
Outline of Weather Proposal

October 1945

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Introduction¹

In October 1945 Vladimir K. Zworykin, Associate Research Director at the Radio Corporation of America (RCA) Laboratory in Princeton wrote his influential, but now all but forgotten mimeographed “Outline of Weather Proposal.” He began by discussing the importance to meteorology of accurate prediction, which he thought was entering a new era. Modern communication systems were beginning to allow the systematic compilation of scattered and remote observations, and new computing equipment was becoming available that could either solve the equations of atmospheric motion or at least search quickly for statistical regularities and past analogue weather conditions. He imagined “an automatic plotting board” that would quickly digest and display all this information.

Zworykin suggested that “exact scientific weather knowledge” might allow for effective weather control. If a perfectly accurate machine could be developed that could predict the immediate future state of the atmosphere and identify the precise time and location of leverage points or locations sensitive to rapid storm development, then intervention might be possible. A paramilitary rapid deployment force might then be deployed to intervene in the weather as it happens—literally to pour oil on troubled ocean waters or use physical barriers, giant flame throwers or even atomic bombs to disrupt storms before they formed, deflect them from populated areas, and otherwise control the weather. Zworykin suggested a study of the origins and tracks of hurricanes, with a view to their prediction, prevention, and even diversion. Even long-term climatic changes could be engineered by large-scale geographical modification projects involving such areas as deserts, glaciers, and mountainous regions. In effect numerical

experimentation using computer models would guide field experiments and interventions in both weather and climate. According to Zworykin:

The eventual goal to be attained is the international organization of means to study weather phenomena as global phenomena and to channel the world's weather, as far as possible, in such a way as to minimize the damage from catastrophic disturbances, and otherwise to benefit the world to the greatest extent by improved climatic conditions where possible. *Such an international organization may contribute to world peace by integrating the world interest in a common problem and turning scientific energy to peaceful pursuits. It is conceivable that eventual far-reaching beneficial effects on the world economy may contribute to the cause of peace* (original emphasis).

John von Neumann formally endorsed Zworykin's view in a letter enclosed with the proposal dated 24 October 1945. Von Neumann wrote, "I agree with you completely. . . . This would provide a basis for scientific approach[es] to influencing the weather." Using computer-generated predictions, von Neumann envisioned that weather and climate systems "could be controlled, or at least directed, by the release of perfectly practical amounts of energy" or by "altering the absorption and reflection properties of the ground or the sea or the atmosphere." It was a project that neatly fit von Neumann's overall agenda and philosophy: "All stable processes we shall predict. All unstable processes we shall control." Zworykin's proposal also contained a long endorsement by the noted oceanographer Athelstan Spilhaus, then a U.S. Army major, who ended his letter of 6 November 1945, with these words: "In weather control, meteorology has a new goal worthy of its greatest efforts."

Note

¹ James R. Fleming, "Fixing the Sky: The checkered history of weather and climate control," Columbia University Press, forthcoming.



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by

V. K. Zworykin



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RCA LABORATORIES
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See Von Neumann
and
Pitkin's
comments
in back.
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OUTLINE OF WEATHER PROPOSAL

I. Introduction

The importance of accurate, detailed weather prediction, whether regional or worldwide, cannot be exaggerated. In the first place, exact prediction makes it possible to plan ahead to avoid the consequences of unfavorable conditions, or take advantage of favorable weather. A foreknowledge of intense heat or cold or floods and droughts would benefit agriculture. Information about the coming fog, sleet and storms would aid transportation, particularly air transportation. Adequate hurricane warnings alone would justify almost any effort in improving prediction. In the second place, weather prediction based on a scientific knowledge of the factors influencing weather would be a first step in any attempt in the control of weather, a goal recognized as eventually possible by all foresighted men.

