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SATNET PROJECT

USER SPECIFICATION

REFERENCE: SATNET-1-USERSPECIFICATION

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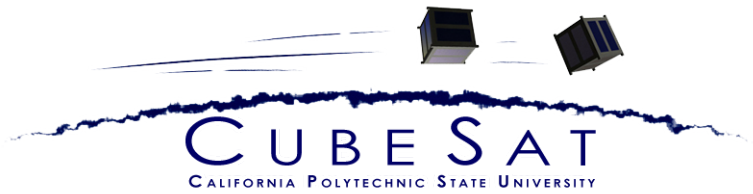

1 Document Control Data

1.1 Change History Log

Date	**Revision**	**Author**	*Description of Changes*'
2013.10.08	DRAFT1	Ricardo Tubio	* Initial DRAFT version.

1.2 List of Acronyms

AD	Applicable Document
API	Application Programming Interface
ASR	Availability and Scheduling Rules
	Set of rules that define the availability and scheduling for sharing a given ground station.
G-Client	Ground Station Client
	Software component of the SATNet network for ground station operators to share their facilities.
G-Client-IF	Ground Station Client Interface
	Communications interface provided by the SATNet network to the G-Clients.
G-Operator-UI	Ground Station Operator User Interface
	User interface for ground station operators to access to the services of the SATNet network.
M-Client	Mission Operation Client
	Software component of the SATNet network for satellite operators to utilize remote ground station facilities.
M-Client-IF	Ground Station Client
	Communications interface provided by the SATNet network to the M-Clients.
N-System	Network Communications System
	Central cloud-computing based component of the SATNet network for interconnecting G-Client(s) and M-Client(s).
Non-SCS	Non-Scheduled Communications Service
	Communications service provided by the SATNet network for permitting ground stations to store data received without previous request by spacecraft operators.
Pre-SCS	Pre-Scheduled Communications Service

	Communications service provided by the SATNet network for enabling the data messages exchange between spacecraft operators and ground stations.
RD	Reference Document
S-Operator-UI	Spacecraft Operator User Interface
	User interface for spacecraft operators to access to the services of the SATNet network.
SATNet	SATellite Network
SOR	Spacecraft Operation Request
	Request placed on the N-System by satellite operators for requesting the utilization of certain ground stations.
TBC	To Be Confirmed
TBD	To Be Determined
TBW	To Be Written
UHF	Ultra High Frequency

1.3 Table of Contents

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1.4 Applicable Documents

ID	Title	Reference	Author	Issue
AD-00	SATNet Project Management Plan	satnet-0-ManagementPlan	CalPoly - rtubiopa@calpoly.edu	TBD

1.5 Reference Documents

ID	Title	Reference	Author	Issue
RD-00	Space Engineering - System Engineering General Requirements	ECSS-E-ST-10C	ECSS - www.ecss.nl	C
RD-01	Space Engineering - Technical Requirements Specification	ECSS-E-ST-10-06C	ECSS - www.ecss.nl	C
RD-02	Space Engineering - Software	ECSS-E-ST-40C	ECSS - www.ecss.nl	C
RD-03	Space Engineering - Ground Systems and Operations	ECSS-E-ST-70C	ECSS - www.ecss.nl	C
RD-04	www.genso.org	GENSO	N/A	

1.6 Object & Scope

- The object for this document is to establish a high-level specification of how users expect to interact with the SATNet network. It also contains the definitions of which are the different actors that will utilize the network.
- Along the different reviews to be carried out on this document, the requirements and the high-level definition of the network may evolve and, therefore, may lead to changes in its implementation. These changes will be reflected in subsequent releases of the software.
- This document is divided in the following sections:
    1. A first section in which a network concept is provided, together with the actors and use cases involved in its operation.
    2. A second section that contains the user requirements baseline. This is a definition, in terms of user requirements, of the network concept provided in the previous section.
- The contents of this document are applicable along all the design and implementation cycle of the project.

2 Network Concept

2.1 Identification of User Needs

The design of this system is focused on addressing the needs of the CubeSat community when it comes to carry out the operations of their spacecraft. Current solution for this issue is based on the usage of amateur radio station in the UHF band used as standalone facilities. This way, CubeSats are normally operated once each orbit in the best of cases, even though no other limitation (such as low battery charge, for example) restricts their exploitation.

