THE NASA DATA SYSTEMS STANDARDIZATION PROGRAM RADIO FREQUENCY AND MODULATION

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ABSTRACT

As space missions have become more expensive, the search for methods to improve efficiency has intensified. One approach offering great potential focuses upon multimission designs in order to avoid early obsolescence. Data handling systems are attractive candidates for the multimission concept because of the high cost of redesign and because the process should be amenable to a high degree of uniformity.

By cooperating in the specification of their data systems, NASA and ESA should achieve significant uniformity. Apart from improving the design, this unified approach will facilitate the cross support of one agency’s spacecraft by the other agency’s tracking network.

Here, we are concerned with the radio frequency subsystem which links spacecraft instruments with ground-based users. In large measure, the telecommunications system’s characteristics are determined by the ground station’s design. For the concept of cross support to succeed, there must be a substantial similarity between these NASA and ESA designs.

Both NASA and ESA have large capital investments in their ground networks. While it might be theoretically satisfying to speak of a single ground system configuration for both agencies, the high cost of the required revisions renders this approach practically unachievable.

This paper describes a process for maximizing the commonality of the two agencies’ radio frequency and modulation systems that is consistent with budgetary and scheduling

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constraints. The two-part program consists of identifying present system similarities and developing a plan for eliminating substantive differences where they are found to exist.

INTRODUCTION

An important objective of the standards program is the development of multimission data system designs that will lower mission support costs. Additionally, NASA has expended a substantial effort to ensure international participation in the selection of these standards. Apart from eliminating costly redesign for each mission, the approach also enables international cross-support agreements to become a reality. If one agency finds its tracking facilities taxed to an unacceptable limit because of a coincidence of critical events, it can call upon the resources of another agency to provide temporary relief.

System's commonality is a cornerstone of the cross-support concept. Without substantial similarities in the data transfer process, it may not be possible to provide tracking of another agency's spacecraft. Thus, some degree of standardization is intrinsic in the notion of cross-support agreements.

The Radio Frequency (RF) and Modulation system provides the basic transport mechanism for linking spaceborne experiments with ground-based users. The fundamental character of this system is evident from the Reference Model contained in the Rationale and Scope paper by R. E. Smylie. Without a high degree of standardization at this level, the concept of cross-support begins to disintegrate. Complete uniformity at higher levels becomes irrelevant if the data cannot be transferred because of differences in operating frequencies or modulation techniques.

Because the radio frequency and modulation characteristics are so important, the NASA-ESA Working Group (NEWG) devised a two-phase program for dealing with their standardization. These phases involved initially exploring areas of commonality and, thereafter selecting specific subsystems to be standardized through a longer term development program. This paper describes the two-phase approach adopted by the NEWG.

PLANNED DEVELOPMENTS BY 1985 (Phase I)

Ideally, both NASA and ESA should employ communications systems having identical radio frequency and modulation characteristics. Unfortunately, reality often misses the mark of perfection. It is not surprising that there are differences between the two agencies' facilities for their programs developed quite independently. Yet, the objectives of these programs are not so dissimilar, and one might expect to find significant commonality in the respective tracking systems.

Both NASA and ESA have large capital investments in their tracking networks. While it might be theoretically satisfying to speak of a single, unified design for both agencies, the high cost of the required revisions renders this approach practically unachievable.

Hence, the focus of Phase I was upon those currently planned radio frequency and modulation characteristics that are common to the ESA and NASA tracking systems in the post-1985 time period. This date was selected because NASA's MKIV A DSN will have been completed. By comparing the NASA and ESA RF and Modulation systems, the NEWG hoped to achieve two goals: first, planned system commonalities would be identified permitting an accurate assessment of the cross-support opportunities; second, areas of difference could be isolated which would become the focus of Phase II, the long-range standardization program. Ideally, at the conclusion of the second phase, the NEWG would have a program for eliminating the major differences between the two agencies' RF and Modulation systems.

Before beginning this search for commonality, it became necessary to identify the specific tracking networks to be considered. NASA has three: the Shuttle Orbiter's Interrogator subsystem, the MKIV A Deep Space Network, and the Tracking and Data Relay Satellite System (TDRSS). NASA's Ground Spaceflight Tracking and Data Network (GSTDN) was not considered separately because by 1985 it will have been merged into the MKIV A DSN.

Figure 1 illustrates the process employed during Phase I. Each of the two circles respectively represents the set of capabilities possessed by the ESA Network and one of the named NASA tracking facilities. The focus was upon the area of overlap representing common capabilities of the two networks being compared. As one might suspect, the degree of overlap varied with the particular NASA facility being studied.

Comparisons were made in each of several areas which technically characterize RF and Modulation systems. Foremost among these is the frequency of operation. Fortunately, frequency standardization has been handled for many years by a well-established, internationally recognized institution.

