MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO DE PESQUISAS ESPACIAIS

AUTORIZAÇÃO PARA PUBLICAÇÃO
AUTHORIZATION FOR PUBLICATION

PALAVRAS CHAVES/KEY WORDS
ON BOARD CROSS SUPPORT, CCSDS ON BOARD CROSS SUPPORT, SPACE DATA SYSTEMS ON BOARD CROSS SUPPORT.

AUTORIZADA POR/AUTHORIZED BY
Clovis Solano Pereira
Space Tec. Eng. Dir.

AUTOR RESPONSAVEL
RESPONSIBLE AUTHOR
Eduardo W.Bergamini

DISTRIBUIÇÃO/DISTRIBUTION
☐ INTERNA / INTERNAL
☒ EXTERNA / EXTERNAL
☐ RESTRITA / RESTRICTED

REVISADA POR / REVISED BY
Leon Lonneux

CDU/UDC
621.398

DATA / DATE
November, 1989

PUBLICAÇÃO Nº
PUBLICATION NO
INPE-5005-PRE/1562

ORIGEM
ORIGIN
DEL/VSS

PROJETO
PROJECT
ENCOMP

Nº DE PAG.
NO OF PAGES
54

ULTIMA PAG.
LAST PAGE
40

VERSÃO
VERSION

Nº DE MAPAS
NO OF MAPS

TÍTULO/TITLE

"ON BOARD CROSS SUPPORT SCENARIOS"

AUTORES/AUTHORSHIP

Eduardo Whitaker Bergamini

RESUMO-NOTAS/ABSTRACT-NOTES

A concept for On Board Cross Support Scenarios is presented. In this case, the cross support is characterized as a Communication Service. To some extent, a basic specification, covering aspects of Protocol, Service and Management is proposed for structuring the cross support communication service. The already established CCSDS recommendations for Conventional and Advanced Orbiting Systems, are commented as part of specific On Board Cross Supporting Scenarios. The "complementary" nature of the proposed concepts in this work is enchanced with respect to the already existing scenarios, which are based on the current CCSDS recommendations. Therefore, if judged appropriate, the concepts which are presented in this work could be a start for development of new CCSDS recommendations directed to On Board Cross Support for Space Data Systems.

OBSERVAÇÕES/REMARKS

Este trabalho foi apresentado na V Reunião Plenaria do Consultative Committee for Space Data Systems - CCSDS, realizada em Ottawa, Canada, de 24 de setembro a 04 de outubro de 1989.

Consultative Committee for Space Data Systems - CCSDS
Panel 3 - CCSDS System Aspects

"ON BOARD CROSS SUPPORT SCENARIOS"

- Concept Paper -

prepared by:

Eduardo Whitaker Bergamini

August, 1989

OBS. - This paper was prepared as a response to Action Item No. 07, resulting from the Management Committee Meeting, held in Toulouse, France, on May 30-31, 1989. As a contrubution to Panel 3, this work is to be submitted for review and comment at the next Management Committee Meeting, to be held in Ottawa, Canada, from September 25 to 29 1989.

Instituto de Pesquisas Espaciais - INPE
Directorship of Engineering and Techonology - ETE
Line of R&D in Computer Engineering
São José dos Campos, SP - BRASIL

- SUMMARY -

A concept for On Board Cross Support Scenarios is presented. In this case, the cross support is characterized as a Communication Service. To some extent, a basic specification, covering aspects of Protocol, Service and Management is proposed for structuring the cross support communication service. The already established CCSDS recommendations for Conventional and Advanced Orbiting Systems, are commented as part of specific On Board Cross Supporting Scenarios. The "complementary" nature of the proposed concepts in this work is enchanced with respect to the already existing scenarios, which are based on the current CCSDS recommendations. Therefore, if judged appropriate, the concepts which are presented in this work coukd be a start for development of new CCSDS recommendations directed to On Board Cross Support for Space Data Systems.

- SUMÁRIO -

Um conceito para Cenários de Apoio Cruzado de Bordo é apresentado. Neste caso, o apoio cruzado é caracterizado como sendo um Serviço de Comunicação. Em certa extensão, uma especificação básica, cobrindo aspectos de Protocolo, Serviço e Gerenciamento é proposta para estruturar o serviço de comunicação para apoio cruzado. As recomendações já estabelecidas pelo CCSDS, para Sistemas Orbitais Convencionais e Avançadas são comentadas como parte específica de Cenários para Apoio de Bordo. A natureza "complementar" dos conceitos propostos neste trabalho é realçada com respeito aos cenários já existentes e que são baseados nas atuais recomendações do CCSDS. Portanto, se for julgado apropriado, os conceitos que são apresentados neste trabalho poderiam representar o começo do desenvolvimento de novas recomendações CCSDS, direcionadas ao Apoio Cruzado para Sistemas Espaciais de Dados.

- ACKNOWLEDGEMENTS -

The author wishes to express his gratitude for the extensive typing support received from Ms. Natalia Santos Gomes, Ms. Ana Maria da Silva Vadõ, Mrs. Maria Aparecida de O.M. Moreira, and for the careful drafting work executed by Ms. Ana Lucia S. de Castro in the preparation of this concept paper.

TABLE OF CONTENTS

Chapters	Page

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The main purpose of this work is the conception of basic space data system on board cross support scenarios.

The on board cross support scenario is defined by the characterization of **communication services** between two facilities, where one facility acts as the service **provider** and the other as its **user.**

It is fundamentally important to notice that, in the current concept, the user is characterized as such because it is assumed that, for operational reasons, it must rely on the **communication resource** that may be avaible from the service provider facility. More specifically, it is understood that the communication resource available with the service provider may be needed for local use, in the same on board communication environment, or remotely, by means of space-to-space or space-to-ground links, which may extend the service provision facilities to remote sites. Therefore, the service provider facility may be a complex, multi hop or multi link compound of facilities which may, as a whole, provide the basic communication sevice in need by the requesting on board service user.

The connection between the provider and the user facility is defined as being the **On Board Service Access Point (BSAP).**

This work proposes, whith some degree of detail, the basic concepts of **architecture, protocol and management** for data commnication services which address on bord cross support scenarios. The on board cross support scenario **basic architecture** considered in this word is illustrated in Figure 1.

Figure 1. Basic architecture of the on board cross support scenario.

The communication **service provider** is defined as the on board facility which supports the communication service access to the on board user facility.

The on board service user which is considered as typical would be a facility which is in **need of a Communication Service that can be cross-supported** by and/or through an on board service provider facility. This type of cross support may put the on board service user in connection to other users which may have access to the same local on board service provision facility and/or to any remote access which may be seen as an extension of the service provision facility complex. It is out of the scope of this work to develop application level concepts between the service provider and the on board service user. However, it should be clear that the concept of cross support at communication service level which is defined in this context is intended for use by upper layers of protocol, where the application layer is certainly included. The application is actually the ultimate motivation for obtaining this type of cross support.

The **communication cross support service** defines the execution of data communication between the on board service user and the service provider.

Three basic types of end-to-end service scenarios for on board cross support are defined after the introduction of the basic architecture represented in Figure 1.

After definiton of the three scenarios, basic concepts for the **data communication protocol, services and management**, referred to the basic scenario introduced in Figure 1, are proposed. A preliminary, partial specification is also given, related to the same concepts.

The characterization of the On Board Cross Support concept is also introduced in the context of the CCSDS recommendations for conventional and Advanced Orbiting Systems. A Scenario case is commented for each one of the two possible Orbiting Systems.

Final comments are made, relating the detailed concepts proposed for the basic scenario to the other three scenarios which were introduced earlier in the work.

END-TO-END BASIC CROSS SUPPORT SCENARIOS

The communication service provider can ve limited to an on board facility, or not. That is, the communication service provider can be **complemented by other external** facilities which may be also located not only on board but, alternatively, on ground, depending on the location of the service user in the other end, i.e., the **user** which wants to have access to the on board service user. As a result, **two** different, basic **end-to-end service types** can be conceived. Namely, they are:

- **Local Service**
- **External Service**

The two basic architecture scenarios which represent the mentioned end-to-end service are illustrated in Figures 2 and 3.

