OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D00472

ID

United Nations Industrial Development Organization

[illegible]
[illegible] Is
Peoria, Illinois, [illegible] ber 19[illegible]

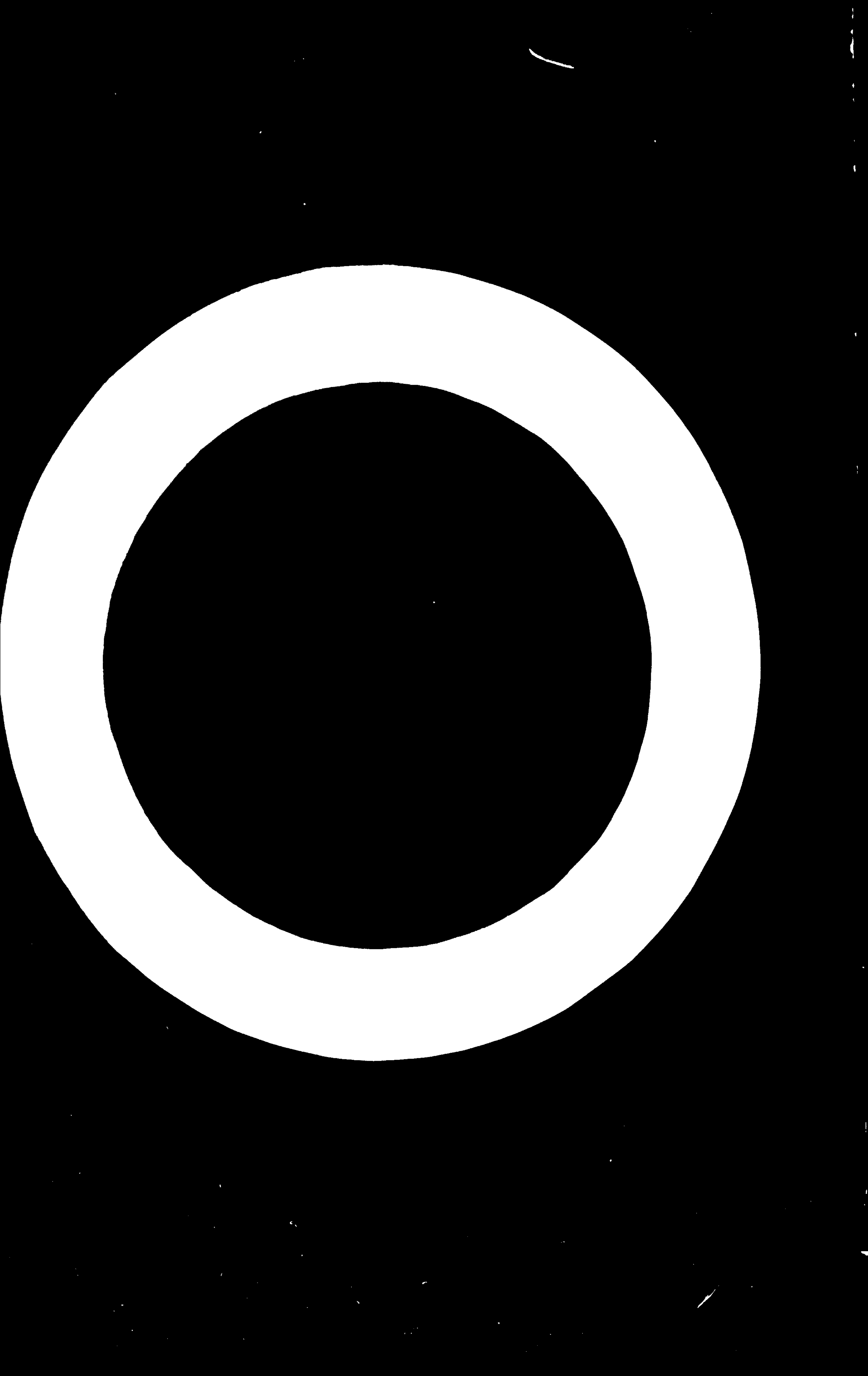
TH[illegible] CAS[illegible] FOR [illegible]ING - [illegible] SOY PROTEIN FOOD PRODUCT[1]

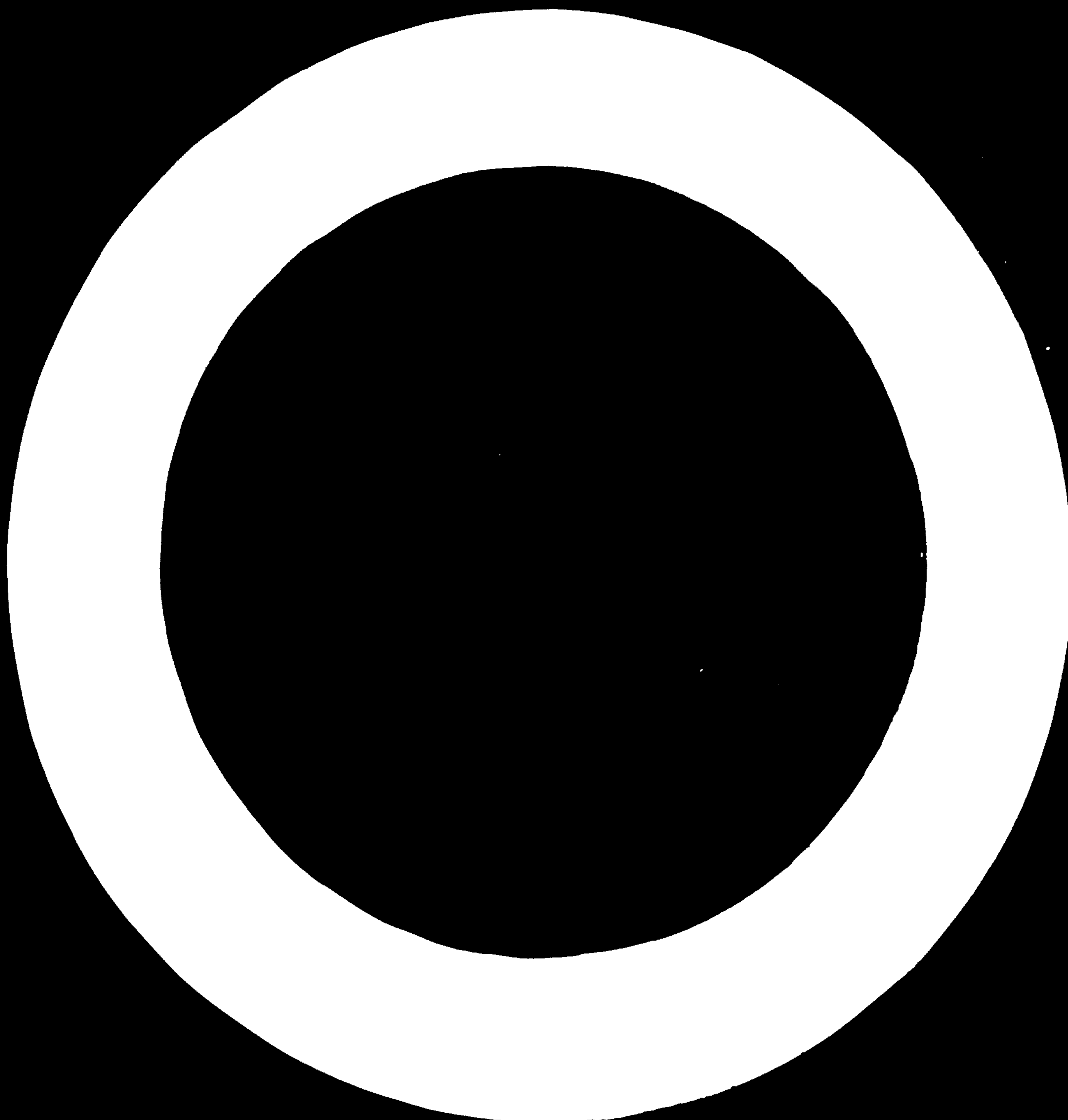
by

[illegible]
Department of Agricultural Engineering
Ohio State University
Columbus, Ohi

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.70-240





A MISSION - SO CAREFULLY PLANNED

The year 1969 probably will be noted in history as the onset of adolescence for one of man's leading obsessions - space travel. Some ten years after jet passenger planes initiated service, the first manned spacecraft touched down on the moon.

