A Relational Data Base for the Space Plasma Data collected by the SACI-1 Mission

Maria de Fatima Mattiello Francisco [a], Jose Angelo da Costa F. Neri [a], Romualdo Alves Pereira Junior [b]

[a] National Institute for Space Research - INPE, São José dos Campos, Brazil
[b] Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq

ABSTRACT

The study of the space plasma environment is the goal of the experiments named: PLASMEX, ORCAS, MAGNEX and PHOTO. They constitute the payload of the first small Brazilian satellite for Scientific Applications (SACI-1).
The SACI-1 is a low earth polar orbit satellite which shall be launched as China-Brazil Earth Resource Satellite (CBERS) piggyback, by the Chinese launcher Long March IV, in the beginning of 1998.
All the space plasma data measured by the SACI-1 payload will be received and archived in the SACI-1 Ground Station by a software system which uses the relational data modelling to build the system data base.
Focusing on the space plasma data base, this article describes the Ground Station Software facilities such as: quick-looks of the SACI-1 remote sensing data and the data access in raw form from the investigators, via INTERNET.

Keywords: database, telemetry, telecommands, satellite remote sensing, space plasma, payload data quick-look, query.

1. INTRODUCTION

SACI is a low earth polar orbit scientific microsatellite intended for systematic observations of the ionosphere where the air is highly ionized and the Ultraviolet radiations disturb the ionic equilibrium of the high Earth atmosphere regions, affecting radio wave transmissions.
In its first mission, 4 experiments named: ORCAS, PLASMEX, MAGNEX and PHOTO constitute the SACI-1 payload.
Figure 1 illustrates the SACI network configuration. The main components are the SACI-1 Satellite (with On Board Computer (OBC) and four microcontrolled scientific experiments), the antenna (to track the satellite based on orbit preview calculation), the transmitter & receiver equipments (to transmit telecomands and receive telemetry), a router to Internet and an Ethernet local area network configured with five workstations: Antenna Control, Telemetry, Telecomand, Telemetry Data Visualization System & Database Remote Control (DV&DC) and Database Server with both current data and an optical drive to store the historical data. The Telecommand, Telemetry and Data Visualization Systems are based on Personal Computer platforms[1] with Pulse Code Modulation (PCM) developed-in-house microcontrolled cards. These cards allow the systems to receive parallely all the Telemetry Application Packets transmitted from OBC to Ground Station.

2. SACI-1 PAYLOAD

The study of the space plasma environment is the goal of SACI-1 experiments which operate autonomously and simultaneously in data acquisition, performing the required rate of each one. A brief description of each experiment is presented bellow.

ORCAS

The ORCAS experiment intends to monitor, in the inner magnetosphere, the fluxes and spectra of electrons, protons and He to Ne ion populations of energies bellow 100 MeV/nuc. On board of SACI-1, this experiment consists of two telescopes: Monitoring System of the Alphas and IoNs (MAIN) and PRoton and Electron Counter Telescope (PRE).

Further author information -
M.F.M.F.: E-mail: fatima@dss.inpe.br
J.A.C.N.: E-mail: neri@dea.inpe.br
R.P.J.:E-mail:romualdo@jerimum.crn.inpe.br

It is expected that 8.1 Mbytes of ORCAS raw data will be acquired per day. After compressing, OBC will transmit to Ground Station 4 Mbytes per day of ORCAS payload.

