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Space data and information transfer systems — XML Telemetric and Command Exchange (XTCE)

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National foreword

This British Standard is the UK implementation of ISO 18424:2013.

The UK participation in its preparation was entrusted to Technical Committee ACE/68/-/7, Space systems and operations - Space data and information transfer systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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ISBN 978 0 580 80289 8

ICS 49.140

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 June 2013.

Amendments issued since publication

Date	Text affected

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INTERNATIONAL STANDARD

ISO 18424

First edition
2013-06-01

Space data and information transfer systems — XML Telemetric and Command Exchange (XTCE)

Systèmes de transfert des informations et données spatiales — Échange XML des télémesures et commandes (XTCE)

Reference number
ISO 18424:2013(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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ISO 18424 was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 660.0-B-1, October 2007) 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*.

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Space data and information transfer systems — XML Telemetric and Command Exchange (XTCE)

1 Scope

This International Standard addresses the need for a standardized information model capable of supporting Telemetry/Telecommand (TM/TC) definitions across the widest possible range of space domain activities. The goal is to allow TM/TC definitions to be exchanged between different organizations and systems, often at the boundaries of mission phases, without the need for customized import/export, re-validation, or even re-implementation of mission databases.

The scope of this International Standard is limited to the satellite telemetry and commanding meta-data constructs necessary to perform satellite and payload data processing. This International Standard includes the meta-data needed to:

- Define the structure and sequence of both CCSDS packets and TDM frames;
- Define the data manipulation required for packaging and unpacking of individual data items;
- Describe command data including command identification, argument specification, and validation criteria;
- Define parameter and command encoding;
- Define data properties including including default values, validity criteria, and data dependencies.

The scope of this International Standard does not extend to:

- Data distribution mechanisms or rules;
- Command and data protocol specifications;
- RF or analog stream characterization;
- Data grouping including aggregation and coherent data sets;
- Data representation (visualization properties);
- Scheduling configuration properties;
- Orbital properties;
- Displays;
- Flight Software.

This International Standard addresses only the definition of TM/TC data, but is not a specification for the transfer of live or historical TM/TC data – **this is a meta-data specification, not a data specification.**

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 660.0-B-1, October 2007, XML Telemetric and Command Exchange (XTCE).

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For the purposes of international standardization, the modifications outlined below shall apply to the specific clauses and paragraphs of publication CCSDS 660.0-B-1.

Pages i to iv

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

Page 77

Add the following information to the reference indicated:

[7] Document CCSDS 301.0-B-2, April 1990, is equivalent to ISO 11104:2011.

3 Revision of publication CCSDS 660.0-B-1

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 660.0-B-1. To this end, NASA will act as a liaison body between CCSDS and ISO.

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The Consultative Committee for Space Data Systems

Recommendation for Space Data System Standards

XML TELEMETRIC AND COMMAND EXCHANGE (XTCE)

Recommended Standard

CCSDS 660.0-B-1

Blue Book
October 2007

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AUTHORITY

Issue:	Recommended Standard, Issue 1
Date:	October 2007
Location:	Washington, DC, USA

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 *Procedures Manual for the Consultative Committee for Space Data Systems*, and the record of Agency participation in the authorization of this document can be obtained from the CCSDS Secretariat at the address below.

This document is published and maintained by:

CCSDS Secretariat
Space Communications and Navigation Office, 7L70
Space Operations Mission Directorate
NASA Headquarters
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The Consultative Committee for Space Data Systems (CCSDS) is an organization officially established by the management of its members. 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 **Recommended Standards** and are not considered binding on any Agency.

This **Recommended Standard** is issued by, and represents the consensus of, the CCSDS members. Endorsement of this **Recommendation** is entirely voluntary. Endorsement, however, indicates the following understandings:

- Whenever a member establishes a CCSDS-related **standard**, this **standard** will be in accord with the relevant **Recommended Standard**. Establishing such a **standard** does not preclude other provisions which a member may develop.
- Whenever a member establishes a CCSDS-related **standard**, that member will provide other CCSDS members with the following information:
  - The **standard** itself.
  - The anticipated date of initial operational capability.
  - The anticipated duration of operational service.
- Specific service arrangements shall be made via memoranda of agreement. Neither this **Recommended Standard** nor any ensuing **standard** is a substitute for a memorandum of agreement.

No later than five years from its date of issuance, this **Recommended Standard** will be reviewed by the CCSDS to determine whether it should: (1) remain in effect without change; (2) be changed to reflect the impact of new technologies, new requirements, or new directions; or (3) be retired or canceled.