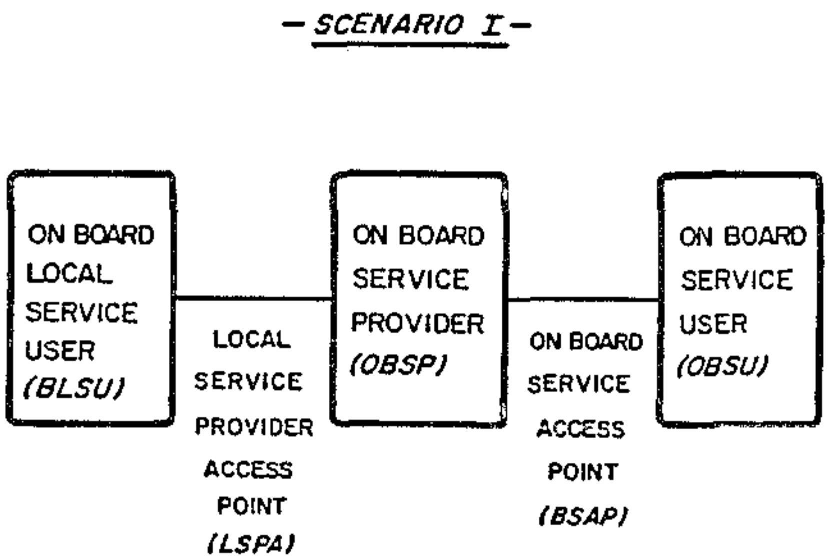

Figure 2. Basic Local Service Provision Scenario.

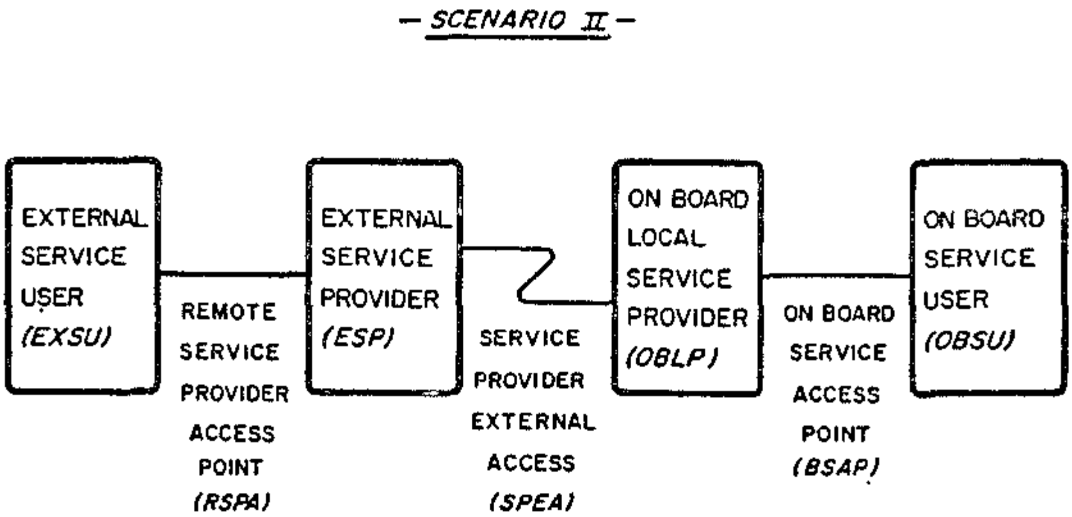

Figure 3. Basic External Service Provision Scenario.

The external user which access the on board service user may be also located on board or on the ground. These two possibilities result in two different basic service types which are conceived with the following denominations:

- **On Board External Service**

- **On Ground External Service**

The basic service architecture scenarios which result from the two types of external service are represented in Figures 4 and 5.

Other architecture scenarios can be conceived if it is considered that additional, intermediate external space based and/or ground based service provision facilities may be involved in the path that may characterize the end-to-end users. It is also pertinent to observe that more than one combination of end-to-end external service provision may be configured with the same basic scenario. For instance, there may be pratical interest in more than one combinations of local and/or remote also on space and/or on ground user access points to the service provision facilities, besides the on board service user. However, without incurring in loss os generality, it is **not** considered in the scope of this current current the exprapolation of concepts beyond the cross support scenario which have alrteady been introduced.

— SCENARIO II A —

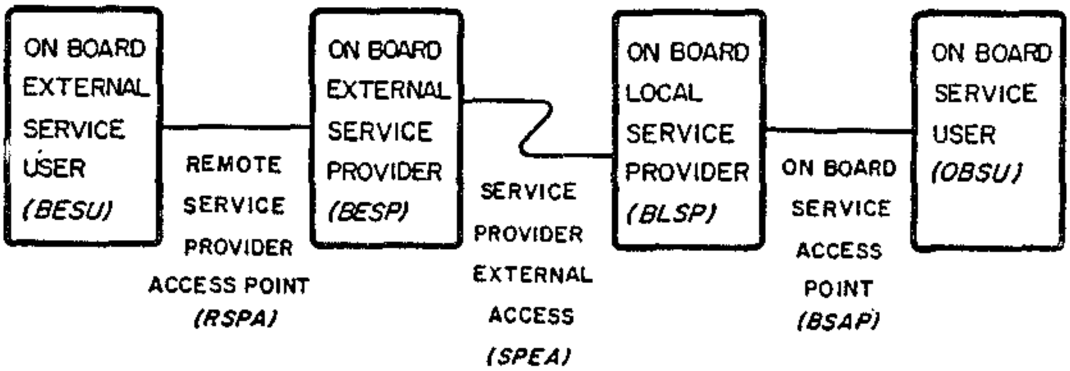

Figure 4. Basic External **On Bord** Service Provision Scenario.

— SCENARIO II B —

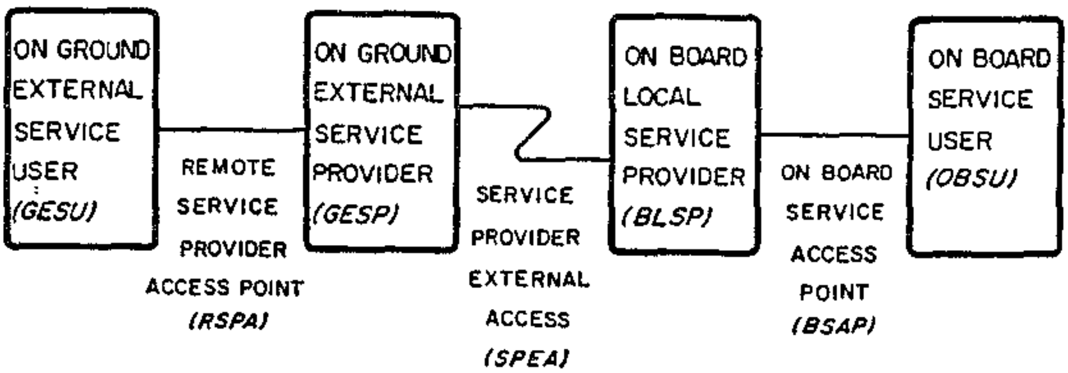

Figure 5. Basic External **On Ground** Service Provision Scenario.

BASIC FUNCTIONAL SPECIFICATIONS

Independently of the specific communication cross support scenario which may be in consideration, there is some degree of functional commonality that can be conceived among them. Three aspects, related to the mentioned **functional commonality** of the communication cross support are specified:

- **Protocol**
- **Services**
- **Management**

The basic architecture of Figure 1 is used to develop these three functional aspects.

The **Protocol** under consideration is restricted to that is necessary to guaranteee the communication cross support through the On Board Service Access Point and at End-to-End service level.

The **Services** are characterized as those which rely on the Protocol, to formalize the sequence of **actions** which are expected between the Service Provider and the On Board Service User to effectively execute the cross support. The Services are based on Service Elements.

The **Management** aspects of the communication cross support are basic for orienting the service conception and the operations which result from their execution.

COMMUNICATION PRINCIPLES

The On Board Service User is considered as a facility which must rely on the Service Provider to obtain cross support in a **communication service,** be it related to **local** and/or to **remote access.**

The Service Provider is conceived as having a self contained and self sustained communication system. Communication facilities which are local and/or remote to the On Board Service User may characterize the Service Provider. Although in a transparent fashion, different cross supporting agencies may characterize the chain of facilities that cinstitute the Service Provider. Therefore, on board data handling systems, on board local networks, interconnected (or not) by gateways, space-to-space, space-to-ground communication systems, ground networks, with possible internetworking resources, may actually characterize the **whole** Service Provider facility. The **"front-end"** facility of the Service Provider which is expected to be connected to the On Board Service Access Point is **also** expected to be a **host** of the Service Provider facility. It can be defined as being **Service Provider Access Facility (SPAF).**

The On Board Service User facility may have its own communication system, if any, which is assumed to be **not** intrisically compatible with the Communication System of the Service Provider. This is identified as being the main motivation to define the On Board Cross Support Scenarios which are the subject of this current work. It is a result from the natural assumption that the On Board Service User may have the **operational need** to obtain cross support from the Communication System available at the Service Provider facility.

