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p. 8

A STANDARD SATELLITE CONTROL REFERENCE MODEL

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Abstract - This paper describes a Satellite Control Reference Model that provides the basis for an approach to identify where standards would be beneficial in supporting space operations functions. The background and context for the development of the model and the approach are described. A process for using this reference model to trace top level interoperability directives to specific sets of engineering interface standards that must be implemented to meet these directives is discussed. Issues in developing a "universal" reference model are also identified.

INTRODUCTION

The need for a standard approach to identify where standards would be beneficial in supporting space operations functions has been expressed by many people in the field.

- To show a link between the selected standard and the desired benefits of applying the standard.
- To broaden understanding and acceptance of recommended standards.
- To permit benefits of standardization to be spread across several networks.

This "standard approach to selecting standards", based on a functional satellite control reference model, should not be "benefit dependent"; that is, it should permit identification of standards needed to support any specific benefit such as interoperability, cost reduction, etc. Ideally this standard approach would apply to all space operations networks and would allow each standard to be easily tied to its supporting operational function and therefore the benefits could be evaluated.

The Air Force has funded the development of such a standard approach that is based on an extension of the approach in Vol. 7 of the DoD Technical Architecture for Information Management (TAFIM) developed by the Defense Information Systems Agency (DISA). The approach is being applied to the Air Force Satellite Control Network (AFSCN). Representatives from other Government agencies and the commercial space operations community have expressed interest in extending the initial approach by developing a more universal reference model as its basis. Benefits from standardization in one satellite control network can then be evaluated for use in another network using the same functional and interface definitions.

BASIS OF REFERENCE MODEL

Satellite Control Systems can be defined as "A configuration of communications and data processing subsystems that collectively provide the capability to control satellites". Implicit in this definition is the fact that these systems are used in all phases of satellite control, including prelaunch, launch and early orbit checkout, on-orbit operations, and mission completion. Missions include weather forecasting, missile warning, navigation, and communications. Mission execution and mission data processing systems are not included in this definition, although the capability to perform these mission functions can reside on the same subsystems as the ones used for satellite control. Process control systems are an

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important subset of satellite control systems because their real-time characteristics drive many of the system performance requirements. Based on this definition of a satellite control system, it would be logical to use already accepted frameworks to tie standards to satellite control functions. In this paper the word "standard" refers to an engineering or product standard (physical/electrical interfaces, formats, protocols, etc.), not an operations standard (procedural or administrative).

Information Systems Reference Model.
The Defense Information Systems Agency/Center for Information Management has derived a TAFIM from the NIST Application Portability Profile and the IEEE P1003.0 OSE models (begun in 1986). This architecture defines a target common conceptual framework or reference model for an information system infrastructure and the specific applications that the information system must support. It also subsumes the widely accepted Open Systems Interface (OSI) reference model within the network services and communications area. This architecture, and associated model, is not a specific system design. Rather, it establishes a common vocabulary and defines a set of services and interfaces common to information systems. DISA's Information Technology Standards Guidance (ITSG) and Adopted Information Technology Standards (AITS) documents describe and support this architecture. The associated AITS identifies standards and guidelines in terms of the architecture services and interfaces. The architecture serves to facilitate the development of plans that will lead to interoperability between mission area applications, portability across mission areas and cost reductions through the use of common services.

Satellite Control Reference Model.
Operations that are unique to satellite control need to be addressed in the Mission Area Applications Section of the TAFIM. Therefore specific satellite control services, such as Timing (those aspects unique to satellite control), Tracking and Data Relay, Telemetry Processing, Command, Resource Control, Contact Execution, and Management were added to those in the generic information systems model. Network Services were also broadened in scope to include earth/space and space/space services. By moving the major service areas into an OSI-like reference structure, it is possible to establish a hierarchical "standard" framework for understanding the relationships between satellite control functions. Figure 1 illustrates this framework or Satellite Control Reference Model (SCRM). The hierarchy is based on levels of functional abstraction, from management services, down to control services, further down to basic computer services and finally down to network and point-to-point communications (layers 1 to 6). All of these unique satellite control services would operate at OSI Application Layer 7. Functions in layers 7b and above in the hierarchy would relate to the Mission Area Applications area in the TAFIM. Functions in layers 7a and below relate to information management systems. Note that all services are not used at each location and that these services are not dependent on location nor are they necessarily automated.

