomson, E
Thurston, RH
Whitney, WR
Total: 31

Others
(NTP)

Babson, RW
Baxter, W
Bellamy, E
Chase, S
East, EM
Eliot, GE
Kaempffert, W
Martin, TC
Martyn, TJC
Mitchell, WA
Muller, HJ
Ogburn, WF
Parsons, FW
Shaler, N
Slosson, EE
Suplee, HH
Walker, JB
Wiener, N
Williams, HS
Total: 19

	<u>Good</u>	<u>Bad</u>	<u>Total</u>
TP	205	257	462
NTP	<u>106</u>	<u>209</u>	<u>315</u>
	311	+ 466	= 777

Chi-squared = 7.56; for one degree of freedom, the association is significant at the .01 level

- 3) Predictions made by predictors in their own specialties compared with predictions made by the same predictors in other areas.

<u>Specialty</u>	<u>Expert</u>
Electrical technology	Steinmetz, CP Edison, TA Rentschler, HC Whitney, WR
Chemistry	Furnas, CC Little, AD
Physics	Harrison, GR Millikan, RA Compton, KT
Mechanical Engineering	Fernald, RH Thurston, RH

	<u>Good</u>	<u>Bad</u>	<u>Total</u>
Own Field	42	46	88
Other	<u>55</u>	<u>68</u>	<u>123</u>
	97	+ 114	= 211

Chi-squared is .010; not significant at the .05 level for one degree of freedom.

4) A test of the hypothesis that prediction was a chance process, with each "technical" predictor having a .450 probability of success on each prediction, and each "non-technical" predictor having a .350 probability of success.

Total chi-squared (sum of (observed-expected)²/expected) for all 50 predictors = 34.63.

For 49 degrees of freedom, this is not significant at the .05 level.

The interpretation of this result is that the data on predictions do not refute the chance hypothesis; therefore they do not force the adoption of an interpretation assuming individual differences between predictors.

5) Events predictions vs effects predictions: a test of the hypothesis that event and effect predictions have the same batting average.

	<u>Good</u>	<u>Bad</u>	<u>Total</u>
Events	570	788	1358
Effects	<u>50</u>	<u>148</u>	<u>198</u>
	620	+ 936	= 1556

Chi-squared = 28.5; for one degree of freedom, this is significant at the .01 level. Therefore the hypothesis that event and effect predictions have the same batting average is rejected. Interpretations: the superiority of the batting average of event predictions is not due to chance.

6) The effect of subject matter on prediction.

Event predictions were sorted into eighteen categories, three categories subdividing each of the six major technology areas. A small number of effect predictions (41) closely identified with specific categories were also included.

<u>Category</u>	<u>Number of Predictions</u>	<u>Batting Average</u>
Energy Sources	259	.386
Energy Conversion	128	.344
Energy Handling*	71	.408
Transport, Air	178	.410
Transport, Message**	104	.480
Transport, Land	207	.377
Automation, Automata	9	.445
Automation, Computer	9	.556
Automation, Functional***	23	.520
Home Environment, Heat & Cool	50	.680
Home Environment, Housing	22	.182
Home Environment, Lighting	24	.459
Materials, Processing	55	.472
Materials, Products	18	.780

*e.g., energy storage, energy transmission

**i.e., communications

*** e.g., remote control devices, automatic assembly lines

<u>Category (Continued)</u>	<u>Number of Predictions</u>	<u>Batting Average</u>
Materials, Sources	31	.290
Military, Air	139	.504
Military, Naval	52	.443
Military, Other	20	.500

Under the hypothesis that predictions in each category are independent events, each with probability. .428 of success, chi-square is 26.34, for 17 degrees of freedom. This is barely significant at the .05 level. Interpretation: the data do not disprove the hypothesis of no difference among the predictabilities of the technology categories, but they do make the hypothesis seem unlikely to be true.

7) Optimism and Pessimism in Prediction: a test of the hypothesis that optimistic and pessimistic predictions had the same batting average.

	<u>Optimistic</u>	<u>Pessimistic</u>	
Good	423	176	599
Bad	<u>662</u>	<u>244</u>	<u>906</u>
	1085	+	420 = 1505

Chi-squared = 1.03; one degree of freedom; not significant at the .05 level. Interpretation: the data do not give grounds for rejection of the hypothesis that optimistic and pessimistic predictions have the same batting average.

8) Timing of Predictions.

A) Absolute timing

<u>Time Period</u>	<u>Batting Average</u>
1890-1914	.424
1915-1929	.364
1930-1940	.417

Hypothesis: all three periods have the same batting average (differences caused by chance). Comparing the middle period to the other two, chi-squared = 2.02. For one degree of freedom, this is not significant at the .05 level.

B) Relative timing

	<u>Good</u>	<u>Bad</u>
Short	63	106
Middle	24	38
Long	44	43

Hypothesis: short and long range predictions have the same batting average.

	<u>Good</u>	<u>Bad</u>	
Short	63	106	169
Long	<u>44</u>	<u>43</u>	<u>87</u>
	107	+	149
			256

Chi-squared = 3.88. For one degree of freedom, this is not quite significant at the .05 level. Interpretation: the data gives no grounds for rejecting the hypothesis that short and long range predictions are equally accurate.

9) Categorization of specific classes of technological events by
prediction accuracy.

Correctly Low-Rated

atmospheric electricity	moving sidewalk
earth current energy	"postage stamp" transport
kerosene motor fuel	magne-train
peat fuel	producer gas locomotive
wind power	split-level streets
radium power	telferage
X-ray conversion of fuel	English Channel tunnel
oil-coal colloidal fuel	high-speed surface ship
hydrogen fuel	automatic weather prediction
nuclear-electric direct	artificial intelligence
energy conversion	fully automatic factory
hot-air engine	remotely controlled vehicles
"Maxwell's Demon" engine	electrical vegetation stimulation
"total energy" systems	electrochemical nitra.es
d. c. electric distribution	artificial food
magnetron rectifier	low-cost desalination
solar heat storage	artificial gold
electron beam energy transmission	aluminum replacing copper
long-range pneumatic power	disposable clothing
air-trains	aluminum from common clay
artificial island air base	cellulose-based organic chemistry
flying wing	coal-based organic chemistry
nuclear powered airplane	crop control by UV light
wireless electric airplane	hydroponics
all-metal airship	district air conditioning
antigravity device	district cooking
individual movies	coke for home heat
phonograph letters	district heat
photophone	infrared home heat
pneumatic mail delivery	gas refrigeration
cryogenic telephone cable	"Roadtown" multiple homes
picturephone	rubber houses
frequency-coded radio	steel and plastic houses
home teletypes	panel home lighting
personal wireless telephones	ultraviolet home lighting
"radio by wire"	electric water jet weapons
voice operated typewriter	noise generator weapons
dymaxion auto	TV propaganda as a weapon
rotary engine auto	heat pump
	death rays