The On Board Service User may be represented, for instance, by a **Platform** loaded with Experiments which, in turn, contain their respective Payloads. The user may also be a very simple,

primitive Payload. On the other extreme, if a sophisticated platform characterizes the On Board Service User, it may contain its own On Board Data Handling Systems(s) and/or Local Network(s), for instance. In the **high end** extreme of sophistication the so called On Board Service User could require the On Board Service Access Point only temporarily, be it in periodic and/or on an eventual basis, for operational reasons. In other words, this would be the case where the On Board Service User is not permanently attached to the Service Provider. Situations like this one may result from **periodic or eventual docking of spacecrafts.**

Therefore, it is **not** discarded the possibility that the On Board Service User may have, in fact, its own self-supporting Communicatiions Service Provision, as **well.** This possibility is **not** in conflict with the cross support concept being proposed in this work, provided that proper operational management agreement between the Service Provider and the On Board Service Access Point is adequately settled to direct a proper use of the On Board Service Access Point.

To become eligible and compatible for behaving as an **acceptable host** for receiving cross support from the Service Provider facility, the On Board Service User needs an **adaption.** The term **Adapted On Board Service User (ABSU)** would be a more precise designation for this special type of host facility to be cross supported. However, **the** "adaption" concept is implied and so, On Board Service User is the adopted designation for the cross supported facility.

A natural consequence of the basic concepts which have been introduced for the basic cross support scenario represented in Figure 1, concerns also the need for adoption of the concept of **Master-Slave Hyerarchy** ([1], [2]) between the Provider and the User facilities, respectively, when the Communication Service under consideration is provided through the Service Access Point. Therefore, it is considered that it is up to the Service Provider, as a **Master,** the effective initialization of the cross support communication service. However, it is not discarded that the effective communication service initialization may also be triggered by the Provider facility, as the result of an initial request and placed by the On Board Service which is, formally, considered as being the **Slave** facility.

Independently of the Communication Service level, it may be conceived that, **at Application level,** the acceptance of a (Application) Service request is not, necessarily, restricted to the Service Provider (Master) facility. That is, at Application level, there may be instances where the On Board Service User is requested to provide a specific service. This type of conception, however, extrapolates the context of the current work. In any case, it should be noticed that, also at Application level, the successful service operation is coditioned to previous agreement on compatible Service management rules between the parts which are envolved.

It is also conceived, as a communication principle, that the **same** Service Provider may ve capable of cross supporting **more than one** One Board Service User by means of one Board Service Access Point dedicated to **each** one of the Service User facilities. Service Access **redundancy** is not treated in this context, although it may be also a possible alternative of pratical interest.

PROTOCOL

The communication principles which were proposed for the basic scenario represented in Figure 1 form the background that motivates the following conception of **communication protocol** to be considered for use by the so called On Board Service Access Point.

The conception of a communication protocol architecture for the On Board Service Access Point is proposed in Figure 6. Although this communication protocol is conceived for implementation in the Service Provider, it is not meant, **necessarily**, for the already defined Service Provider Access Facility, as a whole. This will depend on practical conveniences in the internal scenario of the Service Provider.

There are three distinct layers that characterize the communication protocol conceived for the On Board Service Access Point. The related protocol architecture is represented in Figure 6.

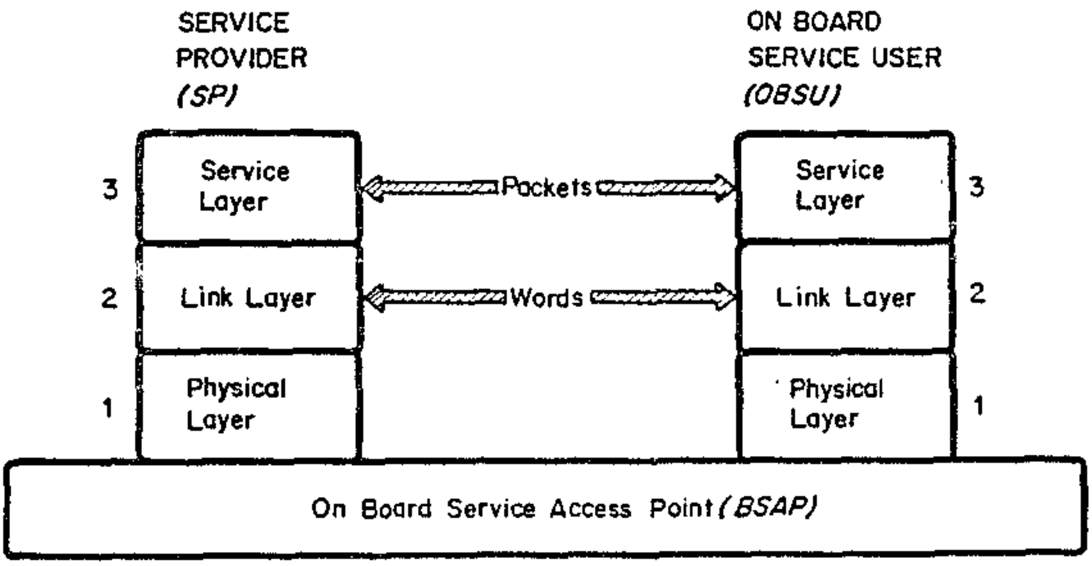

Figure 6. On Board Service Access Point Communication Protocol Architecture.

The **Physical Layer** of the protocol is conceived as a serial interface [1] to operate in **full duplex** communication. Although current technology is well consolidated for realization of the Physical layer with **shielded twisted pair cables**, it is also proposed, as an **alternative implementation** option, the use of **fiber optics cables**, for the same purpose. The fiber optics technology is expected to allow significant data transfer speed up (higher bandwidth), whenever its application can be justified for a specific cross support mission scenario. Due to the intrinsic bandwidth capabilities, besides other advantages, the fiber optics technology may have a significant impact in extending the types of service that may be offered by the On Board Service Access Point. In this case, Voice, Video or ISDN based services could be considered for cross support.

The **Link Layer** is conceived to guarantee the point-to-point **transport** of **WORDS** of data accross the access point. These words can also be used to command the opening, the maintenance and the closing of the point-to-point connection. Above all, the WORDS are to be used in the transport of **user data**, through the access point, in **both ways**. The link layer is expected to have some degree of **error protection**, besides **error recovery** capability. It is also conceived that the link layer may serve as a mean to provide **time distribution and synchronization** between both ends of the On Board Service Access Point.

The **Service Layer** of the communication protocol has two basic assignments. The **first** assignment is to execute the **transport of PACKETS** through the On Board Service Access Point. In this case, the PACKET is characterized by the **"ACCESS PACKET"**. The **second** assignment of the Service Layer is to support the transport of PACKETS as an End-to-End data entity. To comply with the conceived requirements for this second case, the PACKET is characterized by the **"SERVICE PACKET"**, which is defined as **data** for the ACCESS PACKET. The SERVICE PACKET is treated by the Service Layer as the data entity which has to be transported between two end users, i.e., in one of the two possible directions, between the On Board Service User **and** the Local or External Service User. It is up to the **Service Layer** the assignment that executes the **ACCESS PACKET segmentation and composition** in and from WORDS, respectively, in support to an adequate data transport through the On Board Service Access Point (BSAP).

PHYSICAL LAYER

The contents of Table 1 express what is conceived as a basic and partial proposal to specify the **Physical Layer** ([1], [2]) of the communication protocol

Table 1. Physical Layer Specification.

- *Point-to-Point Interface*;
- *Serial Interface*;
- *Full Duplex and Symmetrical*;
- *Physical Components*:
  - *A) Metal Wire Implementation*:
    - *Shielded, Twisted Pair Cable*:
    - *No. of Cables*: 1 or 2 (2 or 4 wires plus ground for each pair):
    - *Electrical Coupling*: Transformers;
    - *Electrical Driving*: Differential, Current Mode, Matched to the Characteristic Impedance of the cable;
    - *Connectors*: T.B.D. - depends on wiring alternatives;
    - *Speed or Bit Rate*:
      - *Selectable or Fixed*:
        - *1.0 Mbits/second (default)*
        - *0.5 Mbits/second (secondary)*
    - *Cable Characteristic Impedance*: T.B.D.
    - *Cable Maximum Length*: T.B.D.
  - *B) Fiber Optics Implementation*: (Specifications T.B.D.)