It is important that we pause momentarily - as we concern ourselves with the need for new soy protein food products - to ponder a "space travel" analogy. The purpose of this analogy is to demonstrate that "nutrition" is only one factor favouring greater utilization of soybeans, and to illustrate that developed nations have as great, or even greater need for adopting the soybean for their basic food crop, as do underdeveloped countries.

Now everyone knows that the resources aboard a space-vehicle are very carefully planned, far in advance of the date of departure. The expenditure of these resources is accurately programmed. Those selected to be passengers on the vehicle are meticulously schooled accordingly.

Hence, following its launch, the space vehicle's resources are relatively finite. Everyone involved knows at what point in time those resources will be expended. Also, the vehicle, with its resources, is always designed for a limited number of passengers, the minimum number of men needed to accomplish the mission safely, and only that exact number of passengers are launched aboard the vehicle.

Years before the launch date, there has been an extremely thorough screening of the men who aspire to be the passengers of that space vehicle. Those ultimately selected are quite stable emotionally, of outstanding moral character and in an excellent state of health. The men are grouped so that their knowledge, talents and skills complement each other in terms of meeting the needs for the mission. Finally, and perhaps of greatest importance, the men selected must be compatible. Their personalities must match, their political and religious beliefs must not become a source of conflict.

WE WOULD NEVER BE SO STUPID???

Now everyone would have been horrified if four men had been inadvertantly launched aboard U.S. Apollo 11, a spacecraft designed for three men. Without a doubt, the mission would have been aborted at the earliest opportunity. Likewise, all of the people throughout the world who were following the events associated with the Apollo 11 mission would have been shocked if:

A. Negligence of an astronaut resulted in eventual contamination of the vehicle's water supply; or

B. Two of the astronauts became so provoked due to a political argument that they ceased to communicate with each other, their failure to co-operate endangering the mission; or

C. To enhance his personal comfort, an astronaut re-adjusted the spacecraft's environmental control system, thereby increasing the rate of energy expenditure to three times mission design value; or

D. Unable to manage his leisure time, an astronaut resorted to eating, and consumed his entire share of the food supply during the first third of the journey.

Jokingly, everyone would respond to the previous paragraph by noting that nobody could be so stupid as to:

A. Permit four men in a three-man space vehicle;

B. Tolerate negligence leading to contaminated resources;

C. Let political differences endanger the mission;

D. Allow excessive energy expenditure to please a crew member;

E. Give a man more than his share of food.

SPACECRAFT "EARTH" - 1969

But what about our old spacecraft "Earth"? The year 1969 should also have been the year to initiate intellectual acceptance of the realization that all of mankind is existing aboard a planet which for all practical purposes is analogous to an Apollo-type manned space vehicle.

Think about it! When man became a passenger on Spacecraft Earth:

A. It was stocked with a finite supply of resources - arable land, fresh water, pure air, minerals, fossil fuel reserves, etc.;

B. There was a finite quantity of energy beamed aboard daily, from a remote source - solar energy.

And by the year 1969, man had succeeded in every possible abuse of his spacecraft:

A. On a craft inherently capable of sustaining less than a billion passengers for an indefinite mission, we now anticipate 6 to 7 billion by the year 2000 and have yet to establish any limits;

B. Absence of conservations measures, plus diversion to non-productive uses have depleted arable land area;

C. Streams, rivers, lakes and oceans are becoming polluted, soil is being desecrated, air is so contaminated it affects solar energy transmission and modifies climate,

D. Energy reserves are being exploited for the benefit of a disproportionate share of the people;

E. Mineral resources are rapidly being exhausted;

F. Contrasting political beliefs continue to thwart communications between groups, leading to occasional warfare with it's resultant accelerated waste of natural resources through build-up and destruction of vast arsenals,

G. About one-third of the passengers on Spacecraft Earth are adequately nourished to the extent that they are quite wasteful with food. The other two-thirds struggle to survive.

Yes, with practically no apprehension about whether his mission may soon be aborted, man continues his reckless behavior aboard Spacecraft Earth.

[illegible]

Given this state of affairs, how can the soyabean modify the situation? Potentially, soyabeans can become a valuable link in the chain for alleviating several of man's leading problems, specifically among those listed, curtailing pollution, conserving natural resources, and improving human nutrition.

When we think about engineering, we contemplate improvement of the material environment through overcoming obstacles which stand between a society and its aspirations, to design machines, structures, processes, systems, which meet some kind of need.

The basic aim of engineering is to optimize the usefulness, the value, of resources to man. The ingredients are:

- human values,
- energy;
- materials;
- space; and
- time.

Now, what machines, structures, processes or systems are needed to expand world food production levels? Which ingredients will result in the best results?

Typical suggestions for expanding world food production invariably fall into these categories:

A. Cultivate more land;

B. Irrigate more land;

C. Apply more fertilizer;

D. Use improved crop varieties.

Cultivate more land?

The largest tracts of arable, but unfarmed soil, are in Africa and South America. Vast areas also remain in North America and Australia. But more than half of this potentially arable land (4 billion acres) lies in the tropics.

Costs for bringing new land into cultivation vary widely, from US$ 1000 per acre in Kenya to US$ [illegible] in the United States and US$ 40 in a Guatemala project. Assuming an average cost of US$ 375 per acre worldwide, the 4 billion acres remaining in the tropics would require an investment of US$ 1.5 trillion, a figure hardly within easy realization.

In large parts of Asia, where water shortages are critical, it would take 100 years at current expenditure levels to add one more acre per person. In the meantime, population will have increased [illegible] times if birth rates continue as projected.

Conclusion - significant increases in world food production will be attained quicker and at lower cost by some other means.

Irrigate more land?

Only 11% ([illegible] million acres) of the world's cultivated land is irrigated. Coincidentally, the diet-deficient regions could gain the most from more irrigation. In India inadequate rainfall and irrigation restricts food production on 65% of the otherwise arable land, and prevents year-around production on another 20%. Only [illegible] of the arable land in India is irrigated.

One-third of the earth's land area lies in arid and semi-arid regions, where irrigation could provide a rapid increase in crop production. But the costs are much higher than present commitments (about US$ 500 per acre for irrigable land in India (US$ 40 billion total), in southeast Asia about US$ 400 per acre (US$ 16 billion total), to cite two examples.

Irrigation water from natural streams and rivers is limited by annual climatic variations. Man-made lakes and reservoirs intended to store water from stream flow will require extensive maintenance to avoid silting. Ground water pumped for irrigation can be over-exploited, as proved by some areas in the southwest United States.

Conclusion - world food production increases by more irrigation will come slowly, and will be costly.

Apply more fertilizer

Where water is not the limiting factor, applications of chemical fertilizer will result in significant yield increases. But water is limiting in many diet-deficient countries, and since farmers must purchase the fertilizer, they must achieve the financial resources to help them pay for it.

To keep every Asian, African and Latin American at mere subsistence levels, about a pound of grain per day, in 1980, production of chemical fertilizers must increase sevenfold. To double crop yields in these diet-deficient areas, production of plant nutrients will need to be increased tenfold, a capital investment of over US$ 20 billion for inorganic fertilizer mining, manufacturing and distribution by 1985.

There are limits to what chemical fertilizer will accomplish in the future for diet-adequate nations. To illustrate, let us review what has been accomplished in the Corn Belt area in the United States. The United States Department of Agriculture computed index numbers (1957-59 = 100) are:

Year	Crop Production Per Acre	Principal Plant Nutrients Used
1940	[illegible]	9
1945	74	[illegible]
1950	82	40
1955	[illegible]	90
1960	[illegible]	113
1965	130	204

Crop production increased about 80 per cent from 1940 to 1965, but use of fertilizer in 1965 was some 23 times greater than in 1940.

Now fertilizer is a tangible input. What these figures do not show are the important intangible factors, plant breeding, optimized plant populations, weed-insect-disease control measures. The critical question is how will the United States Corn Belt farmers increase their land productivity another 50% to provide food for the additional 100 million people expected in the country by the year 2000.