A typical CubeSat mission passes through the following two phases:

1. A first *identification* phase that takes place just after CubeSats are deployed into space. This phase may last a few weeks and, during that time, all CubeSats launched together are so close, that it is difficult for operators to command their spacecraft without interfering with others. When ground stations gather data from spacecraft that they do not expect to operate, that data is normally discarded or, in the base of cases, an email is sent with the notification of the data received, in case the owner of the spacecraft could be identified.

2. A second phase of *nominal operations* starts once the distance in between CubeSats is enough as for operators to command their spacecraft without creating such operational interferences. During this phase, operators utilize orbit predictions based on the two-line elements orbit definitions for tracking their spacecraft.

In this scenario, sharing CubeSat ground stations in between mission operators will permit increasing the available exploitation time of spacecraft. For the first *identification phase*, the usage of multiple ground stations may suppose a shorter time of identification for a given spacecraft. In the second case, using more than one ground station will increase the amount of data received and will decrease the percentage of time that the satellite remains operating autonomously in orbit.

2.2 Communications Concept

For the user needs identified in the section above, the **SATNet** network is intended to provide a centralized, cloud-computing based server solution. This centralized solution will utilize a main central facility for enabling CubeSat ground stations sharing through the Internet. Unlike other projects like GENSO (see RD-04) in which only the authentication of ground stations and satellite operators was centralized, the solution here proposed will also transmit data from the ground stations to the mission operators using the central facilities. This way, it will solve problems that existed in previous projects like the establishment of the connection between ground station and mission operation facilities.

In addition to this, the data transmitted in between mission operation facilities and ground stations will be based on the usage of a raw data bitstream. Therefore, no audio transmissions of the baseband signal are going to be performed. This new approach permits the usage of a central system for handling data messages too, since now bandwidth communications requirements for all the elements of the network can be achieved.

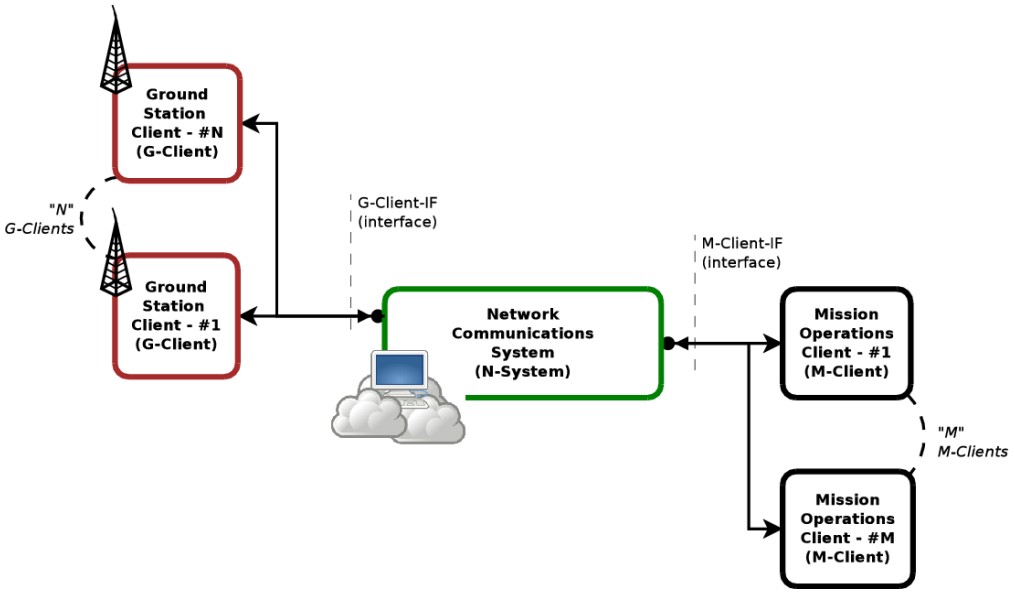
The elements of the network concept are defined in the list below. This network will be composed of the following elements (concept definition is based on document [RD-03]):

- A set of software clients for spacecraft operators to command remotely the satellites. From now on, they will be defined as **Mission Operations Clients** or **M-Clients** for short.
- A set of software clients for providing direct access to the services of the ground station facilities. From now on, **Ground Station Clients** or **G-Clients** for short.
- A central system for the coordination of the communications in between these two types of clients. From now on, **Network Communications System** or **N-System**. It is important to note that the N-System is not a single server but a cloud-computing-based system. This way and depending on further implementation decisions, this central system may evolve into a network of interconnected servers that will provide the service required.

