RAL-92-046

Science and Engineering Research Council
Rutherford Appleton Laboratory
Chilton DIDCOT Oxon OX11 0QX
RAL-92-046

Conceptual Schema for a Space Physics Query Language: Detailed Description

S N Walker D L Giaretta M A Hapgood D R Lepine B J Read
H St C Alleyne L J C Woolliscroft M A Albrecht A Ciarlo
H Stokke and P Torrente

July 1992

Conceptual Schema for a Space Physics Query Language: Detailed Description

S.N. Walker[1]
University of Sheffield, UK

D.L. Giaretta, M.A. Hapgood, D.R. Lepine, B.J. Read.
Rutherford Appleton Laboratory, UK

H.St.C. Alleyne, L.J.C. Woolliscroft
University of Sheffield, UK

M.A. Albrecht[2], A. Ciarlo, H. Stokke and P. Torrente
ESRIN, Frascati, Italy

July 1992

Rutherford Appleton Laboratory Report 92-046.

University of Sheffield, Department of Automatic Control and Systems Engineering Research Report 455.

Abstract

This report presents the specification of a conceptual schema for a Space Physics Query Language (SPQL). This is a model of all space physics data, which has been developed for use in ESA's European Space Information System (ESIS), but is capable of general application. The SPQL schema is specified in terms of the Entity-Relationship Data Model, which provides a homogeneous view of the data that is both natural and data independent. Thus, through use of the SPQL. space physicists will be able query databases using only their scientific knowledge; they will not require a detailed knowledge of internal workings of each database within ESIS. This study has yielded an insight into the way in which space physics is studied. Some differences will exist between the SPQL schema described here and the final ESIS implementation.

---

[1]Present address ESRIN, Frascati, Italy.
[2]Present address European Southern Observatory, Garching bei München, Germany.

1 Introduction

The European Space Information System (ESIS) [1] is intended to provide better access to Space Data archives in Europe. Its development programme is now in a "Pilot Project" phase which began on 1 January 1988 and is scheduled for completion at the end of 1993. One of the first two disciplines to be served by ESIS is Space (or Solar-Terrestrial) Physics, the other is astronomy. The aim of the Pilot Project is to demonstrate the feasibility of ESIS and produce an infrastructure that could be used by a future full ESIS system. Later the full system could, by suitable adaption of the schema described below, serve other disciplines such as Earth Observation and Microgravity.

The pilot phase of ESIS consists of an infrastructure linking several databases queried by astronomers and astrophysicists but only one space physics database — namely the AMPTE database [2] in the Geophysical Data Facility at RAL. The Pilot Project configuration will also include a space physics subset of INSPEC, the scientific bibliographic database that forms part of the ESA-IRS bibliographic database service at ESRIN.

This report is a shortened version of a design study [3] conducted by Rutherford Appleton Laboratory and the University of Sheffield on behalf of ESA. It presents a conceptual schema of Space Physics, which is a model that describes how space physicists view their discipline, its components and their relevant interrelationships. It also looks forward to the acquisition of new data sets that will be available from future missions such as CLUSTER [4] [5]. It must be noted that, since the design study was performed, further work has continued to refine the SPQL conceptual schema and so this document must not be taken to represent its final state. The study has illuminated many aspects of the way in which space physicists work.

We have attempted to identify all possible requirements for a space physics information system, even if we knew that no existing database (or databases) would satisfy them. Thus the aim is to produce a conceptual schema that truly represents space physics. It should not be limited to accessing and querying the one space physics database in the Pilot Project, the GDF/AMPTE database at RAL, but should consider the addition of other databases, both present and future. This represents a "top-down" approach to serve the space physics community. This methodology has also been useful to demonstrate that ESIS can be extended to other disciplines of science and space applications within the European Space Agency.

A parallel study of the requirements for an Astronomy Query Language (AQL) [10] was undertaken for ESA by the Centre de Données de Strasbourg. A highly simplified description of the AQL work would be to say that it explains how to set up a system to allow homogeneous access to a number of existing heterogeneous, distributed databases together with the INSPEC bibliographic database. As such, it represents a "bottom-up" approach to the task.

Despite these differences of approach, the two disciplines (Space physics and Astronomy) have yielded generally similar conceptual schemas. This is a indication that one can have confidence in the value of ESIS.

This paper is aimed at two different groups of readers: (a) data system builders who wish to learn about the properties of space physics data; and (b) space physicists who wish to learn about the use of data models in database management. We have therefore provided two introductory sections to provide the background information which each of these groups may require: section 2 defines the limits of space physics that were adopted for this project and outlines the nature and classification of space physics data, while section 3 looks briefly at the concepts underlying data modelling.

The rest of this paper is structured as follows:- Section 4 discusses the definition of the SPQL schema which is applied to the solution of queries in section 5. The SPQL and the AQL schema are contrasted in section 6 and the implications of future space missions for the SPQL schema are also examined. Conclusions are presented in section 7 which looks forward to some future missions such as Cluster.

2 Space Physics Data

2.1 Scope

It has generally been considered that space physics is the study of ionised phenomena in the neighbourhood of the Earth, other planets, minor bodies and interplanetary space and should include those topics which might be commonly called:

- Space Plasma Physics
- Solar Terrestrial Physics
- Solar Terrestrial Relations
- Aeronomy etc.

Recent debates [11] show that the exact title and scope of the discipline are controversial. This is probably a good thing for an interdisciplinary topic. We define the boundaries of space physics with other scientific disciplines generally as follows:-

- **The boundary with atmospheric science**
  Space physics is concerned with altitudes where an ionised component is significant.

  Space physics is concerned with the neutral atmosphere at altitudes where the neutrals have a significant interaction with the coupled magnetosphere-ionosphere system, e.g. by acting as a sink for magnetospheric energy and momentum.

- **The boundary with Earth observations**
  Space physics is concerned with the magnetic field of the Earth not for what it tells us about the interior of the Earth, but as a force for interactions with charged particles. Space physics also encompasses the remote sensing observations of the Earth where they shed light on the physical processes occurring within ionised regions of the atmosphere.

- **The boundary with astronomy at the Sun**
  Space physics is concerned with the solar wind and its origin in the solar corona, but not in processes within the sun except to the extent that they determine the solar wind and/or provide energy sources for solar/terrestrial interactions.

- **The boundary with planetology**
  Space physics is concerned with other planets, comets and minor bodies within the solar system in that they provide conditions to study interactions between charged particles and solid bodies that may or may not possess an external magnetic field. Space physics is not primarily concerned with the solid bodies or neutral atmospheres of these objects.

- **The boundary with astronomy outside the solar system**
  Space physics is concerned with astronomy outside the Sun - e.g. radio sources - in as far as such studies throw light on space plasma processes. In exceptional cases space physics may be concerned with space plasma physics at other stellar systems.

Although these definitions may exclude some studies, we believe that the top-down approach methodology has led to an understanding which will make it easy to add other parts of space science. Figure 1 shows one view of the solar-terrestrial environment.