The underlying general physical principles governing weather behavior are now mostly well understood, as a result of the advancement of physical and meteorological science through the years. The major obstacles in the way of attaining a better understanding and better prediction of the weather in the past have been difficulties in collecting data and, because of its complexity, difficulties in computing from these data. Data collecting difficulties have now been much reduced. Integrated chains of weather stations can now (or in the near future) furnish data on the movement of air masses, the distribution of temperature, pressure, lapse rate, water vapor, etc. Radiosondes and rockets will be able to provide accurate information on the relevant meteorological variables.) ??

The data are suitable for mathematical treatment but in general represent too formidable a problem to be handled by conventional methods.

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New electrical and electronic computing devices have been developed within the last few years. The demands created by the war have greatly stimulated this development. These new devices offer a possible means of handling and analyzing the vast amount of meteorological data.

In view of these factors, and because of the present high degree of scientific coordination due to the war effort, it appears that now is an opportune time to re-examine the entire problem of weather prediction.

PREDICTION

II. Discussion

In recent years atmospheric measurements made above the surface levels have provided much useful data and have provided observations representative of the general circulation. Present day communication permits the coordination of scattered and remote observation stations into integrated networks. Thus the application of up-to-date scientific techniques makes it possible to provide the necessary meteorological data for prediction on a scale hitherto unknown. Experience with electronic computers and differential analyzers, before and during the war, indicates that with techniques now available (or prospective) practically any mathematical problem can be solved, with as high a degree of precision as is necessary. Rapid computability makes many experimental manipulations possible in a short time. With the aid of card file selection systems ✓ past situations may be examined and experimental judgments facilitated. The combination of rapid computability and rapid statistical reference constitutes a very powerful tool for perfecting the prediction methods, as well as for their application.

The prediction of the motion of well-defined air masses may be

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approached by dynamical and empirical equations dealing with location, size and speed pressure systems, temperature gradients, humidity, etc., and with the effects of these factors on the interaction between nearby air masses. Modern electrical computing techniques make it possible to design equipment for computing special problems not otherwise amenable to numerical treatment. Thus special computing equipment can be built to solve special dynamical equations, perform dynamical extrapolation, and facilitate use of statistical techniques by ready reference to past data on similar situations. Present electronic computing techniques will permit the prediction of mass movements for perhaps several days in advance, with results obtained within a few minutes, once prediction techniques are established. Thus the application of computational tools will make it possible to carry out prediction schemes based on the optimum mixture of dynamical and statistical principles. The eventual aim here would be to develop an automatic plotting board to provide a model of the movement and modification of pressure systems, on an accelerated time base.

III. Recommendations

It is, of course, impossible at this point to design anything approaching a final prediction scheme, but one might consider, as a general possibility, keeping in mind its eventual application to the problem of weather control, a system comprising the following synchronized elements:

- A. A major computing installation tracing mass movements in the atmosphere at an intermediate level, where wind motions are more easily describable by theoretical means.
- B. A computing system based on a map of surface conditions for evaluating surface effects on the intermediate level. The system would duplicate

insolation and other surface phenomena over ocean, land, mountains, etc. Outputs would be fed to the basic computer mentioned above.

C. A third computing system for treating the upper atmosphere also hooked into the basic intermediate level computer. All three basic computers would be tied together by a synchronous computation of the vertical movements, thus providing a simultaneous three-dimensional representation of the atmospheric flow.

D. The unit named in (A) would be supplemented by a rapid reference filing system which would permit efficient use of past data.

An installation of this nature would permit the prediction of mass movements for perhaps several days in advance with results obtained within a few minutes. The rapid reference filing system would facilitate adjustments of the predicting schemes by permitting experimental manipulations on past data and comparing with actual events.

CONTROL

IV. Introduction

An examination of the mechanics of atmospheric circulation leads to the conclusion that the formation of many phenomena involves the gradual storage of large quantities of potential energy, followed or accompanied by conditions of relative dynamical instability and leading to rapid violent release of the accumulated energy. Unstable physical processes of this type may, in general, be subject to alteration or control much more easily than stable processes involving comparable amounts of energy. Thus the energy involved in controlling weather would be very much less than that involved in the weather phenomenon itself.