As will be illustrated later, use of chemical fertilizer may actually have to be reduced in the United States Corn Belt states. Evidence is accumulating that nitrates will become a critical pollution factor. If so, and if nitrogen fertilizer use is curtailed, what will happen to Corn Belt crop yields?

Conclusion - economics limit the use of chemical fertilizer in diet-deficient countries where it will help most - whereas the diet-adequate countries' use of fertilizer may be excessive to the point that pollution results. In either case diversion of more land to a crop capable of nitrogen fixation from air would be desirable.

<u>Use of improved crop varieties??</u>

Improved crop varieties probably offer the greatest potential for enhancing nutrition in diet-deficient countries. There are two opportunities:

A. Breed better varieties of a particular crop;

B. Divert production to another crop which is capable of greater over-all productivity.

Development of a new variety is not without its difficulties. The International Rice Research Institute (IRRI) in the Philippines, succeeded in introducing the "miracle rice" IR8, and later another, IR5. Asian farmers planting these rice varieties experienced what for them seemed like a bumper crop.

But the IR8 and IR5 rice does not produce the clean, hard, flinty grain that allows high recovery of head rice when milled. Its cooking quality also does not quite accord with Asian taste, and palatability is a prime factor in plant breeding.

Also, there is the matter of disease. Bacterial blight and streak continue to take a heavy toll of rice production. Virus infestations, tungro and grassy stunt, are spreading rapidly throughout Asia and may become a major threat to Rice. Tungro disease is reported in the Philippines, Taiwan, Malaysia, Indonesia, Thailand, East Pakistan and India.

To introduce a new characteristic into IR8, or any other existing rice variety, requires at least seven generations. The IRRI, for example, discarded a provisional variety, IR 27-80-1-10, because it did not "tiller" well enough at medium management levels. Yet four years of hard, costly research went into its development.

Regarding the introduction of alternate crops, agricultural educators in diet-deficient countries should study the possibilities. If we wait until mal-nutrition has destroyed a society, then it is too late to try different food crops. But if we subscribe to "nutrient economics", as will be discussed later, then it may well be advantageous to introduce other food crops, teach farmers how to cultivate them, and supply instructions to the housewife so that palatable foods can be prepared.

Conclusion - developing a new crop variety is not a pushover! And food habits do not necessarily change for rational reasons.

FACTORS WHICH WILL FORCE A CHANGE IN AGRICULTURE

There are agricultural production problems emerging in diet-adequate countries which will ultimately change their food production pathways more drastically than anything apt to occur in the diet-deficient nations. Three examples suffice to illustrate: production man-hours; competition for water; and pollution aspects of intensive agriculture.

Production man-hours in United States agriculture

Take the case for dairy farming. Probably it will undergo major shifts within ten years. The average age of farmers in the United States is 5[illegible] years. As the older dairy farmers retire, or switch to less strenuous farming activities, will there be anxious young men ready to rush in and replace the retirees?

Referring to current Ohio farm product prices and USDA man-hour data, the production man-hours required per [illegible] 100 worth of saleable product are:

Soybeans	7.2	Broilers	[illegible].5
Wheat	7.[illegible]	Beef	10.4
Corn	8.7	Hogs	11.7
Eggs	21.6	Milk	26.0

The labour needs for milk production is 3.6 times that for soybeans. In contrast to animal production, a soybean crop requires the farmer's presence for soil preparation in the spring, then harvesting in the fall. The soybean farmer can be engaged in other work for most of the year.

Now take a second look at the [illegible] labour-hours per US$ 100 worth of saleable product for milk [illegible] the average United States dairy farm. [illegible] if wages and fringe benefits for farm [illegible] were equal [illegible] the [illegible], or more, per hour level not uncommon with off-the-farm employment? The labour cost alone for producing US$ 100 worth of milk would [illegible] [illegible], not [illegible] the costs of building and maintaining a milking barn, [illegible], repairing and maintaining the needed buildings and machinery, etc.

Finally, not only is the [illegible] low and hourly requirements high for producing milk, the working hours on a dairy farm are most discouraging. Up at 5 a.m., finished [illegible] p.m., seven days a week, every week, no time off on weekends or holidays. Unheard of are typical United States labour demands such as time-and-a-half pay for hours worked in excess of 40 per week; earned sick leave; six or more paid holidays; paid vacations, etc. Dairying is not the type of life a young man is going to choose in a day when he can earn much more working a single 40-hour week in a non-agricultural industry.

<u>Competition for Water</u>

Probably we will experience soon situations where industries are required to recover and continuously reuse the water they employ in manufacturing and processing. Indeed, [illegible] municipalities may ultimately need to engage in such water conservation measures. Recirculation can be accomplished since most of the water is not "lost" as it is utilized.

But in food production, the story is different. Up to 97% of the water required to grow a food or feed crop is lost via evaporation. It may be returned subsequently as rainfall, but often such rainfall is remote from the cropland where the evaporation took place. Direct recovery and recirculation of water used in field crop production would be, to put it mildly, difficult to accomplish.

Depending upon production procedures and geographic location, 10 to 25 tons of water are required to produce a one-pound [illegible] steak. This includes water to grow the feed for the animal, water to nourish it, plus water needs for processing the slaughtered animal. Five tons of water are needed to produce one pound of organic matter in milk. Nearly 250 gallons of water go into producing each egg we eat in the United States.

As competition for fresh water supplies in the United States increases, certain agricultural activities may be curtailed, the cost of water could go beyond the limits of economic feasibility for certain kinds of crop production. Too, we must remember that systems of animal waste disposal involve enormous use of water to dilute the undesirable fractions. Here again, conventional animal agriculture will be affected.

Polluting aspects of chemical fertilizer

While nitrate is relatively innocuous when ingested, it may be converted by intestinal bacteria into nitrite, which, on combining with hemoglobin in the blood (methemoglobinemia) destroys the oxygen-carrying capability of the blood. Asphyxia, and possibly death will result. Further, nitrite, on reaction with certain organic constituents of food, or with the body, may form nitrosamine compounds which are potent carcinogens.

Nitrate Sources	Increase in last 25 years
Sewage	70%
Automobiles and Power Plants	300%
Nitrogen Fertilizers	1,300%

In the United States, over-all annual biological turnover of nitrogen is between 7 and 8 million tons. At the present time, United States automobiles and power plants are generating 2 to 3 million tons of nitrogen compounds, while agriculture, with nitrogen fertilizer, introduces about 7 million tons of nitrogen compounds into this cycle.

This intrusion, by human activity, in the biological nitrogen cycle cannot proceed without consequences. Currently the safe concentrations of nitrates have been set at:

Source	Safe Concentration PPM
Water	10
Food	300

Studies have indicated water from one-fourth the shallow wells (25 ft. or less) in Illinois already contain more than 10ppm nitrate nitrogen [1]. Studies of nitrates in baby foods show concentrations ranging up to 444 ppm in wax beans, 977 ppm in beets and 1373 ppm in spinach [2].

1/ "Threats to the Integrity of the Nitrogen Cycle: Nitrogen Compounds in Soil, Water, Atmosphere and Precipitation", Annual Meeting, AAAS, December 26 1968 by Barry Commoner.

2/ "New Colorimetric Method for the Determination of the Nitrate and Nitrite Content of Baby Foods" L. Hamm, 1965.

For a comprehensive discussion of the nitrate pollution problems apparent in the United States, you should refer to Commoner's report (see footnote 1 on previous page). You can appreciate, once again, the need for utilizing food crops that are capable of self-fixation of nitrogen from air, crops on which we do not have to heap tons of nitrogen fertilizers to insure suitable yields. Hence our attention [illegible] we also turn to crops such as soybeans, once the consequences of nitrate pollution are recognized by agricultural leader

Polluting by-products of animal agriculture

When the early American Indians roamed throughout this land, waste disposal was not much of a problem; they simply solved it by moving frequently. Then came the settlers who preferred living in one location, often in groups. From the very beginning, these people exercised some form of human waste disposal, but excrement from the settler's animals was permitted to accumulate, or it was utilized as organic fertilizer on cropland.

