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# **Satellite Anomaly Analysis and Prediction System**

## **SAAPS – WP 310 Satellite Anomaly Prediction Module User Requirements Document**

ESA/ESTEC Contract 11974/96/NL/JG(SC)

Version 1.0

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## Abstract

This document describes the user requirements of the satellite anomaly prediction module. The module is one part of the Satellite Anomaly Analysis and Prediction System (SAAPS).

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### **Document status sheet**

Draft version 1, Wednesday 17 November 1999.

Version 1.0, Friday 16 February 2001: Changed SAPM.CAP.10 to Optional.

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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 SAPM.

### **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 will 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 will have access to a database of space weather data, tools for analysing the data, and models for the prediction of spacecraft anomalies. The database will be updated in real time from various external databases on the internet.

#### **1.2.2 Satellite anomaly prediction module**

The satellite anomaly prediction module (SAPM) shall make predictions of satellite anomalies based on the data in the database. The prediction models shall be based on AI techniques, such as neural networks (NN) and fuzzy systems. Various prediction time scales and resolution shall be examined during the development of SAAPS, but as a minimum predictions from one hour ahead to one day ahead shall be implemented. The SAPM shall have two operation modes: prediction mode and training mode. In the prediction mode the existing models can be used for real time predictions or to analyse previous predictions. In the training mode the user can develop dedicated models that are only accessible to the specific user.

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### 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. Haykin, S., Neural networks – A comprehensive foundation, Mac Millan Press, 1999.
4. Kosko, B., Fuzzy systems, 1997.

### 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 SAPM. Then, in Section 3, the requirements are itemised as a number of capability requirements and constraint requirements.

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## **2 General description**

### **2.1 Product perspective**

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

### **2.2 User characteristics**

There will 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 will have full access to the data, source codes, and documentation. This will 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 also have good knowledge in HTML and Java programming.

#### **2.2.2 User level 2**

At UL2 we will 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 will be via a web browser.

#### **2.2.3 The SAPM user**

Anyone potentially interested in studying spacecraft anomalies can use SAPM, but the tools shall be developed with the spacecraft engineers and operators in mind. The SAPM user shall be able to run all the different models from a web browser. The SAPM is especially useful for the users that wish to run the models in real time.

### **2.3 General capabilities**

The SAPM shall provide a number of models for the prediction of satellite anomalies using the data in the SAAPS database. The models shall be based on artificial intelligence techniques, such as neural networks [3] and fuzzy systems [4]. The models shall be able to run in two modes: 1) operational mode, and 2) training mode. In the operational mode one of the existing models is selected and the time period of interest is submitted. The model then requests the relevant parameters over the



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selected time period from the database, perform any necessary normalisation, and runs the neural network which produces the output. The operational mode is used for analysis and real time predictions. In the training mode the user can develop new prediction models.

### 2.3.1 Prediction models

A prediction model is characterised by the input parameters, length of the time delay line, pre-processing, NN architecture, output parameter, prediction time, and the time resolution of the prediction. The exploration of different models shall be part WP 320, and from this, several models will be identified and inserted into SAPM. For each model, the model description is stored in the database. The model description includes a descriptive text and the model characteristics.

### 2.3.2 User interface

All the models shall be available from a web browser. The models shall be displayed in a list. From the list the user can get the model description, run the model in real time operation, or make predictions over a selected time period. The output from the model shall be displayed as a plot or as a table.

### 2.3.3 SAAM interface

All the models in SAPM shall also be available to SAAM. From SAAM a request to run a model for a certain time period will be made and SAPM shall return the result.

### 2.3.4 Training mode

The user shall also be able to develop a new model. The user will be requested to define the model description. In addition to this, the user also has to determine the training, validation, and test sets. He can then proceed to train, validate and test the model. After successful training the user can request the SAAPS system manager to include the new model in SAPM.

### 2.3.5 Online manuals

There shall exist online manuals for the SAPM. The manuals will help the user to operate SAPM.

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## 2.4 General constraints

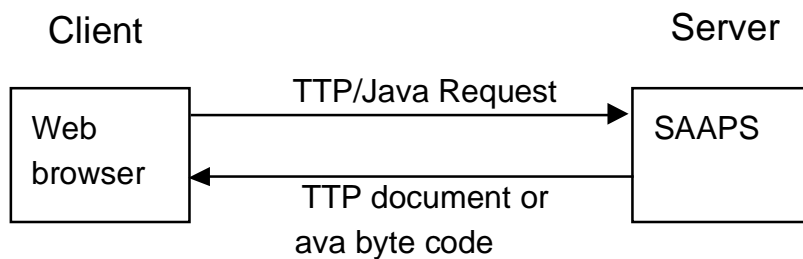
The input to the SAPM shall be the data from the SAAPS database.

## 2.5 Assumptions and dependencies

To be able to run SAPM the DB&T must exist.