For providing these services, the central N-System implements the following interfaces:

- **G-Client Interface (G-Client-IF)**, that permits the ground station clients to connect to the network services.
- **M-Client Interface (M-Client-IF)**, that permits the mission operations clients to connect to the network services.

The following diagram provides a graphical definition of the elements of the network and how they are interconnected with the given interfaces.



Authentication, security and communications privacy is implemented by using a secure transport layer for ensuring that a private communications link is established in between G- and M- clients. The registration process of the clients in the central N-System is the first step for the secure distribution of keys and certificates along the clients of this network.

This network is data transport agnostic and it works as a simple message exchange service. The central N-System never access to the data messages exchanged between those clients: it only distributes messages from one data source to a data sink, through the correspondent access interface.

Since this system is expected to provide only interconnection capabilities for the ground stations and satellite operators, no support for the hardware

of the G- or M- clients is to be provided. Therefore, ground stations and satellite operators must develop their own software and hardware equipment for using the services provided by the standard interfaces of the central system.

2.2.1 Network Users Registration

Any entity who would like to share their ground station facilities with the rest of the SATNet community, must register it first in the SATNet network. Once they have registered their facilities for sharing, they will access to the N-System using a G-Client and they will start sharing their facilities with the rest of the community. On the other hand, CubeSat operators who would like to use one a remote ground station for operating their spacecraft, must also register in the network before they can access to the N-System. After a successful registration process, they will access to the available ground stations of the network by using a M-Client.

The centralized operation of the network requires that both the communications capabilities of the ground station facilities and the requirements of the spacecraft be defined in the central N-System. This way, the central system can match the ground stations that meet the requirements not only of availability for tracking the spacecraft, but also of demodulation and decoding required for data messages transmission and/or reception.

2.2.2 Communication Services

The SATNet network provides two communications services for exchanging data among G- and M- clients:

- A **Pre-Scheduled Communications Service (Pre-SCS)** that enables remote spacecraft operations with bi-directional real time communications. The usage of a ground station through this service must be arranged previously between the operators of the spacecraft and of the ground station. This service is defined for permitting the usage of remote ground stations during the *nominal operations phase* of a CubeSat mission, in accordance with previous section *User Needs Identification*.

- A **Non-Scheduled Communications Service (Non-SCS)** that enables G-clients to store data gathered from spacecraft without a previous request by a spacecraft operator. This way, ground stations can collect data sent from spacecraft and store it in the network, together with information about the reception of that data. This additional information about the reception of spacecraft data is known as **reception context metadata** and is necessary for the network to identify which satellite operators own the messages received. This service is provided for sharing the usage of ground stations during the typical *identification phase* of a CubeSat mission, in accordance with previous section *User Needs Identification*.

2.2.2.1 Pre-Scheduled Communications Service

The utilization of the Pre-SCS service requires that the planning for the operation of a spacecraft be based on the usage of the central N-System. Spacecraft operators must beforehand, retrieve from the N-System the list of which ground stations will be available for the operation of their spacecraft and for how long (this is known as the **operation slots list**). This list will be computed by the central N-System taking into account:

1. spacecraft orbit predictions for tracking,
2. ground stations availability,
3. and communications compatibility between ground stations and spacecraft.

Once the available operation slots list is received by mission operators, they must select which of those slots they will need. The selection of the required operation slots must be sent back to the central system for it to confirm whether this facilities are still available or not (other operators might have reserved them in the time elapse since the reception of the first list). The N-System will confirm the reservation of the ground stations required and coordinate those reservations with each of the ground stations. This process is known as the **Spacecraft Operation Request** or **SOR request** for short.

Each ground station operator can define the **Availability and Scheduling Rules** or **ASR rules** for short, in the central N-System. These rules define, in terms of time slots, the temporal availability of the ground station for remote operations. In addition to this, ground station operators may define additional rules that restrict the usage of their ground station facilities in terms different than the availability time.

