

INTERNATIONAL STANDARD

ISO 12173

Second edition
2003-02-15

Space data and information transfer systems — Telecommand — Command operation procedures

*Systèmes de transfert des informations et données spatiales —
Télécommande — Procédures pour les opérations de télécommande*



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Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 12173 was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 202.1-B-2, June 2001) and was adopted (without modifications except those stated in Clause 2 of this International Standard) by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 13, *Space data and information transfer systems*.

This second edition cancels and replaces the first edition (ISO 12173:1998), which has been technically revised.

Space data and information transfer systems — Telecommand — Command operation procedures

1 Scope

This International Standard specifies the logic required to carry out Command Operation Procedure-1 (COP-1) of the transfer layer. It is applicable only to projects which are compatible with the transfer layer as defined in ISO 12172 (see reference [2] in 1.5).

The scope and field of application are furthermore detailed in subclauses 1.1 and 1.2 of the enclosed CCSDS publication.

2 Requirements

Requirements are the technical recommendations made in the following publication (reproduced on the following pages), which is adopted as an International Standard:

CCSDS 202.1-B-2, June 2001, *Recommendation for space data system standards — Telecommand — Part 2.1: Command operation procedures*.

For the purposes of international standardization, the modifications outlined below shall apply to the specific clauses and paragraphs of publication CCSDS 202.1-B-2.

Pages i to vii

This part is information which is relevant to the CCSDS publication only.

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Add the following information to the references indicated in 1.5:

- [1] Document CCSDS 201.0-B-3, June 2000, is equivalent to ISO 12171:2002.
- [2] Document CCSDS 202.0-B-3, June 2001, is equivalent to ISO 12172:2003.
- [3] Document CCSDS 203.0-B-2, June 2001, is equivalent to ISO 12174:2003.

3 Revision of publication CCSDS 202.1-B-2

It has been agreed with the Consultative Committee for Space Data Systems that Subcommittee ISO/TC 20/SC 13 will be consulted in the event of any revision or amendment of publication CCSDS 202.1-B-2. To this end, NASA will act as a liaison body between CCSDS and ISO.

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Consultative Committee for Space Data Systems

RECOMMENDATION FOR SPACE
DATA SYSTEM STANDARDS

TELECOMMAND

PART 2.1

COMMAND OPERATION PROCEDURES

CCSDS 202.1-B-2

BLUE BOOK

June 2001



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12173:2003(E)

CCSDS RECOMMENDATION FOR TELECOMMAND: COMMAND OPERATION PROCEDURES

AUTHORITY

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This document has been approved for publication by the Management Council of the Consultative Committee for Space Data Systems (CCSDS) and represents the consensus technical agreement of the participating CCSDS Member Agencies. The procedure for review and authorization of CCSDS Recommendations is detailed in the Reference [D1], and the record of Agency participation in the authorization of this document can be obtained from the CCSDS Secretariat at the address below.

This Recommendation is published and maintained by:

CCSDS Secretariat
Program Integration Division (Code MT)
National Aeronautics and Space Administration
Washington, DC 20546, USA

STATEMENT OF INTENT

The Consultative Committee for Space Data Systems (CCSDS) is an organization officially established by the management of member space Agencies. The Committee meets periodically to address data systems problems that are common to all participants, and to formulate sound technical solutions to these problems. Inasmuch as participation in the CCSDS is completely voluntary, the results of Committee actions are termed **RECOMMENDATIONS** and are not considered binding on any Agency.

This RECOMMENDATION is issued by, and represents the consensus of, the CCSDS Plenary body. Agency endorsement of this RECOMMENDATION is entirely voluntary. Endorsement, however, indicates the following understandings:

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 - The STANDARD itself
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CCSDS RECOMMENDATION FOR TELECOMMAND: COMMAND OPERATION PROCEDURES

FOREWORD

This document, which is a technical Recommendation prepared by the Consultative Committee for Space Data Systems (CCSDS), is intended for use by participating space Agencies in their development of space telecommand systems.

This Recommendation allows the implementing organizations within each Agency to proceed coherently with the development of compatible Standards for the flight and ground systems that are within their cognisance. Agency Standards derived from this Recommendation may implement only a subset of the optional features allowed herein, or may incorporate features not addressed by the Recommendation.