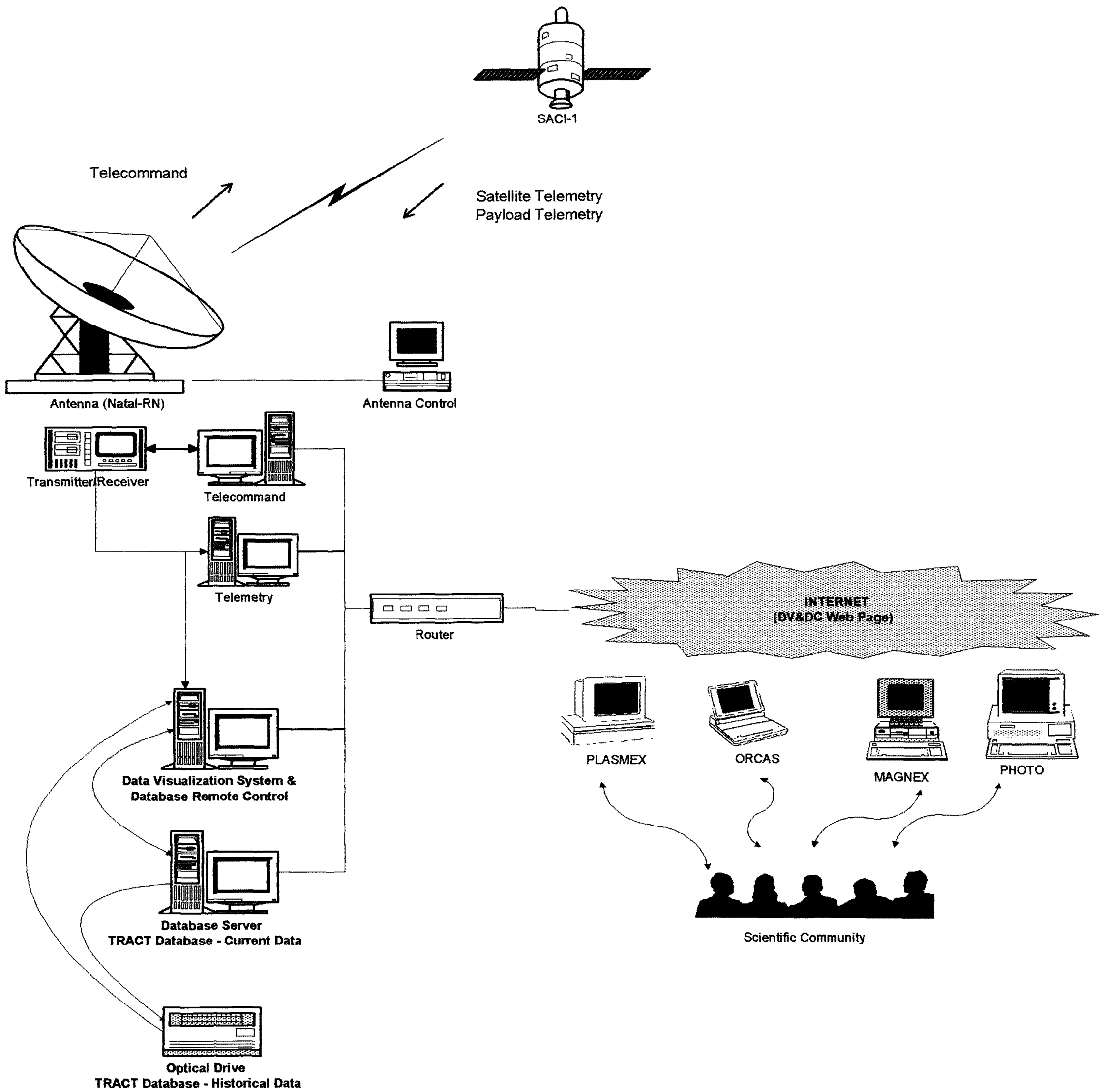

Figure 1 – SACI Network Configuration

PLASMEX

The PLASMa probe EXperiments intend to investigate the phenomenon of ionospheric plasma bubbles, also known as ionospheric depletions, existing in the ionospheric region over a wide range of latitudes. The plasma bubbles and the turbulence associated with them strongly influence diverse space applications systems like trans-ionospheric telecommunication, space geodesy remote sensing with space-borne radars etc. Particularly, the experiment intends to investigate the plasma bubbles generation phenomena, its development and decay over the Brazilian area.

In order to achieve the goals of measuring the density, temperature and spectral distribuition of the irregularities of the plasma, the proposed PLASMEX payload comprises the following set of instruments:

1. High Frequency Capacitance Probe for measuring the plasma density;
2. Fixed bias Langmuir Probe for measuring the electron density profile and the spectral distribuition of plasma irregularities;
3. Electron Temperature Probe for measuring the kinetic temperature of the ionospheric electrons. (This probe shall be fabricated in collaboration with the Institute of Space and Astronautical Science - ISAS, Japan).

It is expected that 155.5 Mbytes of PLASMEX raw data will be acquired per day. After FFT data compactation on part of these data, OBC will transmit to Ground Station 12.3 Mbytes per day of PLASMEX payload.

MAGNEX

The MAGNEX is a geoMAGNetic EXperiment which plans to conduct vector geomagnetic field measurements continuously in three-axis orthogonal components on the SACI-1 scientific satellite. The sensor assembly shall be fixed at the tip of the solar panel in such a way that when the solar panel opens up in space the operation will be smooth.
It is expected that 6,0 Mbytes of MAGNEX raw data will be acquired per day.