Underrated

natural gas adequacy
thermal "cracking" of oil
catalytic "cracking" of oil
gas turbines
pumped water energy storage
long distance pipelines
jet airplanes
color movies
sound movies
3-d movies
communication through space
radio broadcasting
automatic telephone answering
telephonic advances (e. g., undersea cable)
diesel auto
diesel truck/bus
long-span bridges
self-propelled trains
turbo-electric ships
automation of office work
farm automation
industrial remote control
industrial electronics
low-cost oxygen
cryogenics
electric steelmaking
electrochemical industries
electric welding
electric furnaces
Haber nitrogen process
powder metallurgy
increased use of concrete
artificial fibers
synthetic glass
heavy hydrogen
artificial leather
light metal alloys
synthetic rubber
new iron ore supplies
petrochemistry
uses for silicon
adequacy of raw materials

Underrated (Continued)

sufficiency of water
frozen foods
microwave cooking
electric refrigerators
mobile homes
sun lamps
anti-aircraft systems
infrared aircraft detection
radar
air craft carriers
interceptor aircraft
military use of helicopters
nuclear submarines
tanks

Totally overlooked

scientific oil exploration
liquid natural gas technology
communications satellites
centralized railroad traffic control
differential analyzers
numerical machine control
computer control of tools
computerized assembly line
semiconductors
military jet aircraft
stainless steel
anti-aircraft missiles
military satellites
air-to-air missiles
nuclear powered surface ships
proximity fuse
" atomic cannon"

Overrated

shale oil
tidal power
solar power
nuclear fusion
"heat sink" power
alcohol power
by-product coal gas
coal gasification
coal liquefaction
fuel cells
integrated gas-electric plants
electrochemical fuels
gas engines
superpower
high-energy density storage batteries
cryogenic cables
direct current transmission
aerial flivver
diesel airplane
commercial airship
facsimile newspapers
telepathy
electric automobiles
streamlined autos
electric main-line railroads
high speed railroads
cargo-carrying submarines
"chemical" automation (robot)
"mechanical" automation (robot)
industrial photocell
metals from the sea
wood-pulp based fibers
biochemical food production
farm chemurgics
modular homes
"cold light"
interchangeable military/civil aviation
remotely piloted vehicles
military airships
aerial gas warfare

Correct

adequate coal supply
adequate oil supply
geothermal power
water power
nuclear fission
combined-cycle plants
diesel power
steam turbines
a. c. electric distribution
a. c. electric transmission
airplanes
helicopters
rocket-powered space flight
civilian radar
radio telephony
radio telegraphy
television
internal combustion automobiles
automobile trucks
automobile expressways
ship canals, new (St. Lawrence Seaway)
diesel railroads
computers
feasibility of transmuting elements
waste purification
plastics
air conditioning
agricultural productivity improvement
electric cooking
electric home heat
gas/oil home heat
fluorescent light
low-cost incandescent light
military aviation
aerial bombing
ballistic missiles
sonar
submarines
nuclear bombs

BIBLIOGRAPHY

Primary Sources (Sources of Predictions)

1. Articles and Books

- Abbot, Arthur Vaughn. "Industrial Niagara," Review of Reviews, XII (Sept., 1895), 295
- Acheson, Edward G. "The Electrochemist and the Conservation of Our Natural Resources," Trans. Amer. Electrochemical Soc., XV (May, 1909), 19-29
- Ackermann, A. S. E. "The Utilization of Solar Energy," Annual Report of the Smithsonian Institution, 1915. Washington: Government Printing Office, 1916. pp. 145-160
- Adams, Alton D. "Twentieth Century Energy," Scientific American, LXXXIII (July 14, 1900), 19
- Adams, Edwin Plimpton, "Radioactivity," Trans. Amer. Inst. Electrical Engineers, XXXIII (April, 1918) 693-678
- Adams, Henry. "The Rule of Phase Applied to History," in Perry Miller, ed., American Thought, Civil War to World War I. New York: Holt, Rinehart & Winston, pp. 278-304
- Alexanderson, E. F. W. "Radio Photography and Television," General Electric Review, XXX (Feb., 1927), 78-85
- Armstrong, A. H. "The Last Stand of the Reciprocating Steam Engine," Trans. Amer. Inst. Electrical Engineers, XXXIX (1920), 209-218
- Arnold, Ralph. "The Petroleum Resources of the United States," Annual Report of the Smithsonian Institution, 1916, Washington: Government Printing Office, 1917, pp. 273-287
- Arrhenius, Svante. "The World's Supply of Energy," Scientific American Monthly, II (Feb. 1920), 103-106
- Atkinson, Edward. "Coal is King," Century Magazine, LV (April, 1898), 828-830

- Atwood, Albert A. "The Future City," Saturday Evening Post, CCI (September 8, 1928), 10-11
- Babson, Roger W. "Air Flivvers and the Future," Forum LXXXI (March, 1929), 158-162.
- Babson, Roger W. "There's Magic in the Air," Collier's LXXXI (April 7, 1928), 8-9+.
- Bacon, R. F. and Hamor, W. A. American Fuels. 2 Vol. New York: McGraw-Hill, 1922.
- Baxter, William. "The Electrical Transmission of Water Power," Popular Science Monthly, LII (April, 1898), 730-742.
- Baxter, William. "Forecasting the Progress of Invention," Popular Science Monthly, LI (June, 1897), 307-314.
- "Beama." "A Sociologic Aspect of Superpower," Trans. Amer. Inst. Electrical Engineers. XLIII (Jan., 1924), 36.
- Behrend, B. A. and Wessling, A. G. "The Future of the Electric Railway," Electrical World, XXXVII (Jan. 12, 1901), 82-83.
- Bell, Louis. "Electrical Power Transmission," Electrical World, XXXVII (Jan. 5, 1901), 32.
- Bell, Louis. "Natural Sources of Energy," Cassier's, XXIV (Aug., 1903) 305-311.
- Bellamy, Edward. Equality. Boston: Appleton, 1897.
- Bliven, Bruce. "Metropolis, 1960 Style," New Republic, LXXXII (1935), 211-212.
- "The Bogey of War in the Air," Forum, XCII (Dec., 1934), 344-348.
- Bolton, Reginald P. "An Overestimated Value," Cassier's, XLIV (July, 1913) 69-74.
- Brady, A. N. "Electricity in the Service of Man," North American Review, CLXXIII (Nov., 1901), 677-683.
- Brady, John T. "The Inventions of the Future," Popular Mechanics, XLIV (April, 1928), 536-542.