The *Recommendation for Telecommand, Part 2: Data Routing Service* (Reference [2]) defines the standard data structures and data communication procedures within the intermediate telecommand system layers to be used by conventional missions. The Command Operation Procedure forms a subpart of the Data Routing Service, which is described in Reference [2]. This Recommendation contains the definition of the Command Operation Procedure in the form of state tables at the level of detail necessary to allow cross support. It is assumed that the reader is familiar with the terminology and data structures defined in Reference [2].

Through the process of normal evolution, it is expected that expansion, deletion or modification to this document may occur. This Recommendation is therefore subject to CCSDS document management and change control procedures defined in Reference [D1]. Current versions of CCSDS documents are maintained at the CCSDS Web site:

<http://www.ccsds.org/>

Questions relating to the contents or status of this Report should be addressed to the CCSDS Secretariat at the address on page i.

CCSDS RECOMMENDATION FOR TELECOMMAND: COMMAND OPERATION PROCEDURES

At time of publication, the active Member and Observer Agencies of the CCSDS were:

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- United States Geological Survey (USGS)/USA.

CCSDS RECOMMENDATION FOR TELECOMMAND: COMMAND OPERATION PROCEDURES

DOCUMENT CONTROL

Document	Title and Issue	Date	Status/ Remarks
CCSDS 202.1-B-1	Telecommand Part 2.1— Command Operation Procedures, Issue 1	October 1991	Original Issue (superseded— see footnote on page 2-34)
CCSDS 202.1-B-2	Telecommand Part 2.1— Command Operation Procedures, Issue 2	June 2001	Current Issue

Substantive Changes from Previous Issue:

Section	Change	Reason
2.1.1.2	Added Note about meaning of Expedited.	Experience shows that there is widespread confusion/disagreement about the reasons for using the BD service.
2.1.2.1	Definition of FOP-1B	
2.2.1 2.2.1.2 2.2.1.3 2.2.1.4	Deleted from the list "Stored_Lockout_Flag", "Stored_Wait_Flag" and "Stored_Retransmit_Flag".	There is no need for the FOP to store the values of these flags: the values are NEVER used by the FOP. The FOP uses the values in the CLCW as it processes the CLCW. It records the information it needs in the State and in the Sent_Queue.
2.2.1.10	Improved definition of "Expected_Acknowledgement_Fra me_Sequence_Number (NN(R))".	
2.2.1.11	Introduced Alert[T1]	If the Timer expires and the Transmission_Count has reached the Transmission_Limit, an Alert [T1] is generated.
2.2.1.12	Improved description of application of transmission count limit.	Each frame will be transmitted "at least" a number of times corresponding to the value given by Transmission_Limit, unless this value is set to 1. A frame in the Sent_Queue that moves from an intermediate position to the first position, may be transmitted a number of times greater than the value given by Transmission_Limit.
2.2.1.12 3) Transmission_Co unt	There are two different sorts of events which may cause FOP-1 to initiate retransmission of one or more Type-AD frames and there is only one sort of event which may cause FOP-1 to initiate retransmission of a Type-BC frame.	This is the reality.
2.2.1.12	Added new paragraph "When the AD Service is initiated, the Transmission_Count is set to 1".	This works consistently with the rest of the actions in the state table. Setting it to 0 does not.

