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INTRODUCTION

As the world demands less use of energy in food production, the application of present day scientific technology to solving agricultural problems will be necessary. With optimum use of the world's energy resources as a prime concern, the conservation of energy in food production is paramount. Efficient food production will be measured not only in optimizing protein for animal and human consumption, but will also be measured in terms of decreased energy requirements.[1] One area of conservation that can be improved is that of disease control in animals. New methods for disease prediction, detection, and forecast need to be developed.

After a diseased animal is detected, its herd of origin and the source of the disease must be determined so that corrective disease control and eradication procedures may be initiated. To determine their herds of origin, animal populations must be identified. Computer technologies must be applied to manage the extensive records that will be necessary for traceback through commerce to herd of origin. Electronic technology offers long-sought solutions for disease detection and epidemiology problems. Developmental work at present has shown that a subdermally-implanted, electronic transponder (having no batteries) can be remotely activated and transmit temperature and identification information back to a receiver in a few tenths of a second. If this electronic identification and temperature monitoring system is developed into a commercially available product line, and is widely accepted by the cattle industry, it will enable them to carry out more extensive management practices. Better management can result in greater efficiency and productivity. The system will also enable regulatory agencies to trace the movements of diseased animals through commerce, and thus assist in disease control measures.

THE USDA/ERDA IDENTIFICATION PROJECT

The inadequacy of present-day methods for animal identification are well recognized by those in the livestock industry and regulatory veterinary medicine. A cooperative activity between the USDA, Animal and Plant Health Inspection Service (APHIS) and the ERDA, Los Alamos Scientific Laboratory (LASL) has been underway for three years to seek a satisfactory solution by developing a system for effective animal identification.

Several alternative methods of identifying animals were considered. It was concluded that most nonelectronic methods could not satisfy a preponderance of the desired characteristics from the list below.

1. Passive (no batteries)
2. Remote sensing (do not have to hold the animal)
3. Capable of identifying individual animals
4. Error free
5. Suitable for direct input to a computer
6. Long life
7. Low cost

In the winter of 1972, LASL scientists were asked to consider the possibility of passively monitoring the temperature of animals during ante mortem inspection at slaughterhouses. In considering this problem, a remote temperature monitoring system was envisioned using encoded microwave backscatter from a fixed frequency interrogator. It soon became apparent that identification numbers could also be encoded on the temperature signal, and that the resulting concept incorporated most, and perhaps all, of the desired properties on the above list. Thus, a combination of animal identification and temperature monitoring seemed possible, and work was started to determine the technical feasibility of the concept. Since the electronic development was at the forefront of electronics technology, many concepts used in the design had not been proven, and thus, considerable risk was involved in extrapolating existing technology to a practical system. To minimize the cost associated with the risks, the technical development was divided into five stages.

<u>Stage I</u>.

The first stage was to demonstrate the feasibility of a passive, remote transponder having both identification and temperature. Once the concept had been demonstrated as feasibile, it was determined that a subdermally-implanted transponder with 15-decimal digits of identification and 3-decimal digits of temperature was desired by a large segment of the livestock industry and the APHIS.

<u>Stage II</u>.

The next stage of development was the demonstration of a subdermally-implanted transponder which would work under the skin without the use of batteries. This was accomplished with a temperature-only indicating unit in September 1975.

<u>Stage III</u>.

With the successful operation of the equipment in Stage II, it appeared that there were no unsolved fundamental problems which would prevent the development of a practical electronic identification and temperature monitoring system. Although the feasibility of the concept had been demonstrated, considerably more electronic development was necessary before a practical system could be realized.

It was recognized early that it would be necessary to use integrated circuit (IC) chip manufacturing techniques to reduce the size and cost of the transponders to acceptable values. Since a substantial investment is required (up to $100,000) to develop and produce IC chips, it was decided to develop the final circuits with hand-wired and hybrid circuit electronic components. Considerable circuit development was required, and modifications were necessary as a result of field testing. It was also necessary to keep the size of the working models close to that of the final unit. Therefore, a compromise was necessary for Stage III, and it was decided to incorporate only three decimal digits of identification with the temperature measurements; but to incorporate all of the other essential features of the final system. Stage III is currently underway, and a demonstration is expected in the summer of 1976. At the completion of Stage III, it is expected that the major technical problems will be solved, and it will be time to initiate transfer of the technology to industry.

Stage IV.