2.2 Nature

Space physics data are largely concerned with physical processes that characterize the plasma environment of interplanetary space and that surrounding solid bodies such as the planets and comets. These include such processes as:-

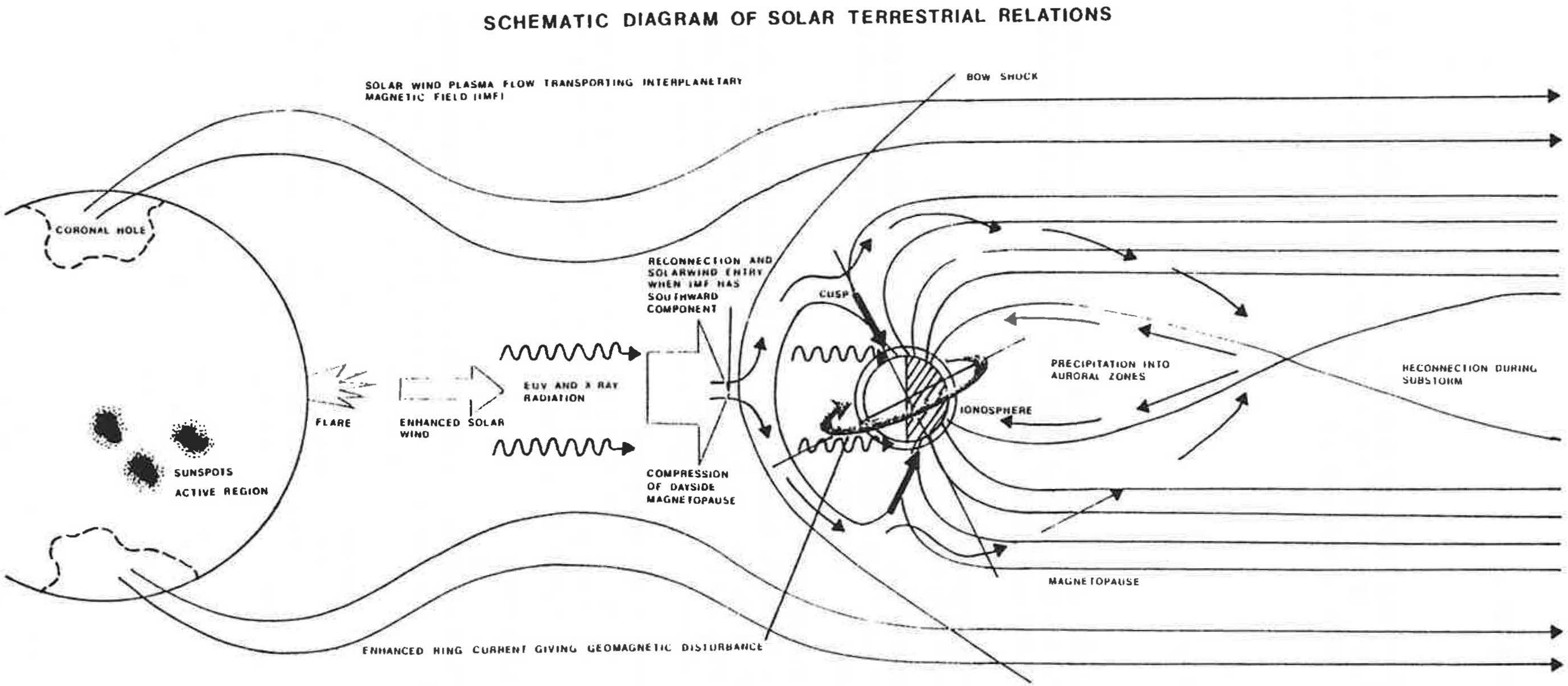

Figure 1: Schematic Diagram of Solar Terrestrial Relations

- The dissipation of solar wind energy and momentum when it either encounters a shock wave set up by a the encounter with objects such as planets at super Alfvénic velocities or due to it own variability when high speed solar wind flow encounters regions in which the solar wind flow velocity is considerably slower.
- The transfer of energy and momentum from the solar wind, through the magnetopause and into the magnetosphere via either a viscous interaction on the flanks of the magnetosphere or by the process of magnetic reconnection.
- The subsequent dissipation of this energy within the magnetosphere, plasmasphere and ionosphere and its physical influences on the Earth.

The use of data from several spacecraft as well as ground-based observations make it possible to track disturbances observed in the solar wind as they propagate through the Earth's bow shock and magnetopause until the energy is finally dissipated in the Earth's atmosphere. A system such as ESIS would be an invaluable tool in the determination of data sets to examine, the extraction of the data and its preliminary analysis.

2.3 Sampling

Space physics experiments measure values of some physical parameter(s) at a time, t, and at position $\mathbf{X} = (X_1, X_2, X_3)$. These data are usually "spot" sampled or averaged over a time Δt so sampling theory applies. The usual problems of aliasing need to be considered both at the instrument design stage and during data processing and analysis. The user should also be made aware of methods used in producing the data and their implications for further processing. As was mentioned above, for many instruments their data are in the form of a time series along a world-line. For some data there is the added complexity due to the data being "gridded", i.e. values of the parameter are interpolated onto a spatial grid.

Spacecraft can make either in-situ observations of their plasma environment and/or carry out remote sensing measurements using onboard imagers and radars/lidars to probe the outer regions of the ionosphere and plasmasphere. In both cases the position vector **X** (of the observation) is directly related to the time coordinate t through spacecraft trajectory. The actual spacecraft position may be re-calculated after the mission has been in progress for a while so that accurate orbital parameters are known. However fine details, such as inter-spacecraft separation, may be further refined in the light of studies with the data.

Ground-based observations can use remote sensing techniques (imagers, radar, lidar or radio wave transmitters) to observe the ionosphere and plasmasphere thus complementing the data obtained by satellites, or carry out in-situ observations of the local magnetic field at the surface of the Earth by magnetometers. There is a calculable but complex relation between **X** (specifying the observation point) and t.

2.4 Classification and Presentation

For many instruments the spatial co-ordinates and temporal co-ordinate are not independent but are related by orbital or other conditions so that there is a unique value of the parameter, measured at a particular value of t, associated with a spatial co-ordinate **X**. The set of measurements of the parameter at $(\mathbf{X}, t)$ then forms a world-line for the data. Some missions, such as ISEE and AMPTE are capable of carrying out simultaneous measurements at two points $(\mathbf{X}, t)$ whilst the Cluster/Soho missions will produce simultaneous measurements at a number of such points, the spacing between them being controlled.

The parameters used in space physics can be conveniently classified as follows:-

- **Scalar**
  These consist of one data field, for example electron number density, average temperature (which is equivalent to the trace of the pressure tensor, see below) measured at each $(\mathbf{X}, t)$.

These are obtained from ground-based radars or by in situ measurements of the particle distribution function. They are invariably displayed as line plots.

- **Vector**
  Typical examples include electric and magnetic fields, bulk velocity etc. requiring three data fields, a magnitude and two (usually angular) directions or as components with respect to an origin plus the field magnitude. They are displayed as line plots of time series. They can be further interpreted as spatial variation or as power spectra of temporal fluctuations. Hodograms and transformations into other co-ordinate systems are frequently used in the analysis of magnetic field data.

- **Tensor**
  This usually takes the form of a square matrix comprising nine components (six unique), for example pressure.

- **Wave frequency spectra and polarization**
  The number of data fields is dependent upon the number of frequency steps /filter channels used by the instrument. Note that this assumes that the spectrum relates to a time interval characteristically shorter than the time between parameter measurements otherwise a scalar or vector time series is more meaningful.

- **Charged particle intensity spectra**
  Differential particle flux – measured in terms of counts per unit time, per unit area, per unit energy interval, per unit solid-angle range, and measured as a function of energy and pitch-angle. (Pitch angle is the angle between the particle velocity vector, **v**, and the local magnetic field direction, **B**.) Fluxes can be displayed as line plots of time series selected according to a range of energy, and/or range of pitch angle; or as spectra or angular distributions taken at fixed time. The time evolution of spectra (or angular distributions) is often displayed using false-colour to reveal complex changes. The moments of the particle distribution function – which represents measurements at all energies over the 4π solid angle – i.e. the density, velocity, pressure and heat-flux vector, are displayed as line plots.

- **Auxiliary data**
  This usually consists of one value for each space-time co-ordinate, for example geomagnetic indices.

3 Data Modelling

In order to describe the structure of databases, the concept of a "data model" has been developed. This model is used to describe the data, data relationships, data semantics and data constraints and so produce an integrated, high level view of data within a database. A good model should provide a natural view of the data whilst at the same time allowing a high degree of data independence. The early models developed for this purpose cannot meet both objectives. The Network model [12] provides a natural view but not data independence, while the Relational [13] and the Entity Set [14] models provide data independence but not a natural view.