LINK LAYER

The following proposed specifications are incomplete. However, the current purpose is to introduce conceptual ideas, desirebly **consistent** with the other layers of the protocol, to serve as a basis for further, complete detailing, if it is decided to do so.

The contents of Table 2 present the basic concept for the Link Layer. Some comments on the topics represented in that table are discussed in the following text.

The WORD format ([1], [2]) to be used by the Link layer has its basic structure represented by Figure 7.

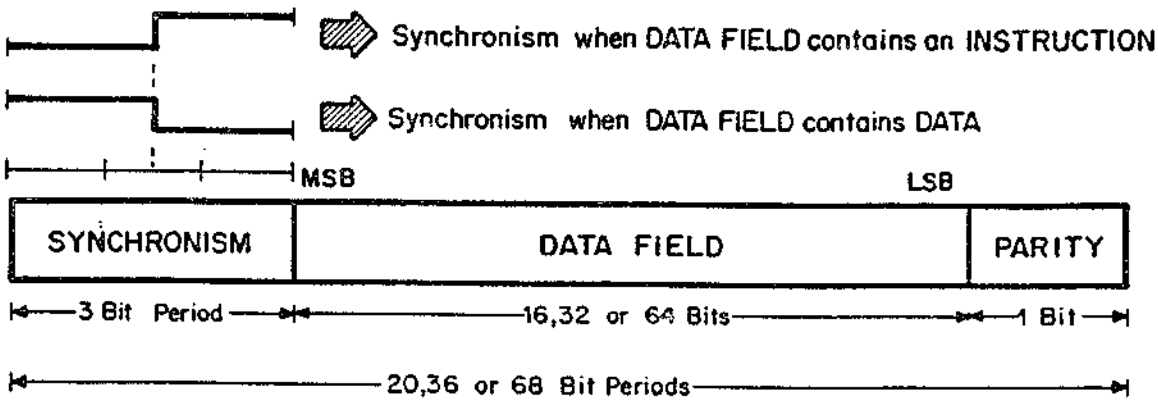

Figure 7. Basic Format for the Link Layer WORD.

It is conceived that a Link Layer WORD may have 16, 32 or 64 Bit long DATA FIELDS. It is certainly an **open question** if a 3 Bit Period Field with **one** state transition may be considered as acceptable for all the three WORD length possibilities which are being considered. It can be considered, for instance, that INSTRUCTION WORDS would be, necessarily, 20 bit long, while DATA WORD could be 20, 36 or 68 bit long, provided that the actual DATA WORD being communicated hasbeen declared by an INSTRUCTION WORD which would have been previously transmitted. If such possibility can be adopted, there would be considerable decrease in the **"overhead"** of communication, which is 20%; 11,12% and 5,88%, respectively, for 20, 36 and 68 bit long DATA WORDs. Considerable advantage in communication speed up can be achieved with longer words, specially if 32 bit, or even, 64 bit processors are foreseen for the purpose.

It is also considered as an **open question** the use of a unique **one bit long** PARITY Check in the three proposed WORD lengths, i.e., for the 20,36 or 68 bit long WORDS. Longer Parity Check fields could be considered for the longer words, possibly with adoption of the error control scheme already recommended for the CCSDS telecommand codeblocks [6], consisting of seven (7) parity check bits plus one (1) appended filler bit, as an alternative. In any case, attention should be paid to the effective "overhead" of communication that could result, besides the fact that a **fairly reliable link** is expected from **the physical layer** of this protocol.

The use of longer DATA WORDS, with 40 or 68 bits could be very convenient to execute the transport of data which compose the PACKETS which are associated to the SERVICE Layer of the protocol. If the segmented PACKETS are transported with the use of DATA WORD "bursts", through the Link Layer protocol, a fairly **higher throughput** of packets would be guaranteed. This would be particulary important for services which naturally demand **higher bandwidth,** like **voice, video (or images)** or **ISDN related services**, among other possibilities.

INSTRUCTION WORDS may be used to exchange information not only at Link level of the protocol. They may also contain data information to be communicated to the upper, Service Layer of the protocol. For instance, one or more specific INSTRUCTION WORDS may

Table 2. Link Layer Basic Specification.

• *Encoding and Decoding* : MANCHESTER

• *Bit Period* : Depends on the selected speed or bit rate ;

• *Modulation and Detection Principle* : A "*ONE*" bit is characterized by a "*MARK*" or "*1*" to "*SPACE*" or "*O*" transition, nominaly, at a mid bit period. The reversed transition at a mit bit period is defined as a "*ZERO*" bit ;

• *Unit of Information* : WORD ;

• *Word Lengths* : 20,36 or 68 Bits ;

• *Word Basic Format* : SYNC + DATA FIELD + PARITY, ordered left to right, from Most Significant Bit (MSB) to the Least Significant Bit (LSB) ;

• *DATA FIELD Carrier Attributes* :
- *INSTRUCTION WORD*
- *DATA WORD* ;

• *SYNC Length* : 3 Bit Periods ;

• *SYNC Detection* : Based on MACHESTER Encoding ;
- *INSTRUCTION WORD SYNC* : Defined when a logical level transition occurs from the "*MARK*" or "*1*" state to the "*SPACE*" or "*O*" state, in the mid of the second bit period of a total of three, with tolerance T.B.D.
- *DATA WORD SYNC* : Defined when a logical level transition occurs from the "*SPACE*" or "*O*" state to the "*MARK*" or "*1*" state, in the mid of the second bit period of a total of three, with tolerance T.B.D. ;

• *DATA FIELD Bits and Parity Bit detection* : Based on MANCHESTER decoding where, within a Bit Period, where "*MARK*" or "*1*" to "*SPACE*" or "*O*" transition means a "*ONE*", or "*ZERO*" in the reversed transition ;

• *DATA FIELD Lengths* : Selectable or fixed
- *16 Bits* - *use by default*
- *32 Bits* - *optional use*
- *64 Bits* - *optional use* ;

• *PARITY* : One Bit Period

Odd Parity Check is proposed, i.e., PARITY Bit is expected to be equal to "*1*" when the sum of bit ones in the DATA FIELD is odd ; otherwise, it should be equal to zero, to certify that parity error condition has not occurred ;

• *Error Detection* :
- *Odd Parity check* : *with Parity Bit* ;
- *Mid Bit Error check* : *If a* "*burst*" error occurs in the mid bit period region, the Mid Bit Error check condition should be positive ;

• *Time Distribution or Correction* : Make use of special instructions to be exchanged through the On Board Service Access Point.

precede and another specific group may follow a burst (sequence) of DATA WORDS which may compose the many segments of a PACKET. In this case, the mentioned INSTRUCTION WORDS may contain opening and closing data information which are passed from the Link to the Service layer **together** with the sequence of PACKET segments, and they may specify parameters related to: type of service, length of packet, error checking, etc.

Although the Link layer protocol specification is out of consideration in this context, a brief concept on a **type of dialogue** that would have to be analysed for implementation with INSTRUCTION WORDs, would go as follows:

1) **PROVIDER ("MASTER") to USER ("SLAVE"):**

"I may have a packet to send if it is announced with my next INSTRUCTION, do you have any?";

2) **USER to PROVIDER:**

"This time I do not have a packet; I will wait for your next instruction";

3) **PROVIDER to USER:**

"This is the opening INSTRUCTION WORD that precedes a series of DATA WORDS with segments of a packet";

4) **PROVIDER to USER:**

"This is a DATA WORD" (burst mode);

5) **PROVIDER to USER:**

"This is an INSTRUCTION WORD that closes a series of DATA WORDS with segments of a packet";

6) **USER to PROVIDER:**

"I received **without** error your complete set of packet segments and associated parameters; I am waiting for your next INSTRUCTION WORD";

7) **USER to PROVIDER:**

"I received with error your complete set of packet segments and associated parameters; send your set of packet segment WORDs and related instructions, again.

SERVICE LAYER

The Service Layer is a Protocol Layer which is conceived as a **two stage** protocol to be embedded in an End-to-End cross supporting protocol architecture scenario. An instance of this scenario is represented in a typical configuration which is illustraded in Figure 8.