Brandt, Alfred. "Has Germany a 'Death Ray'," Forum, CII (Feb., 1940), 64-65.

Byrd, Richard E. "The Coming Age of Aviation," Forum, LIV (Oct., 1927), 600-610.

Campbell, Marius R. "The Coal Fields of the U. S.," General Electric Review, XXI (Sept., 1919), 618-625.

_____. "How Long Will the Coal Reserves of the United States Last?" National Geographic, XVIII (Feb., 1907), 129-139.

Carnegie Endowment for International Peace. International Conciliation: Documents for the Year 1928. New York: Carnegie Endowment, 1929.

Carpenter, F. G. "The Fixation of Nitrogen," Jour. Industrial and Engrng. Chemistry. I (Jan, 1904), 4-5.

Carrel, Alexis and Lindberg, Charles. "The Culture of Whole Organs," Science, LXXXI (June 21, 1935), 621-623.

Chase, Stuart. "The Challenge of Waste to Existing Industrial Creeds," Nation, CXII (Feb. 28, 1921), 284-287.

_____. The Economy of Abundance. New York: MacMillan, 1934.

_____. "The Future of the Great City," Harper's, CLX (Dec., 1929) 82-90.

_____. Out of the Depression. Number 2, the JOHN DAY Pamphlets, 1931.

_____. "Slaves of the Machine," Harper's, CLVIII (March, 1929), 480-489.

_____. "Two Hour War," New Republic, LVIII (May 8, 1929), 325-327.

Chubb, L. Warrington. "Research in the Future," Scientific American, CXLVII (July, 1932), 12-13.

Churchill, Winston. "Fifty Years Hence," Review of Reviews, LXXXV (Jan., 1932), 58.

- Clark, John Bates. "Recollections of the Twentieth Century," Atlantic, LXXXIX (Jan., 1902), 4-16.
- Claudy, C. H. "Aircraft of the Future," Scientific American, CXXIII (Nov. 20, 1920), 520-530.
- Compton, Karl T. "The Battle of the Alchemists," Electrical Engineering, LII (Feb., 1935), 75-80.
- _____. "Put Science to Work," Technology Review, XXXVIII (Jan., 1935), 152-154.
- Cooke, Morris L. "Giant Power: Foreword," Ann. of the Amer. Acad. of Pol. and Soc. Sci., CXVIII, (March, 1925), v.
- _____. "Giant Power and Coal," Ann. of the Amer. Acad. of Pol. and Soc. Sci., CXI (Jan., 1924), 212-216.
- Cooper, Willard. "The Navy and the Next War," Independent, CXIV (June 6, 1925), 640-645.
- Corbett, Harvey W. "The City of the Future," Outlook, CXL (Jan. 1925), 48.
- "Country Roads and Electricity," Scientific American, LXIX (April 15, 1893), 231.
- Craft, E. B. and Copitts, E. H. "Radio Telephony," Trans. Amer. Inst. Of Electrical Engineers, XXXVIII (April, 1919), 305-343.
- Cree, John K. "The Influence of the Air Ship on War," North American Review, CLXII (Jan., 1896), 78-83.
- DeVoto, Bernard. "The Absolute in the Machine Shop," Harper's, CLXXII (Dec., 1935), 125-128.
- Doherty, Henry L. "Our Future Sources of Energy," Jour. Industrial and Engrng. Chemistry, XVIII (Oct., 1926), 1062-1064.
- Donnelly, Ignatius. Caesar's Column. Cambridge: Belknap, 1960 (reprint).
- The Drift of Civilization. London: Allen and Unwin, 1929.
- Duncan, Louis D. "The Future of Electricity in Railroad Work," Jour. of the Franklin Inst., CXLI (June, 1896), 416-435.

- Duncan, Louis D. "The Substitution of Electricity for Steam in Railway Practice," Trans. Amer. Inst. of Electrical Engineers, XII (June, 1895), 374-388.
- Duncan, Robert K. "Problems of Industrial Alcohol," Harper's, CXV (Aug., 1907), 463-469.
- _____. "On the Trend of Chemical Invention," Harper's, CXVII (Nov., 1908), 866-872.
- Durand, William F. "Developments in Prime Movers," Electrical World, LXI (Jan. 14, 1913, 31-37.
- Edison, Thomas A. "If the Answer's Easy, It's Wrong." Collier's LXXIV (Dec. 6, 1924), 5-6+.
- _____. "The Storage Battery," North American Review, CLXXV (July, 1902), 1-4.
- _____. and McMahon, John. "Inventions of the Future," The Independent, LXVIII (Jan., 1910), 15-18.
- Eliot, George F. Bombs Bursting in Air. New York: Reynal & Hitchcock, 1939.
- _____. The Ramparts We Watch. New York: Reynal & Hitchcock, 1938.
- _____. "Three Thousand More Airplanes?" New Republic, XCVII (Jan. 25, 1939) 334-335.
- Elsdale, Henry. "Scientific Problems of the Future," Annual Report of the Smithsonian Institution, 1895. Washington: Government Printing Office, 1896, pp. 667-679.
- Eustis, John R. "The Future of Motor Travel," The Independent, XCVI (Nov. 9, 1918), 174.
- "The Expanding Decade," Fortune, III (June, 1931), 72-74+.
- Fay, Bernard. "In Our Stars-III," Forum, LXXXIX (Jan., 1933), 13-18.
- Fernald, Robert H. "Fuel Wastes: Causes, Effects, and Remedies," Annals of the American Academy of Pol. and Soc. Sci., CXI (Jan., 1924), 232-247.