A more general model, called the Entity-Relationship (ER) Model, has been proposed [15]. It adopts a natural view of the data by means of entities and the relationships between them, as well as semantic information about these relationships. It also achieves a high level of data independence. For this reason, this was the basic data model chosen to define the conceptual schema for space physics.

3.1 The Entity Relationship Data Model

The primary elements of the ER model are:-

• Entities

An Entity represents a set of objects that are distinguishable from other objects. All objects belonging to the same entity set share the same set of properties or attributes. Different entity sets possess different sets of attributes. E.g.

Entity	#1	PERSON
Attribute	#1	Name
	#2	Eye colour
	#3	Height

Entity	#2	BOOK
Attribute	#1	Author
	#2	Title

Thus PERSON and BOOK represent different entity sets because they are described by different attributes.

• Attributes

The attributes that uniquely describe each entity and relationship are expressed as attribute=value pairs. E.g. For the entity PERSON:

Attribute Name	Attribute value
Name	Smith
eye colour	green
height	2 m

• Domains

The values taken by each attribute can be classified into different sets that are known as domains. All values for a particular attribute must lie in the same domain. E.g. For the entity PERSON:

Attribute Name	Attribute domain
Name	A surname
eye colour	A colour
height	A length

Values given to the attributes must lie in the domain for that attribute otherwise they are invalid.

• Relationships

A Relationship represents a logical connection between two entities. E.g. A PERSON writes A BOOK and conversely, a Book is written by a PERSON. This may be represented in the form of a diagram as shown in Figure 2.

Certain attributes may also be associated with the relationship. E.g. A MAN and WOMAN marry on a DATE at a PLACE. The date and place are clearly attributes of the relationship and not of the entities that it links. Thus, for the relationship *marries*

Attribute Name	Attribute value
Date	14 March 1992
Place	London

• Cardinality

The cardinality of a relation is defined as the number of times an instance of an entity can participate in a relation. This represents a constraint to be placed upon the relationship. E.g. A person may write zero or many books, a book, on the other hand, may be written by one or many people. The cardinality of a relationship may be shown in a relationship diagram such as Figure 2.

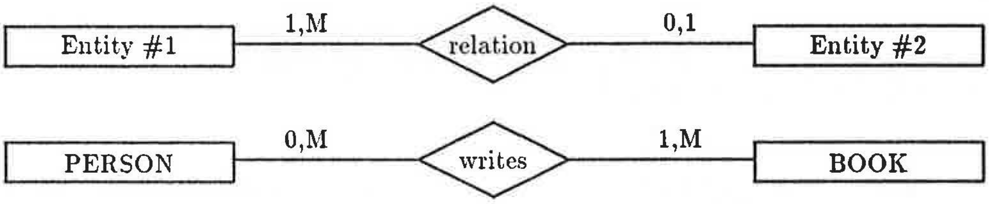

Figure 2: Diagrammatic representation of a relationship. The upper figure gives a general specification of a relationship. Its cardinalities are shown by the values above each branch of the relationship. In this case, instances of entity #1 may participate a minimum of once and a maximum of many times in a particular relationship, whilst instances of entity #2 may participate either zero or once in that same relationship. The lower figure shows the relationship PERSON *writes* BOOK.

- Conceptual Schema

The conceptual schema is the result of applying the data model to a particular application. It is a high level description of the data in the form specified by the data model and contains all the other elements (entities, relationships, attributes, domains and cardinality) presented in this section. It may be represented in the form of a diagram as a semantic network, which provides a readily understood version of the schema.

- Subentities

Subentities are used to represent specializations of general entities where it is felt that entity encompasses a broad range of items e.g. data sets, observation platform and instrument. This addition of subentities allows the conceptual schema to be tailored to fit commonly occurring instances and so create added flexibility to the whole conceptual schema. A global subentity was also added to allow for items that cannot specifically be classified into any of the proposed subentities. If new instances are generated, it should be possible to add a new subentity to the schema so as to incorporate them.

4 Definition of a Conceptual Schema for a Space Physics Query Language

To get a feel of how space physicists carry out their data analysis, a survey of the literature [6] was carried out. From this study a list of around 50 queries that are broadly representative of space physics was compiled. These are given in Appendix D. Three of these queries are used later to illustrate the use of the conceptual schema which we propose.

4.1 The Schema

From the list of typical user queries and possible answer scenarios produced as a result of the literature survey [6, 7], certain objects appear to be fundamental to the scenarios by which the queries were answered. In using the ER model, these fundamental objects form the entities and the method of research establishes a path or relationship between these entities. The ER data model can be represented in pictorial fashion by a semantic network. Using this technique the conceptual schema is easy to comprehend and alter if necessary. The conceptual schema can be used to help answer specific questions as is illustrated in section 5. The conceptual schema drawn up from our analysis is shown as a semantic network in figure 3.

A complete list of the entities together with their associated attributes and domains can be found in Appendix B. A equivalent list of the relationships together with their associated attributes, domains and cardinalities can be found in Appendix C.

