Satellite Anomaly Analysis and Prediction System

SAAPS – WP 110
Database and Database Tool User Requirements Document

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Version 1.1

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Abstract

This document describes the user requirements of the database and the database tool. The database and database tool are one module of the Satellite Anomaly Analysis and Prediction System (SAAPS).

Table of contents

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1   Introduction

1.1   Purpose of the document

The Satellite Anomaly Analysis and Prediction System (SAAPS) contain 3 subsystems: the database and database tool (DB&T), the satellite anomaly analysis module (SAAM), and the satellite anomaly prediction module (SAPM). The purpose of this document is to capture the user requirements for the DB&T.

1.2   Scope of the software

1.2.1   Introduction to SAAPS

The space plasma and radiation form a hazardous environment to Earth orbiting spacecraft. Spacecraft problems are regularly experienced which in extreme cases lead to a failure or loss of the spacecraft. The anomalous behaviour of spacecraft can partly be explained by technological problems or by the human factor, and partly by the space environment.

SAAPS is intended to be a web-based tool for the analysis and prediction of spacecraft anomalies. Spacecraft engineers shall be able to analyse the space environment data to better understand situations for spacecraft anomalies. Spacecraft operators can use SAAPS for real-time monitoring of the space environment data and to make predictions of future anomalies.

The user of SAAPS shall have access to a database of space weather data, tools for analysing the data, and models for the prediction of spacecraft anomalies. The database shall be updated in real time from various external databases on the Internet. The user shall also have access to online documentation and guidelines of what tools to use for a specific problem.

1.2.2   Database and database tool

The database is one important part of SAAPS as it is from the data that the analysis and prediction tools shall be developed. The database shall consist of time ordered data from several different sources describing the solar wind and the magnetosphere. The database shall also contain reported spacecraft anomalies. The database shall first be set up from existing data and shall then be continuously updated with real time data.

The database tool shall provide all the methods for the access to the database. They shall provide the necessary interfaces to the analysis and prediction modules. The database tool shall also update the database in real time from data that exist on the Internet. There shall also be an interface for the addition of new satellite anomaly data to the database.

1.3 Definitions, acronyms and abbreviations

ACE	Advanced Composition Explorer
DBT	database tool
DB&T	database and database tool
GOES	Geosynchronous Operational Environmental Satellites
IMF	interplanetary magnetic field
IRF	Swedish Institute of Space Physics (Institutet för rymdfysik)
LANL	Los Alamos National Laboratory
NaN	Not a Number
NSSDC	National Space Science Data Center
SAAM	satellite anomaly analysis module
SAAPS	satellite anomaly analysis and prediction system
SAPM	satellite anomaly prediction module
SPEE	study of plasma and energetic electron environment and effects
UL1	user level 1
UL2	user level 2
WDC	World Data Center

1.4 References

1. ESA software engineering standards, ESA PSS-05-0 Issue 2, February 1991.

2. Guide to the user requirements definition phase, ESA PSS-05-02 Issue 1, October 1991.

3. NSSDC OMNIWeb, `www.nssdc.gsfc.nasa.gov/omniweb/`.

4. GOES space environment monitor CD-ROM, NOAA, June 1994.

5. GOES space environment monitor CD-ROM, NOAA, September 1997.

6. NSSDC spacecraft anomaly database 1988, NOAA, May 1989.

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1.5 Overview

The structure of this document follows the document template as described in the ESA software engineering standards [1] and user requirements guide [2].

Section 2 describes, in general terms, the user requirements of the DB&T. Then, in Section 3, the requirements are itemised as a number of capability requirements and constraint requirements.

2   General description

2.1   Product perspective

The DB&T is one module of the SAAPS. The other modules depend on the existence of the DB&T for the access to the database. The SAAPS is a standalone system.

2.2   User characteristics

There shall be two levels of user access to SAAPS: user level 1 (UL1) and user level 2 (UL2).

