# INTRODUCTION

G. M. Smith
Jet Propulsion Laboratory
Pasadena, California

The objectives of this Symposium, as stated in the program, are to stimulate the development of CCDs and related devices by the exchange of information on recent advances in CCD technology, and by the identification of applications requirements. The timing of the Symposium has been based upon the emergence of CCDs from the research stage, with devices which have practical scientific applications.

The use of electronic imaging sensors in scientific applications is a relatively new field. Most of the work has been done in the past 10 to 15 years as part of the space program. During this time, we have learned a great deal about how to calibrate and process imaging data, and the number of applications has multiplied. But the electronic sensor technology in use today is not very much different than it was 10 years ago. The recent development of large silicon sensors, and particularly CCDs, may change this situation in the near future.

Scientific imaging is distinct from nonscientific applications in that scientific work requires quantitative information from an image. In the simplest form, this involves being able to accurately measure the amplitude and position of each point in an image. Implicit in this measurement is the need to account for the distortion introduced by the measuring system, and especially the sensor. These simply stated needs translate into very specific requirements for each different application. The applications sessions are intended to discuss several of these applications and then, through a panel discussion, help formulate sensor requirements for various applications areas.

There are a few sensor characteristics which are fundamental to a large variety of scientific applications. These common characteristics include

(1) High sensitivity.

(2) Broad spectral response.

(3) Stable transfer function.

(4) Large format.

High sensitivity is desirable to achieve the most efficient detection of incident photons and minimize the degradation caused by system noise. This is particularly important when the incident energy is low, but even with bright objects, we usually find ways of reducing the useful light with narrowband filters or short exposure times, and in many applications, it is necessary to detect very low-contrast features.

Broad spectral response is needed in a large variety of applications. In most situations, sensor selection involves a tradeoff to achieve high quantum efficiency in one spectral region at the expense of another portion of the spectrum. An imaging sensor with a high quantum efficiency from the near-UV to the near-IR will be a major addition to the capabilities of available imaging sensors.

Stable transfer functions are of critical importance in making quantitative measurements. Most electronic imaging systems in current use do not have a stable, well-behaved relationship between input and output, and measurement accuracies of a few percent are very difficult to achieve. Silicon target vidicons have yielded the best results, but a considerable amount of computer processing is required to compensate for sensor distortions. Routine measurement accuracies of 1% or better will ultimately be needed.

In virtually all applications, it is desirable to have a format with a large number of picture elements. This has been a major limitation in electronic sensors and has been largely responsible for the continuing attractiveness of film in many applications. Sensors with formats of $10^6$ to $10^7$ elements will be needed eventually, but devices with $10^5$ to $10^6$ elements will be useful in many applications.

The development of electronic sensors for scientific imaging historically has involved a long, and mostly unsuccessful, struggle to improve sensors in these four characteristics. The development of CCDs should result in major improvements in three of the four areas. Only in format size will the CCD suffer in comparison to present sensors. The solution to this limitation may come in time from improved processing technology or from mosaics of small format devices. In the meantime, devices of usable format size for many applications now appear practical.

There are many other factors, in addition to the four characteristics already discussed, which are very important in various applications. They include cost, useful lifetime, power, weight, size, and environmental sensitivity. The CCD offers dramatic improvement in some of these factors, while others, such as cost and radiation sensitivity, remain question marks.

The development of CCDs over the past 3 years has been very active. The devices have progressed from very simple demonstration models to the relatively complicated models which are emerging. In the course of this development, the early, optimistic estimates of device simplicity and performance have been moderated substantially by the facts of life learned in making and testing practical sensors. Many of the problems inherent in new technology are now being identified, and solutions are being worked out.

The session on device technology will cover the progress in CCD development and evaluation and bring potential users up to date on current device capabilities. While most of the development work in CCD technology has emphasized direct photon imaging, some very important work has been directed toward an electron bombardment mode for very low light applications; this work will also be reviewed. In spite of the problems and limitations which are now apparent, it is clear that CCD technology will play a major role in future scientific imaging. In some ways, CCDs available today surpass the best available electronic imaging devices, and future work should widen the gap.

In organizing and sponsoring this Symposium, JPL and NASA are providing a vehicle for communication between potential scientific users and device manufacturers which we hope will promote the earliest and most effective application of this new capability to scientific imaging.