- Fernald, Robert H. "Is Our Fuel Supply Nearing Exhaustion?" General Electric Review, XXI (Aug., 1921), 551-556.
- Fessenden, Reginald A. "Light Without Heat," Electrical World, XXXVII (Jan. 5, 1901), 26.
- Fieldner, A. C. and Brown, R. L. "Future Trends in Automobile Fuels," Jour. of Ind. and Engrng. Chemistry, XVIII (Oct., 1926), 1003-1013.
- Flather, John J. "Modern Tendencies in the Use of Power," Science, XVII (Jan. 9, 1903), 48-53.
- Fleming, J. A. "The Sources of Energy Available to Man," Scientific American Supplement, LXXIV (Nov. 30, 1912), 341-343.
- _____. Obstruction of Progress, " Nineteenth Century, XLIX (Feb., 1901), 348-363.
- Fletcher, Henry J. "The Drift of Population to the Cities: Remedies," Forum, XIX (Aug., 1895), 737-745.
- Fournier, D'Albe, E. E. "The Myth of the Death Ray," New Republic, XXXIX (1927), 207-208.
- Furnas, Claude C. "A Chemist's Forecast," New York Times Magazine (Dec. 10, 1939), 14-15.
- _____. The Next Hundred Years. New York: Reynal and Hitchcock, 1936.
- "The Future as Suggested by Developments of the Last Seventy-five Years," Scientific American, CXIII (Oct. 2, 1920), 320-331.
- Ford, Henry, and Crowther, Samuel. Today and Tomorrow. Garden City, N. Y.: Doubleday, Page, and Co., 1926.
- Golois, George. "Is the Practical Helicopter in Sight?" Scientific American, CXXVII (June 4, 1921), 447.
- General Motors Corporation, Preview of Industrial Progress in the Next Century. Privately printed, 1934.
- Gilbert, Chester G. and Pogue, Joseph E. America's Power Resources. New York: Century, 1921.

- Goodman, Lynn S. and Jackson, William B. "Effects of War Conditions on Cost and Quality of Electric Service," Jour. of the Amer. Inst. of Electrical Engineers, XXXVII (Jan., 1918), 1-17.
- Goodwin, H., Jr. "Design of a Super-Power Station," General Electric Review, XXIII (May, 1920), 399-418.
- Gould, Bruce. "Aviation Blues," New Republic, LXIV (Aug. 20, 1930), 10-11.
- Gray, George W. The Advancing Front of Science. New York: Whittlesey House, 1937.
- Greenwood, Ernest. Aladdin, U.S.A. New York: Harper & Brothers, 1928.
- Haines, Harry B. "The Automobile," World's Work, XI (March, 1906), 734-769.
- Hale, William J. "Prophecy of a Chemist," Scientific Monthly, XXII (Feb., 1926), 161-166.
- _____. "When Agriculture Enters the Chemical Industry," Jour. of Ind. and Engrng. Chemistry, XXII (Dec., 1930), 1311-1315.
- Hall, Edwin H. "Liquid Air and Motive Power," Forum, XXVII (Aug., 1899), 713-716.
- Hammond, John Hays, Jr. "The Future Mechanism of Warfare," North American Review, CCIV (Sept., 1916), 373-380.
- Halstead, Murat. "Electricity at the Fair," Cosmopolitan, XIV (1894), 577-579.
- Harrison, George Russell. Atoms in Action. New York: William Morrow and Company, 1939.
- Haskell, Douglas. "From Automobile to Road Plane," Harper's, CLXIX (July, 1934), 171-181.
- _____. "Houses Like Fords," Harper's, CLXVIII (1933), 286-296.
- Haslam, R. T. "The Relation of Chemistry to the Development of Power," Jour. of Ind. and Engrng. Chemistry, XVIII (Oct., 1926) 1047-1051.

- Haslam, R. T. and Thiele, E. W. "Recent Progress in the Field of Fuels and Fuel Technology," Jour. of Ind. and Engrng. Chemistry, XVI (July, 1924), 749-753.
- Haupt, Lewis. "Present Problems for Technology," Proceedings of the Congress of Arts and Sciences, 1904. Boston: Houghton, Mifflin, 1906. pp. 571-590.
- Hazen, Harold L. "Working Mathematics by Machinery," Technology Review, XXXIV (May, 1931), 323-327.
- Henney, Keith. "When Will Television Come?" Review of Reviews, LXXXV (Jan., 1932), 44-48.
- Holland, James P. "The Future of the Automobile," Munsey's Magazine, XXIX (May, 1903), 171-177.
- Horton, J. Warren. "Looking 'Round the Corner," Technology Review, XXXV (Oct., 1932), 5-8+.
- Howe, Harrison E. "Chemicals in Warfare," Jour. of Ind. & Engrng. Chemistry, XXX (April, 1938), 366.
- Howells, William Dean. Letters of an Altrurian Traveler. Gainesville, Fla.: Scholars Facsimiles and Reprints, 1961.
- Hull, Albert W. "The Magnetron," Jour. of the Amer. Inst. of Electrical Engineers, XL (Sept., 1921), 715-723.
- Huxley, Julian. "In Our Stars- IV," Forum, LXXXIX (April, 1933) 241-245.
- "In Debatable Air," Fortune, III (May, 1931), 53-55.
- Ingalls, D. S. "Autogiros," Fortune III (March, 1931), 77-78.
- Jacques, William W. "Electricity Direct From Coal," Harper's, XCIV (Dec., 1896), 144-150.
- Jaeger, F. M. "The Present and Future State of Our Natural Resources," Science LXIX (April 10, 1929), 442.
- Jewett, Frank B. "Wireless Telephony," Review of Reviews, LIX (June, 1919), 503.

Johnson, Albert L. "The Trolley Age," Scientific American Supplement, LI (April 27, 2901), 21180.

Kaempffert, Waldemar. "Aircraft and the Future," Outlook, CIV (June, 1913), 452-456.

_____. "Boundless Fronteirs of Science," New York Times Magazine (May 19, 1940), 10-11+.

_____. "Harnessing Nature," Scientific American, CVIII (April 5, 1913), 308-309.

_____. "A Modern Jules Verne," Literary Digest, XCVII (May 12, 1928), 62-66+.

_____. Science, Today and Tomorrow. New York: Viking, 1939.

_____. "What Shall We Do For Gasoline?" Outlook, CV (Dec. 6, 1913), 755-758.

_____. "When Science Dictates," Current History, XLIII (Oct., 1935), 45-50.

_____. "Will a New Weapon Win the War?" New York Times Magazine (Feb. 18, 1940).

Kettering, Charles F. "Motor Design and Fuel Economy," Jour. of Ind. and Engrng. Chemistry, XVII (Nov., 1925), 1115.

Kingdon, Kenneth H. "Another Step Toward Atomic Power," General Electric Review, XLIII (June, 1940), 229.

Lahm, Frank P. "Airship and Aeroplane in War," Scientific American Supplement, LXXI (March, 1911), 206.

Lake, Simon. "The Art of Submarine Defense," Century, LXXXIX (March, 1915), 724-732.