Stage IV involves the completion of the electronics development and the successful transfer of that technology to industry. Specific inputs from the livestock industries and regulatory agencies will be required to develop specifications for the system developed in Stage IV.

Stage V.

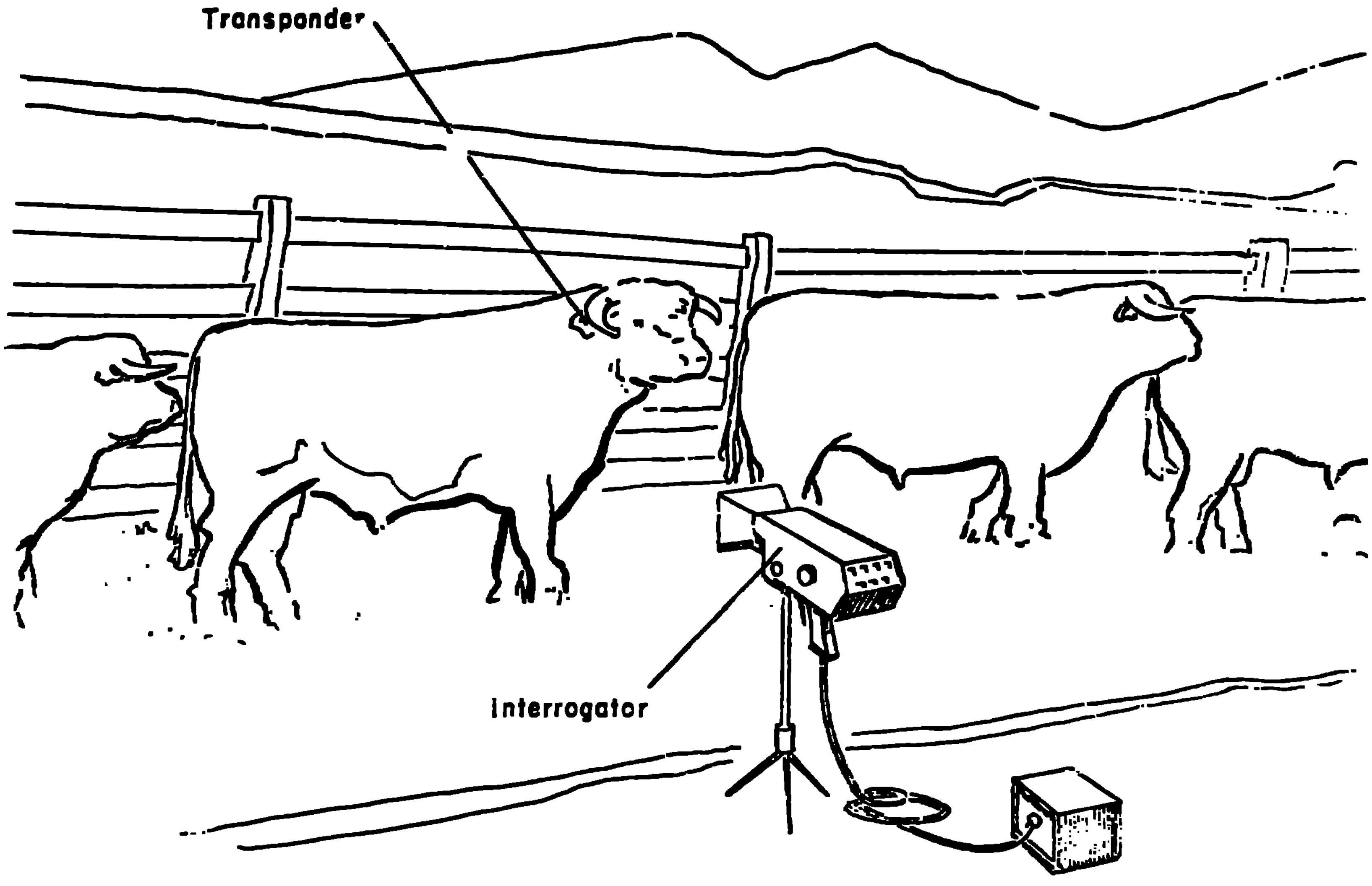
Commercialization and industry-wide utilization of a practical electronic identification system is the ultimate goal of the Electronic Identification Project. Stage V is intended to encompass all of the activities necessary to implement Electronic Identification of Animals.