One **stage** of the Service Layer protocol is conceived to characterize the transport of the so called **ACCESS PACKETS** between the On Board Service User and the On Board Local Service Provider Access Facility. This stage of the Service Layer Protocol is denominated **"Service Access Protocol".**

The other **stage** of the Service Layer Protocol is conceived to characterize the **End-to-End transport** of the so called **SERVICE PACKETS** between **one End**, represented by the On Board Service User and the **other End** which is represented by the Local/External Service User **while** support must be provided for Service Protocol Mapping to be executed, in **between both ends,** by the On Board Local Service Provider Access Facility. This other stage of the Service Layer Protocol is denominated **"End-to-End Service Protocol".** This is the highest level service to be cross supported by the On Board Service Access Point Communication Protocol.

The schemes of Figure 9 introduce the basic formats proposed for the **Service Access Protocol ACCESS PACKETS.** While the **Data Transport** ACCESS PACKET is conceived to transmit data through the On Board Service Access Point, the Acknowledgement ACCESS PACKET is to be used, on a mandatory basis, to confirm the reception of **each** packet of the preceding type, i.e., containing data. Both types of ACCESS PACKETS can be distinguished by the contents of the **STATUS** field. The **PACKET NUMBER** is generated by the packet source as a serial number and can be used, optionally, for sequence control at the receiving end.

The **PACKET LENGTH** designates the number of **octets** that form the whole ACCESS PACKET and can be used for verification when the packet is reconstituted from the WORD segments, besides being useful for storage allocation and management purposes. The **ERROR CONTROL** field is conceived to transport the CRC code when this resource is utilized. The ACCESS PACKET should be rejected by the "Service Access Protocol" if CRC detects the ocurrence of error. The CRC code to be adopted can be exactly the sàme specified for the CCSDS Packet Telemetry Transfer Frame Error Detection, as described in Reference [4].

The scheme of Figure 10 introduces the **basic format** conceived for the End-to-End Service Protocol SERVICE PACKETS. It can be noticed, by comparison with Figure 9, that the SERVICE PACKETS are an **extension of** the ACCESS PACKETS, such that the first three parameter fields of **both** packet formats are the **same**. However, different segments of the **STATUS** word are to be manipulated separately **and** independently by **both** Sages of the Service Layer Protocol. The **Data field** of the SERVICE PACKET is conceived to contain a "**bit stream**", whose contents are intended to be known exclusively by the (end) user who is being cross supported. A Bit stream could be formed, for instance, by a Standard Formatted Data Unit (SFDU), as defined in Reference [13].

The concept of **SERVICE ELEMENT** (SE) is related to the End-to-End nature of the Protocol. A SERVICE ELEMENT is a specific and unique End-to-End service which is expected to be executed with the use of the SERVICE PACKET by the End-to-End Service Protocol. The SERVICE PACKET has a specific field in its format to be used in the assignement of the SERVICE ELEMENT which it is associated with.

It is considered beyond the scope of this work the proposal of a specific **set** of SERVICE ELEMENTS.However, the contents of **Table 3** furnish what are conceived to be the basic **SERVICE ELEMENT** attributes. These atributes would be sufficient to derive the specification of what would be a complete set of SERVICE ELEMENTS that could be partially or completely implemented for cross support, depending on specific service requirements placed by the user and that could be provided, in practice. The conception of the attributes of Table 3 do not pretend to be exhaustive but there is, **on purpose**, the intention to not extend the complexity of the service elements to be cross supported, for the sake of simplicity and efficiency in the process of implementation which naturally results.In principle, the Service Elements (SEs) are intended for **bidirectional** implementation, when they are applicable and necessary. For instance, this could be the case for a SE that requires "On Line Delivery with Intermediate Storage and with Delivery Time-out", for telecommand (one way) and Telemetry (the other way) related bit streams.

It is noticed that under the point of view of **compromising allocation of physical resources, real time constraints and Service Element management**, the Service Provider Access Facility would be the natural candidate to **execute** the management concept for: Intermediate Storage, Intermediate Storage Retrieval Time-out (if any) and Off Line Delivery, in the execution of a Service Element.

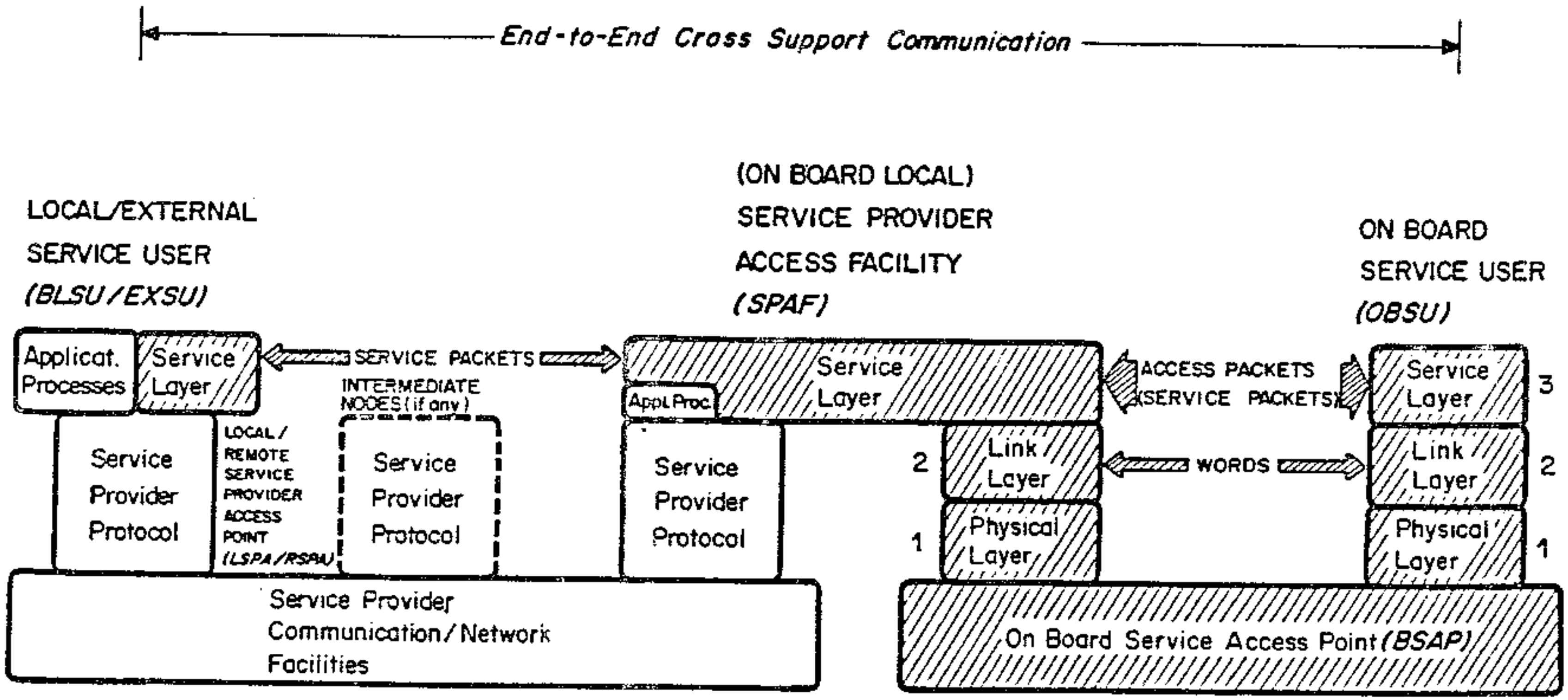

Figure 8. End-to-End Cross Support Protocol Architecture Scenario with Mapping for the Service Layer Protocol.