_____. "The Future of the Submarine," World's Work, LV (June, 1928), 604-611.

_____. The Submarine in War and Peace. Philadelphia: Lippincott, 1918.

- Lang, Daniel. "Ike and Mike on the Air," New Republic, XCIV (May 13, 1939), 41.
- Lanier, Charles D. "Thomas A. Edison," Review of Reviews, VIII (1893), 50-53.
- Leavitt, Robert K. "What Shall We Sell When the Upturn Comes?" Forum, LXXXIX (March, 1932), 341-347.
- Ledwinka, Joseph. "The Automobile Will Come Back," North American Review, CCXXXIII (Jan., 1932), 59-64.
- Leonard, Jonathan N. "When the Oil Gives Out," Nation, CXXIII (December 1, 1926), 557-559.
- Lewes, V. B. "The Future of Coal Gas," Scientific American Supplement LVI (1903), 23143-23144.
- Lincoln, Paul M. "Limitations of Long-Distance Electric Power Transmission," Cassier's, XXVI (June, 1904), 129-130.
- Linde, Carl Von. "Practical Liquid Air Possibilities," Cassier's, XXIV (June, 1903), 139-144.
- Little, Arthur D. "The Chemist's Place in Industry," Jour. of Ind. and Engrng. Chemistry, II (Jan., 1910), 63-65.
- _____. "The Fuel Problem," Atlantic, CXXVII (Feb., 1921), 190-199.
- _____. The Handwriting on the Wall. Boston: Little, Brown and Co., 1928.
- _____. "Our Power Problem," Collier's, LXX (Aug. 19, 1922), 5-6.
- MacKaye, Benton. "Cement Railroads," Survey LXVIII (Nov. 1, 1932), 542-542.
- _____. "Townless Highway," New Republic LXII (March 12, 1930), 93-95.
- Martin, Thomas C. "Fixing Nitrogen," Review of Reviews, XXVI (Sept., 1902), 338-342.

Martin, Thomas C. "The Protean Power," North American Review, CXXIII (July, 1923), 48-58.

Maxim, Hudson. "Plenty Left to Invent," Literary Digest, LXXVI (March 17, 1923), 28.

_____. Reminiscence and Comments. New York: Doubleday, Page and Co., 1924.

_____. "Warfare of the Future," Science, XXVIII (Dec. 11, 1908), 830-831.

McClatchie, S. "Industrialism Near Journey's End," North American Review, CCXXXII (Oct., 1931), 328-335.

McKenzie, K. G. "Petroleum Motor Fuel," Jour. of Ind. and Engrng. Chemistry, XVII (Nov., 1925), 1108-1113.

McMillan, Wheeler. "Chemurgy," Jour. of Ind. and Engrng. Chemistry, XXXI (May, 1939), 540-545.

Melville, George W. "The Engineer and the Problem of Aerial Navigation," North American Review, CLXXIII (Dec., 1901), 820-831.

_____. "The Submarine, its Promises and Performance," North American Review, CLXXII (April, 1901), 584-590.

Mershon, Ralph D. "Long Distance Power Transmission," Engineering Magazine, XXVIII (Feb., 1905), 830-832.

Merz, Charles. "Twentieth Century Medievalism," Century, LXXXIV (June, 1923), 228-236.

Midgeley, Thomas, Jr., "The Application of Chemistry," Jour. of Ind. and Engrng. Chemistry, XIV (Sept., 1927), 849-851.

Midgeley, Thomas Jr., "Chemistry in the Next Century," Jour. of Ind. and Engrng. Chemistry, XXVII (May, 1935), 494-498.

Millikan, Robert A. "Alleged Sins of Science," Scribner's, LXXXVII (Feb., 1930), 118-125.

_____. "Available Energy," Science, LXVIII (Sept. 28, 1928), 279-284.

Millikan, Robert A. Science and the New Civilization. New York: Charles Scribner's Sons, 1930.

Mitchell, William. "Building a Futile Navy," Atlantic, CXLII (Sept., 1928), 408-413.

_____. Winged Defense. Port Washington, N. Y.: Kenniket Press, 1971.

Moody, W. S. "General Trend of Development in Transmission and Distribution of Electric Power," General Electric Review, XV (1912), 337-341.

Morgan, Appleton. "The Successor to the Railway," Popular Science Monthly, XLVI (April, 1895), 750-759.

Morrow, L. W. W. "Economics of Power," Trans. Amer. Electro-chemical Soc., LXX (1936), 165-170.

Morton, Henry. "Liquid Air as a New Source of Power," Scientific American, LXXX (April 22, 1899), 245.

Muller, Hermann J. Out of the Night. New York: Vanguard, 1935.

Mumford, Lewis. "The Flaw in the Mechanical House," New Republic LXVII (June, 1933), 65-66.

_____. "In Our Stars - II," Forum, LXXXVIII (March, 1933), 339-347.

_____. "The Intolerable City," Harper's, (April, 1926), 283-293.

Murray, W. S., et. al. "The Economical Supply of Electric Power," Jour. of the Amer. Inst. of Electrical Engineers, XXXIX (Mar., 1922), 219-222.

Newcomb, Simon. "Is the Airship Coming?" McClure's, IV (May, 1903), 432-435.

_____. "The Prospect of Aerial Navigation," North American Review, CLXXXVII (Mar., 1908), 337-347.

"9000 Billion Horsepower of Solar Energy," Fortune, XVIII (Nov., 1938), 87+.

Newell, F. H. "Relation of By-Product Coke Ovens to Superpower,"
Jour. of Ind. and Engrng. Chemistry, XVIII (Oct., 1926), 1052-1054.

Norris, J. F. "A Look Ahead," Jour. of Ind. and Engrng. Chemistry,
XVIII (Oct., 1926), 994-997.

Ogburn, William F. "The Future of Man in Light of His Past,"
Scientific Monthly, XXXII (April, 1931), 294-300.

_____. "A Sociologist's Forecast," New York Times
Magazine (Dec. 10, 1939), pp. 14-15.

Ogden, Wilfred S. "Deep Sea Anchor to Revolutionize Ocean Travel,"
Popular Science Monthly C (May, 1932), 29-32.

O'Neill, J. J. "Enter Atomic Power," Harper's, CLXXXI (June, 1940),
1-10.

Ormandy, W. R. "Alcohol as a Motive Power," Engineering Magazine,
XXVII (June, 1904), 430.

Parker, Ralph C. "Nothing But Airplanes?" North American Review,
CCXXXIII (April, 1932), 252-259.

Parr, S. W. "Future Trends in Low Temperature Carbonization,"
Jour. of Ind. and Engrng. Chemistry, XVIII (Oct., 1926), 1015-1016.

Parrish, Wayne A. "Technocracy's Question," New Outlook, CLXI
(Dec., 1932), 13-16.

Parsons, Floyd W. "Inventions of the Future," Saturday Evening Post,
CXC VII (March 14, 1925), 26-27.