It is generally recognized that if electronic identification is cost effective, it will be quickly incorporated into the livestock industries. Therefore, it is important that the development of the commercial system meet the needs of the specific industries so that incentive is present for its incorporation. As it becomes widely accepted, the cost effectiveness is likely to increase.

PRINCIPLE OF OPERATION

The principle of operation in the final system is illustrated in Figure 1. The interrogator sends out a beam of 915 MHz radio waves towards the transponder. A small fraction of the microwaves penetrate the skin of the animal and generate enough voltage (about 1-1/2 volts)

Fig. 1



to power the transponder circuitry. The internal circuitry of the transponder is used to change the reflection of the transponder antenna with a frequency (approximately 20 kHz) that is proportional to the temperature of the animal. This relatively low frequency reflection is detected with the same antenna that sent out the interrogating beam. Signal mixing and suitable filters isolate the return signal from the powering beam, and the signal is subsequently decoded into identification and temperature. The digital identification number uses a binary-coded decimal format in which the "zeros" and the "ones" are further encoded into a pattern of 10 kHz and 20 kHz frequency "packets."[2] The receiver circuitry requires that the identical coded signal be received two successive times before it is accepted as a correct signal. This requirement eliminates essentially all erroneous readings. Each reading of the 15-decimal digits takes place in less than one-tenth of a second.

The antenna constitutes the largest item in the transponder package (see Fig. 2). When operated near resonance, its length is proportional to the amount of voltage which can be generated to power the electronics. The present length of 10 cm was chosen to be compatible with present day circuit elements, biological radiation standards, and the frequency of the interrogating beam.

INTERROGATOR UNITS

The identification and temperature monitoring systems may eventually be developed into two basic configurations: 1) a shoulder-harness or back pack model, and 2) permanently mounted models. The back pack models would be used by individuals to identify animals while the permanently mounted models would be interfaced to a computer and be capable of directly transmitting data to a large computer center.

Back Pack Model

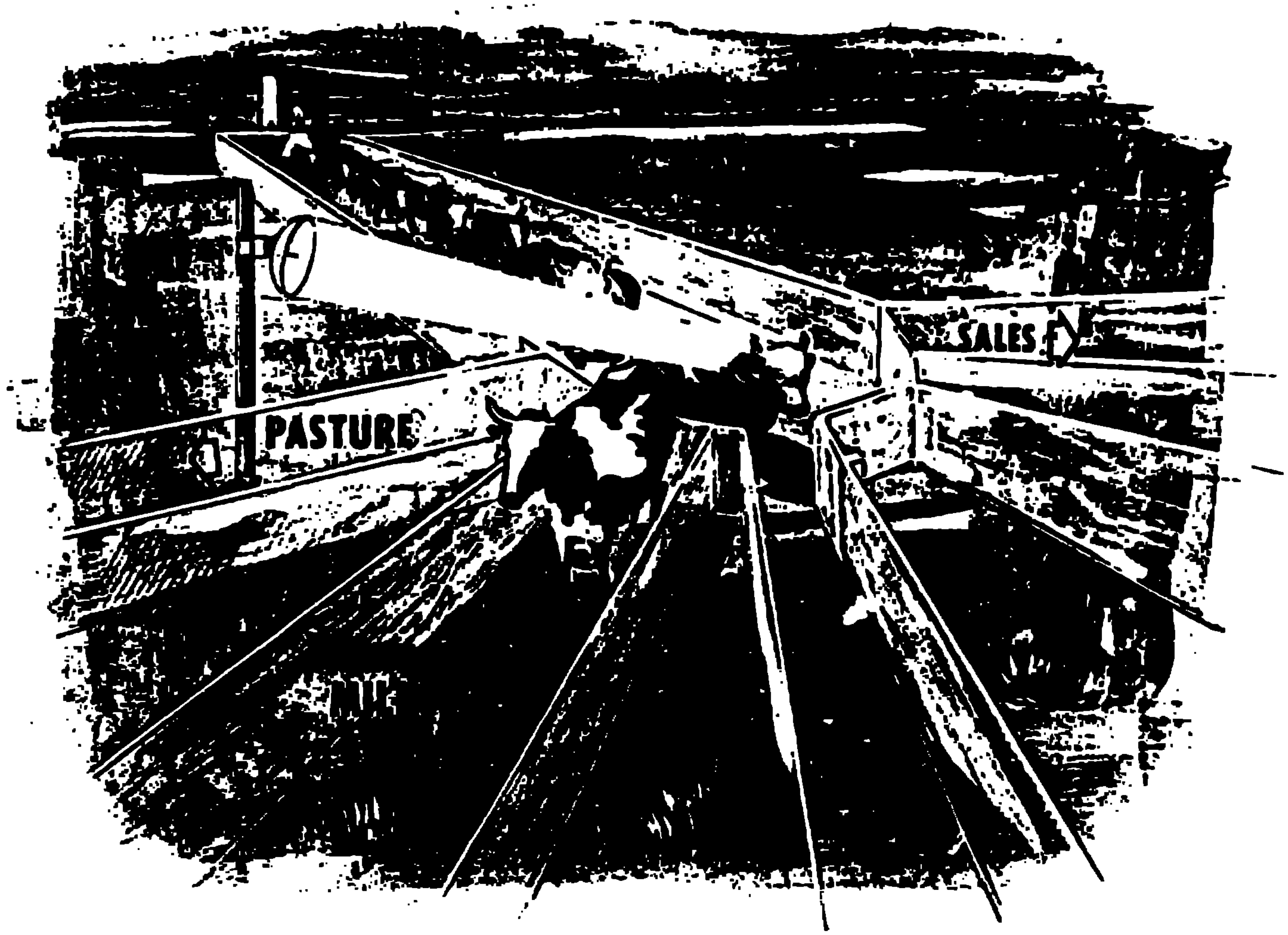
A portable system with visual readout will be available for field use. Variations could have permanent data recording capability. The systems would be battery powered and carried on the operator's back, similar to a back pack, but with a hand-held antenna and readout. These units would be used for recording individual animal temperature and identification. The data could be recorded on a magnetic tape for subsequent transmission to a computer for analysis.