In those instances when a new version of a **Recommended Standard** is issued, existing CCSDS-related member standards and implementations are not negated or deemed to be non-CCSDS compatible. It is the responsibility of each member to determine when such standards or implementations are to be modified. Each member is, however, strongly encouraged to direct planning for its new standards and implementations towards the later version of the Recommended Standard.

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FOREWORD

Through the process of normal evolution, it is expected that expansion, deletion, or modification of this document may occur. This Recommended Standard is therefore subject to CCSDS document management and change control procedures, which are defined in the *Procedures Manual for the Consultative Committee for Space Data Systems*. 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 document should be addressed to the CCSDS Secretariat at the address indicated on page i.

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DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 660.0-B-1	XML Telemetric and Command Exchange (XTCE), Recommended Standard, Issue 1	October 2007	Current issue

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CONTENTS

Section Page

XML TELEMETRIC AND COMMAND EXCHANGE (XTCE) 1

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Date: 2006-11-03

XML Telemetric and Command Exchange (XTCE)

Version 1.1

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Contents

XML Telemetric and Command Exchange (XTCE) 1
Contents 2
Foreword 5
Introduction 6
1 Scope 8
2 Conformance 8
3 Normative references 8
4 Terms and definitions 9
5 Symbols (and abbreviated terms) 9
6 The Specification 10
6.1 The Root Object – The SpaceSystem 10
6.1.1 The Header Record 11
6.1.2 TelemetryMetaData 11
6.1.2.1 ParameterTypeSet 13
6.1.2.2 ParameterSet 14
6.1.2.3 ContainerSet 14
6.1.2.3.1 BaseContainer 15
6.1.2.4 MessageSet 16
6.1.2.5 StreamSet 16
6.1.3.6 AlgorithmSet 17
6.1.3.6.1 MathAlgorithm 17
6.1.3.6.2 SimpleAlgorithm 17
6.1.3.6.3 InputAlgorithm 17
6.1.3.6.4 InputOutputAlgorithm 17
6.1.3.6.5 InputOutputTriggerAlgorithm 17
6.1.3 CommandMetaData 19
6.1.3.1 ArgumentTypeSet 19
6.1.3.2 MetaCommandSet 20
6.1.3.2.1 BaseMetaCommand 20
6.1.3.2.2 ArgumentList 20
6.1.3.2.3 CommandContainer 21
6.1.3.2.4 TransmissionConstraintList 21
6.1.3.2.5 DefaultSignificance and ContextSignificanceList 21
6.1.3.2.6 ParametersToSuspendAlarmsSet 21

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Full document details: BS ISO 18424:2013

6.1.3.2.7 Interlock 21
6.1.3.2.8 Verifiers 21
6.1.3.2.9 ParameterToSetList 21
6.1.4 ServiceSet 22
6.2 Common Types 22
6.2.1 MatchCriteria 22
6.2.2 Polynomial 22
6.2.3 Unit 22
6.3 The Schema 22
Annex A -The SpaceSystem Schema 23
Annex B - Schema Style Notes 76
Bibliography 77

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Foreword

This XML Telemetric and Command Exchange (XTCE) data specification presents a robust information model and data exchange format for telemetry and commanding in all phases of the spacecraft, payload, and ground segment lifecycle: system design, development, test, validation, and mission operations.

This specification addresses a compelling need for a standard exchange format recognized independently by each of its authors and contributors. Lockheed Martin, ESA, Boeing, NASA GSFC, USAF SMC, Harris, Raytheon, SciSys, CSC and GST have all made significant contributions representing a wide and varied sampling of the space industry.

Space mission implementations face a very dynamic environment with fast-paced information technology advancement and shrinking space budgets. A more focused use of decreasing public investments in space requires a cost reduction over their entire lifecycle, from development up to the end of the useful life of a spacecraft. The use of standards specifications from the early stages of satellite development through mission operation will reduce life-cycle cost.

The XTCE specification is intended to provide a robust international standard for data exchange, one that can be easily become a central element in a simplified contract to Space System providers for Telemetry and Command definition – from simple space components to entire constellations.

Satellite design and development is performed today through the use of a number of disparate tools and techniques. The interface design for spacecraft systems and spacecraft payloads is still a manual and time-consuming effort. Data design, both telemetry and commanding, is still performed multiple times by multiple contractors during the lifecycle of the satellite – well before the satellite is ever deployed for mission operations. The standardization of satellite telemetry and command data for spacecraft health and safety, as well as payload interfaces, will reduce the cost of these implementations as well as decrease the schedule of development, integration, and test of the satellite and its component systems. This specification can also be used to support multiple, heterogeneous missions, facilitating interoperability between ground control systems, simulators, testing facilities, and other types of spacesystems.