PHOTO

The airglow PHOTOmeter experiment intends to investigate the equatorial ionospheric anomaly, South Atlantic magnetic anomaly and dynamic process in the mesosphere in global scale.
The mission of the photometer is to measure intensities of the terrestial airglow emissions, atomic oxygen OI 557,7 nm, OI 630.0 nm, hydroxyl OH (8,3) at 724 nm and Continuum at 578 nm as a function of the latitude and longitude. These measurements of the airglow emissions are done by the proposed PHOTO payload on the first Brazilian scientific microsatellite using 4 sensors with their operation being limited only in the nightside hemisphere. In the polar region, it is also aimed to measure the atomic oxygen auroral emissions.

The photometer will be mounted on one of the satellite boards with its optical axis perpendicular to the spin axis of the satellite which allows spatial scanning of the photometer. The photometer collects the data across the orbit in the tangential direction to the Earth´s surface.
Due to Photometer operation constraints, collecting data only in the nightside hemisphere, the PHOTO acquires data continuosly for 5,67 hours per day. After doing data compactation, the experiment payload to be transmitted to the Ground Station is 3,5 Mbytes per day.

All of the remote sensing data are sent to OBC by each experiment. This task is done under OBC control, following the master-slave approach. The acquired data of all experiments are compressed whenever necessary, and stored in Payload Telemmetry Application Packets (1K bytes each) in OBC for further transmission to Ground Station.
Therefore, an average of 4K packets per day from ORCAS will be received in Ground; 12.3 K packets per day from PLASMEX; 6 K packets per day from MAGNEX and 3.5 K packets per day from PHOTO.
The payload telemetry plus the satellite telemetry are transmitted to Ground Station in 250Kbps rate (an average of 30.2 packets per second). Matching the satellite orbit with the SACI-1 Ground Station position, the satellite visibility will occur, in worst scenario, 15 minuts per day. Thus, an average of 27 K packets of telemetry data can be received and stored per day in the Ground Station Database.

3. SACI-1 GROUND STATION

During the passage DV&DC software system is dedicated to performing Real Time Telemetry reception and visualization while both the Telecommand software system controls the telecommand transmission and the Telemetry software system receives, separates and stores in hard disk the other satellite and payload telemetry data.

Imediatly after each passage, all of the payload telemetry data, previously separated in files, one for each experiment, will be transferred to DV&DC platform.

DV&DC system is a multiuser software system which uses PENTIUM PRO platform with WINDOWS NT environment in order to support many users concurrently in the following tasks:

- Real Time telemetry reception and visualization in real time and playback. This software was implemented in graphic language using the LabVIEW 4.0 facilities;
- Quick-look of all payload telemetry data also using the LabVIEW 4.0 facilities. A unique process was developed. This process is configurable to execute quick-look/playback for each one of the experiments. Many instances of this process can be run concurrently allowing the Ground Station operator to visualize four windows on screen;
- Remote Control of both TRACT database and telemetry data recording in optical drive.

The Payload Telemetry Application Packets with the experiment raw data received in Ground are decompressed and stored in TRACT database as active data. The "very old data" called historical data are transferred to Optical Disk indexed by a predefined period of time (e.g.: per week). Backups and all other Data Base Management System (DBMS) utilities such as loading and performance monitoring are provided by the database server with an efficient fault tolerance system and roll-forward recovery, as described in section 4.

The DV&DC System also provides facilities for queries and reports using Web Page. Through these forms the scientific community can access the SACI-1 remote sensing data.
Specially for the experiment investigators, authorized users, the DV&DC System provides telecommand query forms. With this facility, telecomands can be transmitted directly or by the active feature of the TRACT database. In this case, when an event is automatically detected by checking a telemetry and a condition is matched, an e-mail message with an attached telecommand form is sent to the experiment coordinator. That form is already filled with all parameters and predefined rules. If the coordinator agrees with the suggested automatic telecomand, he sends the form back with no modifications, else he can make changes. After that, the form is forwarded to the Telecomand platform and then transmitted to SACI-1 by the Telecommand Software System.