ESIS SPQL Semantic Network Version dated 8th December 1990

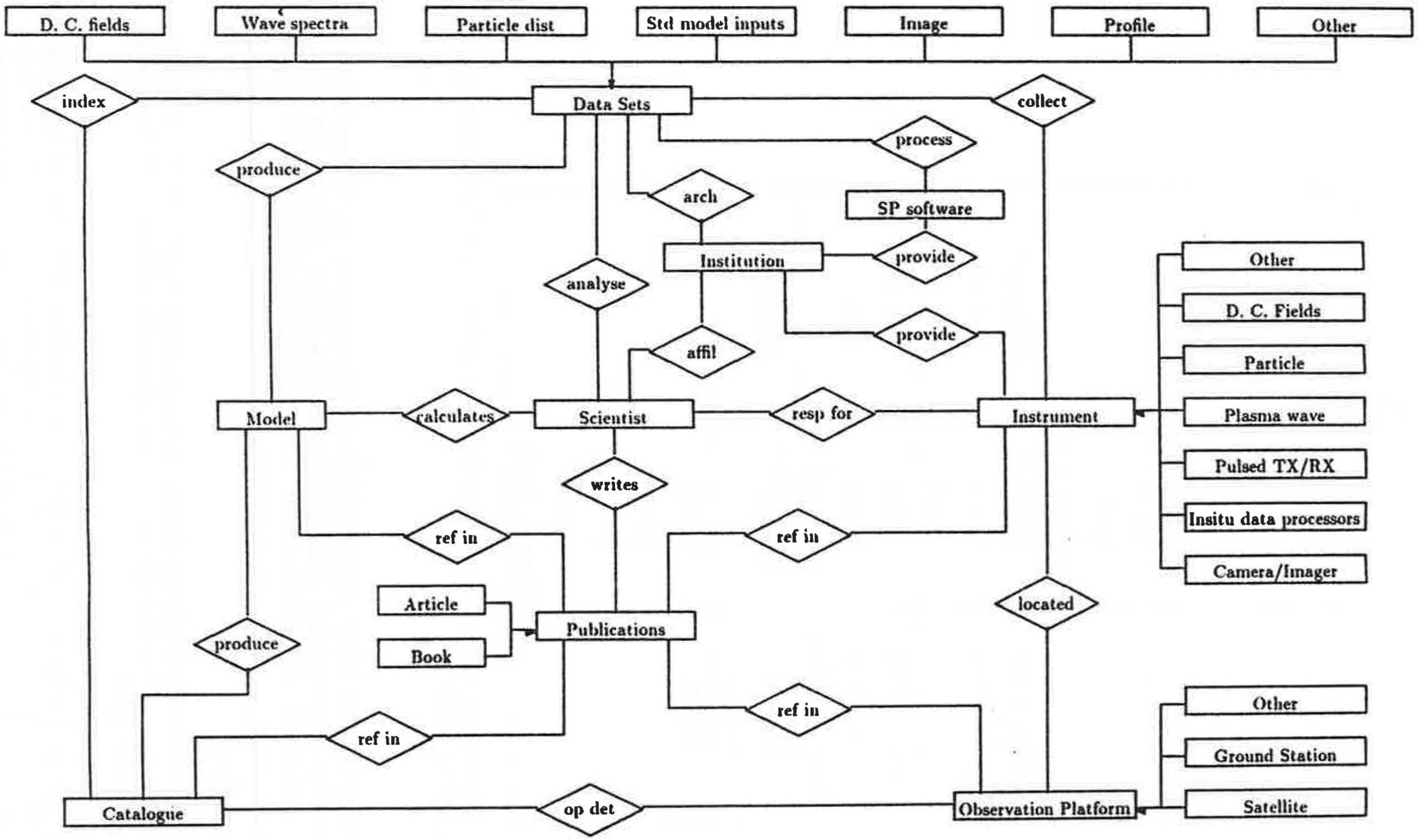

Figure 3: The ESIS SPQL semantic network. There are, of course, many ways in which this conceptual schema could be drawn without any changes to the entities and relationships, and the choice of entities and relationships must be based on what is found to be the most useful by testing against typical queries. The relationships in diagrams such as this are not simple SQL relationships.

Data Source	Data type	Degree of Processing
Magnetometer	Scalar/ Vector	Calibrated
Particle Detector	Scalar Vector Tensor Spectra Image 3-D	Derived Calibrated
Plasma and Radio Waves	Spectra Vector Tensor	Calibrated Derived
Pulsed TXRX Experiments (RADAR/LIDAR)	Scalar Vector Image 1-D	Calibrated Derived
Imagers Cameras	Image 2-D	Calibrated
Models	Scalar Vector Tensor Spectra Image 1, 2, 3-D	

Table 1: Typical instrument types, their resultant data types and the degree of data processing required to achieve the results.

The schema proposed is, we believe, an essentially complete representation of Space Physics and is therefore adequate to construct a Space Physics Query Language. However, the schema is not unique; other equally valid solutions exist – as discussed in the following sub-section.

4.2 Subentities

There are a number of ways by which subentities may be classified. These ways are all equally valid. To decide which is used in the schema, one must choose the solution which best serves the type of queries to handled.

For example, consider the entity data sets. Subentity schema can be generated by viewing the data sets from different standpoints as shown below: as a function of the type of instrument that produced them, as the type of data produced and in relation to the degree by which the data has been processed. These views may not be the only ones available, and thus are shown only as an example of the problems of defining subentity schema. The relationships between the various subentity types are shown in table 1 and discussed in the following sections.

- Instrument.
Data sets are grouped according to the instrument that produced them – as shown in Figure 4. E.g. all data produced by particle instruments are similar in nature and consists of a distribution function and the moments of the distribution function, magnetometers produce vectors and wave instruments produce frequency spectra. If a new instrument that measures new data fields is used, one simply has to add a new subentity in order to take this into account. It is not foreseen in the near future that such occurrences will take place.

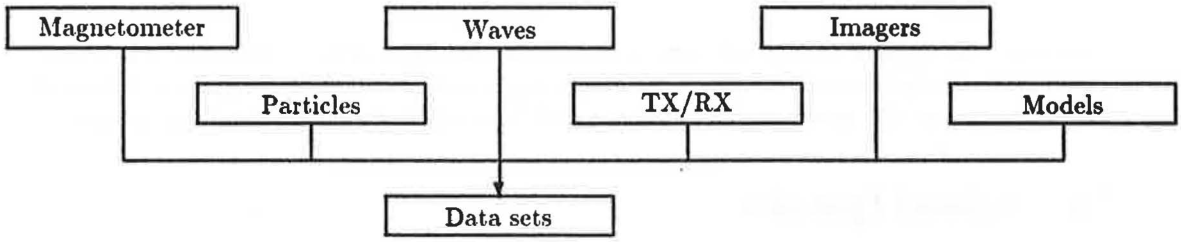

Figure 4: Subentities of datasets classified by instrument

- Data Structure.
Data sets can be classified by their structure – as shown in Figure 5. The vast majority space physics data sets form a time series. These time series may be subdivided by the nature of the data i.e. scalar, vectors, tensors, spectra, images (1D (profiles, scalars), 2D (remote sensing) and 3D (in-situ distribution functions)).

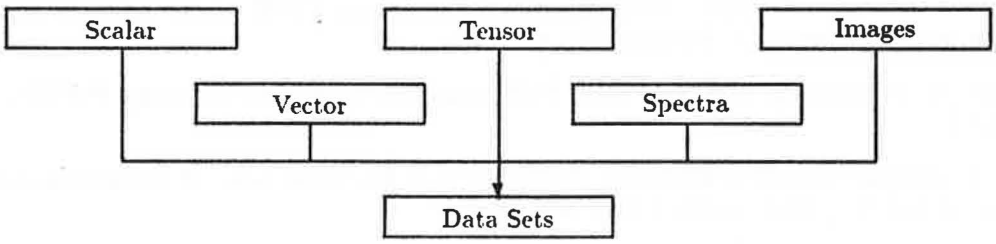

Figure 5: Subentities of datasets classified by data structure

- Degree of Processing.
Data sets may range between raw data (little or no processing has been performed) and highly processed forms of data – as shown in Figure 6. E.g. in the case of particle data, the raw data consists of digital signals that require calibrating to give the particle counts measured by the instrument at specific energies, in specific look directions and specific charge/mass ratios. This basic data is then used to construct a particle distribution function. Successive integrations of the particle distribution yield what are termed the moments of the distribution such as density, bulk velocity, pressure tensor and heat flux. Data bases tend to contain either calibrated data e.g. from wave instruments, magnetometers whilst particle data usually consists of moments of the measured distribution function (derived data).

Since the SPQL conceptual schema is intended to solve scientific queries, we have used a subentity schema based on the instrument classification above. This allows a space physics user

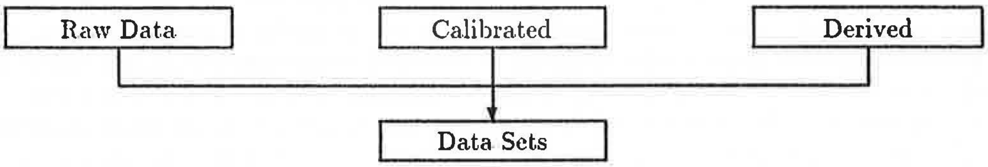

Figure 6: Subentities of datasets classified by processing level

to select the type of dataset in familiar terms – by the type of measurements. On the other hand, if our objective were different we might make a different choice, e.g. to build a system which monitors the processing of data we might have select the data processing viewpoint.

5 Solved Queries

To illustrate the application of the SPQL semantic network, three representative queries of increasing difficulty are taken from Appendix D. User choices are underlined.

5.1 Example 1

Whom do I contact to get more information about WHISPER ?

Use of Semantic Net

- The user selects the entity SCIENTIST.
- Since we wish to contact the person responsible for WHISPER, the attribute fields Scientist name and E-mail address are assigned to the command FIND, which indicates that these attributes are to be determined by the query.
- Using the relationship RESPONSIBLE FOR (resp for), we pass to the entity INSTRUMENT.
- In the attribute field INSTRUMENT NAME the user fills in the name of the instrument about which they wish to obtain more information.
- The query can then be submitted to the ESIS query processor. Here the query is broken down and reformulated in the internal query language. The system then decides to which archive the query is dispatched and formulates the query into the local query language. Finally the query is sent to the remote data base.