In case an unexpected event such as a problem with the ground station occurs, ground station operators can redefine its availability for marking the ground station as unavailable until the problem gets solved. The N-System will be responsible for the notification of this problem to those spacecraft operators that had already received a confirmation for the operation with those ground stations.

2.2.2.2 Non-Scheduled Communications Service

For the utilization of the Non-SCS service, ground stations will only have to provide both the data gathered and the **reception context metadata** for the central N-system to temporary store it. In case the metadata received is enough as for identifying the satellite that originated the transmission, the N-system will associate the data to that satellite. Once the operator of that satellite connects to the system, a notification will be sent and data will be available for retrieval through the M-client.

2.3 Network Operators

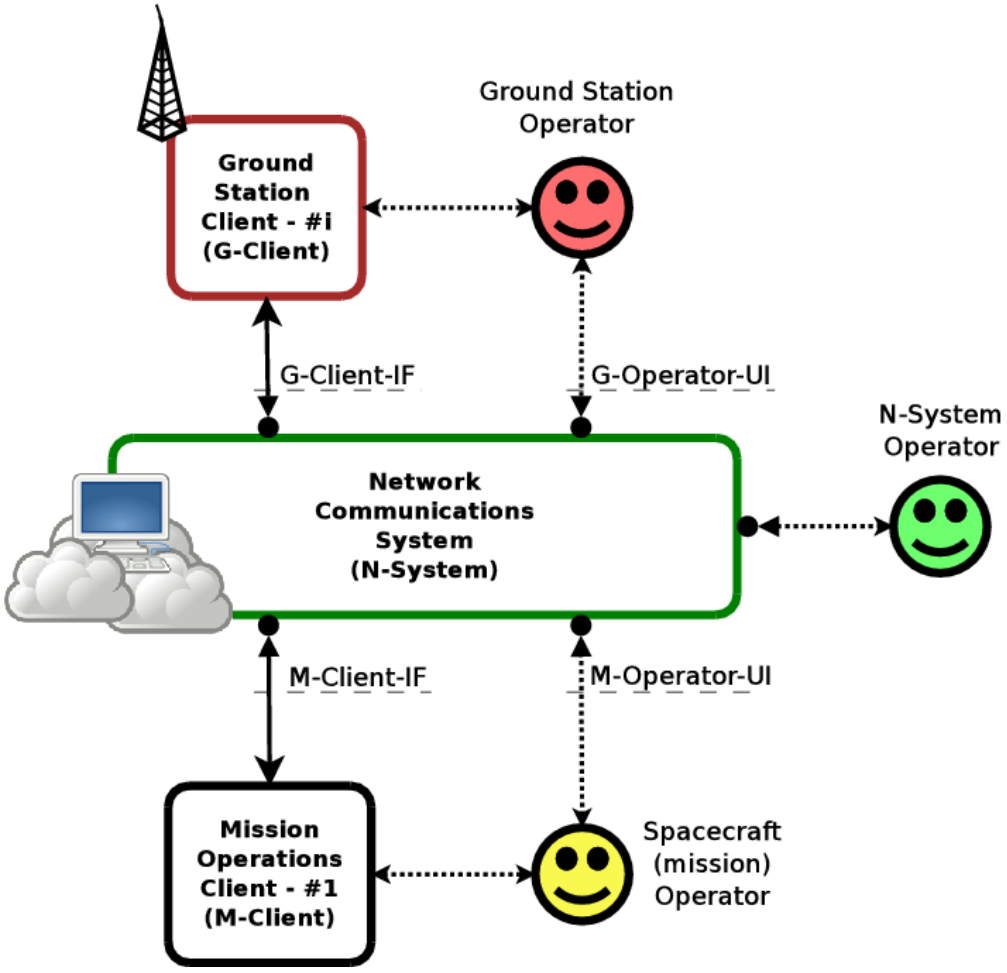
The different operators involved in the usage of this network are the following (see figure on the following page):

- **Ground Station Operator**: this operator is responsible for the operation and maintenance of the G-Client. In addition to this, ground station operators are also responsible for registering their in the SAT-Net network, defining its ASR rules set and for keeping the registration information up to date.
- **Satellite Operator**: this operator operates a spacecraft using the M-Client and is also responsible for the registration of this client and of the spacecraft configuration in the network.
- **Network Communications System Operator**: this operator is responsible for the maintenance of the central N-System and is the contact person for any problem in the usage of this system.