## 2.6 Operational environment

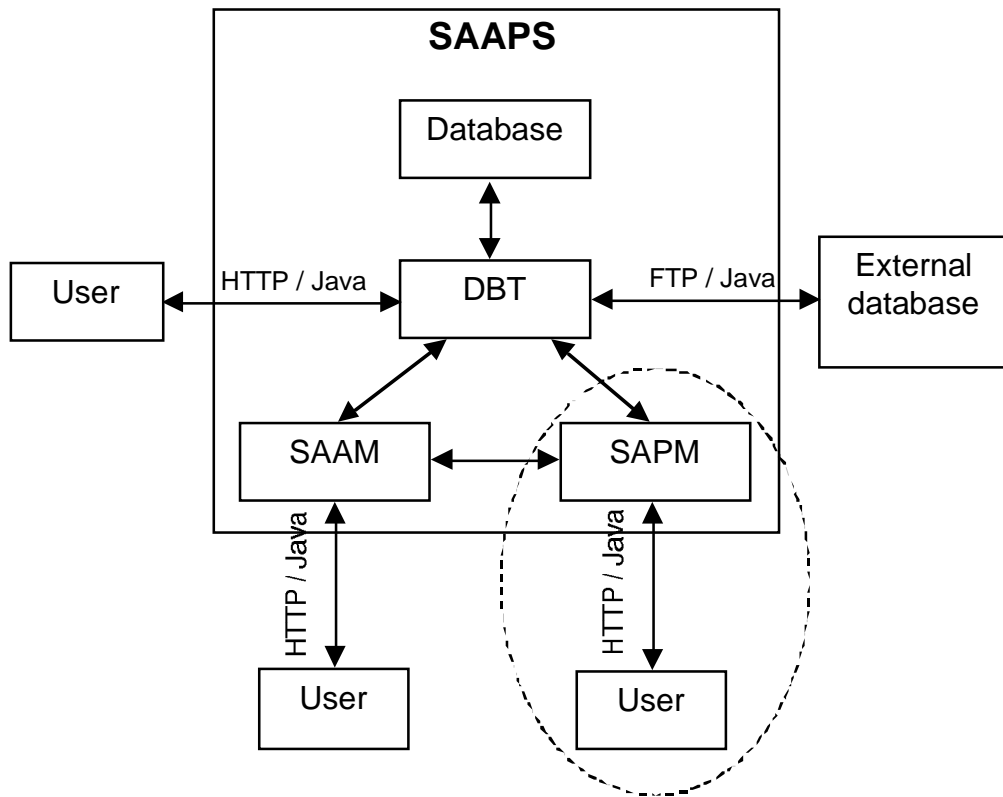
The SAPM shall be platform independent. To fulfil this requirement SAPM shall be written in Java. The module shall be operated via a web browser such as Microsoft Explorer 4 or Netscape Communicator 4 (Figure 1). During the contract time the module will be running on a server within the IRF, and at the final presentation be delivered to a server at ESTEC.



**Figure 1** The figure illustrates the communication between the client (user) and the server.

The SAAPS can be further divided into its subsystems as shown in Figure 2. The SAPM will have three interfaces: access to the database via the DBT, connection to users via a web browser, and connection to SAAM.

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**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 will 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.

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### 3.1 Capability requirements

<b>SAPM.CAP.1.</b>	The SAPM shall contain models for satellite anomaly predictions.
Source	Section 2.3.1
Criticality	Mandatory
Verification	
<b>SAPM.CAP.2.</b>	The SAPM shall be extendible to include new prediction models.
Source	Section 2.3.4
Criticality	Mandatory
Verification	
<b>SAPM.CAP.3.</b>	Each prediction model shall be stored in the database.
Source	Section 2.3.1
Criticality	Mandatory
Verification	
<b>SAPM.CAP.4.</b>	The models shall be accessible from a web browser.
Source	Section 2.3.2
Criticality	Mandatory
Verification	
<b>SAPM.CAP.5.</b>	The models shall be accessible from SAAM.
Source	Section 2.3.3
Criticality	Mandatory
Verification	
<b>SAPM.CAP.6.</b>	There shall exist the possibility to plot the predictions in the web browser.
Source	Section 2.3.2
Criticality	Mandatory
Verification	
<b>SAPM.CAP.7.</b>	There shall exist the possibility to list the predictions in the web browser.

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Source	Section 2.3.2
Criticality	Mandatory
Verification	
<b>SAPM.CAP.8.</b>	The user shall be able to run the predictions in real time.
Source	Section 2.3.1
Criticality	Mandatory
Verification	
<b>SAPM.CAP.9.</b>	The user shall be able to run the predictions for a selected time period.
Source	Section 2.3.1
Criticality	Mandatory
Verification	
<b>SAPM.CAP.10.</b>	The user shall be able to train a neural network.
Source	Section 2.3.4
Criticality	Optional
Verification	
<b>SAPM.CAP.11.</b>	There shall exist online manuals for the operation of SAPM.
Source	Section 2.3.5
Criticality	Mandatory
Verification	

### 3.2 Constraint requirements

<b>SAPM.CON.1.</b>	The SAPM shall only use data from the SAAPS database.
Source	Section 2.4
Criticality	Mandatory
Verification	