Attribute of Scientist	Value	Attribute of Instrument	Value
Scientist name E-mail address Fax number Telex number Telephone number Other Information	<u>FIND</u> <u>FIND</u>	Instrument name Description Instrument mode Sensitivity Reference	<u>WHISPER</u>

Query Answer
Scientist name is Dr. P.M.E. Decreau
E-mail address (SPAN) CRPEIS::DECREAU

5.2 Example 2

Which particle instruments have a time resolution of less than 1 second ?

Use of Semantic Net

- User selects the entity INSTRUMENT.
- The attribute field NAME in given to the command FIND.
- User then selects the subentity PARTICLE.
- The attribute field name TIME RESOLUTION is given the value < 1 sec.
- The query is then submitted.

Attribute of Instrument	Value	Attribute of Particle	Value
Instrument name Description Instrument modes Sensitivity Reference	FIND	Energy Range Sensors Time res M/Q res E/Q res Polarity Efficiency	 ≤ *1sec*

Query Answer

A list of particle instruments fulfilling the specified criteria, e.g. CLUSTER RAPID, ULYSSES FAST PLASMA

5.3 Example 3

What was the solar wind density on 1st November 1984? (In the pilot phase this will imply data from the UKS spacecraft).

- User selects the entity OBSERVATION PLATFORM.
- The attribute field PLATFORM NAME is assigned the value AMPTE-UKS.
- Using the relationship OPERATIONAL DETAILS, the user transfers to the entity CATALOGUE.
- User assigns values to the various attributes i.e. SUBJECT = REGIONS, DATA FIELD DAY = 84/306, DATA FIELD REGION = SOLAR WIND.
- The attributes DATA FIELD START and DATA FIELD STOP are given to the command FIND.

Attribute of Observation Platform	Value	Attribute of Catalogue	Value
Platform name Description	AMPTE-UKS	Subject Compiler Data Fields	Regions DAY = 84/306 REGION = solar wind START = FIND STOP = FIND

- Using the relationship INDEXES, the user transfers from the entity CATALOGUE to the entity DATA SETS.

- The user assigns values to the various attributes i.e. START TIME and STOP TIME based on the results of the previous step.
- The attribute field DATA FIELD ION BULK DEN is given to the command FIND.

Attribute of Catalogue	Value	Attribute of Data Set	Value
Subject Compiler Data fields Data Sets	Regions	Data fields Format Creation date Start time Stop time	ION BULK DEN = FIND Start Stop

Query Answer
The answer to this query would be a table containing the relevant data values. (This was a day of rather high solar wind velocity.)

5.4 Non-SQL queries

Note that the last query requires two distinct steps with the results of the first step being used to formulate the query condition in the second step. The overall query cannot be formulated as an SQL query, since, as we understand it, the SQL approach assumes that queries can always be formulated as a single, possibly complex, step. If this is so, the example shows that even simple scientific queries may require an extension to SQL.

6 Discussion

6.1 Contrasts with Astronomy

One reason for the present study was to compare the resultant SPQL schema with the AQL schema produced from a similar study covering the discipline of astronomy. However, it is obvious that there are a number of basic areas in which the disciplines of astronomy and space physics contrast strongly in their methodology. These are:–

1. The nature of the science.
   Astronomy tends to be an object orientated science, concerned with the attributes of definite entities at a particular epoch.
   Space physics is more process orientated, trying to describe both temporal and spatial variations observed in relatively short time scales.

2. Data storage.
   Since astronomy is object orientated, astronomical data are conveniently stored on an object by object basis.
   Space physics data are stored as time series reflecting the fact that the processes observed are evolving either temporally, spatially or both.

3. Data access.
   Astronomers tend to access data by use of either a specific identifier or property.
   Space physicists access data by time using a catalogue as a guide.

A comparison of our SPQL semantic network with that resulting from the AQL work shows that there are a number of entities common to both schema and that these entities have, in the most part, identical attributes. This is likely to be true for any natural science discipline. These common entities, together with their common attributes are listed in table 2. Attributes that

Entity	Attribute
Publication	Title
	Year
	Keyterms
Book	Publisher
Article	Journal
	Volume
	Page
	Type of Article
Catalogue	Subject
	Compiler
	Data fields
Scientist	Scientist name
	E-mail address
	Fax number
	Telephone number
	Field of interest
Instrument	Instrument name
	Location
	Description
	Reference

Entity	Attribute
Institution	Name of Institution
	Address
	Telephone
	Telex
	Fax
	Activities
Models	Name of model
	Description
	Input fields
	Output fields
	Category
Data Sets	Format
	Creation Date
Software	Program Name
	Description

Table 2: Comparison of attributes.

are not shared are probably deemed to have been included in a general description attribute. If this is the case, and it is indeed with a number of the entities, then the information may be removed from the general description and added as an extra attribute of the entity involved and may thus help the user to formulate a more specific query. Some attributes, though having different names, have similar definitions and probably serve the same purpose. It may, therefore, be possible to find a common name for the attributes in question.

The overall structure of the parts of the semantic network that are common to both the SPQL and AQL show only one difference in the way in which the common entities are interconnected (relationships). This probably reflects a difference in the two disciplines in the sense of who is responsible for the design, manufacture and testing of a particular instrument. In the space physics case a new relationship has been added to match the existing AQL relationship in the sense that an instrument is provided by an institution (but this may not prove useful), the production of the instrument being the responsibility of the P.I.. Astronomical investigations are generally run as observatory class missions, few being P.I. class missions. The use of the relationship *resp for* allows the user to find the address of the instrument P.I. directly from the network in case further information about a particular instrument is required. In the case of further information regarding an astronomical instrument a researcher contacts the institution responsible for the instrument.

6.2 Future Extensions

Within the pilot phase of ESIS, only the AMPTE-UKS database at RAL will be implemented. However, to show that ESIS may be extended to other space programmes and databases is an extremely important aspect of the ESIS demonstration. By this means ESIS will show that it is not only able to serve the two existing client communities but also other space science groups.

The Inter-Agency Consultative Group (IACG) initiative in Solar-Terrestrial Physics has lead to the coordination of a large number of current and future space missions. These form one list of possible missions which ESIS could consider as extensions. This list is very large and, of course, not wholly European. For this reason it is premature to suggest that ESIS becomes the European route to access all of the IACG information and data systems. However, two ESA/NASA missions should be considered as potential ESIS material. These are the Ulysses mission to study the heliosphere out of the ecliptic plane and the Cluster mission to study small scale processes in the terrestrial magnetosphere and the solar wind.

6.2.1 The Ulysses Mission

The Ulysses mission is a joint ESA/NASA mission (formerly called the International Solar-Polar Mission). It was launched in October 1990.

The main objective of Ulysses is to provide the first study the heliosphere out of the plane of the ecliptic - a Jupiter flyby deflected the probe into a high inclination orbit in February 1992.

The Ulysses instruments and data generally fit easily into the semantic network presented in this report with the exception of those instruments which are outside the definition of space physics. Solar X-ray data and instrumentation will probably be easier to fit into the astronomy and astrophysics semantic network. This points out the need for ESIS to adopt a uniform approach to its modelling of information so that such boundaries become transparent and interdisciplinary science in the widest possible sense becomes possible.

6.2.2 The Cluster Science Data System

The ESA/NASA Solar Terrestrial Science Programme mission Cluster has been designed primarily to study small-scale structures (from a few to a few tens of ion Larmor radii) in the Earth's plasma environment. Although of relatively small scale, the processes leading to the formation of such structures are believed to be fundamental in determining the behaviour of key interaction processes between two cosmic plasmas [16].

The key aspect of the Cluster mission is the use of four identical spacecraft to help distinguish and characterize the events observed as the satellites traverse our planetary plasma environment. In particular, the data from the satellites will be used to:-

- Calculate gradients in the magnetic field and hence determine the current flowing (curl **B**)
- A wave telescope to determine the wave numbers of magnetic oscillations and electromagnetic/electrostatic emissions
- Studies of discontinuities to determine their vector velocity as well as observations of surface features
- Distinguish between spatial phenomena and temporal effects

The Cluster Science Data System (CSDS) is evolving rapidly and it should be noted that it is expected that CSDS will use ESIS.