In over 300 years, we have not changed these practices. Either approved individual home septic tank systems, or community sewage treatment plants are considered essential according to modern health standards. I doubt that we would consider accumulating human excrement in a pile, nor would we permit spreading it on our lawns and gardens as a fertilizer. Yet, today, large quantities of animal excrement pile up in [illegible] until conditions are favorable for spreading it on cropland. There are numerous United States livestock producers feeding over 1,000 beef animals in confined lots. The animal excrement from just one such operation is equivalent to the total human excrement from a city of 15,000 people, [illegible] and 100,000 animal meat production operations today, [illegible] to human populations of 1 to 1.5 billion humans.

In 1967, 22% feedlots in the United States marketed one-fourth of the fed cattle. Only one percent of our feedlots fed over 1000 head of beef animals, but that one percent group marketed 40% of the cattle. The trend toward large, confined beef and pork feeding operations is moving ahead rapidly without concern about the pollution aspects.

United States Department of Agriculture officials estimate animal wastes in the United States now total 10 billion pounds per day, 1.7 billion tons per year.

If all this waste were [illegible] on railroad cars, it would fill [illegible] million, 50-t[illegible] cars per year. The accumulated length of this train [illegible] of [illegible] waste would be equivalent to [illegible] distance from the earth [illegible] half way back.

Consider a beef animal [illegible] ration:

Gross daily [illegible] weight	[illegible] lb.
Edible daily gain (20[illegible] of gross gain)	[illegible] lb.
Edible daily protein produced ([illegible] of edible gain)	[illegible] lb.
Body waste produced daily by animal	[illegible] lb.

Hence, the animal excretes [illegible] lb. of body waste per pound of protein produced. [illegible] remains [illegible] of protein [illegible] per year [illegible] if all food protein came from [illegible], the animal excrement would be [illegible] lb. annually per person.

Was the animal excrement pollution [illegible] critical? Yes, court [illegible] and injunctions are [illegible] filed [illegible] neighboring couples suing [illegible] builders, [illegible] in damages. [illegible] largely on odour, [illegible] defence, to no avail, [illegible] that it had followed [illegible] widely recognized and accepted authorities "Agricultural [illegible]"

If, as the [illegible] York State Health Report [illegible] indicated [illegible] charges against [illegible] farmer, livestock farmers must [illegible] and [illegible], [illegible] coming for animal agriculture [illegible] State Health Department "air pollution" [illegible] emitted. [illegible] life and property [illegible]."

If it were to be decided that [illegible] of the United States should [illegible] treat [illegible], [illegible] the animal protein picture changes [illegible], [illegible] investing [illegible] in disposing of livestock wastes [illegible] picture [illegible] farmer, required by public health regulations to provide [illegible] treatment facilities for his animals similar to the sewage [illegible] for [illegible] city of

2,500 inhabitants. A modern sewage treatment facility for a city of 2,500 would cost from one-fourth to one-third of a million dollars. Daily operating cost for the system would be [illegible] - [illegible]

Yes, probably we can [illegible] less costly systems for animal waste disposal, than are employed by the municipalities. But even if the investment if only US$ 25,000 for a [illegible] dairy farm, the cost of appropriate waste treatment would have an impact on the market price of milk, and the additional headaches which will go with suitable waste control systems will compound the problems which discourage dairy farmers.

I believe animal waste pollution problems will do much to stimulate a great interest in vegetable protein foods, and the popularity of the soybean as a commercial farm crop in the United States makes it a leading contender for filling the [illegible].

<u>WHY [illegible] PROTEIN?</u>

We have been discussing [illegible] constitute a threat, in diet-adequate countries, [illegible] meat, milk and eggs diet. But we must not forget that [illegible] In fact nutritionally, the human body does not require meat, milk and eggs per se. Rather, essential to health is an adequate and balanced diet of protein, carbohydrate, fat, vitamins, and minerals. [illegible] talk a lot about nutrition, but many of us do not appreciate its critical aspects.

Food [illegible] of carbon compounds which have been selected by processes of Darwinian evolution. If the human body ever possessed the ability to self-synthesize all its essential building and maintenance materials from random sources of carbon, hydrogen, nitrogen, sulphur, etc. certain of these capabilities were lost as man evolved to his existing form. Other animals are plagued with the same problem. Only plants and micro-organisms possess the necessary mechanisms for natural synthesis of certain amino acids, fatty acids, enzymes, etc.

All three classes of foodstuffs, protein, fat and carbohydrates, can and do serve as sources of the thermal energy which is required for man to remain alive, to maintain a constant body temperature, and to carry out his daily activity pattern. Any fat not immediately required can be stored in the body and even very modest reserves of carbohydrate can be built up. Man's dietary problem lies in the fact that he is [illegible] unable to store excess protein in the body, to be drawn on as needed.

It is for this reason that, from the moment that his daily protein intake drops below his minimum daily requirement, he is in serious trouble. Daily wear and tear never ceases, even at absolute rest. Since wear and tear can only be counteracted by replacement of worn out cells with new ones, and since protein is absolutely essential for this purpose, this protein must be found immediately. If it is not, then the body, in order to protect its most vital functions, such as heart muscle contraction, reacts in the only fashion possible: by self-cannibalization. Of necessity, there is a sort of self-digestive priority system whereby the least essential tissues are sacrificed first in order to supply and protect the most vital.

The urgency of this process gains credence from the fact that the average human heart relies on it's tiny muscles (11 ounces) to work at the rate of over 11,000 ft lb. per hour - [illegible],000 ft lb day. This is the work equivalent to lifting a 4,000 lb. automobile to a height of 66 ft in 24 hours. Whereas, when a man is standing or sitting, other muscles in his body undergo very little activity.

A protein is like a long string of beads, with each bead being one of 23 amino acids; the sequence of amino acids determines the protein's specific properties and thus it's function. The stringing together of amino acids into proteins, in sequences determined by the cell nucleus, is the key chemical step in the growth process. Physiologically, animals (including man) cannot synthesize 8 of the essential amino acids. These must be supplied to the animal body from external sources - ultimately derived from plants and micro-organisms.

The body produces a prodigious variety of proteins, which serve it in all sorts of capacities. Structurally, they are the major components of hair, skin, muscle, bloodvessels and internal organs. Functionally, they supply enzymes, the blood's hemoglobin and some hormones, such as insulin. From birth to age 20, a human body synthesizes an estimated 500 to 1,000 pounds of protein, but nearly all of this enormous quantity is required to replace aged or damaged cells. The net buildup in body protein is a very modest 20 to 40 pounds. In muscle, protein makes up 80 per cent of the nonwater weight; in blood, 90 per cent. Even in bone the dry weight is 35 per cent protein.

Living tissues are continually being degraded and replaced by new tissues, the so-called dynamic equilibrium. For example, the liver, the blood serum, the heart and the kidneys are being broken down and replaced at such a rate that half of the organ is renewed in 10 days; i.e. they have a "half-life" of 10 days. The muscles, skin and bone are more stable and have a half-life of 158 days. The proteins of the body as a whole have an average half-life of 80 days.

Since children require protein both for replacement and new growth, their minimum requirement is 1.4 g per kg body weight, compared with 0.35 g for the adult. An adult can live in reasonable health on protein supplies that are totally inadequate for a child. A child of 4 years of age and weighing 17 kg needs the same minimum intake of protein as an adult - namely 25 g per day. The child eats normally about half the quantity of food as the adult, (1500 calories compared with 3000), therefore his food should be twice as concentrated as the adult's in protein.

Protein nutrition is especially critical during pregnancy for the mother, and during the first four years after a child is born. At birth, the human brain is gaining weight at the rate of one to two milligrams per minute, and the brain continues to grow more rapidly than the rest of the human body. Its brain cells are proliferating so rapidly that by the time a child is four years old, the circumference of its head is 90 per cent as large as it will ever be.

It can be expected, then, that protein deficiency, serious enough to limit normal gain in body weight and height, will seriously affect brain growth. Scientists studying malnutrition in diet-deficient countries estimate that from one-third to one-half of all children born on earth today are affected mentally by protein deficiencies.