_____. "A Look Ahead," Saturday Evening Post, CXCII
(Aug. 9, 1931), 150+.

_____. "Looking Ahead," World's Work XLIV (July, 1922),
143-149+.

Patrick, Mason M. "Military Aircraft and their Use in Warfare,"
Jour. of the Franklin Institute, CLXXXIX (Jan., 1925), 51-63.

Platt, Haviland Hull. "A New Source of Power," Scientific American,
CXXXI (Dec., 1924), 120.

- Pogue, J. E., "Mineral Resources in War," Scientific Monthly, V (Aug., 1917), 120-134.
- _____. Economics of the Petroleum Industry. Preprint: 1939.
- Polakov, Walter. "Oil," New Republic, XXXI (June 14, 1922), 68-70.
- Pope, Charles H. Solar Heat. Boston: Pope, 1903.
- Porter, Horace C. "Coal Carbonization and the World's Fuel," Jour. of Ind. and Engrng. Chemistry, XV (April, 1923), 335-338.
- Proceedings of the International Conference on Aerial Navigation. New York: Amer. Engrng. and Railroad Journal, 1894.
- Proceedings of the International Electrical Congress. Chicago, August 21st to 25th, 1893. New York: American Inst. of Electrical Engineers, 1894.
- Rentschler, Harvey C. "How Shall We Live in the Future," Scientific American, CXLVI (Feb., 1932), 71-74.
- Report of the Eightieth Meeting of the British Science Guild. London: John Murray, 1911.
- Rice, E. W., Jr. "Research and Power," Scientific American, CXXXI (Oct., 1924), 234-5+.
- Richards, Joseph W. "Conditions of Progress in Electro-Chemistry," Trans. Amer. Electrochemical Soc., III (Jan., 1903), 67-73.
- Roeber, E. F. "Some Economic and Aesthetic Aspects of Electro-chemistry," Jour. Ind. and Engrng. Chemistry, VI (May, 1914), 436-439.
- Ronald, Malcolm B. "Autogyro," Atlantic, CLIX (Jan., 1937), 20-27.
- Ruggles, C. O. "Problems in the Development of a Super Power System," Harvard Business Review, II (June, 1924), 160-173.
- "S.O.S. Calls by Noted Men," Popular Science Monthly, C (Feb., 1922), 68-69.
- Scarritt, Winthrop E. "The Future of the Automobile," Cassier's, XXIX (May, 1906), 427-430.

"Science and Industry in the Coming Century," Scientific Monthly XXXIX (July, 1934), 68.

Scott, Riley F. "Dropping Bombs from Flying Machines," Scientific American, CX (Oct. 28, 1911), 388-389.

Seldes, Gilbert. "The 'Errors' of Television," Atlantic, CLIX (May, 1937), 531-541.

Severy, Melvin L. Gillette's Industrial Solution. Boston: Hall, 1908.

Shaler, Nathaniel. Man and the Earth, New York: Fox, Duffield, and Co., 1905.

Sherwood, Robert E. "Beyond the Talkies--Television," Scribner's, LXXXVI (July, 1929), 1-8.

Shuman, Frank. "Letter," Scientific American, CX (June, 27, 1914), 519.

Sims, William S. "The Battleship and the Airplane," World's Work, XLIII (May, 1921), 25-28.

Skinner, Charles M. "The Electric Car," Atlantic, LXXXIX (June, 1902), 799-808.

Sloan, Alfred P. "The Forward View," Atlantic, CLIV (Sept., 1934), 257-264.

Slosson, Edward E. "The Expansion of Chemistry," Jour. of Ind. and Engrng. Chemistry, XVI (May, 1924), 447-449.

_____. "An Inventory of Energy," Scientific Monthly, XVI (Feb., 1923), 217-219.

_____. "Gasolene as a World Power," Science Remaking the World. New York: Doubleday, Page, and Co., 1923, pp. 12-47.

_____. Snapshots of Science. New York: Century Co., 1928.

Smith, A. W. "The Nature of the Next War," Harper's, CLXIX (July, 1934), 190-201.

Smith, Willard Hart. "The Wings of To-Morrow," Forum, LXI (Feb., 1919), 197-209.

Soddy, Frederick. Science and Life. London: Murray, 1920.

- Spear, L. V. "Battleships or Submarines?" Foreign Affairs, VI (Oct., 1927), 106-115.
- Spoehr, Hermann A. "Civilization Must Fall Unless Solar Energy is Utilized," Science, LVI (Dec. 8, 1922), x.
- _____. Photosynthesis. New York: Chemical Catalog Co., 1926.
- Sprague, Frank J. "The Future of the Electric Railway," Forum, XII (Sept., 1891), 120-130.
- Squier, George O. "The Present Status of Military Aeronautics," Annual Report of the Smithsonian Institution, 1908. Washington: Government Printing Office, 1909. pp. 152-166.
- Steinmetz, Charles P. America and the New Epoch. New York: Harper and Brothers, 1916.
- _____. "America's Energy Supply," Trans. Amer. Inst. of Electrical Engineers, XXXVII (Dec., 1918), 985-999.
- _____. "The Effect of Electrical Engineering on Modern Industry," General Electric Review, XVII (May, 1914), 392-396.
- _____. "You Will Think This a Dream," Ladies Home Journal, XXXII (Sept., 1915), 12.
- Straus, Joseph. "Air Power-- the Myth and the Reality," Outlook CXL (May, 1925), 290-291.
- Stuart, A. T. "Hydroelectric Fuel," Jour. of Ind. and Engrng. Chemistry, XIX (Dec., 1927), 1321-1324.
- Studley, Barrett. "Bombing Planes or Battleships?" North American Review, CCXXVII (June, 1929), 727-736.
- "Submarines to the Scrap Heap," Independent, CXV (Nov. 28, 1925), 602-603.
- "Superpower-- a National Resource," Trans. of the Amer. Inst. of Electrical Engrs., XLII (June, 1923), 648.
- Suplee, Herbert H. "Applied Science," Forum, XXXVIII (July, 1906), 62.

Sutherland, George. Twentieth Century Invention. London: Longmans, Green and Co., 1901.

"Television," Fortune, XIX (April, 1939) 53-59+, and (May, 1939), 69-74+.

Tesla, Nikola. "On Electricity," Electrical Review (Jan. 27, 1897) copied in Nikola Tesla. Beograd, Yugoslavia: Tesla Museum, 1956.

_____. "The Problem of Increasing Human Energy," Century, LXIX (July, 1900), 175-211.

_____. "Transmission of Electrical Energy," Electrical World and Engineer (Jan. 7, 1905), 21-24.

_____. "When Woman is Boss," Collier's, LXXVII (Jan. 30, 1926), 17+.

Thomson, Elihu. "Alcohol and the Future of the Power Problem," Cassier's XXX (Aug., 1906), 310-312.