7 Conclusions

In the production of the space physics semantic network an attempt was made to give a global view which would be adequate for the work of the whole space physics community. It should be pointed out that different people from different fields within space physics may produce slightly differing networks reflecting their own views of space physics. Thus this network is not unique in its representation of space physics but it is one that we feel adequately fulfills the role of a conceptual schema for space physics within ESIS.

The proposed conceptual schema for the inclusion of space physics within ESIS should be considered by the space physics community to see if it represents a valid picture of space physics. Feedback already received is positive about the method by which ideas are presented. It is, however, felt that the method and general inclusion of some entities require further considered —

- Is the list of data set subentities the best method of tackling the problem of specialization?
- Space physics analysis software - should this belong in a query language?

Some of the missions coordinated by the Inter Agency Consultative Group [17] are collaborations between ESA and other national space agencies e.g. Cluster is a joint mission by ESA and NASA which plans to rely on ESIS to provide its communication infrastructure and user interface. Hence international links between the database systems produced by these organisations would greatly further the ESIS goal of data provenance.

Some satellites, e.g. Ulysses, carry instruments that we consider to be beyond the scope of space physics. However, information regarding these instruments and the data sets produced by this satellite will probably be of interest to space physicists and astronomers alike. Hence the best path to take to allow such interdisciplinary science to occur is to have a uniform approach to the way in which the data is modelled, i.e. similar semantic networks. This allows the user to navigate around either one or both networks with the same ease and create a seamless join between the two networks.

The differences between the sciences of astronomy and space physics have also been examined. These differences stem from the fact that astronomy tends to be an object orientated science with evolution processes occurring on time scales of the order of thousands of centuries. Space physics, on the other hand, deals with both *in situ* and remote sensing measurements collected as a function of time and position in an environment that changes both spatially and temporally on relatively short scales (seconds or minutes). The role of catalogues is somewhat different in the two disciplines. [18] gives an approach to the way in which catalogues should be described and may help reconcile the use of catalogues within ESIS. These differences effect the methodology by which data are collected, stored and accessed.

In spite of these substantial differences, the top level semantic network produced for each scientific discipline are very similar in nature. This similarity between the two networks indicates that a similar approach to the handling of data in two different disciplines of natural science is a valid concept.

8 Acknowledgements

We would like to take this opportunity to thank the people who have provided assistance in the work discussed in this document, namely L. Denizman, S. Ansari, D. Egret and A.Preite-Martinez (CDS) for discussions regarding the astronomy semantic net and members of the ESIS Space Physics Working Group and others in the space physics community for the generation and development of the ideas expressed in this document.

References

[1] Albrecht, M. A., G. Russo, A. Richmond and M. A. Hapgood, Towards a European Space Information System, Vol. 1, General Review of User Requirements. ESA internal report, 1988.

[2] D.R. Lepine, I. Beharrel, D.A. Bryant, R.J. Ely, J.R. MacDougall, E. Gershuny and A.J. Norris, Data Handling for the UKS Spacecraft, *IEEE Trans. Geosci. and Remote Sensing*, Vol. GE-23, pp. 221-229, 1985.

[3] European Space Information System – Space Physics Query Language, Rutherford Appleton Laboratory and University of Sheffield, May 1991.

[4] Cluster Science Data System Announcement of Opportunity, ESA SCI(90)/1, July 1990.

[5] The Cluster Mission. ESA SP-1103, October 1988.

[6] European Space Information System – Space Physics Query Language and Correlation Environment WP1.1 Report: User Scenarios, Rutherford Appleton Laboratory and University of Sheffield, July 1990.

[7] European Space Information System – Space Physics Query Language and Correlation Environment WP1.2 Report: Analysis of User Scenarios and Semantic Network, Rutherford Appleton Laboratory and University of Sheffield, September 1990.

[8] European Space Information System – Space Physics Query Language and Correlation Environment WP1.3 Report: ESIS Space Physics Lexicon, Rutherford Appleton Laboratory and University of Sheffield, November 1990.

[9] European Space Information System – Space Physics Query Language and Correlation Environment WP1.5 Report: Integration with Query Environment, Rutherford Appleton Laboratory and University of Sheffield, October 1990.

[10] Egret, D., S. G. Ansari, L. Denizman, A. Preite-Martinez, The ESIS Query Environment, CDS Report, July 1990.

[11] Tsurutani, B.T., SPR Name Change to Space Physics and Aeronomy, *EOS*, Vol. 72, No. 15, p. 172, April 1991.

[12] American National Standards Database Committee, Draft Proposed Network Database Language NDL, Ref X3H2-84-100 , ANSI Inc., August 1984.

[13] E. F. Codd, A Relational Model for Large Shared Data Banks, *Communications of the ACM*, Vol. 13, No. 6, June 1970.

[14] Senko, M. E., E. B. Altman, M. M. Astrahan and P. L. Fehder, Data Structures and Accessing in Data-Base Systems, *IBM Sys. J.*, Vol. 12, No.1, 1973.

[15] P. P.-S. Chen, The Entity-Relationship Model – Toward a Unified View of Data, *Association for Computing Machinery: Transactions on Database Systems*, Vol. 1, No.1, March 1976.

[16] R. Schmidt and M.L. Goldstein, Cluster Science Data System, Final Report of the CSDS Working Group, ESA CL-EST-RP-001, February 1990.

[17] The Solar-Terrestrial Science Project of the IACG. Key Data on Participating Projects, R. Reinhard and B. Battrick, ESA SP-1107, November 1990.

[18] Guidelines for an Internationally Interoperable Catalogue System, Issue 1.0, CEOS, September 1991.

A Table of Acronyms

AMPTE	Active Magnetospheric Particle Tracer Explorers
CDHF	Cluster Data Handling Facility
CDS	Centre de Données Strasbourg
CE	Correlation Environment
CoI.	Co-Investigator
CSDS	Cluster Science Data System
DBMS	Data Base Management System
DC	Data Centre
ESA	European Space Agency
ESIS	European Space Information System
FTE	Flux Transfer Event
GDF	Geophysical Data Facility
IACG	Inter-Agency Consultative Group
ISEE	International Sun Earth Explorer
IRM	Ion Release Module
NASA	National Aeronautics and Space Administration
P.I.	Principal Investigator
RAL	Rutherford Appleton Laboratory
SQL	Structured Query Language
SPQL	Space Physics Query Language
UKS	United Kingdom Subsatellite

B Definitions and Attributes of Entities

This section contains a list of the entities encountered in the space physics semantic network together with their associated attributes. The attributes are defined together with their domains and argument sets, examples of which are given in the definitions.

The argument sets can take one of the following forms:–

- List_of{} Open ended list of arguments.
- Any_of{} Arguments are members of a finite set.
- Range_of{} Range of values or acronym accepted.

Table 3 gives a list of the domains that can be taken by the attributes. It should be noted that for many of the domains, there exist several commonly used formats and that table 3 contains only examples of possible formats.

B.1 Publication

Definition Published articles and books of interest in the field of Space Physics.

Title		S	Title of publication
Year		I	Year of publication
Keyterms	List_of{}	S	Terms relating to the subject of the publication e.g. AMPTE, ions, bow shock........