STANDARDS IDENTIFICATION APPROACH

Since the unique satellite control services are not part of core information management systems, they may require standards unique to the satellite control domain that are not covered in the AITS. An approach, based on the SCRM, is needed to accomplish this standards identification. Of special interest is identification of those standards that are most appropriate to reap the benefits of interoperability.

The approach is based on describing the functional flows between each of the satellite control service areas in enough detail so areas where standards would be beneficial can be easily identified and existing standards evaluated to see if modifications/replacements are necessary to achieve the benefit desired. To this end, a baseline set of functional diagrams for every satellite control service area has been developed. These simple functional diagrams show input, output, and the basic functions provided by each service area. In the future we will generalize the functional descriptions related to levels 7b and above, remove operational procedures inherent in the functional descriptions and move as many currently "unique" satellite control functions into the information management category (black background) as possible.

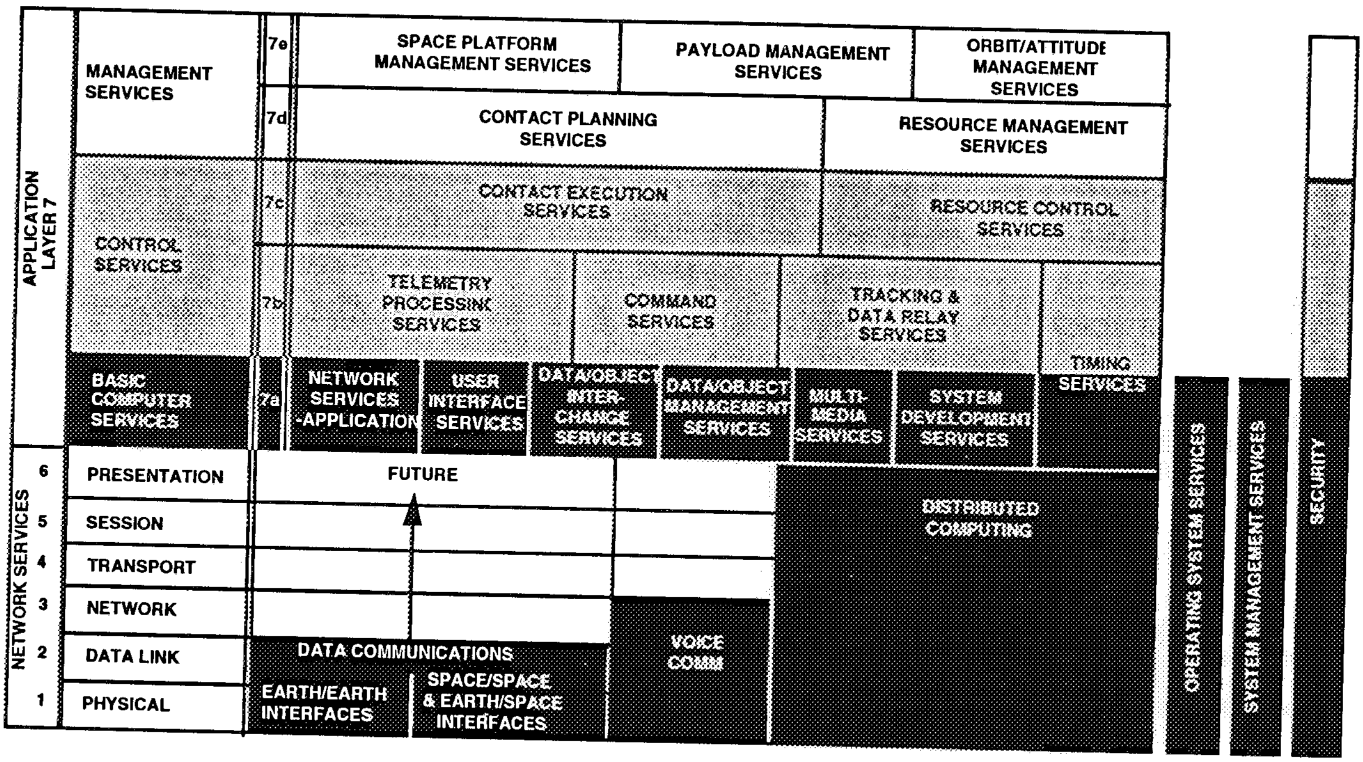


Figure 1 STANDARD FRAMEWORK FOR SATELLITE CONTROL -Defines functions and interfaces for all services provided-

Overview of Approach.

The specific approach, which facilitates identification of the relevant standards to apply to development and implementation of the satellite control functions, is outlined in the following steps:

Step 1: Describe the desired benefit of standardization for the relevant program. For each major satellite control service area in the SCRM, review the baseline functional diagrams to ensure they match the functional flow for the relevant program. If they need to be modified, do so.
Step 2: Based on the functional diagrams, the desired benefit, and expertise about how various services are provided, identify areas where use of standards would be beneficial, (are needed), and list these areas so they are tied directly to a relevant function and service area.
Step 3: For each of the beneficial standardization areas identified in Step 2, identify what standards are currently being used and which emerging standards, if any, might be applied to that area to achieve the desired benefit. Coordinate with other satellite control organizations for review and feedback, and to ensure commonality among interested groups. List these standards under the appropriate "standard needed" heading on the form used in Step 2.
Step 4: From the compiled information, identify what relationships exist among the standards. Where multiple standards are used for the same satellite control functions, investigate the feasibility of joint adoption of a future common standard and devise an evolutionary path to it.