Permanently-mounted Model

The major uses for electronic identification will be found in permanent installations. These systems can be used to control feed mixutres and medication to individual animals, open and close gates (Fig. 3), and assign weight and performance information to the proper animal.

Fig. 2 - This photo shows the implantable temperature monitoring transponder before and after encapsulation.

Fig. 3 - The passive identification system is being used to automatically sort cattle.



These systems can be used to monitor animals as they enter a slaughter plant. The animal identification number will allow traceback to the herd of origin. This information is extremely important if the animal is found to be diseased and disease control procedures are initiated.

APPLICATION OF REMOTE ELECTRONIC IDENTIFICATION AND TEMPERATURE MONITORING

To define uses of the remote, passive electronic identification and temperature monitoring system, we must assume completion of current developmental activity,[3] acceptance by the livestock industry of the need for implanted identifiers, and their subsequent use in domestic animals. We have also assumed that a network of large computers can be developed to manage the large amount of data that will be generated.

Disease Detection and Eradication

Animal diseases cause reductions in production efficiency. Since elevated body temperature is frequently associated with disease, the measurement of temperature offers an early disease detection capability. Therefore, frequent monitoring of animal temperature and detection of variations from normal temperature patterns can have significant impact on the economic losses associated with disease.[4] This is particularly true in disease eradication programs where it is important to detect the disease early in an outbreak and initiate appropriate control measures. Small changes in the average temperature of a large animal population may give an indication of a physiological change associated with disease.

Continuous temperature monitoring of individual animals is currently underway to show the effects of environmental conditions and infectious agents on the body temperature.[5,6,7,8] Many animal diseases cause specific perturbations in temperature histories. These perturbations are related to the multiplication of the infectious organism, and in some instances can be used for determining the type of organism. Initial temperature profile research at the USDA's Plum Island Animal Disease Center (PIADC) in Long Island, NY,[5] showed the potential of using animal temperature histories in remote detection of foot-and-mouth disease in deer and cattle.

Continuous temperature measurements show that there are considerable temperature variations in animals under normal conditions. Thus, it appears that it will be necessary to develop methods for cancelling out the normal fluctuations due to the environment, so that abnormalities can be identified. It is expected that computer codes will be developed to assist in the identification of temperature abnormalities.

Metabolism

In cattle and swine, adequate intake of nutrients provides for physiological stability in the absence of disease. Prudent use of plant protein in producing meat and dairy products will become more and more critical, and genetically efficient production animals must be fed exactingly to produce the end product with optimum consumption of plant protein. Electronic identification and temperature monitoring coupled with computer controlled feeding stations and weighing stations, will make it possible to monitor changes in conversion efficiences associated with changes in metabolism. Computer programming will allow the producer to become aware of animals going off their feed, or off their milk production. Since altered metabolic or physiological activity is associated with ovulation, parturition, and other disturbances, it is expected that these will be detectable by frequent temperature measurements.