Specializations of the entity PUBLICATION

Book

Publisher	W	Publishing house

Article

Journal	S	Name of periodical, proceedings etc.
Volume	W	Volume including the article
Page	I	Page number on which the article commences
Type of Article	W	Nature of subject matter
Abstract	Te	Abstract of the article

Relationships to other entities

A PUBLICATION

is *written* by a SCIENTIST
can *include references* to CATALOGUES
can *include references* to MODELS
can *include references* to INSTRUMENT
can *include references* to OBSERVATION PLATFORM

Domain		Definition
INTEGER	I	an integer value
REAL	F	a real value
WORD	W	a single alphanumeric value
STRING	S	up to 80 alphanumeric characters on a single line
ADDRESS	A	up to 80 alphanumeric characters per line on a maximum of 8 lines
TEXT	Te	up to 80 alphanumeric characters per line on a maximum of 40 lines
POSITION	P	The position of an observatory or field station can be expressed in a number of formats depending upon the coordinate system used. E.g. latitude and longitude of an object where latitude is composed of a real in the range ± 90 and a character (either N or S), longitude consists of a real in the range ± 180 and a character (either E or W).
TELEPHONE	T	Integer fields separated by alpha–numeric characters or spaces
DATE	D	Many different forms of specifying the date exist in space physics e.g. 3 integer fields separated by alpha–numeric characters or spaces or as a decimal such as the Julian date.
TIME	Ti	A multitude of different formats exist e.g. 5 integer fields representing year, day of year, hour, minute, second or 5 integer fields year, date, hour, minute, second and either an integer or word to represent the month
VALUE	V	Composed of a real number + word
RANGE	R	Composed of two real numbers + a word

Table 3: Possible domains of the attributes.

B.2 Catalogue

Definition A tabular list of either phenomena observed in Space Physics data, predictive data produced by models or information pertaining to an observation platform.

Subject	Any_of{}	S	Name given to a specific phenomena e. g. FTE, magnetopause crossing, telecommand........
Compiler		S	Name of scientist responsible for producing the catalogue
Data fields	List_of{}	S	Data fields to be found in the catalogue with units e.g. position vector in Re, time in UT....

Relationships to other entities

A CATALOGUE

indexes space physics DATA SETS
can be *referenced in* PUBLICATIONS
contains *operational details* of an OBSERVATION PLATFORM
produced by a MODEL

B.3 Observation Platform

Definition This is the 'observatory' that houses Space Physics instruments.

Name of Platform	Any_of{}	S	Name of 'observatory' e.g. AMPTE-UKS, Halley Bay....
Description		Te	Brief description of the 'observatory'

Specializations of the entity OBSERVATION PLATFORM

Satellite			
Stabilization technique	Any_of{}	S	Details of how the satellite is stabilized giving, for example, the spin vector direction or direction of longest axis.
Launch date		D	Date of launch
Operational status		S	Present status of satellite and modes of operation or date of demise (if appropriate)
Ground Based			
Geographic Location	Range_of{}	P	Geographic latitude and longitude
Geomagnetic Location	Range_of{}	P	Geomagnetic latitude and longitude
Conjugate Point	Range_of{}	P	Geographic latitude and longitude of conjugate point
Operational status		S	Present experimental modes available and software details
Installation Date		D	Date experiment first gave useful results
Other			
Field names		S	List of fields relevant to the observation platform

Relationships to other entities

An OBSERVATION PLATFORM

is *Referenced in* PUBLICATIONS
is the *location* of INSTRUMENTS
has its *operational details* kept in a CATALOGUE

B.4 Scientist

Definition Any person who is involved with the analysis of Space Physics data.

Scientist name	S	Surname and forename
E-mail address	S	Address to which electronic mail should be sent
Fax number	T	Full fax number including international and local area codes
Telex number	T	Full telex number including international and local area codes
Telephone number	T	Full telephone number including international, local area codes and extension
Other Information	T	Text giving a scientists fields of interest, committee's served. This should be updated by the user.

Relationships to other entities

A SCIENTIST

writes PUBLICATIONS
is *Responsible for* an INSTRUMENT
is *Affiliated* to an INSTITUTION
Analyses DATA SETS
Calculates SPACE PHYSICS MODELS

B.5 Instrument

Definition A device that is capable of performing or aiding Space Physics observations

Instrument name	Any_of{}	S	Name of instrument e.g. 3D ion expt, electron expt... (on UKS), WHISPER, PEACE, RAPID (on CLUSTER)...
Description		Te	Basic overview description of instrument including technique used
Instrument modes label		S	Name of specific mode of operation
Sensitivity		V	Estimate of accuracy
Reference		S	Published reference to instrument

Specialization of the entity INSTRUMENT

Magnetometer

Sample rate		V	Number of vectors measured per second

Particle Experiments

Energy Range		R	Energy range sampled by the instrument
Sensors used		W	Number and look direction of sensors used for observation
Time resolution		V	Length of time required to build up a complete distribution function
M/Q resolution		V	Mass per charge resolution
E/Q resolution		V	Energy per charge resolution
Polarity	Any_of{}	W	Charge on particle e.g. positive, -ve
Efficiency		S	Limitations on the detectors ability

Wave Experiments

Frequency range		R	Frequency range of instrument
Bandwidth		V	Frequency resolution
Number of frequencies sampled		I	
Time resolution		V	

Pulsed TX/RX Systems

Height range	R	
Height resolution	V	
Time resolution	V	
Beam direction	V	
Derived quantities	S	

In Situ Data Processors

Data sources	S	List of instruments whose output is fed into the data processor
Algorithms	Te	Descriptions of processes applied to the data

Other

Fields	S	Data fields appropriate to the instrument

Relationships to other entities.

An INSTRUMENT

is *referenced in* PUBLICATIONS
is *located* on or in an OBSERVATION PLATFORM
produces DATA SETS
is the *responsibility of* a SCIENTIST

B.6 Institution

Definition An establishment carrying out research in the field of Space Physics.

Name of Institution	S	Institution name
Address	A	Institution address
Telephone	T	Telephone number including international and local area codes
Telex	T	Telex number including international and local area codes
Fax	T	Fax number including international and local area codes
Activities	T	Fields of research which are carried out at the institution

Relationships to other entities

An INSTITUTION

archives DATA SETS
adopts SCIENTISTS

B.7 Models

Definition An algorithm that models Space Physics phenomena

Category	Any_of{}	S	Category of model e.g. geomagnetic, bow shock...
Name of model	Any_of{}	S	Model name e.g. MSIS, IGRF....
Description		Te	Brief description of the model
Input fields	List_of{}	S	Details of input fields required and their units
Output fields	List_of{}	S	Details of output fields and their units

Relationships with other entities

MODELS are

Referenced in a PUBLICATION
Produce DATA SETS
Calculated by a SCIENTIST
Produce CATALOGUES

B.8 Data Sets

Definition The smallest aggregation of self-consistent data items which can be independently managed, usually a series of time ordered measurements.

Data fields	List_of{}	S	A list of the data fields available together with their units
Format		S	Local data format
Creation Date		D	Date when data sets were created
User Start time		Ti	Start time of user specified period
User stop time		Ti	Stop time of user specified period

Specialization of the entity DATA SETS.

DC Fields			
Type of field	Any_of{}	W	Either electric or magnetic
Particle Distributions			
Particle type	Any_of{}	W	i.e. either positive ions or electrons
Wave Spectra			
Wavelength range		R	Frequency range of detection of waves
Nature of emission	Any_of{}	W	i.e. either electric or magnetic portion of wave
Height Profiles			
Height range	Range_of{}	R	Altitudes observed by the experiment. e.g. F2 layer, thermosphere.
Height resolution		V	
Image			
Image number		I	Number of image
Wavelength		R	Recorded wavelength of image
Coordinates of image		P	Geographic position of image
Resolution of image		V	Image resolution (pixels per unit length)
Standard Model Inputs			
Model name	Any_of{}	S	Name of associated model e.g. MSIS, Ephemeris...
Other			
Title		S	Title of data set
Fields		S	Data fields available

Relationships with other entities.

DATA SETS

are *Indexed* in CATALOGUES
are *Analysed* by SCIENTISTS
are *Collected* by INSTRUMENTS
are *Produced* by MODELS
are *Archived at* INSTITUTIONS

B.9 Space Physics Software

Definition Algorithms and packages used to process space physics data.