Considerations of this nature indicate a possibility of doing some-

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thing about the weather. However, meteorologists have long recognized that a systematic program for controlling weather must await more complete knowledge of the interrelations among the many complex factors involved. Numerous proposals have been made for altering weather both local (use of explosive charges to precipitate rain) and world-wide (altering the course of the Gulf Stream and various other ocean currents) but they have not been founded on anything like adequate knowledge of cause and effect. Only with exact scientific weather knowledge will effective weather control be possible.

Intensified research on weather prediction would provide the necessary scientific background for the evaluation of weather control measures and also provide tools for rapid and convenient laboratory study. Thus, the high speed prediction technique would ultimately be adaptable for determining what control measures should be taken, and at what point in space ^{this control should be applied} and time, in order to obtain a desired effect with the least expenditure of energy.

There are a variety of possibilities for modifying local heat balances. Any treatment which changes absorption and radiation characteristics either at the earth's surface or at various heights in the atmosphere will have some effect; for example, by raising surface air, eventually to condensation point. In addition, local heating by releasing heat of combustion such as by widespread use of flamethrowers, or by release of atomic power may be worth consideration. Treatment of a number of suitably selected spots may have considerable cumulative effects. Reflection and absorption characteristics may be modified by the use of oil over water, carbon or aluminum over land. Artificial fog on both land and water surfaces can also be used. Precipitation of persistent cloud mass may be encouraged by

shock, or by penetration of cloud with particles of ice, dust, or other material. Ocean currents may be modified or diverted by means of heat sources and sinks, physical barriers, or surface treatment.

Long term climatic changes may be made by means of large-scale vegetation programs, alteration of desert areas, glaciers, mountains, et al; in fact, any large scale geographical modification is likely to have extensive climatic consequences, through its effect on the local heat budget, surface friction, and moisture distribution.

All of the above control possibilities are inherently difficult to apply throughout a large experimental program because of the size of areas and the amounts of energy involved. This means that a rapidly computing model of the type mentioned above would be indispensable in selecting the areas, type, and degree of treatment to be used in the verification of experimental work. In short, it permits the rapid study, in the laboratory, of a multitude of situations in a comparatively short time, thus enabling the research personnel to weed out costly experiments which might take considerable time.

In view of the present stage of scientific development and coordination it seems appropriate to suggest a coordinated program of research on weather prediction and control.

V. Recommendations

A. A long range, large scale program for weather and climatic prediction and control should be established, eventually on a global basis. For initial study and trials a particular region should be selected. The Florida and Gulf area appears to be a good candidate for early work.

B. An elaborate network of complete meteorological observation stations

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should be set up, not only in the region being used for initial study, but also in the areas from which disturbances entering this region originate.

(e.g. The Cape Verde region, the Coast of Africa and points in Central America if the Florida Gulf area is selected for initial tests).

*also Pacific
Ocean, North America
& Atlantic Ocean*

C. Concurrent with establishment of weather stations, the prediction problem for this area should be vigorously attacked in order to design specialized computing equipment appropriate for setting up the motions of air masses in model form favorable to rapid computation and automatic plotting board representation. Past weather records can be used as test inputs to the predicting machine, which will be modified and adjusted until faithful reproduction of air mass movements is obtained.

D. Various methods of alteration of terrain and of effects of insolation can be reproduced in the model and investigated, thus permitting study of the possibilities of deflecting air movements with consequent changes in the weather. Physical and chemical research should be applied to the problem of treating surfaces, effecting precipitation, and to the general problem of physical techniques in weather control.

E. At this point the results of physico-chemical research can be combined with plotting board results and verified under actual conditions.

Before global studies on a wide international scale are well organized, one can start with the study of local (comparatively) problems, such as the prediction, prevention, or diversion of hurricanes. Study of storm origins may involve more widespread geographical areas than study of factors affecting storm paths. Moreover, comparatively less is known about storm origins than about their paths. For example, detailed investigation of hurricane genesis probably involves coordination of weather stations at least as far as Africa.