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Introduction

Purpose: This specification is an information model for spacecraft telemetry and commanding data. For a given mission there are a number of lifecycle phases that are supported by a variety of systems and organizations. Additionally, many of these organizations support multiple heterogeneous missions using a common ground segment infrastructure. Telemetry and command definitions must be exchanged among all of these phases, systems, and organizations. This is made difficult and costly because there is no standard format for exchanging this information. The lack of standardization currently requires custom ingestion of the telemetry and commanding information. This customization is inherently error-prone, resulting in the need to revalidate the definitions at each step in the lifecycle.

A typical example of this process is between the spacecraft manufacturer and spacecraft-operating agency. The spacecraft manufacturer defines the telemetry and command data in a format that is much different than the one used in the ground segment. This creates the need for database translation, increased testing, software customization, and increased probability of error. Standardization of the command and telemetry data definition format will streamline the process allowing dissimilar systems to communicate without the need for the development of mission specific database import/export tools.

Ideally, a spacecraft operator should be able to transition a spacecraft mission from one ground system to another by simply moving an already existing command and telemetry database compliant with this specification to another ground system which equally supports this specification. In addition, standardization will enable space or ground segment simulators to more easily support multiple heterogeneous missions.

The XTCE specification provides a standard format for defining the Telemetric and Telecommand (TM/TC) data required to perform the processing shown in **Figure 1**.

Overview: The normative portion of this specification is presented as a single XML schema compliant with the W3C recommendation of May 2, 2001. The schema is found in Annex A or may be obtained as an independent convenience document.

The schema has an object-oriented structure where all the elements of this specification belong to a single root object – the SpaceSystem.

Philosophy: The space industry is currently divided between Packet telemetry and commanding and Time Division Multiplexing (TDM) telemetry and commanding. While the basic construction of either TDM or packet telemetry is fundamentally similar, nomenclature differences between the two give the appearance of a larger divide. The XTCE specification avoids using nomenclature from either the TDM or Packet worlds to avoid any possible confusion; terms like ‘minor frame’, ‘major frame’, or ‘packet’ are nowhere in this specification other than in examples. Furthermore, the XTCE specification does not itself use any existing Packet or TDM standards (such as CCSDS packet formats, or IRIG-106 minor frame dxestandards), but it does provide a mechanism to use XTCE to build libraries of available containers that represent these standards.

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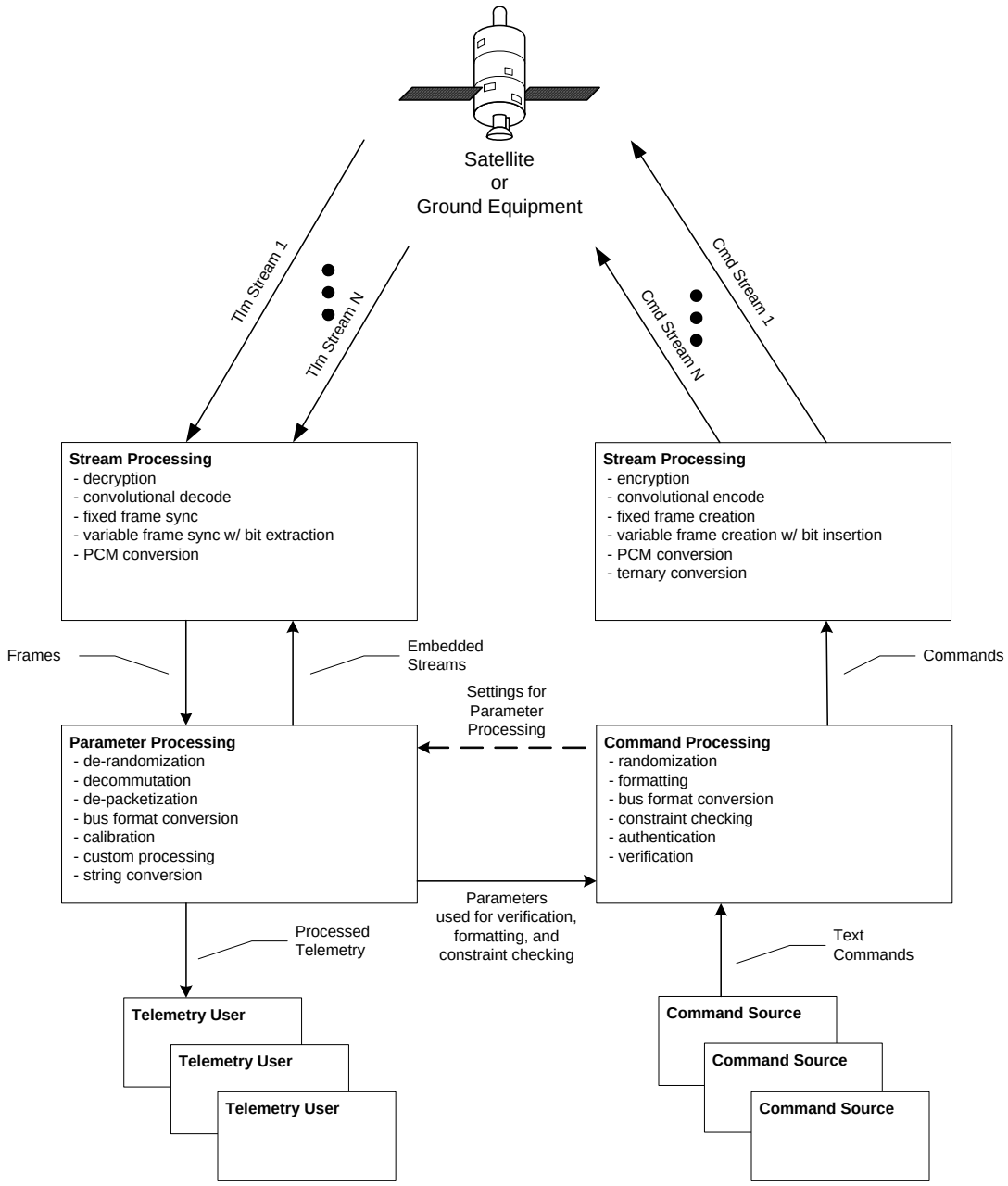