The term "protein" covers thousands of different proteins, alike in that they are all composed of permutations of the same 23 amino acids, and as different as peas from pork. At first glance, it appears difficult to understand how protein from peas or bread can be of use in the synthesis of human tissue proteins, but the picture becomes clear when it is realized that the pea or bread protein is digested to its constituent amino acids, and these, after absorption into the blood stream, are reconstituted into human tissue proteins.

It follows that the amino acid composition of the dietary proteins should be to some extent similar to that of the tissues, and this is the basis of the term "quality" as applied to proteins. If a protein contains the essential amino acids in the same proportions as they are present in body tissues, then it is of "high quality", or in precise terms, has a high "biological value". There are proteins completely lacking in one amino acid, for example, gelatin lacks tryptophan and whole blood protein is almost completely lacking in isoleucine. These, if fed alone, are useless for tissue synthesis and have a biological value of zero. This is rather an academic point as completely deficient proteins are rare, and more important, no one eats single porteins - rather mixtures of proteins.

The nutritive value of a protein food is a combination of QUALITY and QUANTITY. In many cases, a protein of low quality consumed in sufficient quantity can be as effective as ingesting a lesser quantity of high quality protein. But in either case, to avoid the need for excessive eating, we must have foods which offer protein in a relatively concentrated state.

Now that we appreciate the importance of protein in our diet, let us take a look at traditional agriculture and determine how efficiently we produce protein and see what the possibilities are for improvements.

IMPACT - AGRICULTURE

In a dozen words, or less, what is a good definition of agriculture? For our purposes, I think most dictionaries fail to provide the kind of meaningful definition we need to execute understanding. I prefer to think of agriculture as:

> "A basic strategy - or plan- for converting solar energy to useful products through photosynthesis".

Now, over the long haul, do we want to continue to depend upon photosynthesis and solar energy. I believe the answer is a very strong "YES!". The sun is the only:

- relatively non-depleting
- non-polluting

energy resource we have!

How much energy is available?

You can think of an acre of land as a square plot of land 209 ft. by 209 ft. The average solar energy reaching one acre in Central Ohio is 22,000 horsepower-hours per day. This is enough energy to propel a 4000 lb. automobile 32,000 miles at 60 mph - or 1.3 times around the world. It is equivalent to 485 gallons of gasoline daily, per acre - over 177,000 gallons per year.

Theoretically, if we could capture all of this solar energy and convert it to food with a 100% efficiency, we could sustain 5,360 humans on one acre. It would mean that 34,000 acres, or 53 square miles of Central Ohio farm land could supply the food needs of all the 200 million people in the United States today. This is a land area of 7.3 miles by 7.3 miles - much less than the incorporated areas of many large cities.

How much energy do we capture?

In real life we aren't doing nearly so well. The 34,000 acres mentioned actually would sustain only about 7,000 humans on a beef diet, and around 70,000 humans on a corn or rice diet.

Today, based upon average production data, we must begin with the equivalent of one cutting of alfalfa from 20 million plants in order to produce the 4.5 beef animals which are needed to provide the protein for growing one boy to age 12. We start with 17,750 lb. of alfalfa to produce the 2250 lb. of beef needed to add 105 lb. of human tissues. In terms of energy, the sun delivers 63 billion Kcal to this alfalfa. The plants capture 11.9 million Kcal. The beef animals eat the alfalfa and retain 1,190,000 Kcal. The boy consumes the edible portions of the beef animals and his body gains the equivalent of 8,300 Kcal in added tissue. The ratio of solar energy delivered to human tissue added is about 8 million to one, i.e. it takes an input of nearly 8 million Kcal to result in an output of one Kcal.

Nitrogen conversion efficiency

The nitrogen conversion efficiency of a plant or animal is a measure of its protein production efficiency. Since our need is to increase food protein production, let us examine the nitrogen conversion efficiencies encountered in conventional agriculture[3]

[3] Collaborative Research, by J. Mawry et al, W. R. Grace and Co. 1966.

	Conversion	Per Cent Efficiency
Step 1.	Nitrogen in air to fertilizer nitrogen	30
Step 2.	Fertilizer and soil nitrogen to plant protein	50
Step 3.	Balanced rations of plant products to animal proteins:	
	Milk	28
	Broiler meat	24
	Eggs	23
	Pork	17
	Beef	[illegible]

To establish an appreciation of these figures, let us look at the number of days of protein requirement for one person, which we produce on one acre 4′:

Food Product	Number of Days	Ratio to Beef
Beef	77 (0.2 year)	1.0
Pork	129	1.68
Poultry	185	2.4
Milk	[illegible]	3.06
Rice (brown)	772 (2.1 years)	10.02
Corn meal	773	10.03
Wheat flour (whole)	877	11.4
Beans (dry edible)	1,116	14.5
Peas (split)	1,785	23.2
Soybeans (edible)	2,224 (6.1 years)	28.9

It becomes quite obvious that the predominantly beef-pork-poultry diet enjoyed in diet-adequate countries is a most luxurious preference. Note that a soybean protein subsistence would be nearly 29 times more efficient than with animal protein?

We feed a lot of protein to our farm animals which is never recovered in the animal product:

Pounds of protein required in the animal's feed	To produce one pound of crude or total protein in the animal product
3.2	Milk
4.1	Eggs
4.6	Broilers
6.2	Turkeys
7.1	Pork
10.0	Beef
12.5	Lamb

4′ "Feedstuffs" by H. L. Wilcke, 1966.

Utilization of urea to supplement plant nitrogen may improve the figures cited for ruminant animals, but there is another aspect of animal production improtant to our thinking - a lot of the protein accumulated is included in non-edible tissue - it never becomes food:

Animal	Live weight	Per cent of live weight which is edible
Broiler	4 lb.	54
Turkey	16 lb.	55
Swine	200 lb.	45
Beef	1000 lb.	42
Lamb	85 lb.	33

Can we improve animal protein conversion efficiency?

Often we hear agricultural leaders expound on the great progress diet-adequate nations have made in animal production during recent years. There is ample proof that we have reduced significantly the labour input to animal production. We have learned to produce more in less time with, in some cases, fewer animals. But let us review USDA data for this country regarding the relative food units required for various animal products:

	Feed Units Required				
Year	Per 100 lb. Milk	Per 100 lb. Beef	Per 100 Eggs	Per 100 lb. Broiler	Per 100 lb. Pork
1940	105	970	61	490	537
1945	114	1,029	63	455	606
1950	112	966	60	374	531
1955	109	904	56	331	536
1960	110	995	52	289	574
1964	113	1,028	50	288	587

Essentially, in the United States, there has been no improvement in the picture for milk, beef and pork since 1940. There has been an 18 per cent reduction in feed requirements for eggs and a 41 per cent reduction for broilers.

At the 57th annual meeting of the American Society of Animal Science, T. C. Byerly presented his calculations of the protein content of beef, veal, milk, and offal from beef and veal slaughter in the United States from 1909 to 1963, compared to the protein content of feed imputed to cattle of all sorts during the same period.

Period	Per cent Protein Conversion Efficiency in U.S. for Beef, Veal and Milk
1910-1919	10.[illegible]
1920-1929	12.[illegible]
1930-1939	14.[illegible]
1940-1949	1[illegible].[illegible]
1950-1959	11.[illegible]
1960-1963	11.[illegible]

As mentioned previously, introduction of urea as a nitrogen source in the diet of ruminant animals may improve this picture. But as we look ahead in animal production, the facts are that we will have to content ourselves with "mini-increments", and probably more often "micro-mini increments" of improvement in food protein production efficiency. We must remember too that about 70 percent of all meat and milk foods are produced on protein and carbohydrate feeds that can be suitably consumed by the human population.

For really significant increases in food protein availability to man, we will have to search elsewhere.

WHAT ABOUT VEGETABLE PROTEIN?

A look at the proteins available in plants reveals two problems. First, most oil seed proteins are slightly deficient in the amino acid methionine. But methionine is produced synthetically and can be added to correct the deficiency. Cereal crops also may be deficient in lysine, but it too is being produced synthetically.