4. *TRACT* DATABASE

FEATURES

TRACT database carries the main features of advanced databases. It's called TRACT because of the Temporal, Relational, Active, Scientific and Textual capabilities, giving the idea of extended databases.
Due to using the SOLID Server Relational Data Base Manager System (RDBMS) developed by Solid Information Technology Ltda, TRACT database temporal approach considers current data and old data, not just a point in time but a period or range of time as well [2]. This historical data recovery feature requires a maintenance of an internal efficient indexing method for the database, which might support a very large database. Most databases get slow as they grow. In order to solve this problem, the active new data (current data) are separeted from older ones (historical data). According to this strategy, the SOLID Server uses a small active index, the unique *Bonsai Tree*™ , in the central memory. More historical data is maintained in the storage server. Thus, the fast and efficient Bonsai Tree provides conflict detection and a consistent view of data ensuring optimal performance also with very large databases.

Aditionally, the SOLID Server RDBMS Engine provides true multi-thread SMP architecture and parallel processing; intelligent row-level transaction management; unique combination of pessimistic and optimistic concurrency control; multiversion to offer efficient post-relational object references; variable lenght columns and powerful BLOB support; reduced memory usage by prefix and suffix compressing of index leaves; automatic roll-forward recovery and other features like low-cost that justify its use in this project [3].
Using all of those facilities, TRACT database model is relational and it is represented as a collection of tables, where each table can be stored as a separated file. It uses SQL as the relational database language. More tables are in the third normal form (3NF) with eventual controlled data redundances.

A special feature of TRACT database is that it is an active database based on event-conditions-actions rules predefined by the experiment coordinators. When an event occurs and a condition expression evaluates to true, an action is automatically triggered by the database without the interference of a traditional external operation[4]. This capability is useful to treat some anomalous conditions identified by the database. The action can be an e-mail message or an alert signal presenting the ocurred event.

TRACT is a scientific database and it makes difference. Its data are relatively static and the retention is indefinite. TRACT has a low update frequency and old data are never discarded. Then, becoming a very large database is a question of time. The raw/sensor data consists of the values obtained directly from the measurement devices of each sensor experiment in SACI-1 satellite. Normally, they are seldom saved. The calibrated data consists of raw physical values, corrected with calibration operators in the experiment microcontrollers. After that, data can be validated by a filtering process with quality-assurance procedures. In some cases, data can be derived, consisting of aggregations like FFT process. Finally, the data are interpreted. This consists of the data that is related to other data sets or to the literature of the field [5].
The last feature of TRACT is that it is textual. The literature of the field and some considerations of specialists can be stored in the database for textual searches. Data are stored in two parts: the header and the body. The first one has the standard and formatted data like title, authors, keywords etc. and the body is a free textual block identified by a file with a *.txt* extension.

The architecture of Telemetry Data Visualization & Database Remote Control System is client/server, with two basic platforms: Linux and Windows NT. TRACT database is maintained and stored in the server, under Red Hat Linux operating system. For database administrators (DBAs) the client machine provides a complete database managing and remote control with an user-friendly interface under Windows NT environment, where the application modules for end-users take place. Such modules are REFERENCE (the scientific textual references module), TEMPORAL (the temporal query interface module) and BASIS (the most common queries module). Each one of those modules are accessible by authorized scientists (by giving a valid password for the System) in Internet. It will be possible using World Wide Web pages with prepared query forms that gives back the results in HTML format documents for the users.

DATA MODELLING

The Entity-Relationship model (ExR) for TRACT database is illustrated in the figure 2. In this model the EXPERIMENTS entity is an generalization of PLASMEX, PHOTO, MAGNEX and ORCAS entities. One of these entities is described, as an example in the figure 3.

Three distinct data modules can be considered in the model: textual data, telemetry data and telecommand data modules. Entities and relations data are described in Tab. 1, and in Tab.2 for the example mentioned above, where primary keys are indicated by an asterisc. The analogic acquired signals are converted to digital ones on each experiment microcontroller boarded on the SACI-1 satellite.