Figure 1 - Telemetric and Command Processing Meta Data Encapsulated in XTCE XML

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1 Scope

This specification addresses the need for a standardized information model capable of supporting Telemetry/Telecommand (TM/TC) definitions across the widest possible range of space domain activities. The goal is to allow TM/TC definitions to be exchanged between different organizations and systems, often at the boundaries of mission phases, without the need for customized import/export, re-validation, or even re-implementation of mission databases.

The scope of this specification is limited to the satellite telemetry and commanding meta-data constructs necessary to perform satellite and payload data processing. This specification includes the meta-data needed to:

- Define the structure and sequence of both CCSDS packets and TDM frames
- Define the data manipulation required for packaging and unpacking of individual data items
- Describe command data including command identification, argument specification, and validation criteria
- Define parameter and command encoding
- Define data properties including including default values, validity criteria, and data dependencies

The scope of this specification does not extend to:

- Data distribution mechanisms or rules
- Command and data protocol specifications
- RF or analog stream characterization
- Data grouping including aggregation and coherent data sets
- Data representation (visualization properties)
- Scheduling configuration properties
- Orbital properties
- Displays
- Flight Software

This specification addresses only the definition of TM/TC data, but is not a specification for the transfer of live or historical TM/TC data – **this is a meta-data specification, not a data specification.**

2 Conformance

The Schema (.xsd file) in Annex A is normative. A compliant database is an XML file that complies with this schema. Fully compliant implementing software will interpret and/or generate any databases compliant with this specification. Compliant implementing software will interpret and/or generate all database elements required by the schema.

3 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this specification. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

W3C Recommendation - Extensible Markup Language	http://www.w3.org/TR/REC-xml

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(XML) 1.0 (Second Edition, 6 October 2000)	
W3C Recommendation - XML Schema Part 0: Primer (2 May 2001)	http://www.w3.org/TR/xmlschema-0/
W3C Recommendation - XML Schema Part 1: Structures (2 May 2001)	http://www.w3.org/TR/xmlschema-1/
W3C Recommendation - XML Schema Part 2: Datatypes (2 May 2001)	http://www.w3.org/TR/xmlschema-2/

4 Terms and definitions

For the purposes of this specification, the following terms and definitions apply.

Telemetering

(IEEE Std 100-1996 [1996]) "Measurement with the aid of intermediate means that permit the measurement to be interpreted at a distance from the primary detector." Measurements on board the spacecraft are transmitted via one or more telemetry streams to spacecraft monitoring systems. Telemetry as used here refers to these measurements originating from both the spacecraft and from systems (such as ground system components) used to support the spacecraft. Most telemetry measurements will require engineering unit conversion and measurements will have associated validation ranges or lists of acceptable values.