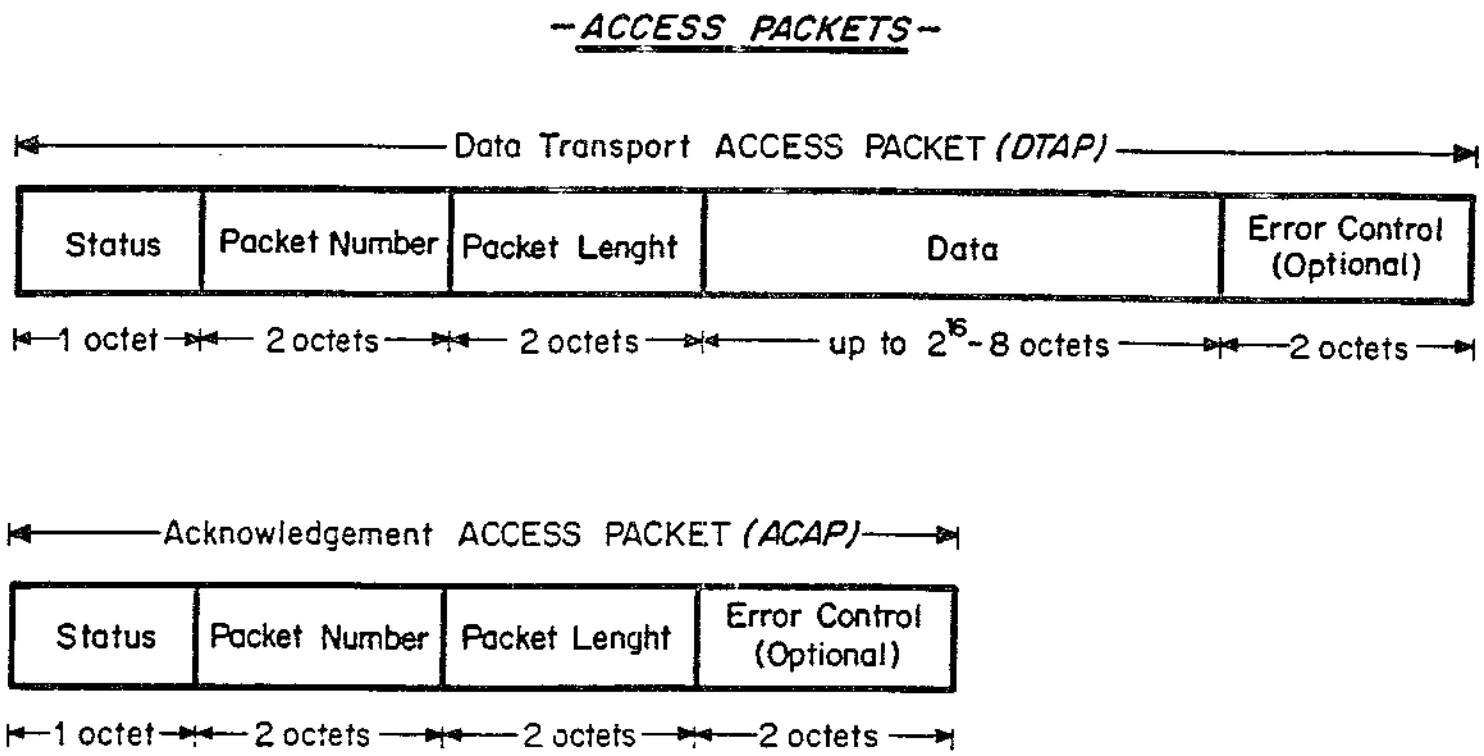

Figure 9. Basic Formats of ACCESS PACKETS for the Service Layer Protocol.

-SERVICE PACKETS-

Field / No. of Octets	-Usage-
Status / 1 Octet	-mandatory
Packet No. / 2 Octets	-mandatory
Packet Lenght / 2 Octets	-mandatory
SERVICE ELEMENT / 1 Octet	-mandatory
Source User Address / 3 Octets	-mandatory
Destination User Address / 3 Octets	-mandatory
Intermediate Storage Address / 3 Octets	-optional
Absolute Time-Out for Delivery from Intermediate Storage / $\leq$ 8 Octets	-optional(※)
Absolute Time-Out for Delivery to LOCAL / EXTERNAL SERVICE USER / $\leq$ 8 Oct.	-optional(※)
Data / $< 2^{16}$ Octets	-optional(※※)
Error Control / 2 Octets	-optional

OBS.

(※)-Use of CCSDS Unsegmented Time Code *(CUC)* is recommended, with adoption of 1958 January 1st, epoch (Level 1)-TAI Scale.

(※※)-The "Data" field is NOT used in SERVICE PACKETS used for Acknowledgement.

Figure 10. Basic Format of SERVICE PACKETS for the Service Layer Protocol.

Table 3. Basic SERVICE ELEMENT Attributes.

- *On Line Delivery*:
  - *with/without delivery acknowledgement*
  - *with/without intermediate storage*
  - *with/without time-out for delivery*
  - *with/without time-out for intermediate storage retrieval;*

- *Off Line Delivery*:
  - *with/without off line storage retrieval and delivery acknowledgement*
  - *with/without intermediate storage*
  - *with/without time-out for off line storage retrieval and delivery*
  - *with/without time-out for intermediate storage retrieval.*

MANAGEMENT ASPECTS

The concept of inter-Agency "cross-support" which relies on the capability of one Space Agency to transfer information to another Agency has inspired the concepts proposed in this context.

Another basic concept that was explored to the foreseeable extreme in this work is related to the conception of cross supporting services which would cause minimum disturbance, to say the least, to already existing or planned physical implementations of the "Service Provider" facilities in the supporting Agency.

The two premises mentioned above have direct consequences in management aspects related to the On Board Cross Support Scenario concepts which are proposed in this work.

If Management Access Points (MAPs) are defined as those which can support, whenever applicable:

- **Service Set-up**
- **Service Execution**
- **Service Reporting**
- **Service Closing**

it can be derived from the End-to-End Cross Support Protocol Architecture Scenario represented in Figure 8 the following management related aspects. They are:

1. The LOCAL/EXTERNAL SERVICE USER(s), the SERVICE PROVIDER ACCESS FACILITY and the ON BOARD SERVICE USER which are, naturally, **Management Access Points (MAPs)**;

2. The SERVICE PROVIDER ACCESS FACILITY must provide an **interface, at Application Process level,** to the Service Layer which it cross supports;

3. The **three** mentioned **MAPs** rely on the Service Layer Protocol to obtain Cross Supported Services;

4. The **Service Manager**, at **each** MAP, should be capable of obtaining from the process associated to the Service Layer Protocol, whenever applicable, the SET-UP, EXECUTION, REPORTING and CLOSING for **each** SERVICE ELEMENT when it is **allowed** to be invoked;

5. A previous inter-Agency agreement on a **PLAN-OF-OPERATIONS** should be settled to establish: **rules, routines and schedules** for using each of the Service Elements which will be utilized for cross-support at each MAP;

6. Also, an **inter-Agency agreement and development** must be executed to implement the specific On Board Scenario to be cross-supported;

7. The previously agreed upon PLAN-OF-OPERATIONS will determine the **operation routines for each MAP** manager **and/or operator.**

CONVENTIONAL ORBITING SYSTEMS SCENARIOS

The so called conventional orbiting systems are those that observe CCSDS Recommendations specified in References [3] to [9], CCSDS Recommendations which are being developed for ground internetworking would be also included in this context, as long as they are independent fron space/ground or space/space Recommendations which are also being specified for Advanced Orbiting Systems.

The conventional orbiting systems are characterized by complex free flying Spacecraft operating at: moderate data rates and servicing; moderate number of users; limited on board and ground computer networking and exploiting; somewhat limited opportunities for international, inter-Agency cross-support; asymmetric data transfer configuration with the use of CCSDS Packet Telemetry and Telecommand in the space to ground and ground to space communication channels.

An On Board Cross Support Scenario where the conceived main protocol architecture layers are represented interfacing with CCSDS protocol architecture, as recommended for the so called Conventional Orbiting Systems, is illustrated in Figure 11. The CCSDS protocol architecture, in this case, is concentrated in the space/ground link segment of the scenario. In **both** ends of the **space/ground link segment**, the **interface** with the continuing scenario is conceived by means of specific **application processes** which would "**map**" the information flowing through the end-to-end path, to be properly carried by the service provider facilities.

More specifically, in the scenario illustrated in Figure 11, the On Board Cross Support **SERVICE PACKETS** would be carried, **down link**, as bit streams, in the data field of CCSDS Telemetry Source Packets. In the **up link** segment, the SERVICE PACKETS would be carried, as **bit streams**, in the **(user) data field** of a **telecommand packet**, as recommended by CCSDS.