For functions where standards are needed but none exist or are emerging, describe how such a standard might be developed for the benefit of all networks.

Example of Application of Approach to Identifying Standards.

Figure 2 illustrates a functional diagram for the Contact Planning Services function. The primary inputs, subfunctions, and outputs are shown, along with a short description of how the services are to be accomplished to provide a context for understanding where standards might be appropriate. To increase interoperability, the input-output external interfaces are of primary interest.

INPUT		OUTPUT
Resource Management Services - Twenty four hour schedule **Platform, Payload and Orbit/Attitude Management Services** - Status and contact requirements	**Contact Planning** **• Prepare resource schedule request for the seven day schedule (PAP)** **• Coordinate the 24 hour schedule** **• Develop Contact Support Plans for contacts on the 24 hour schedule**	**Resource Management Services** - Resource schedule request for contact support (PAP) **Contact Execution and Payload and Orbit/Attitude Management Services** - Contact Support Plans

Description: Contact Planning Services involves the analysis of status and requirements to determine what needs to be done for the SV. These SV needs are then expressed in a contact support plan (CSP) that results in an agenda for a scheduled contact with the SV. The CSP is then provided to Command services where it is executed under the control of Contact Execution Services. The resources needed for the contact are requested by Contact Planning Services through the PAP input to the seven day schedule prepared by Resource Management Services.

Figure 2 CONTACT PLANNING SERVICES FUNCTIONAL DIAGRAM

Figure 3 portrays a form used to assess where standards would be beneficial for the Contact Planning Services function. The form provides space for indicating what service(s) are interfaced with, the interfacing function, and the context (input, output, HCI) and type (Protocol/Format, Electrical/Mechanical/Physical) of that interface. In addition, there is space for indicating the areas where standards are needed and a column for indicating the current standard status, as defined in the lower part of the Figure. This assessment approach can then be used for each function within the Satellite Control Service areas to assure a level of consistency and completeness in the eventual results.

Once areas of needed standards are identified, the status of any applicable standards can be more readily assessed. The assessment occurs for three time periods: currently, near term and long term. It is effective to record this assessment on the same form shown in Figure 3. For the Contact Planning function, it was noted that there is no standard format for requesting use of network resources by an external user. Standardization on an interface format would facilitate interoperability in scheduling and allocation of the network assets.