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2.3.1.1	Added note on possible misuse of the "Set V(S) to V*(S)" Directive.	Consider the sequence: - Suspend (with AD frames on the Sent_Queue) - Set-V(S)-to-V*(S) - Resume The actions for the Set-V(S)-to-V*(S) include setting NN(R) and V(S) to the new V*(S) value, so that NN(R) = V(S). However, if there are AD frames on the Sent_Queue, then NN(R) < V(S). So after the Resume, the FOP has an inconsistent set of FOP-1 variables, with frames on the Sent_Queue and NN(R) = V(S).
2.3.1.1	Added note on possible misuse of the "Terminate" Directive.	In the "Initial" State (S6) the "Terminate AD Service" directive is not effective in the case that the Suspend_State (SS) is not equal to zero.
2.3.1.1 3) Alert Indications	Added Alert[T1] and distinction with respect to Alert[limit].	In case a CLCW arrives which negatively acknowledges a frame and the value of the Transmission_Count has reached the value of the Transmission_Limit, FOP-1 generates an "Alert[limit]". In case the Timer expires and the value of the Transmission_Count has reached the value of the Transmission_Limit, FOP-1 generates an "Alert[T1]". (Note: This "Alert" Indication cannot occur if the Timeout_Type variable is set to "1".)
2.3.1.1 3) Alert Indications	Allowed number of transmissions exhausted for a Type-BC frame derived from a directive (e.g., "Initiate AD Service" Directive with "Unlock" or with "Set V(R)") now generates Alert[T1] and not Alert [limit].	This case happens only when the Timer expires. See State table.
2.5.1	Modified "(Note: Purging the Sent_Queue only occurs as part of the termination of an AD Service)." Footnote inserted.	Purging is also needed when the AD Service is initiated (because the FOP can reach S6 via a Suspend).
2.5.1	"Initialise" includes also "setting the Transmission_Count to 1".	This works consistently with the rest of the actions in the state table. Setting it to 0 does not.
2.5.1	The "Exceptions" also include Suspend.	
2.5.1 and 2.5.2	Text added to clarify that modulo 256 arithmetic should be performed for fields related to 8-bit FOP-1 and FARM-1 sequence numbers.	
Events E6, E7, E8 and E9 in States S4 and S5	Replaced all the text in each of the eight boxes S4/E6, S4/E7, S4/E8, S4/E9, S5/E6, S5/E7, S5/E8, S5/E9, with "Not applicable".	In S4 and S5, V(S) is equal to NN(R) so there is no possible value of N(R) for which both N(R) < V(S) AND N(R) >= NN(R).
Events E101 and E102 (between E7 and E8)	Added the two new events to take into account the case that Transmission Limit is set to 1.	When Transmission_Limit is set to 1, no retransmission will be tried and each frame will be transmitted only once. The FOP table presented in Annapolis stated that E101 and E101 were "Not applicable (TBC)" in S2 and S3. This is correct in the sense that we cannot get into any retransmit state if the transmission limit is 1. However, it is possible to issue the "Set Transmission_Limit" directive in any state, including S2 and S3, so it is theoretically possible to get into state S2 while the transmission limit is greater than 1, then to have an imaginative operator setting the limit to 1 and receiving another CLCW with retransmit flag set. Therefore we have decided to react the same way as for S1, i.e. to remove the acknowledged frames (if any) and issue an Alert[limit], just to have a clean approach for this case, though it is indeed not very probable but not impossible.

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Events E8, E9, E10, E11 and E12	The column "Transmission Limit > 1" has been added among Event Conditions.	These events are now only applicable to the case Transmission Limit > 1.
Event E12 in S1, S2, and S3	The event does not produce any more Alerts in S1, S2, and S3.	The Alert was actually produced too early, without waiting any time to allow the frame to reach the spacecraft and then to allow the generated CLCW to arrive on ground. Actually the Alert would have been produced by an "old CLCW" (only for the very last retransmission).
Events E12 and E103 (after E12)	E103 has been added and the state transition for E12 in S2 and S3 have been modified. The column "Wait Flag = 0 (or 1)" has been added among Event Conditions.	This considers that the conditions producing event E12 in FOP-1A shall be differentiated depending on the value of the Wait Flag.
Events E16, E17 and E18	The type of Alert possibly produced when Timer Expires has been modified to Alert[T1] (instead of Alert[limit]).	The distinction between Alert[T1] and Alert[limit] gives better information to the FOP user..
Events E16 and E104 (after E16)	E104 has been added. The column "TT = 0 (or 1)" has been added among event conditions. E104 differs only for S4: Alert[T1] for E16; Suspend with SS=4 for E104.	It follows this comment "it is not clear to me why E16 s4 causes a limit alert while E18 s4 causes the FOP to suspend - from my point of view E18 s4 is "not applicable" as the transmission counter is always 0, but probably somebody else will have thought about it more seriously than I did." Actually the value of Transmission Count in s4 was "undefined" (e.g. consider the sequence S1-Terminate-E24) but now the value of Transmission Count in s4 is always 1 (as part of the Initialise action performed in E24-S6). Therefore E104 is needed and more likely than E18 (that would be true only when Transmission Limit = 1).
Event E21	Removed from each of the six boxes S1/E21, S2/E21, S3/E21, S4/E21, S15/21 and S61/E21 the text "BD_Out_Flag = Not_Ready".	The action "Transmit Type BD Frame" already includes setting the flag.
Events E25 and E27	Removed from the boxes S6/E25 and S6/E27 the text "BC_Out_Flag = Not_Ready".	The action "Transmit Type BD Frame" already includes setting the flag.
Event E27	Added "Accept" as first action in S6.	This works consistently with the rest of the Directives in the state table. Most likely it was a left over "typo".
Events E31 to E34	Replaced all the text in each of the twenty boxes included in the States S1 to S5 and Events E31 to E34 with "Not applicable".	The boxes all require SS non-zero but SS is ALWAYS zero except in State S6.
Event E35	The "Set V(S) to V*(S)" Directive is rejected in S6 when SS is not zero.	The "Set V(S) to V*(S)" Directive, setting the Transmitter_Frame_Sequence_Number (V(S)), was always accepted when FOP-1A was in the "Initial" State (S6). When SS is not equal to zero it means that the FOP-1 AD service has been suspended and in case the value of V(S) is changed while FOP-1 is suspended, FOP-1 may be unable to execute the COP-1 protocol correctly. For this reason FOP-1B limits the use of the directive to the case that the Suspend_State (SS) is equal to zero.
Annex B	Last sentence "There are no specific responses defined in this document from the receiving-end Higher Layer to a Lower Layer." has been deleted.	The sentence was not quite true. The layer above the FARM indicates to the FARM whether it can accept another frame (the "Wait Flag"). A change of state of this flag IS a service primitive. Since the Annex B seemed to be designed to give a very high level overview of the interlayer interfaces, it was considered not appropriate to include all the details of the Wait Flag and the last sentence was simply removed.