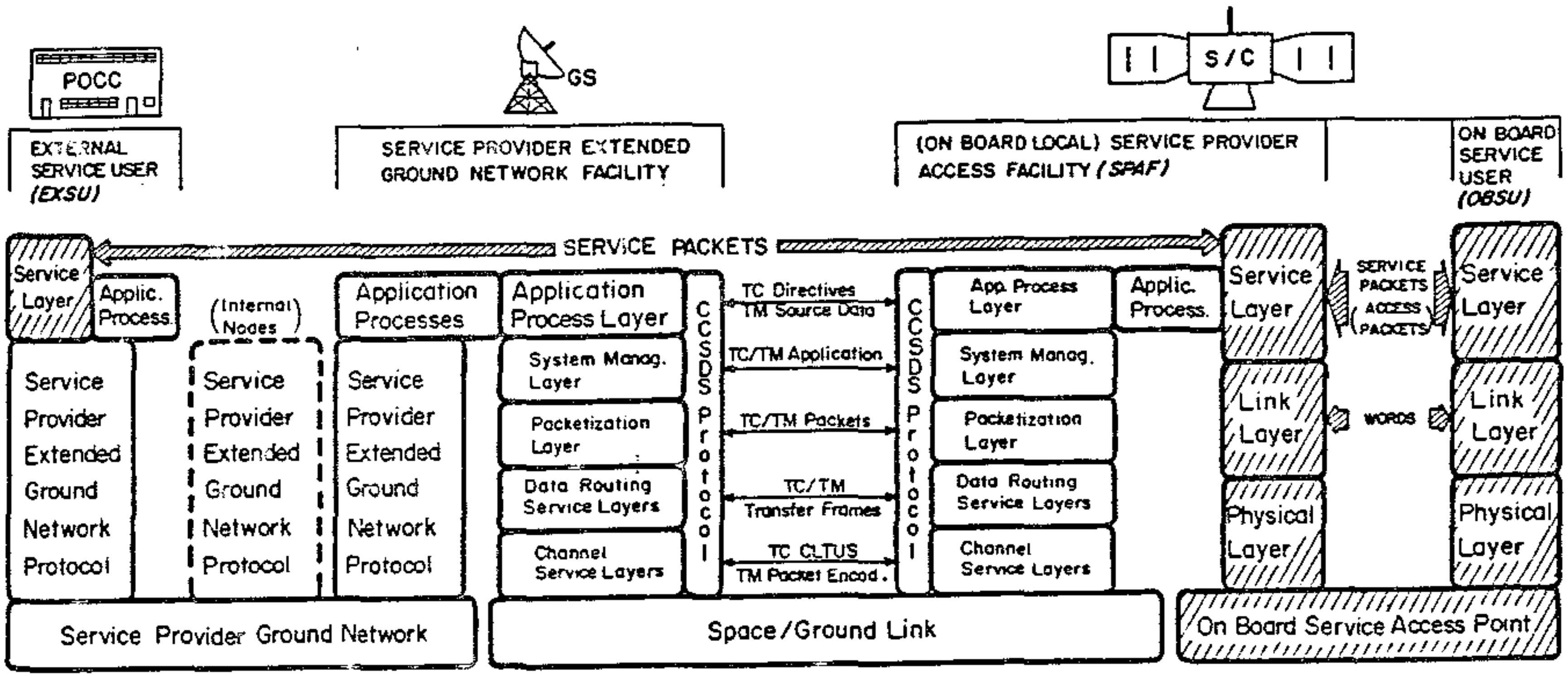

Figure 11. An On Board Cross Support Protocol Architecture Scenario with CCSDS Recommendation/Standards for Conventional.

ADVANCED ORBITING SYSTEMS SCENARIOS

The CCSDS Recommendations which specify the so called Advanced Orbiting Systems (AOSs) are destribed in the latest versions of References [10] to [12].

The CCSDS Recommendations [10] for Advanced Orbiting Systems have their scope oriented for applications directed to: complex international constellations of spacecraft, including manned and man-tended space stations, unmanned space platforms, free flying spacecraft and advanced space transportation systems operating for a very wide range of users, data rates and serving options, extensive on board and ground computer networking which are also expected to extensively support the use of the "Open Systems Interconnection (OSI)" standards.

The Recommendations for Advanced Orbiting Systems extend the CCSDS Recommendations for Conventional Orbiting Systems without exclusion. It is, therefore, expected that "mixed" or "hybrid" Orbiting Systems may be conceived and implemented by using the Advanced and the Conventional concepts and their related CCSDS recommendations. The concepts being introduced in the current work do **not** exclude any of **both**, Conventional and Advanced Orbiting Systems Concepts. In this sense, the on Board Cross Support Scenarios introduced in this work are being structured based on a "**complementary nature**" to the already established CCSDS Conventional and Advanced Orbiting Systems concepts and their recommendations.

The scheme of Figure 12 contains an On Board Cross Support Scenario where the CCSDS Recommendations for Advanced Orbiting Systems are also part of the same scenario. Many other instances of On Board Cross Support Scenarios based on Advanced Orbiting Systems could be conceived. However the basic concept implied by Figure 12 is a sufficient introduction, without loss of generality.

Analysing the scenario illustrated in Figure 12, the following observations are pertinent to the On Board Cross Support concept which is represented.

The On Board Service User would have its Service Access Point connected to a **host** facility of the Extended On Board Network. In this case, before the Service Access Point, this host facility would act as the already defined "On Board Service Local Service Provider Access Facility (SPAF)". This SPAF facility would, at Application Process level, execute the Service Layer Protocol, as already defined, to treat the Service Packets according to the Service Elements which they invoke. It is reasonable to assume that the Service Packets would flow through the intermediate subnetwork, which include the CCSDS Principal Network (CPN), to and from the other End, i.e., the Extwernal Service User, as a "Bit stream". Therefore, the SERVICE PACKETS would be a "Bit stream" for the External On Board and Ground Networks which, in turn, would make use of the Internet Service or Path Service, (cross) supported by the CCSDS Principal Network (CPN), depending whether the access to the CPN is done by means of an interface using the protocol ISO 8473 or to the CCSDS Path Protocol, respectively.

Depending on timing related constraints, if any, specified for the Service Elements being cross supported and, therefore, to be specified by the SERVICE PACKETS being transported End-to-End, the Extended On Board and Ground Networks, including the CCSDS Principal Network must be analysed, concerning their capabilities for "asynchronous" (and) or "isochronous" data transfer. The capability of sequence preserving in the SERVICE PACKET transport is not being considered at this level of conception, in this current work. However, Service Elements could also be conceived, taking into account the preservation of sequence in the transport of SERVICE PACKETS.

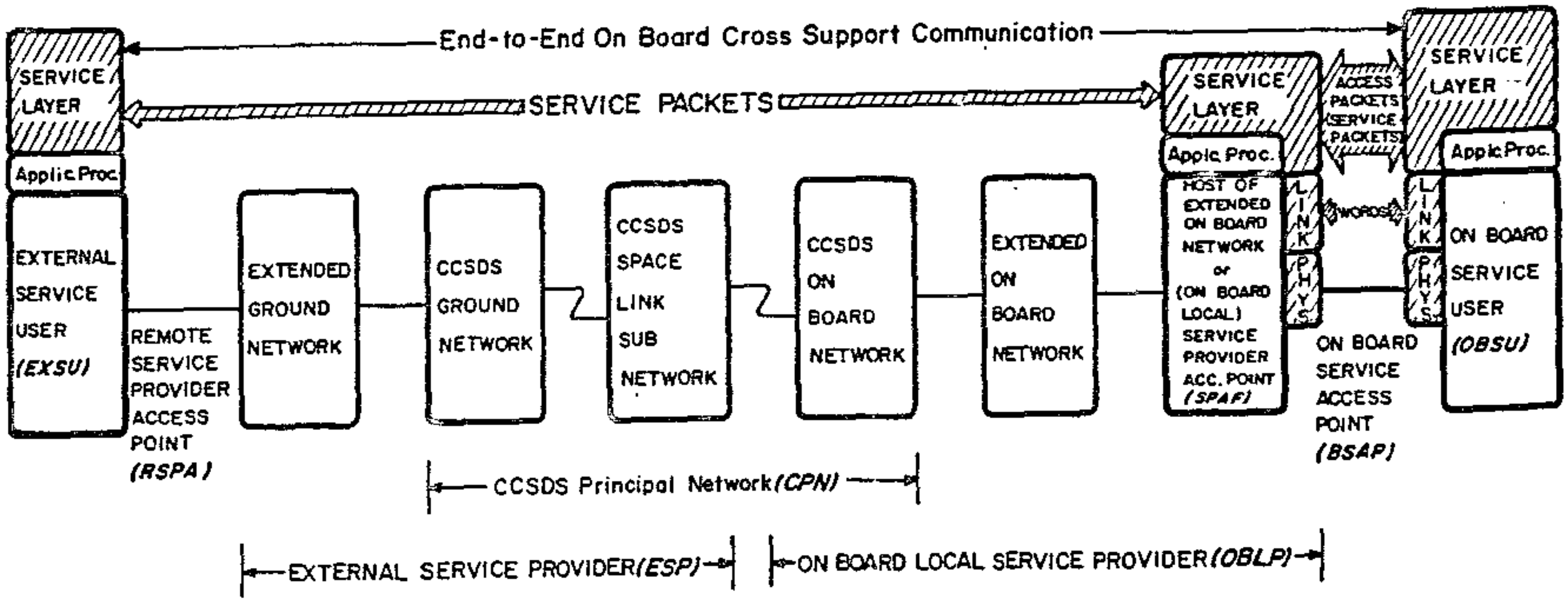

Figure 12. An On Board Cross Support Scenario for Advanced Orbiting Systems.