The second problem encountered is the low concentrations of protein in most plant tissue. To acquire 65 grams of protein daily, a person would have to consume these quantities:

Source	Daily needs, Pounds
Soybeans	0.41
Wheat	1.25
Corn	1.75
Cocoanut	2.
Rice	2.
Potatoes	8.
Tapioca	25.
Sugar Cane	32.

Now, is it possible to process plant tissues or plant products so that we can feasibly extract and concentrate the available protein? And can we incorporate the resulting protein into palatable food products? The answer is yes in both cases.

One technique is to extract protein directly from leaves of grasses and legumes. Research has demonstrated that <u>we can recover up to 30 times more protein per acre</u> by direct extraction as compared to feeding the same quantity of material to beef animals. Yes, problems remain before leaf protein extraction can be be reduced to practice [illegible] less than [illegible] scientists have devoted their attention to exploring the process, [illegible] within the last [illegible] years. In contrast, how long have we [illegible] attention to livestock nutrition, and how many scientists are working full-time [illegible] animal nutrition today?

In reality, we have not really begun to research leaf protein. But <u>the potential gains are [illegible] large</u>. [illegible] think of doubling the protein productivity of [illegible] accomplishment. But via direct leaf protein extraction we could expect [illegible] protein yields per acre up to 30 times greater than with [illegible]

A second concentration operation, the subject of this meeting, and one which has been fairly well researched, is [illegible] protein from the seeds of plants. In the case of soybeans, [illegible] been developed whereby 10 to 25 times more protein can be [illegible] compared to feeding the soybean protein [illegible] protein isolates are available commercially [illegible] used as protein fortifier in processed meat products [illegible], and [illegible] in the production of textured foods, mostly "meat analogs."

Considerable [illegible] to improving the palatability of foods textured from [illegible] advances [illegible] resulted in soybean protein bacon and [illegible], [illegible], [illegible] are difficult to distinguish from the "real" products. [illegible] the two speakers who follow me will go into detail [illegible] for concentrating and isolating soy protein, then incorporating it [illegible] food.

To maintain an appropriate perspective, we must remember that many of our favourite foods have evolved from [illegible]'s days. Whereas attempts to develop meat analogs from plant proteins were initiated just a few years ago. Most appealing is the fact that protein, carbohydrate and fat contents of textured foods can be adjusted to satisfy our needs. But with non-processed meat from animals, the protein and fat levels are relatively fixed.

A comparison of the approximate composition of meats and today's soy-protein textured food can be achieved from these data:

	Per cent, dry basis			
Food Product	Ash	Carbohydrate	Fat	Protein
Choice Beef (trimmed, raw)	2	–	[illegible]	40
Medium Fat Pork (trimmed, raw)	3	–	[illegible]1	[illegible]
Chicken, Rooster (raw)	2	–	4[illegible]	4[illegible]
Textured Food (ready-to-eat)	3	17	20	60

Contemplate the advantages of such "formulated" high protein foods, high or low calorie, normal or salt-free, etc., to meet the physiological needs of people of all ages and levels of activity.

Conventional vs. non-conventional plant protein sources

Since our prime interest is world food supply, we should ask which class of land plants captures the most solar energy [illegible]? Deevey[5] presents data we can summarize in these figures:

Vegetation	Per cent of world land area	Per cent of net carbon fixed via photosynthesis
Cultivated crops	[illegible]	[illegible]
Forest	30	[illegible]
Grassland	[illegible]	[illegible]
Other	[illegible]	4[illegible]

I am intrigued by the fact that man works hard at cultivating [illegible] per cent of the land area, only to succeed in capturing [illegible] per cent of the net solar energy fixed by land plants. Yet on 30 per cent of our land, growing wild for the most part,

5 "Readings in Resource Management" by [illegible] Deevey, Jr., University of Chicago Press, 1965.

unfertilized, non-hybridized, and on soil generally unsuitable for traditional agricultural pursuits, trees capture nearly seven-eighths of the net solar energy fixed by land plants. Are we overlooking a potential food resource - our forests?

Let us probe further! Calculations from data by Odum[6], using averages from areas of highest recorded yields, provide these figures for comparison where corn is used as the reference:

Cultivated crops	Relative net primary production
Hay (California)	92.9%
Corn (Illinois) ....Reference	100.0%
Wheat (Netherlands)	123.5%
Rice (Italy and Japan)	142.4%
Sugar beets (Netherlands)	145.25%
Sugar Cane (Hawaii)	339.0%
Algae (Japan)	448.0%

There is an inverse relationship between the concentration of protein in the dry matter of a particular field crop, and the dry matter yield of that crop. Some 35 years ago, O. W. Wilcox recognized this basic relationship in higher plants which, for the most part, has been ignored by agricultural "scientists".

> "...of two or more different kinds of plants growing simultaneously on the same acre of soil, the crop with the smallest percentage of nitrogen in the dry substance will be found giving the largest acre-yield."

Equation:

$$\text{Dry matter yield} = \frac{318}{\%\text{ N in dry matter}}$$

Wilcox found that there must be 2230 lb. of available N (nitrogen) in an acre of soil to achieve maximum yield. He determined that common types of agricultural crops growing on that soil could ultimately absorb only 318 lb. of N/acre. Hence, per crop cycle, 318 x 6.25 or approximately 2000 lb. of protein can be produced per acre per year with corn, soybeans, etc.

Now the constant "318" established by Wilcox may not be exact. But the key principle [illegible] in Wilcox's studies is that <u>any attempt to achieve a higher</u>

---

6 "Fundamentals of Ecology", 2nd Edition, by E. P. Odum, Saunders, 1959.

plant protein yield per [illegible] over-all dry matter yield

The following [illegible]

Crop	Nitrogen	Protein	[illegible]	[illegible]	[illegible]
Soybeans	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Alfalfa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Corn	1 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rice	0 [illegible]	5 [illegible]	[illegible]	[illegible]	1 [illegible]
Sugar cane (P.O.J.2878)	0 [illegible]	1	11 [illegible]	[illegible]	[illegible]
Unknown plant [illegible]	[illegible]	1 [illegible]	[illegible]	[illegible]	[illegible]
" " [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11 [illegible]
" " [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1 [illegible]
" " [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Dr. [illegible], University of [illegible] computed the energy data appearing in [illegible] and demonstrates that Willcox's inverse yield [illegible] yield for a crop ( ) [illegible] protein [illegible] rather closely with that predicted from solar radiation at the latitude of [illegible]

Now let us take a look at [illegible]

Non-cultivated crops	Relative net primary production compared to corn
Giant ragweed (Fertile [illegible], Oklahoma [illegible])	[illegible]
Deciduous forest ([illegible])	[illegible] %
Tropical forest	[illegible]
Coniferous forest ([illegible])	[illegible]
Tall spartina salt marsh (Georgia, [illegible])	[illegible]

Note that Giant ragweed, growing in [illegible] rainfall area, is over 40 [illegible] more effective than our best Illinois corn crop in capturing solar energy. How would this "weed" perform in Illinois if we [illegible], planted it in neat rows, fertilized it heavily, [illegible] cultivation and herbicides to keep the corn and soybeans from [illegible] it?

6/ "Fundaments of Ecology" by E. P. Odum, 2nd Edition, Saunders, 1959.

Turning to aquatic plants, we find salt marsh in Georgia capturing 3.26 times more solar energy than Illinois corn. Any plant that behaves so well in a salt water environment [illegible] attention. How would it respond to culturing?

Finally, note the net productivity of a coniferous forest. Various species of these trees are prevalent throughout much of the United States.

SCP - Single Cell Protein

[illegible] of the non-cultivated crops being suitable for human diet [illegible] considered in their natural form; the woods, trees, [illegible] sources of cellulose, and cellulose is an organic polymer of [illegible] molecules. Through acid hydrolysis or enzymatic hydrolysis we could convert [illegible] per cent of wood, for example, to simple sugars.

Next, we need a mechanism for using these wood sugars as an energy source for producing protein. Currently, food yeast production offers unusual potential. If we supply [illegible] with sugar, [illegible] culture effectively, add appropriate quantities of nitrogen and other essential elements, etc., note their protein production capability relative to [illegible] beef animal.