Name	Any_of{}	S	Program name e.g. UKS ELECTRONS, Peak Finder..
Description		Tc	Description of software

Relationships with other entities.

SPACE PHYSICS SOFTWARE

processes space physics DATA SETS
is *provided by* an INSTITUTION

C Definitions, Cardinalities and Attributes of Relationships

This section contains a list of the relationships encountered in the space physics semantic network together with their cardinalities and associated attributes. The attributes are defined together with their domains and argument sets, examples of which are given in the definitions. The relationships and cardinalities are also shown in diagrammatic form.

C.1 Analyse

A scientist may analyse one or more data sets.
A data set may be analysed by zero or more scientists.
Attributes:

access rights	Any_of{}	List of scientists to whom the data is available.

C.2 Affiliated

A scientist is affiliated to zero(unusually), one (or on some occasions more) institutions.
An institution contains one or more scientists.

C.3 Responsible for

An instrument is the responsibility of one scientist (the P.I.).
A scientist may be responsible for zero or many instruments.

C.4 Writes

A scientist may produce zero or many publications.
A publication can result from the effort of one or more scientists.
Attributes:

Role	Any_of{}	Role played by scientist e.g. author, editor

C.5 Calculates

A model may be written by one or many scientists.
A particular scientist can be involved with zero or many models.

C.6 Indexed

A space physics catalogue can be used to index zero or many data sets.
A data set can be indexed by zero or many catalogues.
Attributes:

Date	Date when the catalogue was produced
Criteria	Criteria used for compilation

C.7 Collect

Data set comes from a model.
A specific data set is collected by one particular instrument.
An instrument can collect one or many data sets.

C.8 Archived at

A data set (and back-ups) can be archived at one or more institutions.
An institution may archive one or more data sets.
Attributes:

Database name	Name of database in which data is stored

C.9 Produce

A data set is produced by zero or one models.
A model may produce one or more data sets.

A model may produce zero or one catalogue.
A catalogue may be produced by zero or many models.

C.10 Referenced in

A model may be referenced in one or more publications.
A publication may have been produced using the results from zero or more models.

An instrument may be referenced in one or more publications.
A publication may have been produced using the results from zero or more instruments.

A catalogue may be referenced in one or more publications.
A publication may have been produced using zero or more catalogues.

An observation platform may be referenced in one or more publications.
A publication may contain references to zero or more observation platforms.

C.11 Operational Details

An observational platform has its operational details contained in zero or more catalogues.
A catalogue may contain operational details relevant to more than one observation platform.

C.12 Located

An observation platform is the location of one or more instruments.
An instrument may be located on one observation platform.

C.13 Process

A piece of software may be able to process zero or more data sets.
A data set may be processed by zero or many pieces of software.

C.14 Provide

A piece of software is produced by one institution or jointly by many institutions.
An institution may provide zero or many pieces of software.

An instrument may be produced by one or more institutions.
An institution may provide zero or many instruments.

D Sample Queries

Here is a list of sample queries that are representative of the use of data by space physicists. The queries have been classified as follows:-

1. Reference - Queries dealing with published papers and articles.
2. Conferences - Queries referring to conferences/meetings.
3. Instrument - Queries about the operation of devices.
4. Background - Useful quick calculations and information.
5. Model - Queries about the input or results using theoretical work.
6. Scientist - Who to contact about specific information and how.
7. Position - Queries that require the position on the spacecraft.
8. Data Sets - Queries that require data set info with no processing.
9. Data Processing - Queries that require data processing.

D.1 Reference

- List all papers using data from the AMPTE-UKS wave experiment.
- In which journal can I find a paper by Kennel and Petshek titled 'Limit on stably trapped particle fluxes' ?
- In which journal can I find a paper by Kenel and Petschek titled 'Limit on stably trapped particle fluxes' ?[3]
- Produce a list of references on the subject of quasi-longitudinal whistler-mode waves ?

D.2 Conferences

- To whom do I send my URSI abstract and by what date ?
- What conferences in the next two years are relevant to the bow shock ?
- When and where is the next COSPAR conference ?

D.3 Instrument

- What instruments measure currents in the magnetosphere ?
- What instruments measure Auroral Kilometric Radiation ?
- What is the angle between the spacecraft spin axis and the magnetic field direction ?
- Which instruments measure the particle distribution function with a time resolution better than 1 second ?

D.4 Background

- What is the bounce period of a 250 eV electron ?
- What are the geomagnetic coordinates of Faraday ?
- What is the Rijnbeek and Saunders criterion for FTE's ?

[3] Note the spellings of the names

D.5 Model

- With what energy of particles will these whistler mode waves resonate ?
- What is the pitch-angle diffusion coefficient at the magnetopause due to these emissions ?
- What is the average ionospheric composition in summer during solar minimum ?
- Which geomagnetic models of the Earth's magnetosphere require the solar wind ram pressure ?
- What is the magnetopause normal direction calculated using Sonnerup's method ?
- What changes are expected in the field/plasma observations due to a solar wind pressure pulse impinging upon the magnetopause ?

D.6 Scientist

- What journal should I send this rather long review paper to, who is the editor, what is the address ?
- Who do I contact to get more information about WHISPER ?
- What is Dave Southwood's e-mail address ?
- How do I get data from a U.S. scientist ?

D.7 Position

- Which spacecraft crossed the bow shock when the moon was between the Sun and the Earth ?
- When will CLUSTER be magnetically conjugate to Halley base.
- When will a spacecraft in equatorial orbit be magnetically conjugate to one in the cusp.
- List the events in which spacecraft # 1 crosses the magnetopause and spacecraft # 2 monitors the upstream conditions.
- Which spacecraft will be in the tail after the occurrence of a flare.
- Where were the AMPTE spacecraft on 25th December 1984 ?
- List the UKS magnetopause crossings when $20 < Ap < 100$.
- Where do crossings of Jupiter's magnetopause occur relative to Jupiter ?
- What point on the Earth's surface is conjugate to a point (x,y,z) on the magnetopause ?
- Is there a spacecraft within 2 R_e of UKS at (x,y,z,t) ?
- What is the separation of spacecraft #1 and #2 and the bulk plasma flow speed ?
- Are there simultaneous crossings of the cusp at different local times ?
- Are there simultaneous crossings of the magnetopause at different magnetic latitudes ?

D.8 Data Sets

- When and where was the bulk plasma flow sunwards ?
- List times when the interplanetary magnetic field was > ±45° from the hose-pipe angle.
- What was the solar wind density on 1st November 1984 ?
- Are there any EISCAT/STARE observations of a westward travelling surge with IRM conjugate ?
- Is there plasma data from a satellite available in the period 10 hours before a Jupiter type II radio burst ?
- Is this a layered or convecting structure ?
- Is this a good day on which to look for reconnection events ?
- When was ISEE in the solar wind and in high bit rate and on a connected field line and with a small ($< 100\ km$) separation and ISEE-3 solar wind data available ?

D.9 Data Processing

- List the events where fluctuations of the magnetic field occur with periods less than 2 seconds and no waves observed.
- Are these wave emissions at a frequency of $(n + 1/2)\Omega$?
- Does the electron distribution function exhibit $\partial f(v_\perp)/\partial v_\perp > 0$?
- Is the wave power measured at 2 kHz modulated by the spin of the spacecraft ?
- What is the polarisation of these magnetic field oscillations ?
- What is the refractive index of the plasma ?
- What is the ratio of magnetic to particle pressures ?
- What is the average ion gyroradius for this period ?
- Is the plasma Debye length greater than the electric field boom length ?
- Does the direction of mid-latitude electric field measured by the STARE radar at 12 UT agree with that predicted by the convection electric field model of the ionosphere ?
- How do the number of whistler ducts detected at Faraday vary with season and longitude ?
- How does the flux of 200 eV electrons with pitch-angles in the range 80 – 100 ° change during this period ?