Markets

Individual animal identification will make it possible to institute considerably more automation in business transactions.[9] In the livestock markets, an animal can be immediately identified upon reaching the facility. The animal's identification number could be transmitted to a large computer center and verification of ownership could be quickly obtained. If the animal was removed from an infected herd, proper disease control procedures could be initiated. If the animal is determined to be disease free, its sale could proceed normally. Animals with certain diseases could be consigned to slaughter-only status.

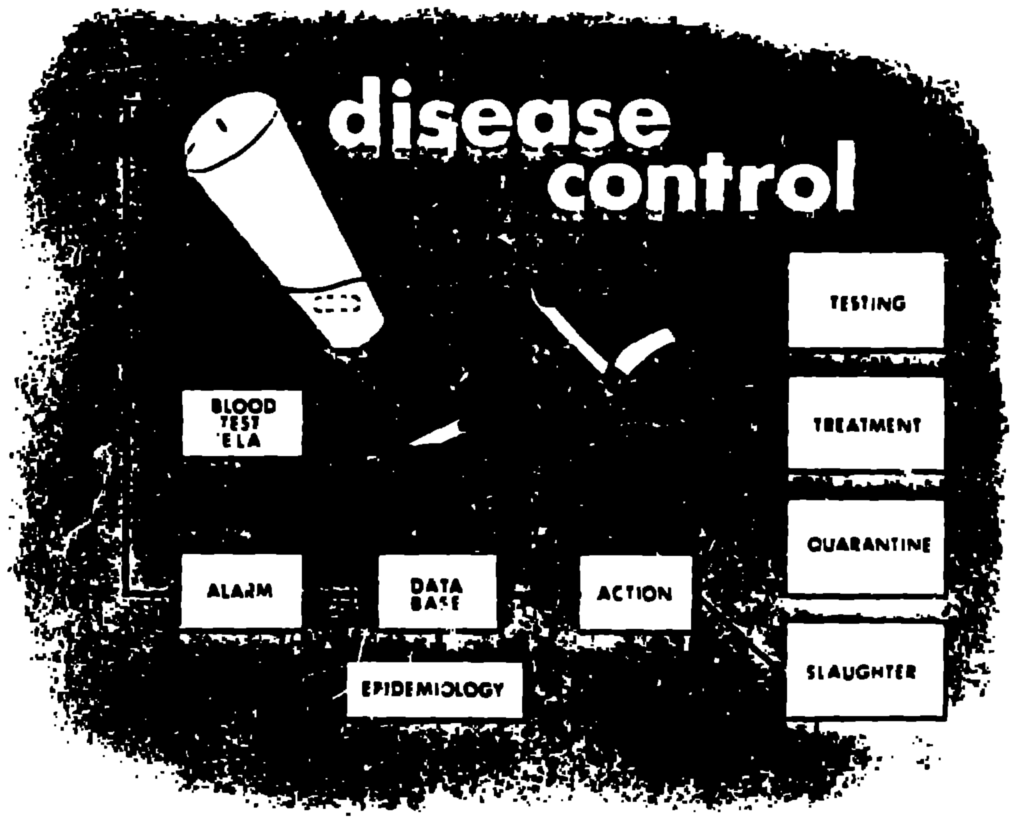
A small computer would necessarily be a part of this system. This computer could be used to automate many of the market operations. Sales transactions, animal weight, seller information, market commissions, and buyer information could all be handled by this computer for rapid and efficient operation. The resulting market data could be transmitted to a large computer facility. There it would be summarized and indexed to provide information to agencies and individuals in need of, and qualified to receive, the information. These data could be used to forecast world food supplies.

CONCLUSION

Passive electronic identification with temperature monitoring of animals appears to be technically feasible and offers the potential for practical individual animal management. While there are additional developments and experiments which must be done, there is good reason to expect that a practical system will evolve in the next few years.

The development and widespread use of an accurate passive livestock identification and temperature monitoring system is the key to the control and subsequent eradication of animal diseases (Fig. 4). This will lead to more efficient food production. With the systems that we have discussed, the livestock industry will be able to better optimize the production of animal protein.

Fig. 4 - The animal identification and disease detection systems are shown as they may be used in disease control programs.