_____. "Electricity in the Coming Century," Electrical World, XXXVII (Jan. 5, 1901), 20-21.

_____. "Fuel Into Electrical Energy," Electrical World, XXIX (Jan. 2, 1897), 4.

_____. "Future of Electrical Development," New England Magazine, VI (July, 1892), 623-635.

_____. "Possibilities of Liquid Air in Electrical Work," Scientific American, LXXVII (Jan. 1897), 118.

_____. Selections from the Scientific Correspondence of Elihu Thomson, Harold J. Abrahams and Marion B. Savin, eds. Cambridge: MIT Press, 1971.

(Lord) Thomson. "Aerial Warfare or Disarmament," Survey Graphic, LIII (Feb. 1, 1925), 503-507.

Thurston, Robert H. "The Next Great Problems of Science," Forum, XIV (Sept., 1892), 42-50.

_____. "The 'Rotary' Steam Engine," Scientific American, LXXVI (April 3, 1897), 211.

- Thurston, Robert H. "The Steam Turbine," Scientific American Supplement, LI (Sept., 1901), 20930.
- _____. "Utilizing the Sun's Energy," Annual Report of the Smithsonian Institution, 1901. Washington, Government Printing Office, 1902. pp. 263-270.
- Tichenor, Frank A. "Wings for the Nation," North American Review, CCXXVII (March, 1929), 521-528.
- "To Nine Unknowns," Technology Review XXXIX (Jan., 1937)
- Towle, Herbert L. "The Automobile of Tomorrow," Scribner's Magazine, XLIII (May, 1908), 581-586.
- Train, Arthur, Jr. "Catching Up With The Inventors," Atlantic, CLXIII (March, 1939), 371-375.
- Transactions of the First World Power Conference. London: Percy Lund Humphries, 1925.
- Transactions of the Third World Power Conference, 1936. Vol. I. Washington: Government Printing Office, 1938.
- "The Trend in Electrical Development," Scientific American, LXXIII (Oct. 26, 1895), 267.
- Tripp, Guy E. "The Electrification of North America," World's Work, XLVI (Sept., 1923), 498-504.
- "Unsolved Problems that Edison is Studying," Scientific American, LIX (July, 1923), 25.
- Vanderbilt, Cornelius. "Electricity as a Motive Power," North American Review, CLXXV (Dec., 1902), 779-790.
- von dem Borne, Georg. "Energy Sources of the Future," Scientific American Supplement, LXXVII (Jan. 31, 1914), 80.
- Waldron, George B. "Harnessing the Sea and the Sun," Current Literature, XXXI (Dec., 1901), 735-736.
- Walker, John B. "Great Inventions and Discoveries Which are Changing the World," Cosmopolitan, XXXVII (June, 1904), 621-622.

- Walker, John B. "The Final Conquest of the Air," Cosmopolitan, XXXVI (May, 1904), 501-514.
- Walsh, George E. "An Electric Farm," North American Review, CLXIII (May, 1895), 509-515.
- _____. "A New Era in Rapid Transit," New England Magazine, XXXVII (Feb., 1904), 181-186.
- Warner, Edward P. "Can Aircraft Be Limited?" Foreign Affairs, X (April, 1932), 431-443.
- Warren, Arthur. "The Turbine: A New Era of Steam," Review of Reviews, XXIX (June, 1904), 695.
- Warren, Edward C. "Lines of Progress in the Efficiency of the Combustion Engine," Engineering Magazine, XXVI (Feb., 1904), 664.
- Wells, Philip A. "Our Federal Power Policy," Survey Graphic, LI (Sept., 1924), 570-573.
- Wenstrom, William H. "Inventions Win Wars," Scientific American, CLXII (June, 1940), 324-326.
- West, A. G. "The Anti-Aircraft Fable," North American Review CCXXXII (May, 1931), 504, 511.
- Wetzler, Joseph. "Will the Electric Motor Supersede Steam?" Scribner's XVII (May, 1895), 594-600.
- Wheeler, Edgar C. "Tomorrow's Motor Car," World's Work, LIV (May, 1927), 77-85.
- White, Bert H. "They've Got Your Future All Planned," Saturday Evening Post CCXI (June 10, 1930), 11.
- White, Eugene R. "Niagarics, the New Force," Munsey's XXIX (April, 1905), 29-30.
- White, William C. "Radiotelephony," General Electric Review, XVIII (Jan., 1915), 38-41.
- Whitford, H. N. "Possibilities of the Plant Growth of the Moist Tropics to Furnish Materials for Liquid Fuel," Journal of Industrial and Engineering Chemistry, XIV (Feb., 1922), 151-157.

Wiener, Norbert. "Putting Matter to Work," Technology Review, XXXVI (Nov., 1933), 47.

Wiley, Harvey. "Zero at the Equator Some Day," New York Times Magazine (Jan. 1, 1911), 3+.

Williams, Henry S. "Six Ways to Make A Billion Dollars," American Magazine, CX (July, 1927), 13-15.

Williams, W. A. "Our Future Petroleum Industry," General Electric Review, XXI (Jan., 1918), 70-77.

Wilson, Otto. "Gases in Commerce and Industry," Jour. of Ind. and Engrng. Chemistry, XVIII (Dec., 1926), 1273.

Woodward, Calvin M. "Lines of Progress in Engineering," Science, XXI (Jan. 6, 1905), 8-14.

World Power Conference, Power Resources of the World. London: World Power Conference, 1929.

Yates, Raymond W. Machines Over Men. New York: Frederick A. Stokes and Co., 1939.

2. Public Documents

U. S. Congress, House, Committee on Military Affairs, Aeronautics in the Army, 63d Congress, 1st Sess. (Aug. 12, 1913), House Doc. 5304.

_____, Committee on Naval Affairs, Hearings on H. R. 9218 to Establish the Composition of the United States Navy, Jan. 31, 1938. Washington: Government Printing Office, 1938.

_____, Committee on Science and Astronautics, Applied Science and Technological Progress. Washington: Government Printing Office, 1937.

_____, Special Message of the President, Jan. 15, 1909. 60th Congress, 2d Sess., House Doc. 1850.

U. S. Congress, Senate, Staff Corps Increase, Submarine Boats. 57th Congress, 1st Session (June 6, 1902). Senate Doc. 395.

_____, Committee on Military Affairs. An Act to Provide More Effectively for the National Defense. U. S.: Government Printing Office, 1939.