Commands

Commands are messages which initiate actions on a remote system. Commands as used here may mean both commands destined for the spacecraft and to the systems used to support the spacecraft. Spacecraft commanding usually implies coding and packaging of the command information, validation and verification, as well as authorization to perform. Telemetry and Commanding data are necessarily related to one another, with some command information originating from telemetry and commands relating to particular telemetry measurements. Therefore, the ability to relate individual telemetry with one another and to commands is a very important part of this specification.

5 Symbols (and abbreviated terms)

List of symbols/abbreviations

In general, the XTCE specification favors expressive, fully spelled out terms over abbreviated notation. The exceptions are modifiers used as prefixes or postfixes to objects used within the schema, and of course 'XTCE' the name of the standard itself. These terms are listed below.

Abbreviations:

DOM – Document Object Model

Parm – is an abbreviation sometimes used for Parameter

XTCE – XML Telemetric and Command Exchange format

Prefixes and Postfixes

Meta – Is a description. For example a MetaCommand is a command description

PCM – Pulse Code Modulation

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Set –an unordered collection, for example a MetaCommandSet is an unordered collection of command descriptions

List –an ordered collection, for example an ArgumentList is an ordered collection of arguments.

Ref –a reference (by name) to an object defined elsewhere in the XML document, for example an ArgumentRef is a named reference to an Argument defined elsewhere.

SAX – Simple API for XML

TDM – Time Division Multiplexed

UCS – Universal Character Set

UTF – UCS Transformation Format

W3C – World Wide Web Consortium

6 The Specification

6.1 The Root Object – The SpaceSystem

Recognizing that spacecraft operations involve much more than simply controlling the spacecraft, the top-level object is not 'Spacecraft' but the more generic term 'SpaceSystem'. This name reflects that a spacecraft operations center must control antennas, recorders, ground processing equipment, RF hardware and many other assets that may use this data specification; each of these objects is a 'SpaceSystem'. A SpaceSystem, like all of the major objects in an XTCE database, may have a short description, a long description (that may contain HTML markup documentation), and a list of alias names. A SpaceSystem may have a Header, zero or more sub-SpaceSystems, CommandMetaData and TelemetryMetaData. The CommandMetaData and TelemetryMetaData components provide boundaries for command mata-data and telemetry meta-data. The SpaceSystems (as are many other XTCE Schema Types) are types of NameDescription. A NameDescription simply contains useful descriptive information about the objects. SpaceSystem may contain sub-SpaceSystems, thereby giving the data a hierarchical structure.

Note on the sub-SpaceSystem and the hierarchical structure

Because a SpaceSystem may itself contain other SpaceSystems, the data may also have a hierarchical structure – similar to the structure of a real space system. The hierarchical organization offers several important advantages over a flat entity list:

- Fewer name space collisions – Almost every spacecraft contains redundant components for reliability or to accomplish the mission. A communications spacecraft may have a dozen transponders each with the same set of telemetry points and commands. In a flat namespace each of those telemetry points needs to be mapped into a unique name. Using a hierarchical namespace, those identical telemetry points can be simply placed into separate sub-SpaceSystems.
- Better organization – modern spacecraft typically have thousands of commands and tens of thousands of telemetry parameters; this number is trending upward. The directory structure provided by this specification provides an improved way to manage this large volume of data. Each subsystem developer can deliver SpaceSystems representing their subsystem without integration issues.
- Spacecraft, which are normally thought of as a SpaceSystem may actually be sub-SpaceSystems for a constellation of spacecraft SpaceSystems.
- Natural hierarchy – spacecraft designs are increasing in complexity and are normally comprised of systems of systems. The hierarchical organization allowed by a directory structure reflects this.

Note on Names

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Parameter, and MetaCommand and other major entity names within this database may be any length but may only contain numeric, a-z letters, underscores, hyphens, or backslashes. The characters '/', '.', '[', ']' and ':' are expressly reserved. The '/' is used as the SpaceSystem separator (Unix and HTTP style). The ':' is reserved for future use as a selector for data from other SpaceSystems. The '.' is used to select members of aggregate Parameters and Argurments. The square brackets are reserved for array indexes. Names are case sensitive.