There is an important balance between plant foods for animal and human consumption, animal products and by-products, world human population dynamics, and political and international economic considerations (Fig. 5). All available technology should be used to maintain this delicate balance. New disease detection methods, remote electronic identification and temperature monitoring, and space-age plant-crop assessment, offers the means for maintaining this delicate balance. Further application of scientific technology to agricultural problems is needed.

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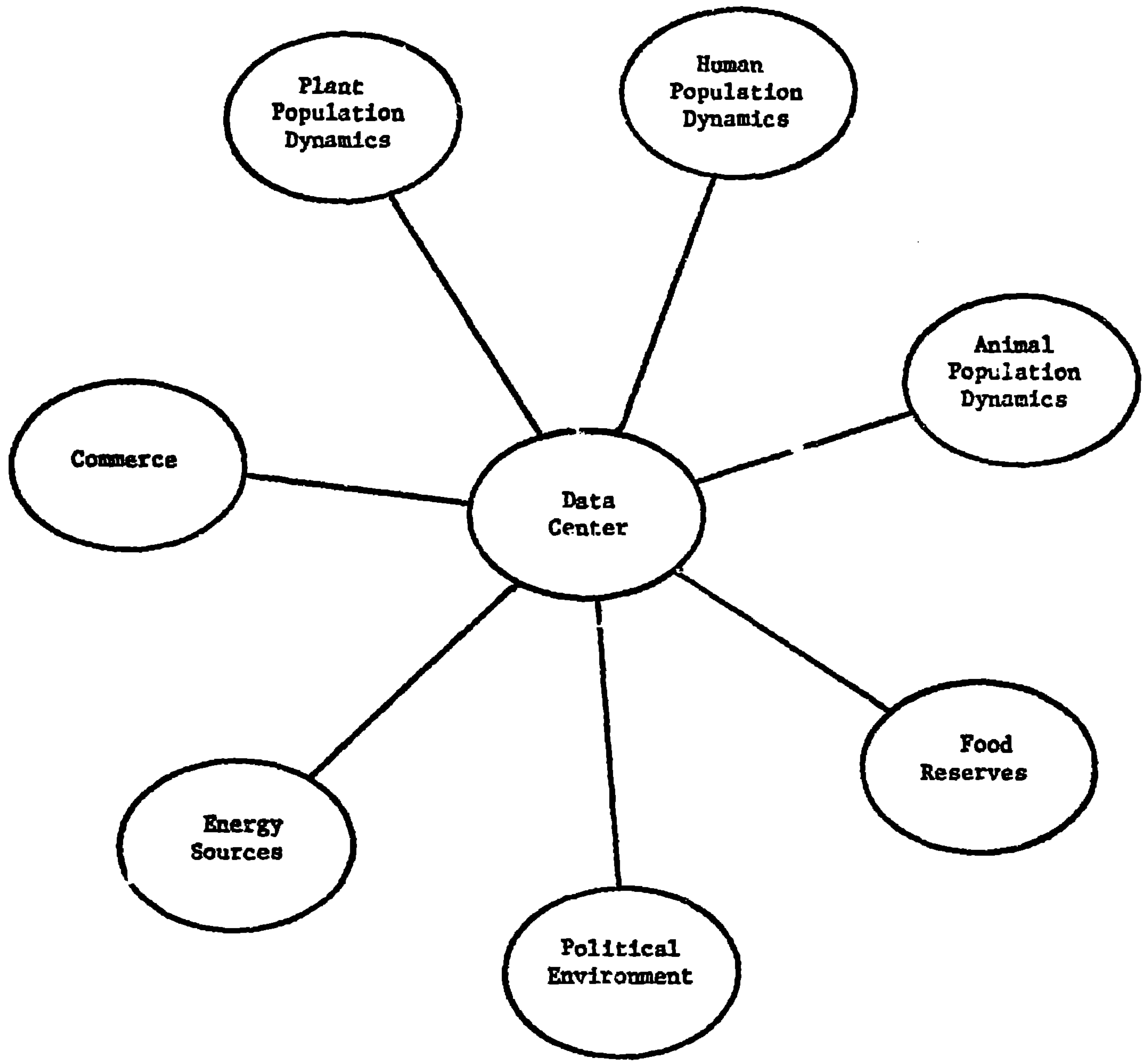
Fig. 5 - The interaction of food and energy supplies are shown.



FOOD ASSESSMENT PLAN