Organism	Growth conditions	Protein yield per 24 hours
1,000 lb [illegible]	culture tank	[illegible] - [illegible],000 lb.
1,000 lb [illegible]	[illegible]	[illegible] lb
1,000 lb [illegible]	[illegible]	[illegible] lb

If a beef animal [illegible] microorganisms, it would achieve the size of a three-car garage in [illegible] hours. Unlike animals, food yeast organisms synthesize the essential amino acids from inorganic nitrogen; while the chief by-product is carbon dioxide – [illegible] with [illegible] yields up to [illegible] per cent protein. Unlike [illegible] it is [illegible] by undesirable colour, taste and odour. It is now [illegible] foods as a protein fortifier. Also, as with soybeans, the protein can be [illegible] for production of textured meat analogues.

If you would prefer to [illegible] conventional, cultivated crops, as the energy source, let us see what we can accomplish via the microorganism pathway in comparison to beef and soybeans:

Mechanisms	Attainable [illegible] protein production per acre, lb
As we do it now	
Beef animal on high-yield legume	[illegible]0
45 bushel per acre crop of soybeans	[illegible]0
Growth of food yeast on:	
1,000 bushel per acre crop of potatoes	[illegible],500
40 tons per acre crop of sugar beets	[illegible],000
110 tons per acre crop of sugar cane	[illegible],500

This should serve to illustrate [illegible], that we can [illegible] of doubling or even tripling traditional animal protein production per acre [illegible] after [illegible] have worked [illegible] generations [illegible] trying to do it, we must recognize that nature already has provided us with protein production pathways 1[illegible] to 10[illegible] times more productive than [illegible] farm animals.

Biological value of plant proteins

[illegible] extracted, [illegible] the relative Biological Value of the various plant proteins [illegible] discussed. [illegible] Stalder[7] [illegible] determined these estimated Biological Values [illegible] index

Foodstuff	Biological Value
Whole egg	[illegible]
Milk	[illegible]
Beef	[illegible]
Leaf protein	[illegible]
[illegible] protein	[illegible]
Yeast protein	[illegible]

The range in value for soybean protein depends upon the method of preparation employed. Note that leaf, soybean and yeast protein [illegible] favorably with beef. Their Biological Value could be [illegible] by the addition of [illegible] amino acid methionine, with [illegible] tryptophan [illegible].

Availability of plant protein

[illegible] production [illegible] United States farms? Confining ourselves [illegible] protein - in which case we already have the needed technology for commercial extraction - [illegible] billion bushels of soybeans annually.

[7] "Agricultural [illegible] Chemistry", [illegible], 19[illegible]

That is equivalent to 21 billion lbs. of soy protein - enough to supply the annual protein needs of a population twice that in the United States of America, over 400 million people.

FORESIGHT - AGRICULTURE

Organized agriculture has been in existence for some 8,000 years. Yet up to now man has accomplished little towards improving his food supply chains. As is has for thousands of years, agriculture still consists of attempting to provide for plants and animals (only slightly different from those found free in nature) and "environments" suitable for growth. Transformation of plant and animal life, changing the course of its development, as distinct from simply nourishing, inhibiting or killing it, is largely an unfilled goal, one which we must achieve in the next 25 years. Today, our understanding of the properties of biological mechanisms is sufficiently profound and so general as to disclose potential food production systems wholly new to human experience!

Essentially, too, man is still content to employ only simple mechanical and thermal processes to prepare food crop and animal products utilized in his diet. It began by milling wheat into flour, corn into meal, or boiling rice, etc., and the resulting food has to be palatable in its natural state. Salt, native spices, or sugar may serve to enhance flavour. Even in the so-called developed countries, primary cuts of food undergo little more than the primitive process known as "cooking".

Since natural palatability has always ruled, many plants have been relegated to a "weed" category. Either man and his domesticated animals would not eat them, or, if eaten, their natural nutritional value was limited. Yet the photo-synthetic capability of some "weeds" exceeds that of several conventional food and feed crops.

Technology can add a new dimension to food resources. The plants or plant products need not be palatable in their natural state. Nor must any one source contain all or most of the nutrients essential to the human diet. We can extract and formulate the desired nutrients into foods analogous to those we now enjoy.

It is time for those of us involved in food production to look around – to comprehend how far behind we are, technologically, relative to other industries.

A. What would be our mode of travel today, by land, sea or air, had we stuck with only those transportation modes found "ready-made" in nature?

B. What sources of power conversion would we have – water, wind and animal, perhaps?

C. How would we communicate on a national and international scale?

In the compounding of fuels, synthetic fibers, plastics, rubber, etc., we recognize many instances in which a desired end-product is carefully defined, and then research leads to the technology of synthesis. This type of approach is foreign to the food industry.

METHOD – "Market" Oriented Thinking

The most significant feature of food industries is that they are production oriented, rather than product oriented. Just as it all started about 8,000 years ago, we are starting with "natural" production patterns and then being content with whatever products "naturally" result.

Where would the rubber industry be today, had it insisted on retaining its originally strong production oriented thinking? Today, the synthetic rubber tires are superior to natural rubber in many ways. And few, among automobile operators, ever asks about the ingredients that go into synthetic rubber. Tires are not even marked "synthetic" in the United States.

Yet the meat and milk industries would have you label any protein foods as "imitations" and "synthetics" even where the new food is more nutritious.

We know the dietary needs of our bodies, and we can measure influencing factors such as age, level of activity, disease, etc. Flavor, colour, texture, sophistication, and personal preference characteristics [illegible] can define classes of foods if we really try. It seems reasonable, therefore, to ask that the most efficient and economical inputs be chosen which will result in the preferred products.

"Market" oriented thinking proceeds along these lines:

A. Given the customer's needs, the industry then looks backwards – first concerning itself with the physical delivery of customer satisfaction.

B. Then it moves back further to create the things by which these satisfactions are in part realized.

C. Finally, the business moves back still further to finding the raw materials necessary for making its products.

Now [illegible] matter of indifference to the customer - assuming in the case of the food industry that all sanitation, health, food and drug, labelling, etc. standards are strictly adhered to. Hence the ingredients, the particular form of manufacturing, processing, or what have you, cannot be considered [illegible] vital aspect [illegible] the industry.

Let us apply this thought to our food protein needs, and simultaneously think of solving some of our pollution problems. One of our greatest challenges in urban living is what to do with the solid waste by-products of modern existence. The great debate today is whether we should compost, bury or burn the stuff. One of the major ingredients in our solid wastes is paper.

With the appropriate processing we could hydrolyse the cellulose in paper and produce simple sugars. Then we could use these sugars as the energy source for growing food yeasts. That 100 lbs. of paper could result in the production of over 20 lbs. of food protein. Recall, a 100 lb. quantity of round steaks contain about the same amount of protein.

Hence, one pound of paper could serve as the energy source to produce enough protein to meet the needs of two adults for one day. The per capita consumption of paper in the United States approaches 2 lb. per day. So if we collected one-fourth of the paper, preferably the newspaper and magazines which every home owners can accumulate conveniently, we could produce enough food protein to meet the entire needs of [illegible].

Sure, problems in the hydrolysis of cellulose remain to be solved, but not many scientists have devoted their efforts to solving them. Yes, we need to undertake research on bridging the gap between yeast protein and palatable foods, but it will never be accomplished unless we start.

Let us think at the [illegible] Century Level

Protein is essential to physiological health. It should be included in those foods we enjoy and find convenient to consume. For the hundreds of people who enjoy coffee for breakfast, but for some reason will not eat anything else, it is time we synthesize a drink that looks like coffee, tastes like coffee, but offers the consumer one-third of the daily requirement of protein, minerals and vitamins, plus a few extra calories if needed. Or, the material containing the protein, etc., could be developed as a substitute for regular coffee. Or, the breakfast roll can contain the needed protein, etc. Or the bread which becomes toast, the jelly- or jam-like spread consumed on the toast, whatever the preference happens to be.

And with children, let us stop fighting them. Spinach, broccoli, asparagus, green beans, carrots — yuck! I do not care for them myself. Kids enjoy peanut butter sandwiches, potato chips, soft drinks, candy and ice cream. Any, or all of these foods can be made nutritious in terms of protein, minerals and vitamins.