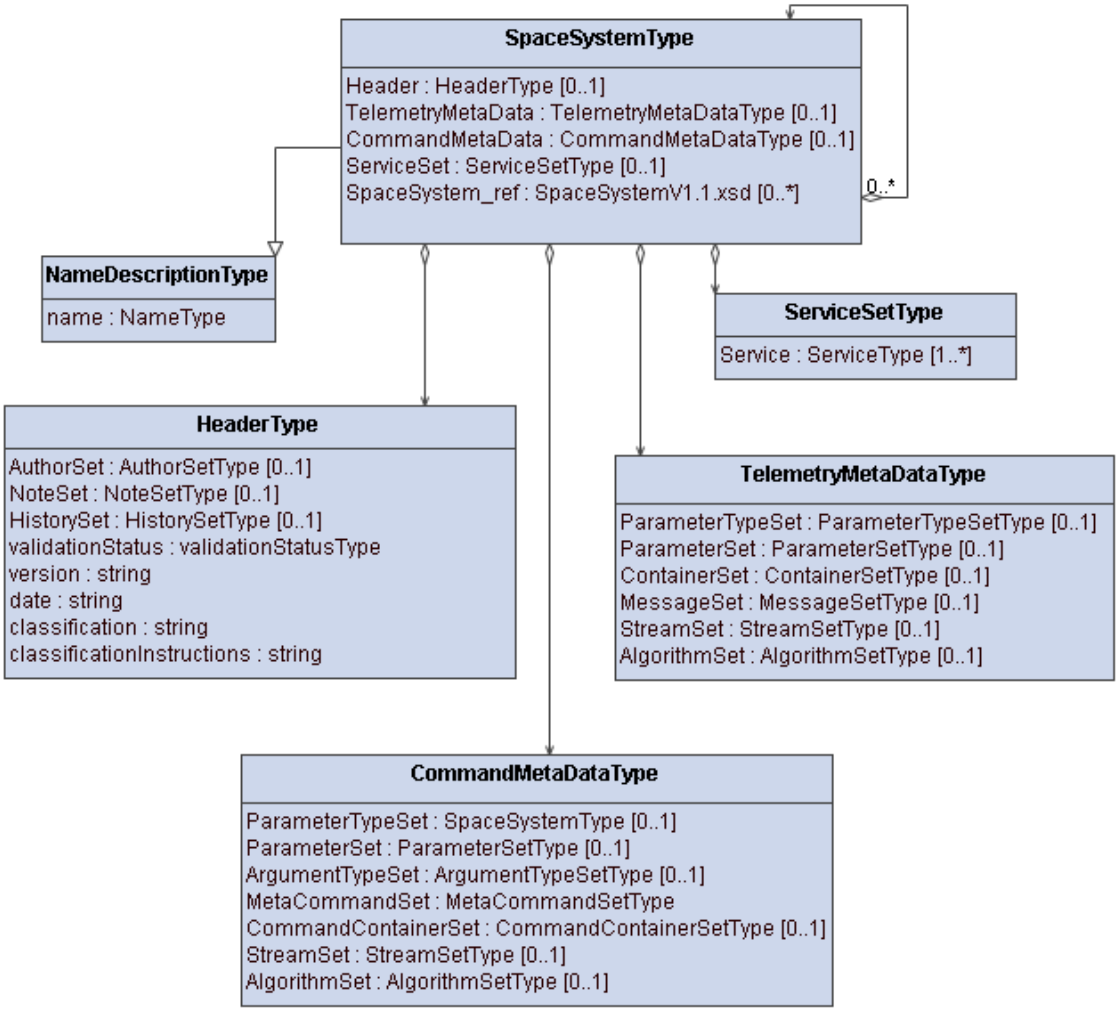

Figure 2 SpaceSystem UML Class Diagram[1]

6.1.1 The Header Record

A SpaceSystem may contain an optional header record. This record contains some basic context on the data itself (e.g. source, version, revision history, notes, and classification).

6.1.2 TelemetryMetaData

Because Telemetry and Command databases are frequently developed and maintained independently, the XTCE format divides TelemetryMetaData and CommandMetaData into separate, but similar sections.

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[1] 'AnonymousType' is used in the UML whenever a new complexType is generated inside an Element definition (without a named ComplexType).

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TelemetryMetaData is really nothing more than a grouping for data about Telemetry. TelemetryMetaData has a ParameterTypeSet, a ParameterSet, a ContainerSet, a MessageSet, a StreamSet, and an AlgorithmSet. Following are descriptions of these collection types.