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CCSDS RECOMMENDATION FOR TELECOMMAND: COMMAND OPERATION PROCEDURES

1 INTRODUCTION

1.1 PURPOSE AND SCOPE

This Recommendation contains the detailed specification of the logic required to carry out Command Operation Procedure-1 (COP-1) of the Transfer Layer.

The *Recommendation for Telecommand, Part 2: Data Routing Service*, (Reference [2]) contains the standard data structures and data communication procedures used by the intermediate telecommand system layers (the Transfer and Segmentation Layers). In particular, it contains a brief description of the Command Operation Procedure (COP) within the Transfer Layer. This Recommendation contains the detailed definition of COP-1 in the form of state tables, along with definitions of the terms used. It is assumed that the reader of this document is familiar with the data structures and terminology of *Part 2*.

In case of conflict between *Part 2* (Reference [2]) and this Recommendation, this Recommendation will take precedence.

1.2 APPLICABILITY

This Recommendation serves as a guideline for the development of compatible internal Agency standards in the field of spacecraft commanding. This Recommendation is not retroactive, nor does it commit any Agency to implement the recommended telecommand concepts at any future time. Nevertheless, all Consultative Committee for Space Data Systems (CCSDS) Agencies accept the principle that all future implementations of telecommand that are used in cross-support situations will be based on this Recommendation.

The CCSDS has developed a layered concept for future spacecraft telecommanding, which is summarized in *Telecommand, Summary of Concept and Service* (Reference [D2]) and defined in the *Recommendation for Telecommand, Part 1: Channel Service* (Reference [1]), *Part 2: Data Routing Service* (Reference [2]), and *Part 3: Data Management Service* (Reference [3]). Standard services are defined within each layer, and Agencies will be encouraged to develop corresponding facilities to provide these services in support of Projects. This Recommendation is applicable only to those Projects that are compatible with the Transfer Layer as defined in *Part 2*.

Where preferred options or mandatory capabilities are clearly indicated herein, the indicated sections of the specification must be implemented when this Recommendation is used as a basis for cross support. Where optional subsets or capabilities are allowed or implied in this specification, implementation of these options or subsets is subject to specific bilateral cross-support agreements between the Agencies involved.

The recommendations in this document are to be invoked through the normal standards programs of each member Agency, and are applicable to those missions for which cross support based on capabilities described in these recommendations is anticipated.

1.3 STATE TABLE FORMAT

This document contains the state tables for the Telecommand Command Operation Procedure (TC COP). For the Frame Operation Procedure (FOP) or Frame Acceptance and Reporting Mechanism (FARM), the state table shows the various "states" (columns) in which the process might be at a given time, and the "events" (rows) which cause "actions" and/or state changes. The action and/or state change appropriate to the occurrence of a particular event, when the processes are in a particular state, is shown at the intersection of the respective row and column. State transitions are indicated by state numbers in parentheses; thus "(S2)" indicates "go to State Number 2". See Figure 1-1.