The RELATIONSHIP names presented in figures 2 and 3 are described bellow:

R1 = *reference*
R2 = *regulate*
R3 = *associate*
R4 = *regulate*
R5 = *activate*
R6 = *has*
R7 = *index*
R8 = *classify*
R9 = *index*
R10 = *index*
R11 = *obtained in*

R12 = *write*
R13 = *reference*
R14 = *from*
R15 = *belong*
RMA1 = *xyz/st* (related to Fig.3)

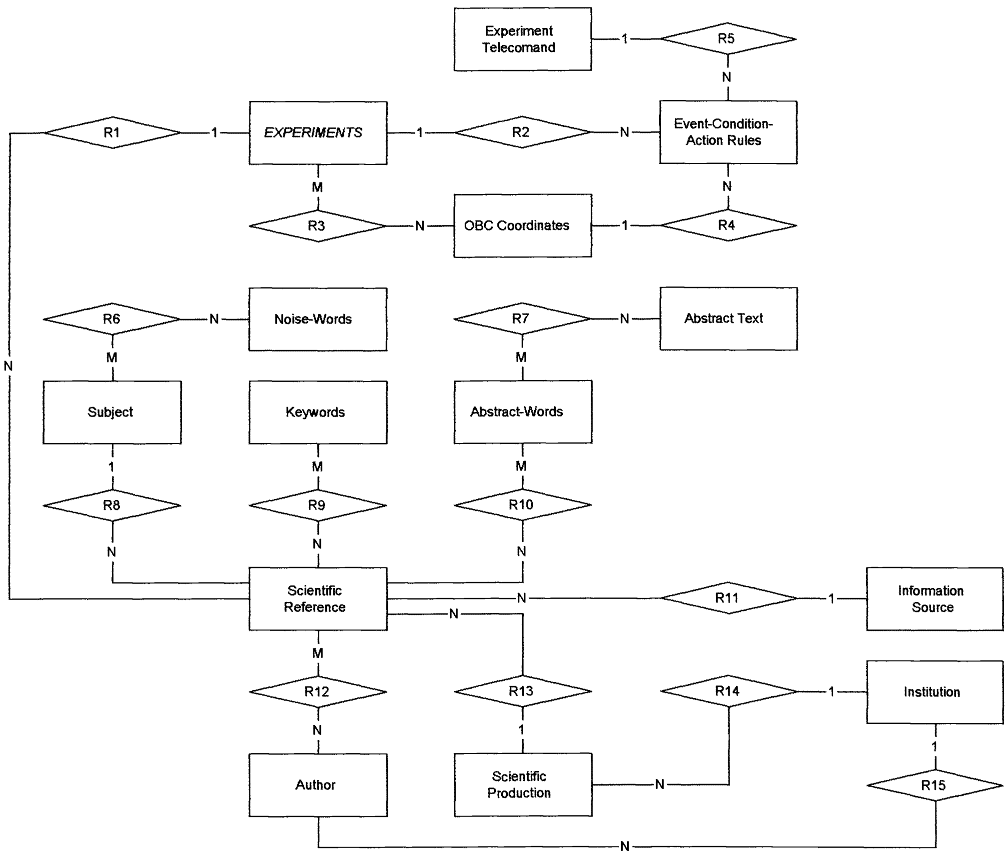

Figure 2 – TRACT DATABASE X ExR Model

Table 1 – TRACT Data Dictionary

Entity/Relationship	Data	Description
Scientific Reference	Ref_code*	Scientific reference automatic code
	Ref_title	Title of the reference
	Subject_acronym	(Foreign-key to Subject entity)
	Prod_type	(Foreign-key to Scientific Production entity)
	Source_code	(Foreign-key to Information Source entity)
	Author_ID	(Foreign-key to Author entity)
	Inst_code	(Foreign-key to Institution entity)
	Inclusion_date	Date of inclusion of the reference data

Author	Author_ID*	Author identification of the reference
	Author_name	Name of the author
	Author_email	E-mail of the author
	Author_inst	(Foreign-key to Institution entity)
Scientific Production	Prod_type*	Type of the scientific production
	Prod_edition*	Edition of the scientific production or publication
	Prod_date	Year of publication
	Prod_inst	(Foreign-key to Institution entity)
	Prod_ISBN	International code of the publication
Subject	Subject_acronym*	Acronym of the subject
	Subject_desc	Description of the subject
Noise-Words	Subject_acronym*	(Foreign-key to Subject entity)
	Stop-word*	Word not significant in context
Abstract Text	Text_filename*	Name of the abstract text file in .txt or .bak extension
	Path	Directoy where the file is stored
Keywords	Ref_Code*	(Primary key of Scientific Reference entity)
	Key_word*	Keyword of the reference
Abstract-Words	Word*	Indexed word from text file
	Ref_Code*	(Primary key of Scientific Reference entity)
	Text_file*	Name of the abstract text file in *.txt* format
Information Source	Source_code*	Code of the source which has the informations to the reference
	Source_desc	Description of the information source
Ref-Source	Ref_code*	(Primary key of Scientific Reference entity)
	Source_code*	(Primary key of Information Source entity)
	Source_volume	Volume identification
	Source_no	Number identification
Institution	Inst_code*	Code of the institution
	Inst_name	Institution complete name
	Inst_address	Address of the institution
	Inst_city	City
	Inst_state	State or Province
	Inst_country	Country
	Inst_URL	URL address for Web pages in the Internet
	Inst_email	E-mail to contact the institution
Experiments	TM_code*	Code of the experiment
	TM_name	Descriptive name of the experiment
	TM_purpose	Purpose of the experiment
	TM_coord	(Foreign-key to Author entity)
OBC Coordinates	OBC_counter*	OBC timer value stamped when the packet is