Also, for the man who does not want to waste energy chewing, as he spends an evening staring at TV, I could "invent" a new protein liquid in a brown glass bottle with a distinctly beery flavour.

Vegetable protein industry needed

To provide food processors with the ingredients needed to produce the foods mentioned in the three previous paragraphs, we need a new emphasis in the food industry. Processors will have to think more in terms of proteins, carbohydrates, fats, vitamins, minerals, etc. — not in terms of heterogeneous farm commodities with all sorts of allied headaches precipitated by unusable by-products.

There has existed for many years, large segments of the food industry devoted specifically to isolating large quantities of food-grade vegetable carbohydrates (sugars, starches, etc.), and fats (vegetable oils). We are plagued by vitamin salesmen, but until recently there have not been comparable efforts directed at isolating vegetable proteins. In its infancy, and emerging as a "by-product" of the oil seed processors, we find limited food-grade protein extraction operations.

Essentially these are at the pilot-plant stage of development. Much more effort will have to go towards producing extracted vegetable proteins with the variety of characteristics essential for formulating both solid and liquid foods. But, again, let us remember that relatively few scientists are engaged in this type of research, and those who are working on vegetable protein extraction have just begun to function.

Let us establish nutrient economics

It is time we ditched the concept of agricultural production in terms of bushels per acre, or in the case of animals, pounds of gain per day. A bushel of soybeans has much greater food value than a bushel of corn. Per acre yields should reflect this fact. A pound of gain on a turkey is not equivalent in food value to a pound of gain on a beef animal, or a pig, and none of the gains in weight equal a pound of milk produced, or a pound of eggs.

Yield concepts, along with product sales values, should be established in terms of ultimate contribution to the end diet. This means thinking of land yields as pounds of protein, etc., per unit area. It means marketing agricultural products on the basis of per cent protein (and its Biological Value) along with compensation for essential vitamins, minerals and fatty acids. These nutritive-economic criteria should follow on up the line from producer to processor to retailer.

As we wake up to favourable geographical, climatological, soil fertility relationships, agricultural production should be zoned on a nutritive-economic basis. High-protein crops need to be encouraged in appropriate localities; whereas, high-carbonate crops should be grown elsewhere.

Let us re-define "food engineering"

For the most part, most people think of "food engineers" as graduate engineers working as high paid plumbers in food manufacturing plants. It is time we recognize a "food engineer" - just as we think of an aeronautical engineer designing aircraft - as an engineer doing research on, designing, developing and fabricating foods.

Just as the aeronautical engineer works with metals, plastics, glass, rubber, etc., along with associated technology to design an aircraft, the "nuts and bolts" of a food engineer include:

- Proteins
- Fats
- Carbohydrates
- Minerals
- Vitamins
- Binders
- Emulsifiers
- Stabilizers
- Preservatives
- Flavours
- Colouring
- Etc.

With these, and "market" oriented thinking as discussed previously, a food engineer goes to work fabricating food which satisfy both the consumer's taste and his nutritional needs.

Let us quit fighting symptoms and eradicate the diseases

Plans for increasing food production per acre invariably involve large-scale efforts at environmental manipulation. Today this means more water, fertilizer and pesticides, not necessarily used with an intelligent concern for the future. We should elevate the level of responsibility and ecological sophistication of people working to increase agricultural output.

Bad land management and poor water control are ruining our soils. In 1776 the United States Soil Conservation Service reports we had an average of 9 inches of top soil in this country. Today we have 6 inches - a loss of one-third in less than 200 years, and only during the last 50 of these years have we practiced intensive cultivation of our cropland.

Regarding synthetic pesticides, their usage, though already massive, will increase substantially. In spite of much publicity, the intimate relationship between synthetic pesticides and population crisis, food shortage, and environmental deterioration often is not recognized. A basic fact of population biology is that stability of an ecological system is inversely proportional to its simplicity. A complex forest ecosystem will persist for hundreds of years if man does not interfere, but a simple homogeneous crop of one species, such as a cornfield, is subject to almost instant failure unless we guard it constantly [8].

We strive to simplify ecosystems by destroying some organisms and encouraging uniform populations of others. Synthetic pesticides are among our most potent modifying tools. They reduce the diversity of life above ground. Too, long-term applications will reduce the diversity in our soils, and soil is not just weathered rock particles - it thrives with a rich population of fauna and flora which are critical to its fertility.

One major disease of traditional agriculture is the simplified ecosystems we have established - the crops and animals we are trying to produce. Instead of

---

8/ "The Food From the Sea Myth: the Natural History of a Red Herring", paper presented to the Commonwealth Club of California, by P.R. Ehrlich, April 1967.

curing the disease, all of our attention has been directed at developing more sophisticated ways of treating the symptoms. We have spent billions of research dollars on developing corn varieties, corn crop disease and insect control, etc., but very little of our attention has [illegible] directed at hydrolyzing cellulose into useful sugars - a process that would permit food production from the forest at levels several times greater than [illegible].

I think we could learn much by studying the accomplishments in allied fields. Not long ago the annual "March of Dimes" campaign was given top billing in the United States - heart and cancer fund drives were less publicized. Millions of dollars were collected, with most of the money being spent to develop treatment techniques and equipment to help patients who contracted poliomyelitis; but treatment of the symptoms of polio did not result in developing any degree of public immunity. Finally, Jonas Salk, and later Albert Sabin, chose to eradicate the disease, rather than fight symptoms, and we know the result.

Today, millions of research dollars are being spent on studying symptoms peculiar to conventional systems of protein production. One example, as emphasized earlier, is the polluting aspects of farm animal excrement. A popular thing for United States Agricultural College research now is animal waste treatment; but regardless of the treatment, the symptoms can only be suppressed temporarily. The only real cure is to eradicate the disease - i.e. turn from an animal protein diet to a vegetable protein diet. It will, indeed, be easier to synthesize milk from vegetable ingredients, than to treat the dairy cow waste symptom.

CONCLUDING THOUGHTS

Whenever I mention non-conventional methods of food protein production, someone is quick to conclude that such methods just are not economically feasible. Economic feasibility is a dynamic and transient characteristic. I have discussed several factors - population, food preferences, farm labour income problems, pollution - which could alter the picture greatly.

People laugh about formulated foods. Give them their steak - they would rather fight than switch. But then there was a day when the preferred mode of transportation in the United States was animal-powered - on the ground.

From our vantage point today it is almost impossible to believe in the jokes, editorial jeers and ridicule which the nation's newspapers used in America [illegible] Samuel P. Langley's attempts to construct a flying machine in 1901. The whole idea was ridiculous - [illegible] mathematician and astronomer, Simon Newcomb, [illegible] the scientific [illegible] Admiral Melville, then Engineer-in-Chief of the United States Navy, wrote:

> "Outside of the proverbial [illegible], there probably exists no field where so much inventive [illegible] with so little return as in the attempts of man to fly successfully through the air. A calm survey of certain natural phenomena leads the engineer to pronounce all confident predictions of success for future success as wholly unwarranted, if not absurd."

That was written in 1901 - and if the Wright brothers read it, they obviously did not believe it. Two years later, at Kitty Hawk, N.C., [illegible], they enjoyed their first successful flight of an aircraft.

An industry runs into trouble when it becomes attached - not to its fundamental purpose - but instead to techniques and methods. The railroad company leaders lost sight of transportation as their fundamental purpose, and became attached to steel wheels on steel rails, the railroad [illegible] their decline. Separate trucking companies [illegible] to take advantage of the new transportation opportunities. Agricultural planners [illegible] stood, today, where the railroad company leaders stood 50 years ago.

William Vogt has expressed it [illegible] in a most effective manner:

> "Behind nearly every human act lies an 'emotion' that sets the act going, and behind the 'emotion' lies a 'thought' or an 'idea'. If such survival [illegible] desire for conservation are to become part of our daily existence, they must be based on knowledge and the thought that stems from it. If we are to live in harmony with the forces of the earth, that purpose must be in our minds - and we must seek, and accept, many new ideas [illegible] must reject many old ones."

25. 5. 72