2.2.1   User level 1

At UL1 one shall have full access to the data, source codes, and documentation. This shall only be a hand-full of people that are involved in the development and the maintenance of SAAPS. One such user is the system manager of SAAPS. The system manager should have a good knowledge of computers, web techniques, and Internet. He should have good knowledge in HTML and Java programming. He is also responsible for the extension of the database, which might come as a request from UL2 that wish to add new data. However, all new data that are added must first be agreed by ESA/ESTEC. It is especially new satellite anomaly data that will be added in this way.

2.2.2   User level 2

At UL2 we find the users that are interested in the SAAPS as a tool, and at least two groups can be identified: spacecraft engineers and spacecraft operators. The access to SAAPS at UL2 shall be via a web browser.

If a user wish to add new anomaly data he must be registered to SAAPS. The registration can be made the first time the user submits data, and after approval by ESA/ESTEC he shall obtain a user id and password for future use. The user id shall be related to the coding scheme to ensure confidentiality.

2.2.3   The DB&T user

As for SAAPS, the user at UL1 shall have full access to the DB&T code, data, and tools.

At UL2 there is no need to access the DB&T directly, this is instead done via the SAAM and the SAPM.

2.3 General capabilities

2.3.1 Database

The purpose of the database is twofold and can be divided into two classes: 1) historic data that are used to derive parameters for the development of models and analysis of anomaly events; 2) real time data that are used to derive the same parameters for real time predictions. The database shall contain solar wind plasma and magnetic field data, electron fluxes from various satellites in the magnetosphere, planetary magnetic indices, and satellite anomaly data. A key parameter is the time of each observation, which shall be stored together with the data. The spacecraft position is another key parameter that shall be stored in the database when available.

2.3.1.1 Historic data

The database shall be created with data from various sources on the Internet and from several CD's. The data that shall be included are summarised in Table 1.

The NSSDC OMNI data set [3] contains several of the parameters that shall be included. The solar wind data is composed from different spacecraft extending from 1963 and onwards. The time resolution is 1 hour. The Dst and Kp indices shall also be downloaded from the OMNI data set.

Magnetospheric keV electron flux data should be included in the data set. Currently it is assumed that the data will be available from LANL. The time resolution, the energy ranges, and the data coverage are to be determined. If LANL data will not be available alternative data sources shall be examined.

Magnetospheric MeV electron flux data from the GOES satellites shall be included. CD-ROM's [4,5] with this data was purchased for the SPEE study and they contain 1- and 5-minute average electron flux data from January 1986 to August 1997.

Currently, the database contains reported anomalies from the Meteosat-3, Tele-X, Marecs-A, and NSSDC [6] anomaly data sets.

It shall be possible to include new anomaly and space weather data sets to the database. This needs the interaction of the SAAPS system manager and must be approved by ESA.

Table 1 Summary of the historic space weather data that shall be included in the database.

Parameter	Time resolution	Period	Source
IMF Bx	1 hr	Nov. 1963 – Feb. 1999	OMNI
IMF By	1 hr	Nov. 1963 – Feb. 1999	OMNI
IMF Bz	1 hr	Nov. 1963 – Feb. 1999	OMNI
Solar wind density	1 hr	Nov. 1963 – Feb. 1999	OMNI
Solar wind velocity	1 hr	Nov. 1963 – Feb. 1999	OMNI
Dst	1 hr	Nov. 1963 – Dec. 1997	OMNI
Kp	3 hr	Nov. 1963 – May 1999	OMNI
Magnetospheric keV electrons	tbd	tbd	LANL
Magnetospheric MeV electrons	1 & 5 min	Jan. 1986 – Aug. 1997	GOES
Magnetospheric MeV protons	1 & 5 min	Jan. 1986 – Aug. 1997	GOES
Solar X-ray flux	1 & 5 min	Jan. 1986 – Aug. 1997	GOES

2.3.1.2 Real time data

The database shall be automatically updated in real time from the sources listed in Table 2.

Solar wind particle and magnetic field data are obtained from the ACE spacecraft with a time resolution of 1 minute.

The models for the prediction of daily average solar wind velocity [7] using Wilcox Solar Observatory (WSO) magnetograms shall be included, under the assumption that the WSO is operating and producing real time magnetograms. This needs further investigation. The high-speed plasma streams can be predicted 2 to 4 days in advance, while transient structures like CME's can not be predicted with this model. Access to European solar magnetogram data shall also be investigated.