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Initial attack on particular kinds of storm paths in restricted areas may encourage refinement of prediction techniques and serve as groundwork for later global study. The development of rapid prediction techniques would provide a powerful tool for deciding on weather control measures by providing for the immediate evaluation of the effect of terrain conditions and consequently permitting experimental manipulations to study the effects of artificial surfaces or other atmospheric changes.

The eventual goal to be attained is the international organization of means to study weather phenomena as global phenomena and to channel the world's weather, as far as possible, in such a way as to minimize the damage from catastrophic disturbances, and otherwise to benefit the world to the greatest extent by improved climatic conditions where possible.

Such an international organization may contribute to world peace by integrating the world interest in a common problem and turning scientific energy to peaceful pursuits. It is conceivable that eventual far-reaching beneficial effects on the world economy may contribute to the cause of peace.

APPENDIX

The discussion which follows, relating specifically to the control of tropical hurricanes, is not presented as a working plan for regulating weather. It is not based on the profound understanding of weather phenomena required for actual control of storms, and is not presented with a view towards its immediate application. It is presented to render more concrete and realistic the general idea of weather control.

VI. Meteorological Considerations

The sun provides the thermal energy necessary for all weather phenomena, including humidity, precipitation, wind, etc. Without insolation the atmospheric system would be brought to rest by frictional dissipation.

Local disposal of solar radiation is affected by clouds, humidity, and other atmospheric states; also by the nature of the earth's surface, whether ocean or land, mountain or plain, forest or desert. For example, a dense cloud reflects about 78% of incident solar radiation; a desert gets continually hotter during daylight, whereas damp soil remains at nearly constant temperature, with much of the absorbed energy going into latent heat of evaporation.

Through processes of heating and cooling, evaporation and condensation, and circulation of both atmosphere and oceans, insolation sets up irregular regenerative motions which represent unsuccessful attempts to attain a stationary situation.

Although the overall system is effectively determinate over periods of, say, several years, its short period behavior is generally unstable or nearly unstable. Particular weather phenomena may evolve through successive phases of instability and various degrees of stability.

Violent transients may come as results of land and water distributions, mountains, etc., permitting gradual storage of potential energy leading up to a condition where a rapid release may be triggered. It may be possible to take advantage of horizontal or vertical instability to alter transients with the expenditure of relatively small amounts of energy compared to the energy represented in the transient itself. Without directly neutralizing the energy release involved in atmospheric phenomena, it may still be possible to exert considerable control over the time, the rate, direction, and form that the release takes.

VII. Hurricanes

Tropical cyclones (hurricanes, typhoons) are examples of energy storage over a long period with a slow process of formation of a storm center. The process takes place over a large ocean area in the belt of doldrums near the equator and involves the gradual storage of energy by evaporation during insolation accompanied by unstable weather over a large area. Frequency distributions of hurricanes by month show a strong relation to the seasonal variation in intensity of insolation in the area of origin.

There is no apparent a priori reason to rule out the possibility of occasional triggering before the potential head reaches hurricane proportions or encouraging nearly continuous dissipation of the energy during the formation period. Considerable further investigation of the genesis of tropical cyclones is needed to determine this.

The other possibility which remains lies in attempting to deflect the path of the storm, without necessarily altering its character greatly. The procedure would involve the combination of semi-permanent measures with action taken soon after identification of the storm, based on prompt predic-

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tion of the undisturbed path. Such procedures would not necessarily involve the expenditure of prohibitive amounts of energy.

In spite of the tremendous energy involved in a hurricane, examination of typical paths indicate certain characteristics that make it reasonable to attack the problem of path deflection. In contrast to the dynamical stability and intensity of the regenerative rotary motion, the linear motion of the storm center is slow and apparently easily influenced by prevailing wind conditions. Hurricanes themselves have comparatively little effect on the surrounding mass movements, thus facilitating hurricane prediction.

Cape Verde hurricanes usually start west in the trough of the doldrums belt and then turn north along the skirts of the prevailing high pressure area.

It is likely that the turning point is a profitable place to affect the hurricane path for optimum effect with respect to the Atlantic Coast.

