THE GENERAL PROBLEM OF DATA RETURN FROM DEEP SPACE*

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1. Introduction

When Columbus discovered America, Queen Isabella had to await his return to learn where he had gone and what he had found out. Even though our space probes travel far greater distances than did Columbus' ships, we can almost instantaneously obtain the kind of information from them that Isabella had to wait months to learn. Indeed, the current state of the art of deep space exploration does not provide for the return of an exploratory vehicle, and we must depend upon communication with it to obtain its scientific and engineering data. Fortunately, as contrasted with radio-frequency communications on earth, the uncertainties or variables in space communications are very small, and the design of the communications system can be quite precise. This is a great advantage, because the tremendous distances that must be covered in deep space exploration make it mandatory that every element of the communications system employ state-of-the-art devices.

It is the purpose of this article to examine the various factors which affect a space communications system, to determine their relative importance, and to assess the potential advancement of each. The problems encountered in obtaining data from deep space are many and varied, and involve most of the engineering and scientific disciplines. A basic understanding of these problems, therefore, is valuable to all who are concerned with the development of science.

The basic purpose of any deep space mission – the return of data – is affected by the mission's scientific activities in that they influence both the functional and detail design of the data system. The amount and kinds of data produced by the science payload must be taken into consideration in the design and interface of the ground and on-board data system, as must the needs of the scientific activities involved in the receipt and use of the data.

The scientific experimenters and their representatives have an important role in defining the mission, formulating functional requirements, and participating in mission operations, in addition to preparing their experiments. Flight projects are usually organized with defined areas of responsibility; the purpose here is to examine

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the functional, design, and operational interfaces between the scientific activities and the data system.

The typical data system for deep space missions (Figure 1) encompasses both spacecraft and ground equipment; it includes three distinct areas in which it is convenient to consider the interactions with the scientific activities—the scientific subsystem and data storage function, the telecommunication system proper, and the ground data-processing and display activity.

The telecommunication system, consisting of the spacecraft and ground antennas, transmitters, receivers, telemetry encoding and decoding equipment, and command equipment, is, as shown in Section 5, basically the same in design for various deep space missions. The available transmitter power, antenna gains, receiver sensitivity, and other system performance parameters ultimately determine the upper limit on the data rate from spacecraft to earth. The detail functional design may vary slightly from one project to the next; however, the variations are usually a result of the efforts to maximize the return of data irrespective of their nature. The influence of the scientific experiments on this design is primarily the indirect result of tradeoffs in available weight and power between the various systems and subsystems (scientific, telecommunications, etc.). The data efficiency with which slow, medium, or high rates can be handled may dictate the choice of a particular design.

It should be noted that all of the spacecraft systems have in common the property of more or less continuous transmission of data. This maximizes the efficiency of data return from a telecommunications viewpoint, and, because spacecraft power systems usually convert solar energy and make power available more or less continuously, little or no spacecraft weight need be devoted to power storage for intermittent increased demand.