For providing these services, the following user interfaces are defined:

- **Satellite Operator Service User Interface (S-Operator-UI)**, that permits satellite operators to access to the services of the N-System.
- **Ground Station Operator Service User Interface (G-Operator-UI)**, that permits ground station operators to access to the services of the N-System.

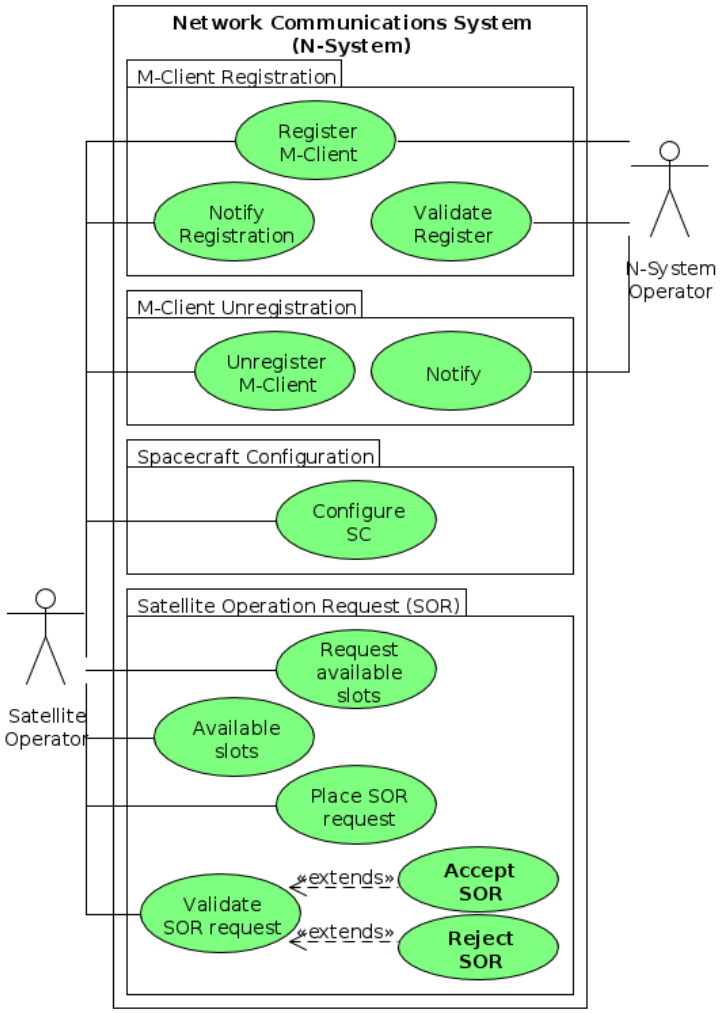
Since the ground communications operator is a maintainer of the central N-System, the definition of the access to the system that this actor has is a design issue for the specific implementation of that system.


Ground Station Operator
Ground Station Client - #i (G-Client)
G-Client-IF
G-Operator-UI
N-System Operator
Network Communications System (N-System)
M-Client-IF
M-Operator-UI
Mission Operations Client - #1 (M-Client)
Spacecraft (mission) Operator