SATELLITE CONTROL TECHNICAL REFERENCE MODEL
ASSESSMENT OF STANDARDS NEEDED AND AVAILABILITY

SERVICE AREA	FUNCTION	CONTEXT:	STD STATUS*	WHAT TYPE OF STANDARD WOULD BE BENEFICIAL AND WHY		
				STD 1993	STD 1994-95	STD > 1995
CONTACT	PLANNING	INPUT	NOW Limited	**• Formats for expressing SV service/control requirements** AZ/EL acqusition format is std.	None known - should be developed to reduce operator training time/cost and increase I/O	
			NOW	**• 24 Hour Schedule** RCC format dev. by ASTRO		
		USER I/F	VOID	**• HCI/Method for generating CSPs**		
			VOID	**• HCI/Method for planning contingency responses** In OOH/TO		
		OUTPUT	NOW	**• Format for Contact Support Plans (CSPs)** Existing Std. Format	(should be automated	where not already done)
			VOID	**• Format for resource request for contact support** Each Program has own format		
			NOW	**• Station Configuration** Existing part of CSP		

* NOW: Standard is reasonably mature with products that are available today or expected to be available within 6 months.

FUTURE: Standard is emerging and may be subject to change but is generally headed toward stability.

GAP: Standard is available as temporary gap-filler. It is recommended for use only if the organization is willing to take a moderate investment risk because the final standard for the area may or may not be compatable with the gap-filler.

VOID: No standards in the area and no known emerging one. The absence of a standard here may translate into significant risk for long-term planning or investment.

UNSTABLE: Standards are emerging and rapidly evolving.

N/A: No standard is needed in this area. This code will be reserved for areas where at first glance it would appear that a standard might be useful, but further analysis shows that the disadvantages of standardization in this area outweigh any potential advantages.

Figure 3 EXAMPLE ASSESSMENT OF STANDARDS NEEDED AND AVAILABILITY

FUNCTIONAL INTEROPERABILITY APPLICATION

There have been several published definitions for "interoperability" including those in JCS Pub 1-02 and MIL-STD-973. According to the JCS Pub 1-02, interoperability is "The ability of systems, units or forces to provide services to and accept services from other systems, units or forces, and to use the services so exchanged to enable them to operate effectively together". While this definition provides overall guidance, more specific information is needed to tie high level (ORD and CON OPS) interoperability requirements to specific engineering and operational consequences/benefits. One approach is to have overall requirement documents address "how much interoperability" is needed between specified programs or domains. That is, to specify the "degree" of interoperability needed.

Degrees of Interoperability

Figure 4 portrays the breakdown of the "Services" to be exchanged, to achieve general interoperability, into more specific functions as the domain of application becomes narrower.