For many years the International Telecommunications Union (ITU) has had the responsibility for allocating frequency bands to a multiplicity of services. Through a process of World Administrative Radio Conferences (WARCs), delegates from approximately 150 member countries meet periodically to consider amendments to the Table of Frequency Allocations. The most recent revision occurred in late 1979 when a General World Administrative Radio Conference was convened in Geneva, Switzerland. Upon ratification by the member governments, agreements reached at these meetings assume the stature of treaties between the member countries.

The ITU recognizes two services which are of interest here. These are the Space Operation Service and the Space Research Service. Virtually all of NASA’s and ESA’s spacecraft communications utilize frequency bands allocated to one of these two services, primarily the latter.

While the ITU has allocated several frequency bands to the Space Research Service, both ESA and NASA have focused their usage on S-band (approximately 2000 MHz) and on X-band (approximately 8000 MHz). By virtue of the allocations made by the ITU, together with preferences for certain bands expressed by both NASA and ESA, much of the frequency standardization has already been accomplished.

The RF and Modulation study compared several other technical characteristics. For example, flight and ground timing stability, telecommand and telemetry modulation, and ranging bandwidth requirements were examined. Additionally, a summary of salient characteristics of each of the ESA and NASA tracking systems was prepared in order to facilitate an understanding of the differences and their importance.

The conclusions reached from this study were both interesting and somewhat surprising. A great deal of commonality was found to exist between the ESA Network and the NASA MKIV A DSN. Except for specific areas such as range codes and antenna sizes, the NASA and ESA ground tracking networks have virtually identical radio frequency and modulation characteristics. The extent of this similarity was unanticipated. From the findings it would appear that significant cross-support could begin almost immediately.

Likewise, the ESA Network had many characteristics in common with the Shuttle Orbiter’s Interrogator system. Given the previous finding, this result follows because the Interrogator was intended to communicate with payloads in their detached phase, thereby simulating a ground station. However, since the Orbiter’s communications path is via the TDRSS, incompatibilities were discovered in the radio metric data. Both the ranging and doppler systems appear to be unusable for cross-support unless the raw data are first processed to provide a state vector.

A very different result was found when the ESA Network was compared with the TDRSS. The TDRSS embodies several innovative features which provide it with a set of unique characteristics. Some of these are: spread spectrum modulation, pseudo-noise ranging, multiple access channel, and megabit per second data rates.

Upon close examination, it was discovered that these novel characteristics had the effect of making the TDRSS incompatible with the ESA Network. Except for frequency allocations, which are established by the ITU, there appeared to be little commonality with the ESA Network.

Results of the foregoing study have been published in a NEWG Report. The intent of that document was to summarize the major common radio frequency and modulation characteristics as well as to list some of the salient features of each of the tracking facilities. A flight project manager wishing to retain an ability to obtain cross-support from one of the networks included in the study could use this publication as a top-level specification for the spacecraft's RF and Modulation system.

FUTURE DEVELOPMENT PROGRAM (Phase II)

Having established a firm benchmark for the NASA and ESA RF and Modulation systems, it became a simple matter to highlight the differences. These differences, along with a set of characteristics thought to be desirable, were prioritized, and the more important items became subjects for study during Phase II.

Unlike the NEWG Report drafted during Phase I, which was a general survey of capabilities, the Guideline to be written at the conclusion of Phase II will cover only selected topics. As the names suggest, the difference between a Report and a Guideline is one of describing existing or planned designs as compared with producing a plan for future development.

During Phase I it was discovered that the ESA Network's command bit rate could not match the lower limit provided by the MKIV A DSN. This could become important in cross-support of deep space missions where the distances involved may require very low rates. The NEWG agreed to study the feasibility and impact of providing rates equivalent to those of the DSN in the ESA Network.

Phase I also revealed that the Shuttle Orbiter's Interrogator subsystem could only provide commands on a 16 kHz subcarrier. Since some ESA spacecraft utilize an 8 kHz subcarrier, the NEWG agreed to explore the possibility of equipping the Interrogator with an 8 kHz command subcarrier as an option.

The ranging equipment was identified during the first phase as a system where there are major differences between the ESA and NASA approaches. Phase II will identify each agency's objectives for making range measurements. Perhaps sufficient common interests can be found to permit the Guideline to include a recommendation for a unified design.

With regard to future communications techniques to be studied during Phase II, the NEWG identified several candidate topics. To date, virtually all of ESA's spacecraft communications have been at S-band. NASA has employed X-band for deep space missions, but only on the downlink. As with ESA, NASA's uplinks and non-deep space mission downlinks have always been at S-band.

Accordingly, spacecraft transponder frequency multiplication ratios are well-established at S-band and for deep space X-band downlinks. However, there has been no attempt to specify the proper ratios where an X-band uplink or a non-deep space X-band downlink is utilized. The NEWG directed that a study of the remaining ratios be made and a set selected for inclusion in the Guideline.