		assembled by OBC
	OBC_altitude	Altitute coordinate of the satellite
	OBC_latitude	Latitude coordinate of the satellite
	OBC_longitude	Longitude coordinate of the satellite
	OBC_atitude	Satellite atitude (orientation information)
	OBC_temperature	Temperature measured by OBC
Experiment Telecomand	TC_seq*	Telecomand generation sequence
	TC_type	Telecomand type: 0 = Automatic generation based on the predefined E-C-A rules of the active database; 1 = Generated by the mission control; 2 = Generated or modified by the coordinator
	TC_resp_code	(Foreign-key to Author entity)
	TC_command	Telecomand to transmit to On Board Computer
	TC_status	Sending status of the telecomand: 0 = Not transmitted; 1 = Sent to coordinator by e-mail 2 = Authorized by coordinator via Internet 3 = Not authorized 4 = Transmitted to On Board Computer
ECA Rules	ECA_code*	Code of the Event-Condition-Action rule
	ECA_rule	Event-Condition-Action rule defined by the coordinator
	ECA_author	(Foreign-key to Author entity)

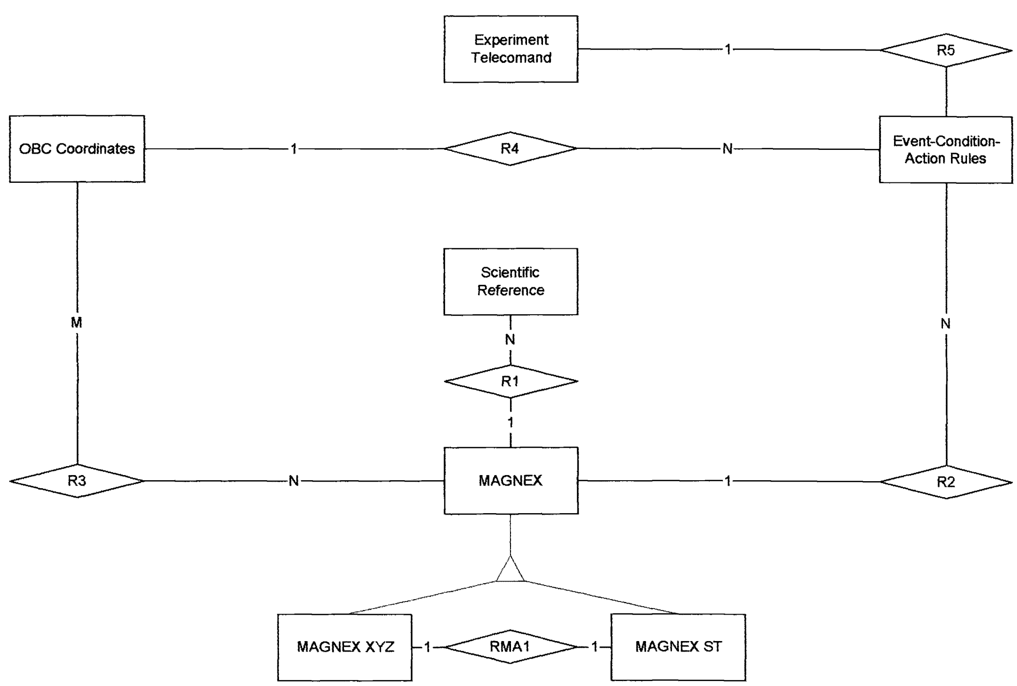

Figure 3 – MAGNEX Module in the ExR Model

Table 2 – TRACT/MAGNEX Data Dictionary

Entity/Relationship	Data	Description
MAGNEX_XYZ	TM_code*	(Primary key of Experiments entity)
	OBC_exp_counter*	Experiment time counter when the data are acquired by Magnex microcontroller (TCK)
	Magnex_oper*	Operation mode in which the data were acquired
	Magnex_rtime*	Experiment real timer value stamped when the data are registered by Magnex microcontroller
	Magnex_seq*	Sequencial number of the measurements, from 0 to n (undefined)
	Magnex_X	X orthogonal component of the geomagnetic field
	Magnex_Y	Y orthogonal component of the geomagnetic field
	Magnex_Z	Z orthogonal component of the geomagnetic field
MAGNEX_ST	TM_code*	(Primary key of Experiments entity)
	OBC_exp_counter*	Experiment time counter when the data are acquired by Magnex microcontroller (TCK)
	Magnex_oper*	Operation mode in which the data were acquired
	Magnex_rtime*	Experiment real timer value stamped when the data are registered by Magnex microcontroller
	Magnex_st_seq*	Sequencial number of the status, from 0 to n (undefined)
	Magnex_status	Status data

QUERY LANGUAGE

The SQL syntax used in TRACT database is provided by SOLID Server and it is based on the ANSI X3.135-1989 standard level 2, including important extensions of ANSI X3.135-1992 (SQL2) standard and new ANSI SQL3 draft.

Some examples of queries are presented bellow:

a) What are the OBC and MAGNEX coordinates in a given latitude (lat) and longitude (lon) of SACI-1 satellite?

```
SELECT *
FROM OBC_Coordinates, MAGNEX_XYZ
WHERE OBC_Coordinates.OBC_counter = MAGNEX_XYZ.OBC_counter AND
        OBC_latitude = 'lat'  AND
        OBC_longitude = 'lon'
```