October, 1945

V. K. Zworykin

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THE INSTITUTE FOR ADVANCED STUDY

School of Mathematics

Princeton, New Jersey

October 24, 1945

Dear Doctor Zworykin:

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I want to express to you my thanks for letting me see your "Outline of Weather Proposal", October 1945. I found your discussion most interesting and inspiring, and I think it is practical and of the greatest importance.

To be specific: I think that the mathematical problem of predicting weather is one which can be tackled, and should be tackled. It will require very extensive computing, but the equipment to do this is now becoming available or can be developed. Clearly the problem can be attacked on various levels of abstraction: anywhere between the purely sorting approach which compares present weather maps with past ones and attempts to establish the closest analogous past situation in order to extrapolate by past experience; and the entirely aerodynamical one which would aim to compute the movements of air masses starting from the present distribution of pressures, temperatures, wind velocities, humidity, and the states of radiation, reflection, and absorption. If it were not for the considerable uncertainties of turbulent heat transfer, even the latter purely-theoretical approach would be feasible with electronic computing that might be made available within the next few years. At any rate this aspect of the problem, together with the important questions of turbulence with which it is connected, should certainly be investigated.

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Quite apart from this however, there must be intermediate procedures, describing the critical turbulent mechanisms of energy transfer partly empirically and statistically, which, used in conjunction with quite advanced computing equipment, will make mathematical weather prediction possible. In this connection I would like to emphasize that I think that the development of new computing equipment using a proper combination of digital and analogy methods will be of decisive importance.

I agree with you completely that once the methods of prediction are sufficiently advanced the immediately following step should be prediction from hypothetical situations. In other words: exploring the consequences of various controllable changes in the absorption and reflection properties of the ground and of a number of suitable atmospheric phenomena which can be brought about artificially. This would provide a basis for scientific approach to influencing the weather. I agree with you that our present inability to influence the weather is not due to the fact that the energies involved in weather are too great, since the most conspicuous meteorological phenomena originate in unstable or metastable situations which could be controlled, or at least directed, by the release of perfectly practical amounts of energy. Also there are very practical methods of altering the absorption and reflection properties of the ground or the sea or the atmosphere immediately above the ground which could.

I hope very much that there will be some way of translating your ideas on this subject into reality. And I would certainly be very glad if I could be of any help at any stage of the process.

Sincerely yours,

John von Neumann

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COMMENTS ON WEATHER PROPOSAL

by

A. F. Spilhaus

The Weather Proposal has been divided into two parts: prediction and control. The immediate contribution to be made to prediction by this proposal is to make available electrical and electronic computing devices which can complete in as many minutes computations which would otherwise occupy a number of man-days. In prognosis, where every hour utilized in analysis and computation, makes the time range an hour shorter (and therefore less valuable) the utility of such computing devices will not be questioned by meteorologists. Those who have seen the abandonment of many promising techniques because they were too time consuming to be practical under the old "hand-labor" method, will immediately appreciate that by the use of such electrical devices all computations may be made to contribute to the forecast.

The application of electrical and electronic computers to meteorological prediction may be regarded as merely another step (but potentially a great one) in a process already started. Prior to the war, the factor of personal experience and local knowledge was a great one in the make-up of a successful forecaster. His experience often resolved into a remembrance of a situation similar to the one whose development he was currently called upon to predict. It was but a short step to the process of classifying map types and subsequently to arranging these so that matching could be accomplished automatically by punched-card index machine rapid reference methods. The use of the electrical computers is as logical a step and coupled with type matching equipment will be a tremendously powerful tool as the methods may be continually checked by experiments on past sequences.

An adequate electrical computer utilized in this fashion in effect takes the place of full scale model experiments which are otherwise hard to envisage in meteorology.

The second and much broader part of the weather proposal deals with weather control and this too should be regarded by far seeing meteorologists

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not as a dream but as a logical development from small beginnings in control which have already been accomplished.