It is assumed that the LANL electron and proton data will be available in real time. If this is not the case alternative sources shall be examined.

Real time data from the GOES 8 and 10 satellites are available at 5 minute time resolution. The electron flux comes in the energy intervals: >0.6 MeV, >2.0 MeV, >4.0 MeV. The proton flux comes in the energy intervals: >1, >5, >10, >30, >50, and >100 MeV. The solar X-ray flux are given at two levels: short (0.5-4 Å) and long (1-8 Å).

The preliminary Kp index is available with about 12 hours time lag and the preliminary Dst index is available with about 24 hours time lag.

From the ACE solar wind data predictions are available of the Kp [8],Dst [9], and AE [10] indices. Kp is predicted up to 3 hours in advance and the Dst and AE indices are predicted 1 hour in advance. Occasional data gaps exist when there are data gaps in the ACE data.

Table 2 Summary of the real time data that shall be included.

Parameter	Time resolution	Time lag	Source	FTP address
IMF Bx	1 min	2 min	ACE	ftp://ftp.sec.noaa.gov/pub/lists/ace/ace_mag_1m.txt
IMF By	1 min	2 min	ACE	ftp://ftp.sec.noaa.gov/pub/lists/ace/ace_mag_1m.txt
IMF Bz	1 min	2 min	ACE	ftp://ftp.sec.noaa.gov/pub/lists/ace/ace_mag_1m.txt
Solar wind density	1 min	2 min	ACE	ftp://ftp.sec.noaa.gov/pub/lists/ace/ace_swepam_1m.txt
Solar wind velocity	1 min	2 min	ACE	ftp://ftp.sec.noaa.gov/pub/lists/ace/ace_swepam_1m.txt
Magnetospheric MeV electron and proton flux	5 min	10 min	GOES	ftp://ftp.sec.noaa.gov/pub/lists/particle/G8part_5m.txt ftp://ftp.sec.noaa.gov/pub/lists/particle/G10part_5m.txt
Solar X-ray flux	5 min	10 min	GOES	ftp://ftp.sec.noaa.gov/pub/lists/xray/G8xr_5m.txt ftp://ftp.sec.noaa.gov/pub/lists/xray/G10xr_5m.txt
Magnetospheric keV electron flux	tbd	tbd	LANL	tbd
Dst	1 hr	24 hr	WDC-C1	http://swdcdb.kugi.kyoto-u.ac.jp/dstdir/dst1/q/Dstqthism.html
Kp	3 hr	12 hr	WDC-A	ftp://ftp.sec.noaa.gov/pub/latest/DGD.txt
Dst, predicted	1 hr	1 hr pred.	IRF-Lund	ftp://ftp.irfl.lu.se/pub/Dst/forecast.txt
AE, predicted	10 min	1 hr pred.	IRF-Lund	ftp://ftp.irfl.lu.se/pub/AE/forecast.txt
Kp, predicted	3 hr	3 hr pred.	IRF-Lund	ftp://ftp.irfl.lu.se/pub/Kp/forecast.txt
Daily average solar wind velocity	24 hr	2 d pred.	IRF-Lund	ftp://ftp.irfl.lu.se/pub/V/forecast.txt

2.3.1.3 Satellite anomaly data

The satellite anomaly data shall at least contain the time of the anomaly. If any further information is available it shall also be stored in the database. It shall be possible to store the following data:

- time of anomaly

- timing uncertainty of the anomaly

- orbit of the satellite (metadata)

- position of the satellite at the time of the anomaly

- description of the satellite (metadata)

- code name (metadata)

Due to the confidentiality of the anomaly data it shall be stored using code names that can not be linked to the provider of the data. The code name shall consist of a three digit number, that is unique for each anomaly set. The anomaly sets will thus have the names ANOM001, ANOM002, and so on. The list linking each code name to the different anomaly data providers shall not be stored in the SAAPS system.