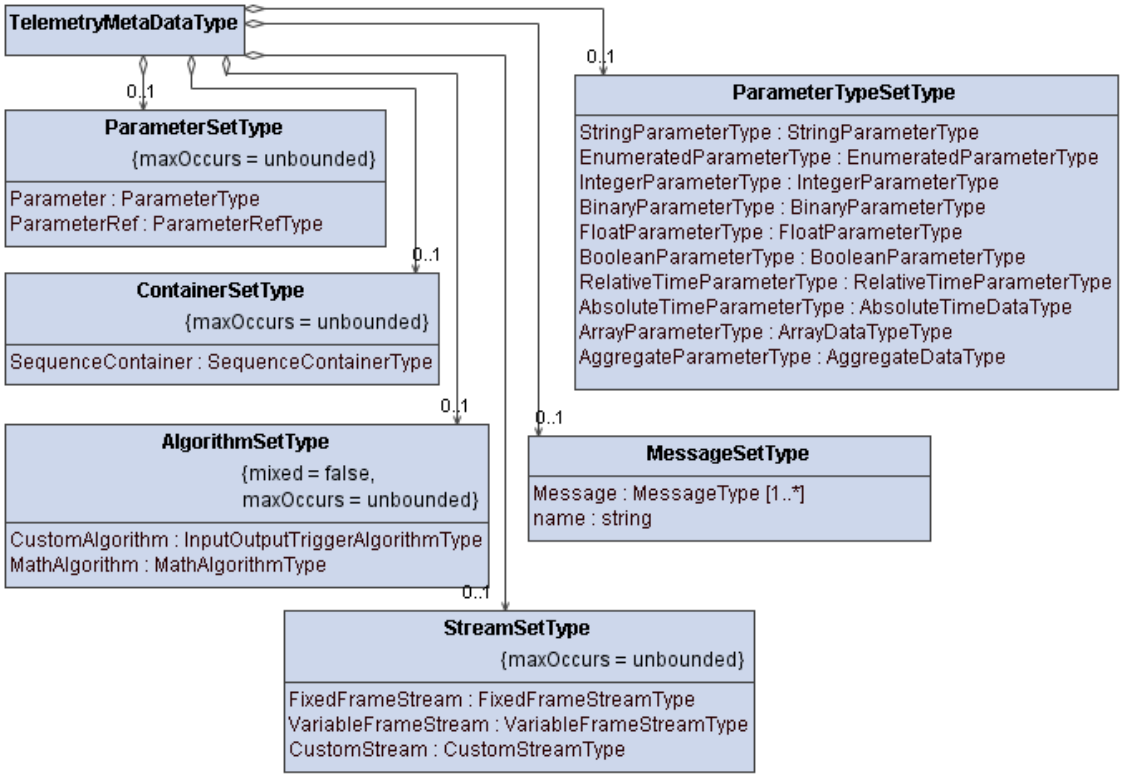

Figure 3 Telemetry MetaData UML Class Diagram

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6.1.2.1 ParameterTypeSet

A ParameterTypeSet is an unordered collection of ParameterTypes. ParameterTypes are the MetaData for Parameters; ParameterTypes are instantiated to create Parameters. ParameterType is the description of something that can have a value (a Parameter). Information contained in ParameterType includes the data type, description, alarm limits, engineering units and string conversion 'ToString' specifications. Parameters may be of variable length. Most Parameters are telemetered parameters (a.k.a measurands) and must also include information about how the Parameter value is encoded for transmission. This information includes size in bits, byte order, data type, calibrations and parity checks. All of the encoding information is in one of four different 'DataEncoding' elements. XTCE supports four different types of encodings:

IntegerDataEncoding: specifies the bit order, size in bits, the encoding (unsigned, signMagnitude, twosCompliment, onesCompliment, BCD, or packedBCD). The byte order in the case of multi byte integers can also be specified, along with error detection (CRC or Parity checks).

FloatDataEncoding: specifies the bit order, size in bits, the encoding (IEEE754_1985 or MILSTD_1750A). The byte order in the case of multi byte floats can also be specified, along with error detection (CRC or Parity checks).

StringEncoding: specifies the bit order, the encoding (UTF-8 or UTF-16), the size in bits or variable size determined by either a termination character, or a leading size parameter, along with error detection (CRC or Parity checks).

BinaryDataEncoding: specifies the bit order, the size in bits, and two algorithms to convert to and from the endcode value, along with error detection (CRC and Parity checks).

Note that the data encoding type only speaks to how the Parameter (or Command argument) is transmitted, not how it is handled on the SpaceSystem or ground.

Figure 4 presents the UML representation of the Parameter Type Set, and therefore all available data types. Encoding data types are children of these elements and not depicted in that figure.