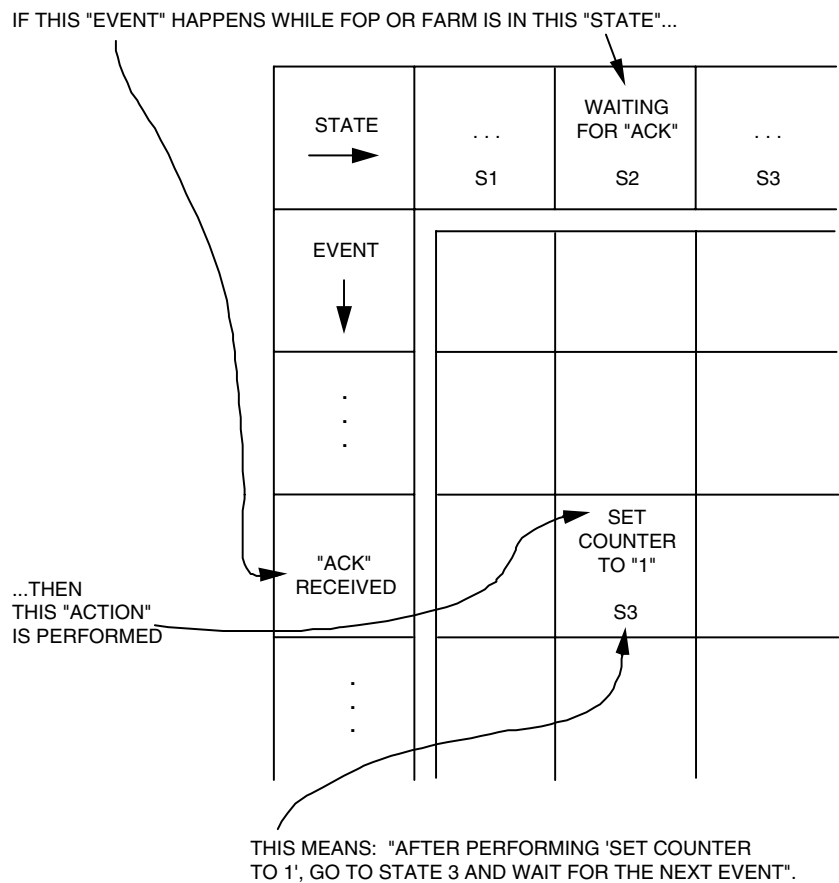


Figure 1-1: State Table Format

NOTE

The table describes the processing for one independent Virtual Channel.

CCSDS RECOMMENDATION FOR TELECOMMAND: COMMAND OPERATION PROCEDURES

1.4 INTERLAYER INTERFACES

In order to define the COP-1 services and protocols completely and clearly, it was necessary to define some of the characteristics of the interface between the COP and the Higher and Lower Layers. For example, a decision had to be made as to whether the Higher Layer may deliver only one frame at a time to Frame Operation Procedure-1 (FOP-1) or may deliver a group of frames. A strategy for ensuring accountability of sequence-controlled frames all the way from the sending-end Higher Layer through the spacecraft and back to the Higher Layer had to be established.

It is realized that there are other ways in which the interfaces could be defined. In particular, if two layers are implemented as part of a single system, their interfaces could be simplified. It is the responsibility of the implementers to ensure that all of the requirements for the basic operation of the COP are met.

Additional information about the assumed interlayer interfaces is included in Annex B.

1.5 REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Recommendation are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS Recommendations.

- [1] *Telecommand Part 1—Channel Service*. Recommendation for Space Data System Standards, CCSDS 201.0-B-3. Blue Book. Issue 3. Washington, D.C.: CCSDS, June 2000.
- [2] *Telecommand Part 2—Data Routing Service*. Recommendation for Space Data System Standards, CCSDS 202.0-B-3. Blue Book. Issue 3. Washington, D.C.: CCSDS, June 2001.
- [3] *Telecommand Part 3—Data Management Service*. Recommendation for Space Data System Standards, CCSDS 203.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, June 2001.