U. S. Congress, Senate, Committee on Naval Affairs, Hearings on H. R. 9218 to Establish the Composition of the U. S. Navy. Washington: Government Printing Office, 1938.

_____. Holland Submarine Torpedo Boat. 56th Congress 2d Session (Jan. 26, 1901), Senate Doc. 115.

_____. Report of the National Conservation Commission. 60th Congress, 1st. Sess. (Feb., 1909), Senate Doc. 676.

_____. Report of the National Waterways Commission on Development and Control of Water Power. 62nd Congress, 2nd Session (1914), Senate Doc. 274.

_____. Report on Bill S. 1344 to Secure Aerial Navigation. 53rd Congress, 3rd Session (Feb. 25, 1895), Senate Report No. 992.

_____. Submarine Torpedo Boat Holland. 56th Congress, 1st Session (Dec. 7, 1899). Senate Doc. 14.

U. S. Congressional Record, XLVIII (Aug. 22, 1912), 11579.

U. S. Geological Survey Bulletin (1907). #316.

_____ (1909). #392; #416.

U. S. National Resources Committee, Subcommittee on Technology. Technological Trends and National Policy. Washington: Government Printing Office, 1937.

_____. Technology and Planning. Washington: Government Printing Office, 1937.

U. S. President's Aircraft Board. Hearings, Sept. 21, 1925- Oct. 15, 1925. Washington: Government Printing Office, 1925.

U. S. War Dept. Military Aviation 62d Congress, 2d Session (1911). House Doc. 718.

3. Unpublished Sources

Alexanderson, Ernst F. W. Development and Future of Television (undated ms.). Alexanderson Collection. Union College. Schenectady, New York.

Bellamy Notebooks. Edward Bellamy Papers and Arthur E. Morgan
Letters Concerning Bellamy. Houghton Library. Harvard University.

Charles Proteus Steinmetz Collection. Union College. Schenectady, N. Y.

Tozer, Lowell. American Attitudes Toward Machine Technology. Ph. D.
Dissertation. University of Minnesota, 1953.

Selected Secondary Sources

1. Information on Predictions and Predictors, 1890-1940

Bowman, Sylvia E. The Year 2000. New York: Bookman, 1958.
(Biography of Edward Bellamy).

Bryan, George S. Edison, the Man and His Work. London: Knoph,
1926. 2 vol.

Bush, Vannevar. Pieces of the Action. New York: Morrow, 1970.

Capek, Karel. RUR. New York: Washington Square Press, 1969, reprint.

Cate, James Lee and Craven, Wesley Frank, eds. The Army Air Forces
in World War II, vol I. Chicago: University of Chicago Press, 1948.

Fessenden, Helen. Fessenden, Builder of Tomorrows. New York:
Coward-McCann, 1940. (Biography of Reginald A. Fessenden).

Flink, James J. America Adopts the Automobile. Cambridge: MIT
Press, 1970.

Franklin, H. Bruce. Future Perfect. New York: Oxford, 1966.
(Anthology of predictive fiction).

Hough, Richard. Death of the Battleship. New York: McFadden, 1965.
(Predictions bearing on the "aircraft-vs. battleship" debate).

Joher, Frederick. Doubters and Dissenters. New York: Free Press,
1964. (Essays on dissenters from the optimism of turn-of-the
century America).

Jewkes, John, Sawers, David, and Stillerman, Richard. The Sources of
Invention. Edinburgh: MacMillan, 1969. 2nd. Edition.

Jordy, William. Henry Adams, Scientific Historian. New Have, Conn.: Yale University Press, 1952.

Leonard, Jonathan N. Loki: the Life of Charles Proteus Steinmetz. New York: Garden City, 1929.

Ley, Willy. Engineers' Dreams. New York: Viking, 1954.

Woodbury, David O. Beloved Scientist. New York and London: Whittlesey House, 1944. (Biography of Elihu Thomson).

2. Outcomes of Predictions

Technology in Western Civilization. Melvin Kranzberg and Carroll W. Pursell, Jr., eds. 2 vols. New York: Oxford University Press, 1967.

3. Current Futurology and Technological Forecasting

Amara, Roy C. and Salancik, Gerald R. "Forecasting: from Conjectural Art Toward Science." Technological Forecasting and Social Change, III (1972), 415-426.

Bell, Daniel. The Corning of Post Industrial Society. New York: Basic Books, 1973.

_____. ed. Toward the Year 2000. Boston: Houghton Mifflin Co., 1968.

Bright, James R., ed. A Guide to Practical Technological Forecasting. Englewood Cliffs, N. J.: Prentice Hall, 1973.

Clarke, Arthur C. Profiles of the Future. 2nd. ed. New York: Bantam, 1964.

Goldfarb, Avrom J. "Technological Forecasting: What and Whither?" Technological Forecasting and Social Change, III (1971), 51-64.

Hill, Kim Quaile, and Fowles, Jib. "The Methodological Worth of the Delphi Forecasting Technique," Technological Forecasting and Social Change, VII (1975), 179-192.

Kahn, Herman, and Bruce-Briggs, B. Things to Come. New York: MacMillan, 1972.

Kahn, Herman, and Wiener, Anthony J. The Year 2000. New York: MacMillan, 1967.

Kaplan, A., Girschick, M. A. and Skogstad, L. "The Prediction of Social and Technological Events," Public Opinion Quarterly, XIV (1950), 93-110.

McGregor, Douglas. "The Major Determinants of the Prediction of Social Events," Journal of Abnormal and Social Psychology, XXXIII (1938), 179-204.

Meadows, Donella H. and Dennis L., et. al. The Limits of Growth. New York: MacMillan, 1972.

Townes, Charles H. "Quantum Electronics and Surprise in Development of Technology." Science, CLIX (16 February 1968), 699-703.

Tversky, Amos and Kahneman, Daniel. "Judgments Under Uncertainty: Heuristics and Biases." Science, CLXXXV (17 Sept. 1975), 1127-1134.

Vita

George Wise was born in Cleveland, Ohio, on November 30, 1944. He was educated at Walnut Hills High School in Cincinnati, Ohio; Lehigh University in Bethlehem, Pennsylvania (B.S. in Engineering Physics, 1966); the University of Michigan (M.S. in Physics, 1968); and Boston University.

Since 1973, he has been employed as a Communications Specialist for the General Electric Company, at the Research and Development Center, in Schenectady, New York. Previous full time employment consisted of two years as a systems engineer with the Mitre Corporation, Bedford, Massachusetts.

Mr. Wise lives in Schenectady, New York, with his wife Bonnie Annis Wise, and his son James, who was born in 1974.