The NEWG also asked that suppressed carrier and spread spectrum modulation techniques be considered. When the ESA Network-TDRSS incompatibility was discovered during Phase I, it was decided to defer consideration of this subject until Phase II. Many of the innovative modulation techniques employed in the TDRSS will be reviewed for possible inclusion in the Guideline.

Finally, for many years, trends in operating frequencies have been in an upward direction. In the early days of the space program, communications were at L-band. Since then, there has been a progression first to S-band and now to X-band. It is logical to ask “Where next?” After some deliberation, the NEWG selected 32 GHz as the next appropriate step in frequency. The ITU has provided a primary Space Research Service allocation, 500 MHz wide, which is reserved for deep space communications in Australia, Spain, and the United States. Elsewhere, the service has a secondary status. Phase II will examine the costs and benefits, as well as surveying the problems associated with sharing 32 GHz with other services.

CONCLUSIONS

Within the NEWG, the program to examine and to standardize the radio frequency and modulation characteristics is well underway. Phase I has been completed and Phase II is currently underway. Position papers for each of the previously named subjects are due by the end of calendar year 1983.

Following a review of the position papers, a draft Guideline summarizing these recommendations will be prepared. The current schedule includes presentation of the draft Guideline, or White Book, at the fifth NEWG meeting in the spring of 1984.

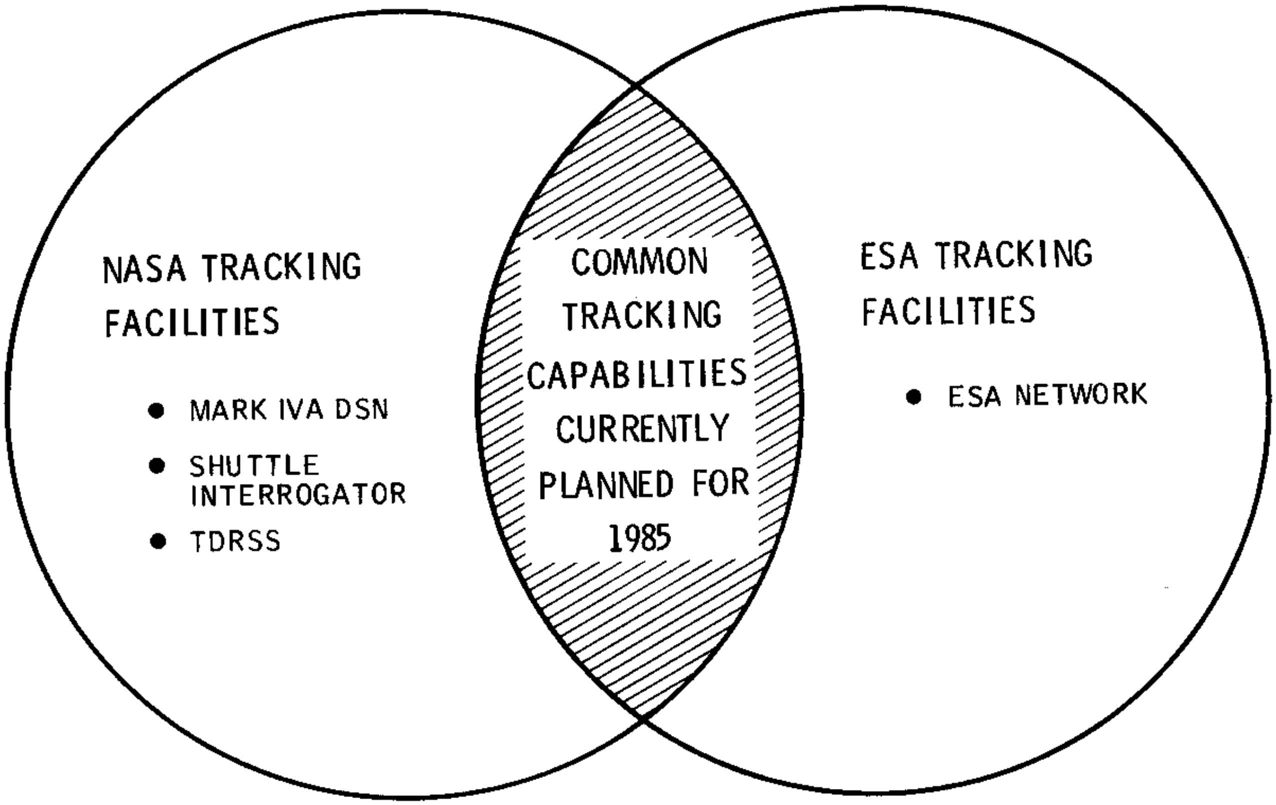

Figure 1. Phase I Search for Common NASA-ESA Capabilities.