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CCSDS RECOMMENDATION FOR TELECOMMAND: COMMAND OPERATION PROCEDURES

2 COP-1

Command Operation Procedure-1 (COP-1) is a closed-loop telecommanding protocol that utilizes sequential ("go-back-n") retransmission techniques to correct Telecommand (TC) Frames that were rejected by the spacecraft because of error. COP-1 allows Type-A TC Frames to be accepted by the spacecraft only if they are received in strict sequential order and their contents can be immediately passed on to the layer above.

Within COP-1, control of sequentiality is provided by the Frame Acceptance and Reporting Mechanism (FARM), and therefore frame sequence numbering is explicit. The Frame Sequence Number must be present in each Type-A frame. Type-A frames must be transmitted by the FOP with their numbers arranged in strict upcounting order. If one or more frames are missed, retransmission is initiated either in response to a "Retransmit" Flag in the Command Link Control Word (CLCW) or a timeout on the ground. Window mechanisms on the ground and spacecraft prevent a new frame with the same sequence number as that of a missing frame from being transmitted or accepted.

Valid Type-B frames (i.e., "Bypass" frames) will always be accepted.

NOTE

In this section, although it may be mentioned that COP-1 handles "frames", these are actually partial frames made up of a TC Frame Data Unit (FDU) plus the Frame Header data generated by COP-1. The remainder of the Frame Header will be generated by the Lower Layer. The Frame Data Unit consists of the data to be inserted in the Telecommand Transfer Frame Data Field, as defined in Reference [2].

COP-1 is just one of the functions performed within the Transfer Layer. It is the first function performed when an FDU is received by the Transfer Layer on the sending end and the last one performed before the FDU is delivered to the Higher Layer on the receiving end. For purposes of defining the interfaces to COP-1, the function following Frame Operation Procedure-1 (FOP-1) on the sending end will be called "Frame Generation", and the one preceding Frame Acceptance and Reporting Mechanism-1 (FARM-1) on the receiving end will be called "Frame Validation Check".

2.1 SERVICES AND PROTOCOLS

2.1.1 SERVICES

COP-1 provides two distinct services to the layer above. These services are "Sequence-Controlled Service" and "Expedited Service".

2.1.1.1 Sequence-Controlled Service (AD Service).

This service concerns two types of frames:

- "AD" for Telecommand Frame Data Units (TC FDUs), which are frames carrying data from the layer above
- "BC" for the two frames carrying protocol control information for configuring COP-1 ("Unlock" and "Set V(R)")

In COP-1, the Sequence-Controlled Service is based on an automatic request for retransmission (ARQ) procedure of the "go-back-n" type with sequence-control mechanisms both on the ground and on board the spacecraft and the necessary presence of a standard report returned in the telemetry downlink, the CLCW.

The Sequence-Controlled Service is initiated by means of four distinct "Initiate AD Service" Directives, as shown in Table 2-1 (FOP-1 State Table). Two of these directives result in the transmission of one of the two control commands (Type-BC frames). Each of the two control commands causes a well-defined action in FARM-1, which is then reflected in the CLCW. A timer is used to cause retransmission of the control command if the expected response is not received, with a limit on the number of automatic retransmissions allowed before the Higher Layer is notified that there is a problem in initiating the AD Service. The other two directives allow the AD Service to be started without waiting for spacecraft action (although one requires receiving a good CLCW).

Once COP-1 for a particular Virtual Channel has been initialised for an AD Service, TC FDUs are inserted into frames and transmitted on that Virtual Channel in the order in which they are presented to COP-1. The retransmission mechanism ensures with a high probability of success that

- no TC FDU is lost
- no TC FDU is duplicated
- no TC FDU is delivered out of sequence

The AD Service guarantees in-order delivery of TC FDUs on a single Virtual Channel. Because of the possibility of retransmission on only a single Virtual Channel, there is no guarantee that TC FDUs on separate Virtual Channels, each using an AD Service, will be delivered to the Higher Layer in the order initially transmitted.

For the Type-AD frames, the automatic retransmission procedure makes use of several variables, the most notable being the Receiver_Frame_Sequence_Number, V(R); the Transmitter_Frame_Sequence_Number, V(S); the Next Expected Frame Sequence Number contained in the CLCW, N(R); and the Frame Sequence Number in the TC Frame Header, N(S). (See Figure 2-1.) These variables are described in Section 2.2.