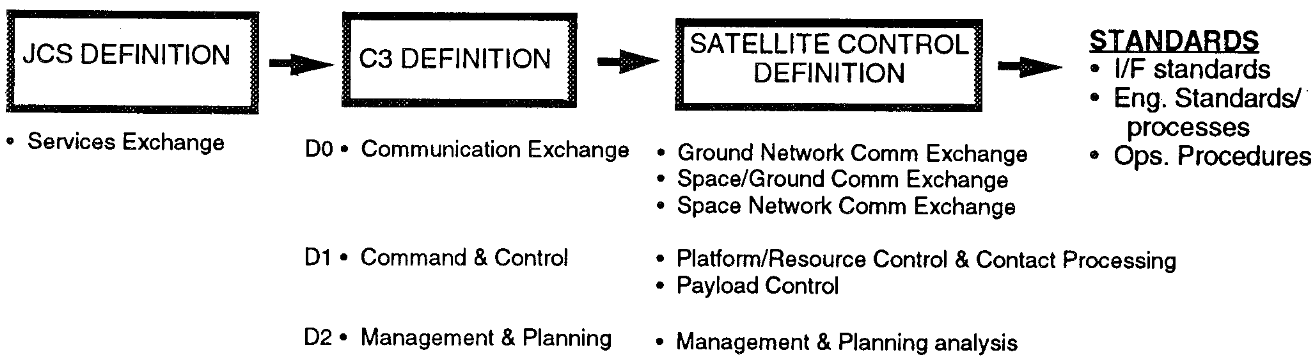
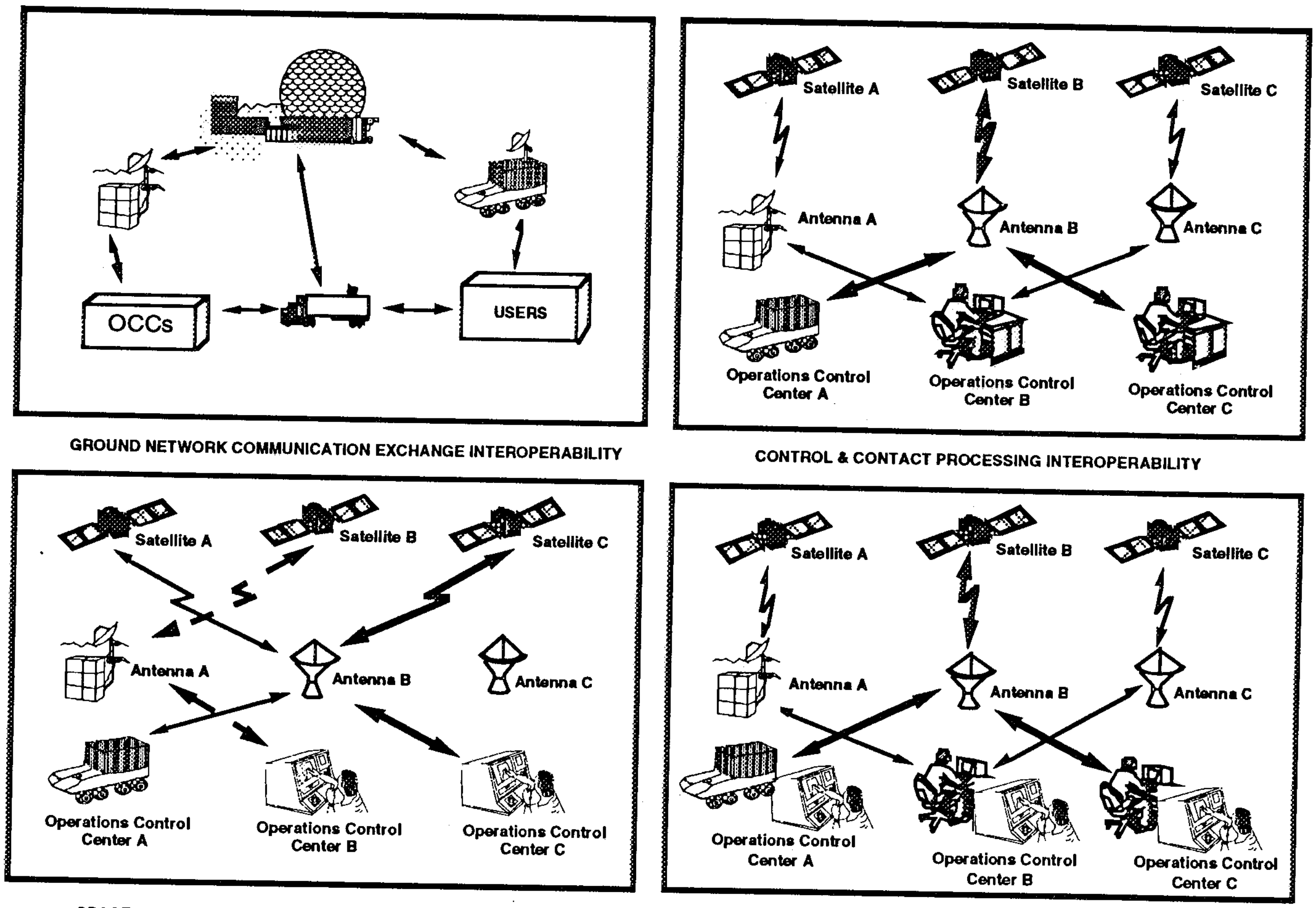