The user shall never be able to list the anomaly data from the SAAPS database. However, the user may provide its own anomaly data to perform analysis locally in the client application. This is part of the analysis module (SAAM).

2.3.1.4 Metadata

Each parameter that is stored in the database shall have associated metadata. The metadata shall hold information about the source of the data, the time resolution, the first and last instance of the parameter in the database, and any other ancillary information.

2.3.1.5 Relation between historic data and real time data

Generally, there will be several versions of the same parameter in the database (Figure 1).The data that are available in real time over the Internet shall also be put into the database in real time. Other data, like much of the historic data, needs the interaction of the system user to be updated.
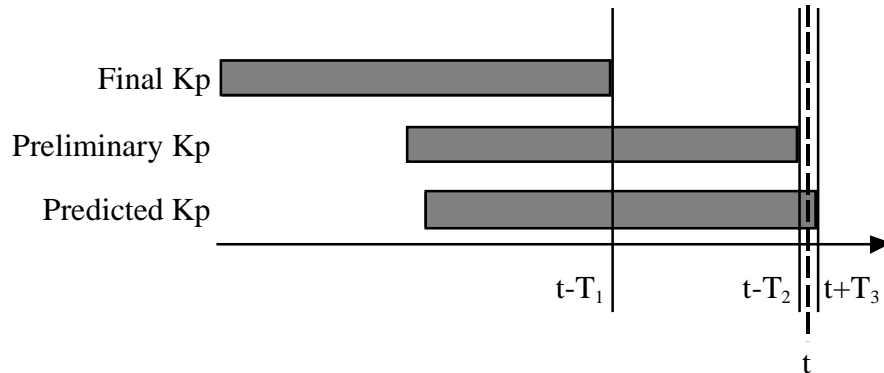
Figure 1. This example shows the three version of Kp: final Kp, preliminary Kp, and predicted Kp, where T_1 is about 1 year, T_2 up to 24 hours, and T_3 3 hours. Current time is t.

2.3.2 Database tool

The database tool provides the interface to the database. The DBT shall support the following basic methods:

- create metadata for a new parameter,

- update the metadata for an existing parameter,

- remove the metadata for an existing parameter,

- store a time series of a new parameter,

- append a time series to an existing parameter,

- remove data for an existing parameter,

- extract the metadata for one or several parameters,

- extract a time series of a given parameter,

- and convert SAAPS data format to and from ASCII format.

When data for a parameter are stored for the first time in the database the metadata shall also be automatically created. The user shall also be queried for additional information that should be stored in the metadata.

The real time data are downloaded from the Internet automatically with regular intervals and appended to the existing data. For example, the 3 hour Kp data are downloaded and stored in the database every 3rd hour.

Adding historic data, or anomaly data, needs the interaction of the SAAPS system user. If the parameter already exists in the database the new data shall simply be appended when the system user runs an existing program. If a new parameter shall be stored it needs the writing of a few lines of code that defines the format of the input data and what data that shall be stored.

The DBT shall also include an interface so that the metadata and data can be inspected. As it shall be possible to convert the data in the database to and from ASCII format, it shall possible to generate files with ASCII data.

The analysis module (SAAM) and the prediction module (SAPM) shall then interact with the database through the database tools (DBT) to provide plotting and further analysis.

2.4 General constraints

The database contains reported satellite anomalies that are to be treated as confidential information. UL1 shall have full access to the data, while UL2 shall have no direct access to the data.

Data gaps may occur in all the parameters used in the database. The DBT shall not make any interpolation of the data gaps, but instead indicate uniquely when they occur.

The network communication may also fail at times, and after such periods the database tools shall automatically trace back in time to ensure that no observations of a parameter is missing. The time the network can be down without introducing data gaps in the database depends on the source. E.g., the latest 1 minute solar wind data from the ACE spacecraft are available over the last 2 hours, whereas the latest preliminary Kp are available over the last 30 days. Thus, the network can be down for up to 2 hours for the ACE data and up to 30 days for the Kp data, without any loss of data. If these limits are exceeded the system manager must manually update the database. The ACE data has been automatically downloaded to a prototype of the database for one month, and during this period the network connection has failed several times but always less than 2 hours.