b) What was the LPSAC127 signal of PLASMEX experiment when the SACI-1 temperature was equal to 'temp', ordered by acquisition time?

```
SELECT LPSAC_rtime, LPSAC_signal
FROM OBC_Coordinates, PLASMEX_LPSAC
WHERE OBC_Coordinates.OBC_counter = LPSAC.OBC_counter AND
        OBC_temperature = 'temp'  AND
        LPSAC_seq =  127
 ORDER BY LPSAC_rtime
```

c) Give me the the references about 'electron' as a word in the body of the textual document. I want the title of the document, the institution, the name and the e-mail of the author.

```
SELECT Ref_title, Author_name, Author_email, Inst_name
FROM Scientific_Reference, Author, Institution, Abstract_Words
WHERE Scientific_Reference.Ref_code = Abstract_Words.Ref_code  AND
          Word like '%electron%' AND
          Scientific_Reference.Author_ID = Author.Author_ID  AND
          Scientific_Reference.Inst_code = Institution.Inst_code
```

5. CONCLUSIONS

The data flow related to the experiment observation of the SACI-1 mission will be transmitted to the Ground Station in the Payload Telemetry Application Packets. Each packet carries 1K bytes of raw data of only one experiment.
The four experiments of SACI-1 mission will assembly an average of 25,8 K packets payload telemetry per day, 95,55% of the total telemetry packets transmited to the SACI-1 Ground Station.
Considering that the estimated satellite life time is about 2 years long, at the end of the SACI-1 mission, a volume of 3.5 Giga packets of payload telemetry will be stored in SACI-1 Ground Station TRACT Database.

After the SACI-1 remote sensing data being acquired, identified and separated at the Ground Station, by the Telemetry Packet Processor Software which was developed in graphical language LabVIEW and runs in the Telemetry platform, all of these data will be forwarded to the Telemetry Quick-looker software resident in Data Visualization platform. That software, also developed in LabVIEW, allows the Ground Station operator to visualize in parallel both the payload telemetry data recently received in the last satellite passage over the Ground Station and the old one by doing playback. The TRACT Database supported by the SOLID Server, resident in the same platform, allows the access of many users concurrently. The investigators can have their experiment data from TRACT Database at any time via INTERNET using SQL syntax.

The TRACT database modelling for SACI-1 mission will facilitate the final analysis of the space plasma data and will result in both quick and well informed management level decisions to the experiment investigators.

ACKNOWLEDGMENTS

This work was supported by the Study and Project Brazilian Financier - Finep.

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