Figure 4 SPECIFIC DEFINITIONS FOR INTEROPERABILITY

Moving from the General Domain to the C3 Domain, "Services" can be broken into Communication Exchange, Command & Control and Management and Planning Services. Moving further into the Satellite Control domain, Communication Exchange can be broken into 3 subsets, (Ground Network, Space/Ground and Space Network), because of the differences in their application environment. Each of these can be specified as a "degree of interoperability" in the satellite control operational environment. Command and Control Services can be broken down into Platform/Resource Control & Contact Processing and Payload Control for the Satellite Control Domain. Each of these can be specified as a degree of interoperability. The Platform/Resource Control & Contact Processing Degree of Interoperability was purposely constrained to routine processing functions and resolution of Level 1 and some Level 2 anomalies because these can be most readily automated and there is high likelihood that many programs will find it beneficial to be interoperable to this degree. The benefits of implementing this degree of interoperability are high, but are dependent on basic Ground Network Communication Exchange being available. Management and Planning Analysis services in the Satellite Control Domain include resolving Level 3 anomalies and require operators to be cross trained on mission and payload information. The benefits of this degree of interoperability are dependent on the "lower" degrees of interoperability being implemented first. Four of these degrees of Satellite Control interoperability are pictured in Figure 5.



GROUND NETWORK COMMUNICATION EXCHANGE INTEROPERABILITY

CONTROL & CONTACT PROCESSING INTEROPERABILITY

SPACE/GROUND COMMUNICATION EXCHANGE INTEROPERABILITY

MANAGEMENT & PLANNING ANALYSIS INTEROPERABILITY

Figure 5 SATELLITE CONTROL DEGREES OF INTEROPERABILITY

Mapping Degrees of Interoperability to Set of Standard Interfaces.
As the degree of interoperability increases from D1 to D3, so too does the emphasis on higher levels of functional abstraction represented in the SCRM. As shown in Figure 6, Ground Network Communication Exchange Interoperability (D1-a) is accommodated almost entirely within the lower six OSI layers, Platform/Resource Control and Contact Processing Interoperability (D2-a) is accommodated almost entirely within OSI layers 7b and 7c, while Management and Planning Analysis Interoperability (D3) is accommodated almost entirely within OSI layers 7d and 7e. Using this correspondence the SCRM can be used to determine the set of interfaces that need to be standardized to support the various degrees of interoperability. Determination of which specific set of standards to select for standardizing these interfaces can then be performed for the environment of interest. The mapping from definition of degree of interoperability to a specific set of standards to be applied is then complete.

CONCLUSION

The standard framework and approach described above is still in the process of being developed. It has the advantage of being based on the already established OSI and TAFIM reference architectures. However, the question of whether the functional interfaces can be defined in enough detail and generically enough to be able to produce a baseline model that supports all satellite control networks has still to be answered.