2.5 Assumptions and dependencies

The continuos update of the database assumes that the data discussed above are available in real time over the Internet. It also assumed that the data format from those sources is not changed.

If the Internet connection is down then, depending on how long the interruption is, the effects on the database can be of two types. Firstly, if the network is down for a period shorter than extent of the source the database will not be affected. Secondly, if the network is down for a period longer than the extent of the source, then the data for this period will be indicated as data gaps in the database. The missing data can be replace afterwards manually by the SAAPS system user.

If the data format of the source is changed, then the code for the data download must be edited and recompiled. This is straightforward and only includes the change of a few lines of code.

2.6 Operational environment

The DB&T shall be platform independent. To fulfil this requirement the DBT shall be written in Java, and the database objects shall be stored as Java binary data. The DBT

shall have methods for automatic download of data. The DBT can only be operated on the SAAPS server. This means that it will not be possible to access the database directly from a web browser. However, the DBT will be accessible from the SAAM and the SAPM, as shown in Figure 2. During the contract time the module shall be running on a server within the IRF, and for the final presentation be delivered to a server at ESTEC.

The SAAPS can be further divided into its subsystems as shown in Figure 2. The DBT shall have five interfaces: access to the database, connection to users via a web browser, automatic downloads from external databases, connection to SAAM, and connection to SAPM.
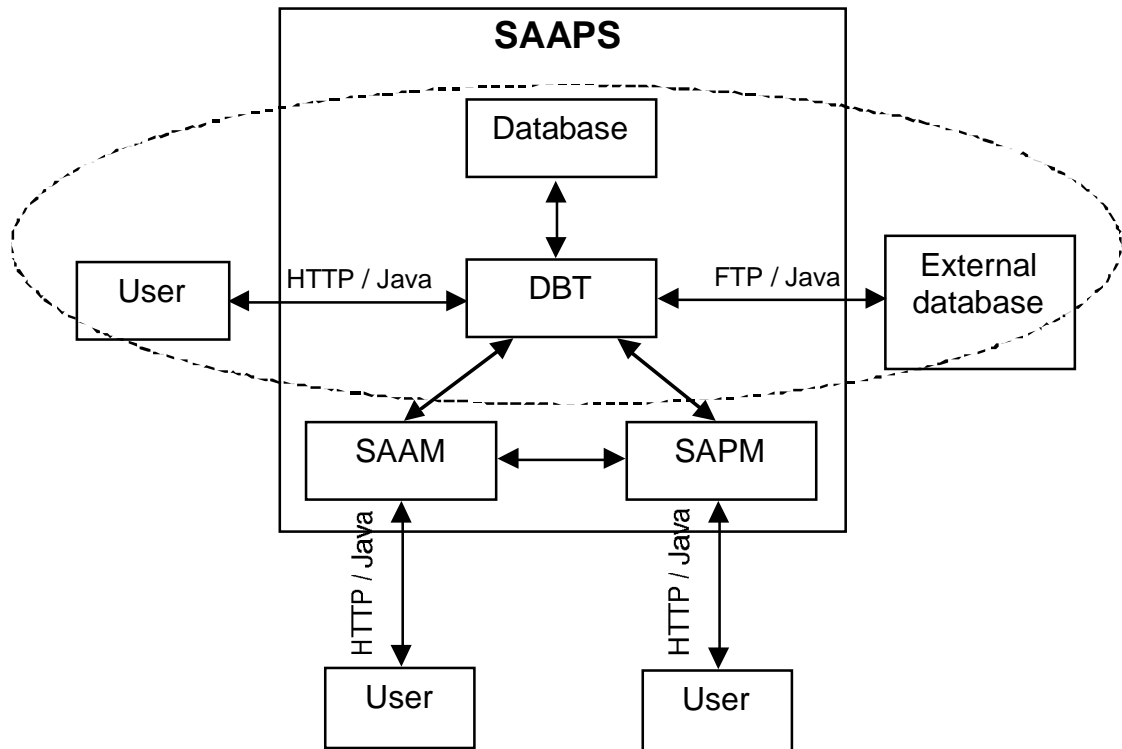
Figure 2 The SAAPS contains the three subsystems: database and database tools (DBT), satellite anomaly analysis module (SAAM), and the satellite anomaly prediction module (SAPM). The encircled region is described in this document.