There is hardly need to comment on the benefits of such control; increasing rainfall a few tenths of an inch may spell the difference between famine and plenty, preventing the temperature from dropping a degree at a critical point may save vast crops from frost damage.

In the fact that such a nice balance often exists in nature lies the all-important contributions which will result from the development of the electrical computing devices for weather prediction. Accurate forecasting from a set of circumstances by the use of electrical computers will not only be valuable in itself but is an essential step in weather control. The result of any attempt at control must be predicted in advance and compared with the prediction of what would have taken place without the control measures in order not only to avoid unexpected deleterious effects but also because otherwise there would be no way of knowing whether the control was successful.

Well known examples of weather control exist - One is the common use of smudge pots in orchards to prevent freezing conditions; whether it is the smoke or the heat which accomplishes the desired result is a matter of controversy. But the fact that more efficient and economical control could be accomplished by adequate study few who have seen the crude smudging methods will dispute. (The efficient ~~smoke~~ producers developed for military purposes come to mind). The fog dispersal scheme employed at English airfields is another example of successful weather control. While the quantities of fuel burned may have been enormous, the saving in lives and material proved this to be a sound weather control method.

Reforestation programs are continually being undertaken, each must have a profound and lasting effect on weather and climate but one which has not been completely analyzed in its relation to rainfall and temperature. It

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is conceivable that reforestation might be undesirable at some place because of its bad effect on another - if such is the case it is not known, and will not be known until systematic studies of weather control are undertaken.

How does the growth of a great city influence its weather? Does its temperature increase because of the heating of the buildings, or does its temperature decrease because of the usually attendant haze cap? Figures have been given for Tokyo; many more such studies are needed. Perhaps in certain cities it is desirable to produce smoke at certain times.

The argument that to control weather requires great expenditure of energy is satisfactorily answered in the proposal. First, relatively small amounts of energy, correctly utilized, under conditions of latent instability may release greatly energetic or extensive phenomena.

It has been noted in South Africa that the thunderstorms which are common over the more-or-less homogeneous surface of the plateau tend to form more frequently over burned patches. In order to make air mass thunderstorms concentrate at one point rather than another, it is only necessary to introduce an artificial inhomogeneity (of reflection or absorption) more marked than the casual inhomogeneities.

Whether the storage of large amounts of potential energy over the hurricane producing parts of the sea surface can be avoided by introducing a checker-board of black and white (reflectively speaking) remains to be seen but must be studied. This concept of the building up of the potential energy for a hurricane because there is insufficient inhomogeneity in the surface to supply a preferred point at which convection may start is like the experiment of boiling water in a vessel the bottom of which is covered with mercury. It is said that such a degree of superheat (instability) may be achieved and ebullition postponed such that when it finally takes place it may have the violence of an explosion.

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The phenomenon of vapor trails behind aircraft is a good example of "triggering" - if the atmosphere is in the right condition these trails grow considerably. Most striking is the report of a German meteorologist who observed and photographed the trails from only three airplanes over Salzburg develop into an overcast in the space of less than an hour.

In a discussion of the energy for weather control one cannot avoid reference to the possible utilization of atomic power, but adequate knowledge of the absorption and reflection of different types of surfaces will permit utilization of that other great source of power - the sun.

The second part of the answer to the argument that weather control requires great expenditure of energy is for the predicting computer to answer whether the results and benefits warrant the expenditure however large or small.

Finally, one may look a little into the future of meteorology. Aviation which in the past years has given the greatest stimulus to the growth of practical meteorology is rapidly going from the erstwhile stage of being dependent on weather for its very safety and successful accomplishment to the stage where airplanes will be able to take off, fly and land where they will regardless of weather. Weather prediction for aircraft will then be relegated to the lesser importance of determining not whether the flight is possible but only what level of flight is most economical or most comfortable. In warfare guided missiles will not be affected much by weather. Even the farmer benefits little by weather prediction; it would not seem sufficient to tell him, however accurately, that he will starve in the coming season.

In weather control meteorology has a new goal worthy of the greatest effort.

/s/ Athelstan F. Spilhaus
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