CONCLUSIONS

Some Space Data System On Board Cross Support Scenarios which were considered basic are conceived in this work. Without extending too much, related aspects to the proposed scenarios have been introduced with different degrees of detailing, whenever it was considered pertinent to the underlying scope.

The On Board Cross Support Scenario, as being conceived, would extend considerably the possibilities of cross support not only in the inter Agency domain but also for those potential users within the domain of a unique Agency. For instance, if an On Board Service Provider facility is "hosted" by a Conventional or an Advanced Orbiting System based on CCSDS recommendations it may, in principle, provide communication service cross support to an "independent" On Board Service User which does not comply, in terms of interface, with the mentioned CCSDS recommendations.

This concept work is an attempt to structure and formalize the considered main topics which could form a new CCSDS recommendation, in this case, oriented for On Board Cross Support. The approach which has been conceived suggests that such recommendation would have a complementary nature, specified for use "on top" of existing CCSDS Recommendations, if this is the case. In principle, it could also be adapted to other space data systems which may be exclusive of an specific Agency. More specifically, at the so called On Board Service Access Point, the proposed recommendation for cross support would have to be specified from the physical layer and up. However, as an End-to-End cross support resource, the recommendation would be, at Service Layer, related to interfaces at Application Level, in order to comply its own service elements with other existing service recommendations or standards, defined by the existing CCSDS Recommendations or by other recommending Committee (ISO, CCITT), if any, and which may be in use by the Agencies envolved in the specific cross-support scenario.

To develop a complete on board cross-support recommendation, further detailing and consolidation of ideas will have to be worked on, concerning functional specifications and communication principles, in view of the scope of expected scenarios. In a folllowing step: the Protocol, the complete set (or repertoire) of Service Elements and related Management Procedures for Operations would have to be specified, as well. A Testebed implementation would follow to validate what would be the recommendations, possibly resulting from custom or semi-custom made hardware devices, which might also contain embedded firmware resources for the higher layers (e.g. Link Layer) of the protocol, with inclusion of their external interfaces to what would be the immediate higher layer.

It is worth to mention, as a last observation, that the physical layer of the Protocol, as proposed for the On Board Service Access Point may have two implementation options. One with the already classical twisted pair electrical cables. This is a convenient choice for low data rates, up to one Megabits/Sec. The other implementation option, for higher data rates, which may be related to digitized voice, video (images) or, even, ISDN services, would make use of fiber optics cables to comply with the requirement for higher (or much higher) data rates.

ACRONYMS

ABSU - Adapted On Board Service User
ACAP - Acknoledgement Access Packet
AOS - Advanced Orbiting Systems
BESP - On Board External Service Provider
BESU - On Board External Service User
BLSP - On Board Local Service Provider
BLSU - On Board Local Service User
BSAP - On Board Service Access Point
CCITT - Consultative Committee for International Telephones and Telegraphs
CCSDS - Consultative Committee for Space Data Systems
CPN - CCSDS Principal Network
DTAP - Data Transport Access Packet
ESP - External Service Provider
EXSU - External Service User
GESP - On Ground External Service Provider
GESU - On Ground External Service User
GS - Ground Station
ISDN - Integrated Services Data Network
LSB - Least Significant Bit
LSPA - Local Service Provider Access Point
MAP - Management Access Point
MSB - Most Significant Bit
OBLP - On Board Local Service Provider
OBSP - On Board Service Provider
OBSU - On Board Service User
OSI - Open Systems Interconnection
POCC - Payload Operations Control Center
RSPA - Remote Service Provider Access Point
S/C - Spacecraft
SE - Service Element
SFDU - Standard Formatted Data Unit

SP - Service Provider

SPAF - Service Provider Access Facility

SPEA - Service Provider External Access

SYNC - Synchronism

T.B.D. - To Be Defined

TC - Telecommand

TM - Telemetry

REFERENCES

[1] MIL - STD - 1553B, Military Standard, Aircraft Internal Time Division Command/Response Multiplex Data Bus, U.S. Departament of Defense, Washington, DC 20300, USA, 1978.

[2] "1984 Harris CMOS Digital Data Book", Harris Co., 1984.

[3] "Procedures Manual for the Consultative Committee for Space Data Systems", CCSDS Document, Issue-2, May 1988 or later issue

[4] "Packet Telemetry", Recommendation CCSDS 102.0-B-2, Issue 2, Blue Book, Consultative Committee for Space Data Systems, January 1987 or later issue.

[5] "Telemetry Channel Coding", Recommendation CCSDS 101.0-B-2, Issue 2, Blue Book, Consultative Committee for Space Data Systems, January 1987 or later issue.

[6] CCSDS 201.0-B-1, "Recommendation for Space Data System Standards. Telecommand Part 1: Channel Service, Architectural Specification", CCSDS Recommendation, Blue Book, Issue-1, January 1987 or later issue.

[7] CCSDS 202.0-B-1, "Recommendation for Space Data Systems Standards. Telecommand, Part 2:. Data Routing Service, Architectural Specification", CCSDS Recommendation, Blue Book, Issue-1, January 1987 or later issue.

[8] CCSDS 203.0-B-1, "Recommendation for Space Data System Standards. Telecommand, Part 3: Data Management Service, Architectural Definition", CCSDS Recommendation, Blue Book, Issue-1, January 1987 or later issue.

[9] CCSDS 401.0-B-1, "Recommendation for Space Data System Standards. Radio Frequency and Modulation Systems, Part 1: Earth Stations and Spacecraft", CCSDS Recommendation, Blue Book, Issue-1, December 1986 or subsequent issue. (Note. Since this Reference does not currently cover data relay satellites, the following document shall be a substitutive Reference: STDN 101.2, "Space Network (SN) Users' Guide", (formerly titled "Tracking and Data Relay Satellite System (TDRSS) Users' Guide"), Revision 6, September 1988 or later issue, NASA Goddard Space Flifgt Center.)

MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO DE PESQUISAS ESPACIAIS

PROPOSTA PARA PUBLICAÇÃO

☐ DISSERTAÇÃO
☐ TESE
☒ RELATÓRIO
☐ OUTROS

IDENTIFICAÇÃO

TÍTULO: "On Board Cross Support Scenarios"

AUTOR(ES): Eduardo Whitaker Bergamini

ORIENTADOR:

CO-ORIENTADOR:

DISS. OU TESE

LIMITE: __/__/__ DEFESA: __/__/__ CURSO: ORGÃO: ETE

DIVULGAÇÃO: ☒ EXTERNA ☐ INTERNA ☐ RESTRITA

EVENTO/MEIO: ☐ CONGRESSO ☐ REVISTA ☐ OUTROS

REV. TÉCNICA

NOME DO REVISOR: Leon Lonneux

RECEBIDO: 20/09/89 DEVOLVIDO: 10/10/89 ASSINATURA: [signature]

APROVAÇÃO

NOME DO RESPONSÁVEL: José Luiz Rodolfo Muzzio

APROVADO: ☐ SIM ☐ NÃO DATA: __/__/__ ASSINATURA: [signature]

REV. LINGUAGEM

Nº: PRIOR: RECEBIDO: __/__/__ NOME DO REVISOR:

PÁG: DEVOLVIDO: __/__/__ ASSINATURA:

DATILOGRAFIA

OS AUTORES DEVEM MENCIONAR NO VERSO INSTRUÇÕES ESPECÍFICAS, ANEXANDO NORMAS, SE HOUVER

RECEBIDO: 15/08/89 DEVOLVIDO: 16/11/89 NOME DA DATILÓGRAFA: Natália Santos Gomes

Nº DA PUBLICAÇÃO: PÁG.:
CÓPIAS: Nº DISCO: LOCAL:

DIRETOR

AUTORIZO A PUBLICAÇÃO: ☐ SIM ☐ NÃO __/__/__

OBSERVAÇÕES E NOTAS

Favor fazer 6 cópias para o autor quando o relatório estiver pronto.