3 Specific requirements

The specific requirements are divided into two categories: capability requirements and constraint requirements. The capability requirements describe what the user wants to do and one requirement defines an operation that the software shall be able to perform. The constraint requirements place restrictions on how the user requirements are to be met. Each requirement has a unique identifier with the following fields:

1**. DB&T.,** indicates that this requirement is part of the database and database tool,

2**. CAP.** or **CON.,** capability or constraint requirement,

3. a sequential number.

3.1 Capability requirements

DB&T.CAP.1.	The DB&T shall contain the data listed in Table 1.
Source	Section 2.3.1.1
Criticality	Mandatory
Verification	Examine database.
DB&T.CAP.2.	**The DBT shall automatically update the database from the sources listed in** .
Source	Section 2.3.1.2
Criticality	Mandatory
Verification	Examine database.
DB&T.CAP.3.	The DB&T shall store the metadata for each parameter in the database.
Source	Section 2.3.1.4
Criticality	Mandatory
Verification	Examine the metadata.
DB&T.CAP.4.	The DBT shall have a method for creating the metadata when a parameter is stored the first time.
Source	Section 2.3.2
Criticality	Mandatory
Verification	Examine the metadata when a new parameter is stored.

DB&T.CAP.5.	The DBT shall have a method for updating the metadata when new data for a parameter is added.
Source	Section 2.3.2
Criticality	Mandatory
Verification	Examine metadata when new data are added.

DB&T.CAP.6.	The DBT shall have a method for removing the metadata from the database.
Source	Section 2.3.2
Criticality	Mandatory
Verification	Inspect database after the metadata has been removed.

DB&T.CAP.7.	The DBT shall have a method for storing data of a new parameter.
Source	Section 2.3.2
Criticality	Mandatory
Verification	Inspect database after a new parameter has been stored.

DB&T.CAP.8.	The DBT shall have a method to append a time series of new data for an existing parameter.
Source	Section 2.3.2
Criticality	Mandatory
Verification	Add a time series with new data. Examine all cases as described in Section 2.3.2.

DB&T.CAP.9.	The DBT shall have a method to read the metadata.
Source	Section 2.3.2
Criticality	Mandatory
Verification	Read the metadata.

DB&T.CAP.10.	The DBT shall have a method for reading a time series of data for a parameter.
Source	Section 2.3.2
Criticality	Mandatory
Verification	Read a time series.

DB&T.CAP.11.	The DBT shall have a method to remove data from the database.
Source	Section 2.3.2
Criticality	Mandatory
Verification	Remove data and inspect the database.

DB&T.CAP.12.	The DBT shall have a method to convert data from SAAPS format to ASCII format.
Source	Section 2.3.2
Criticality	Mandatory
Verification	Convert SAAPS data to ASCII format.

DB&T.CAP.13.	The DBT shall have a method to convert data from ASCII format to SAAPS format.
Source	Section 2.3.2
Criticality	Mandatory
Verification	Convert ASCII data to SAAPS format.

DB&T.CAP.14.	The DBT shall have an interface where the metadata can be listed.
Source	Section 2.3.2
Criticality	Mandatory
Verification	View the metadata.

DB&T.CAP.15.	The DBT shall have an interface where the data for a parameter can be listed over a time period.
Source	Section 2.3.2
Criticality	Mandatory
Verification	View the data over a time period.

3.2 Constraint requirements

DB&T.CON.1.	Only UL1, SAAM, and SAPM shall have access to the DB&T.
Source	Section 2.4
Criticality	Mandatory
Verification	Demonstrate the restricted access.

DB&T.CON.2.	The DBT shall automatically correct for missing data after times of network malfunction, when the missing data is available at the original source.
Source	Section 2.4
Criticality	Mandatory
Verification	Disconnect from the network for a few hours and then reconnect and examine the database.