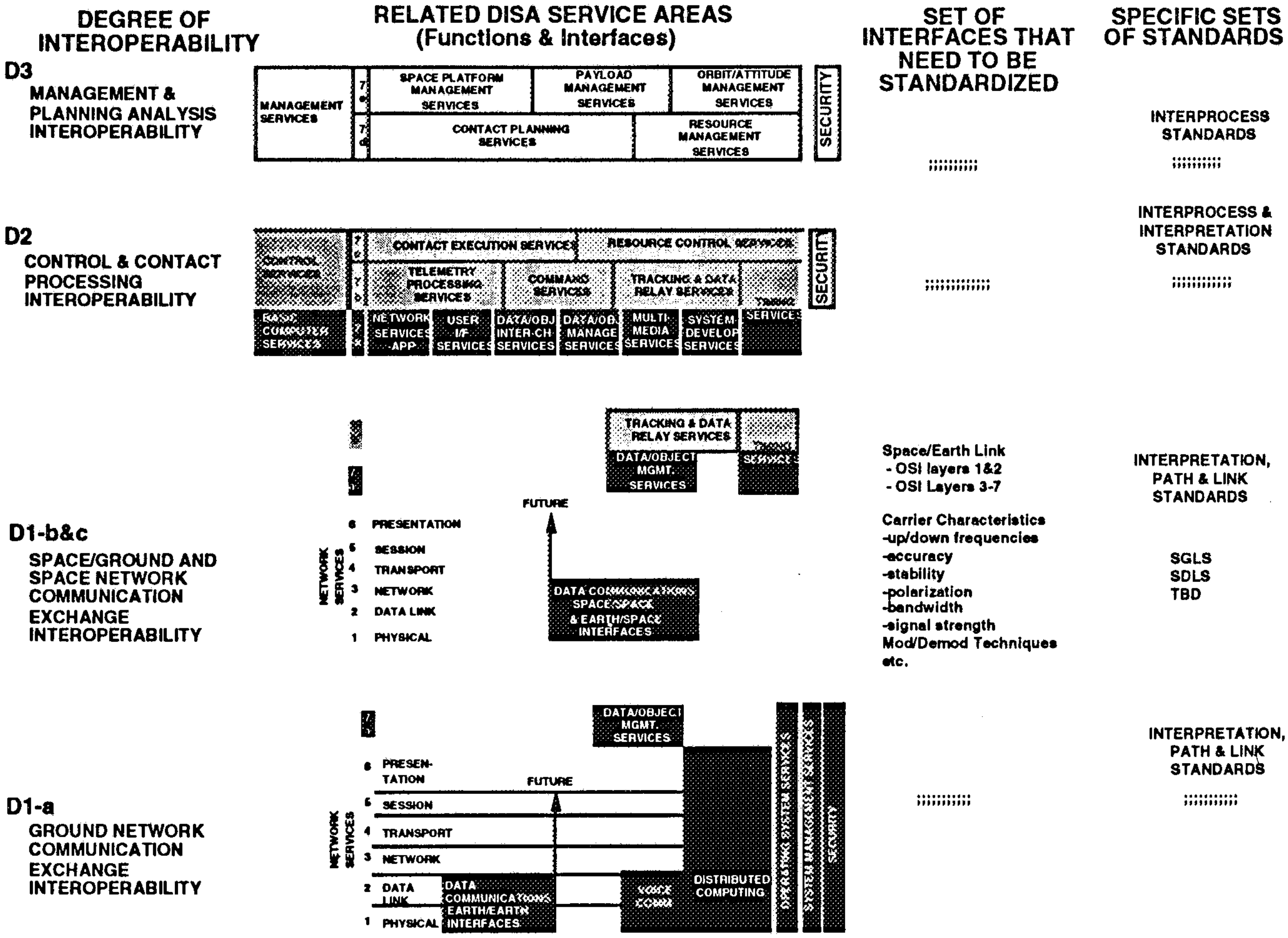


Figure 6 MAPPING DEGREE OF INTEROPERABILITY TO SET OF STANDARD INTERFACES

In the six months that this model has been applied to various situations, it has become apparent that some of the originally identified satellite control unique functions may be able to be defined as generic information systems functions in the future. On the other hand, some of the functions that were initially allocated to information systems are really process control functions and may have to use different standards than those selected for general information systems to meet the real-time response requirements needed. There are several related efforts ongoing and in each a satellite control reference model with standard terms and functional flows has proven to facilitate the analysis.

REFERENCES

1. Defense Information Systems Agency/Center for Architecture, Department of Defense Technical Architecture Framework for Information Management; Technical Reference Model and Standards Profile Summary, (Final Draft), Version 2.0, 1 Nov. 1993

2. Air Force Space & Missile Systems Center, CUE-TR-93-179, Standards for Interoperability, 30 Nov. 93