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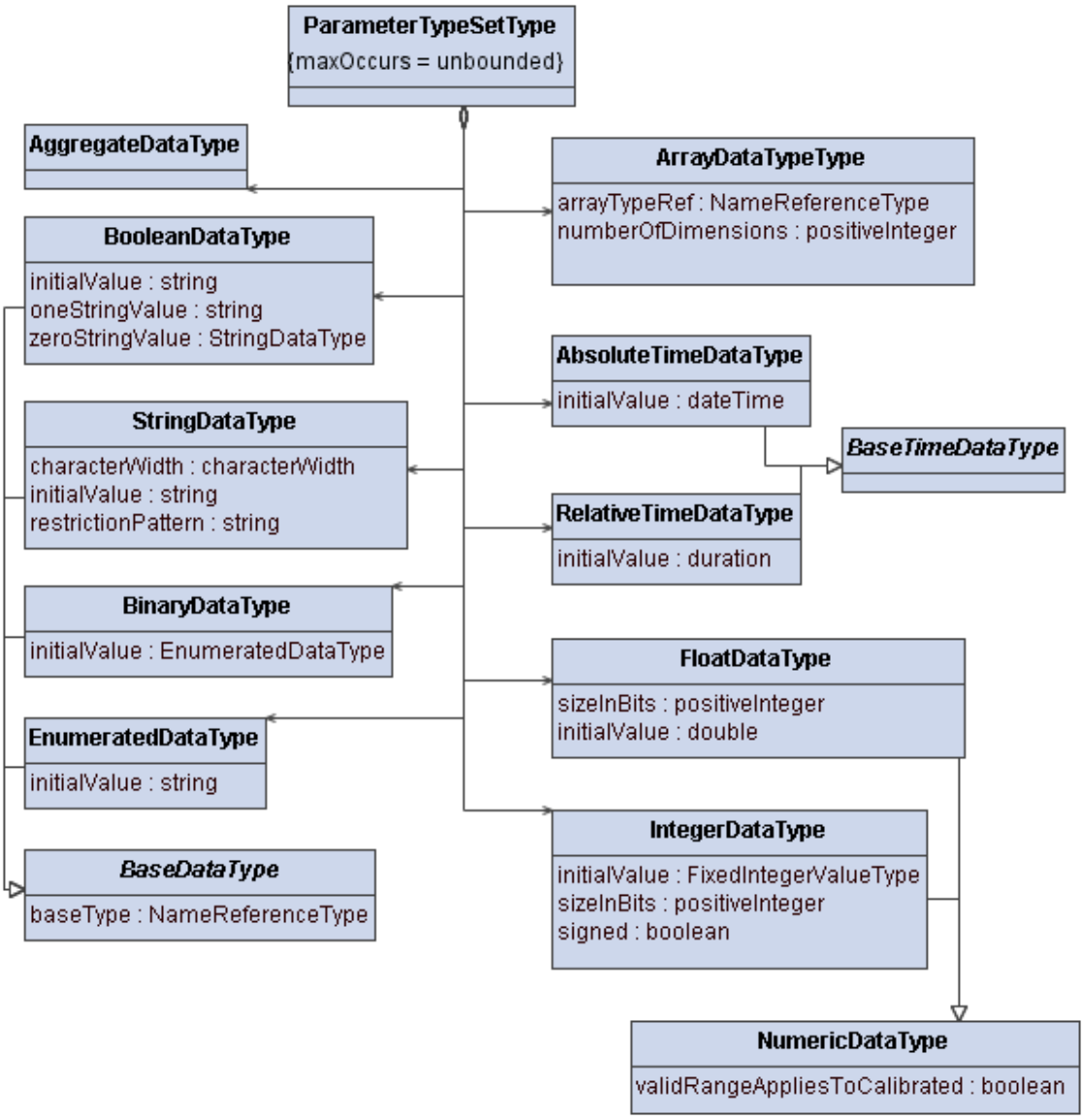

Figure 4 ParameterTypeSet UML Class Diagram

6.1.2.2 ParameterSet

A ParameterSet is an unordered collection of Parameters and ParameterRefs. Parameters are instantiations of ParameterTypes. Parameters are normally a very simple name and reference to a ParameterType. Parameters may also have alias names and may have properties unique to that instantiation. At any point in time (instance) a Parameter has a value; a Parameter is not the value itself. Parameter names follow the same naming rules as for SpaceSystems. The aliases have no restrictions. The sub-element 'ParameterRef' inside of ParameterSet refers to a previously defined Parameter definition in another ParameterSet.

6.1.2.3 ContainerSet

A ContainerSet is an unordered collection of SequenceContainers. A SequenceContainer may represent a packet, frame, a subframe, or any other grouping/structure of data items. The simple form of a Sequence element is an ordered set of Parameter References or other Container References. A SequenceContainer

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