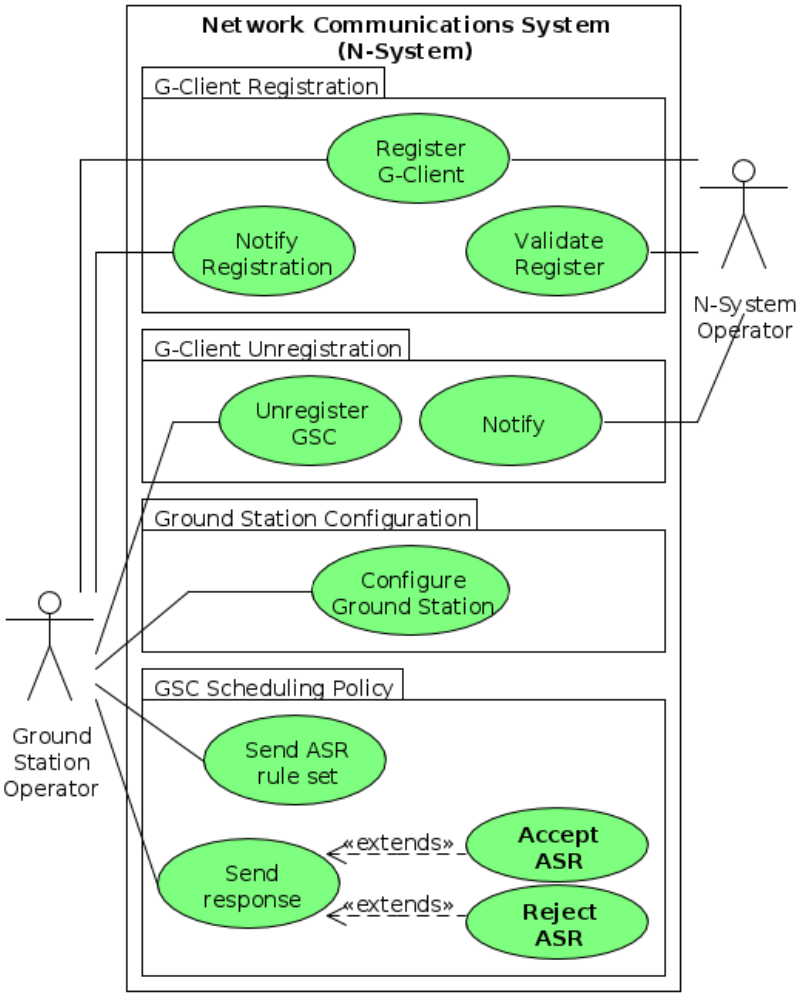
2.4 Use Cases

The following are the main cases considered for the design:

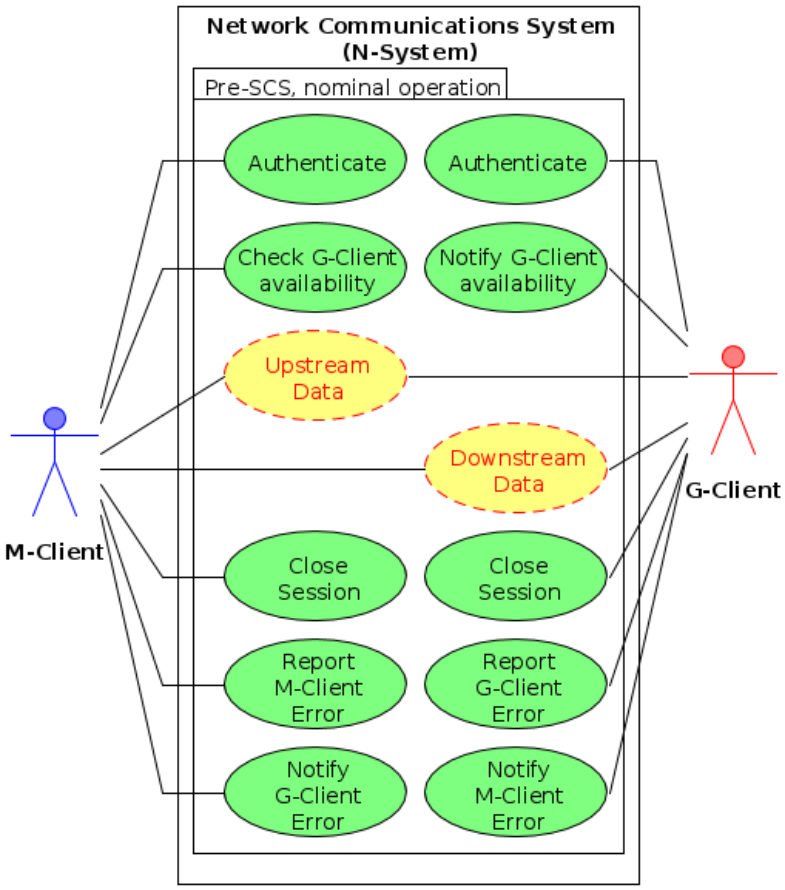
- **Use Case #1: Satellite Operator Use Case.** This use case defines how satellite operators must use the system for their spacecraft to be registered and configured in the network. Satellite operators carry out the following operations: registration and unregistration of their M-Client, configuration of the communications and orbit parameters for tracking their spacecraft and management of SOR requests.



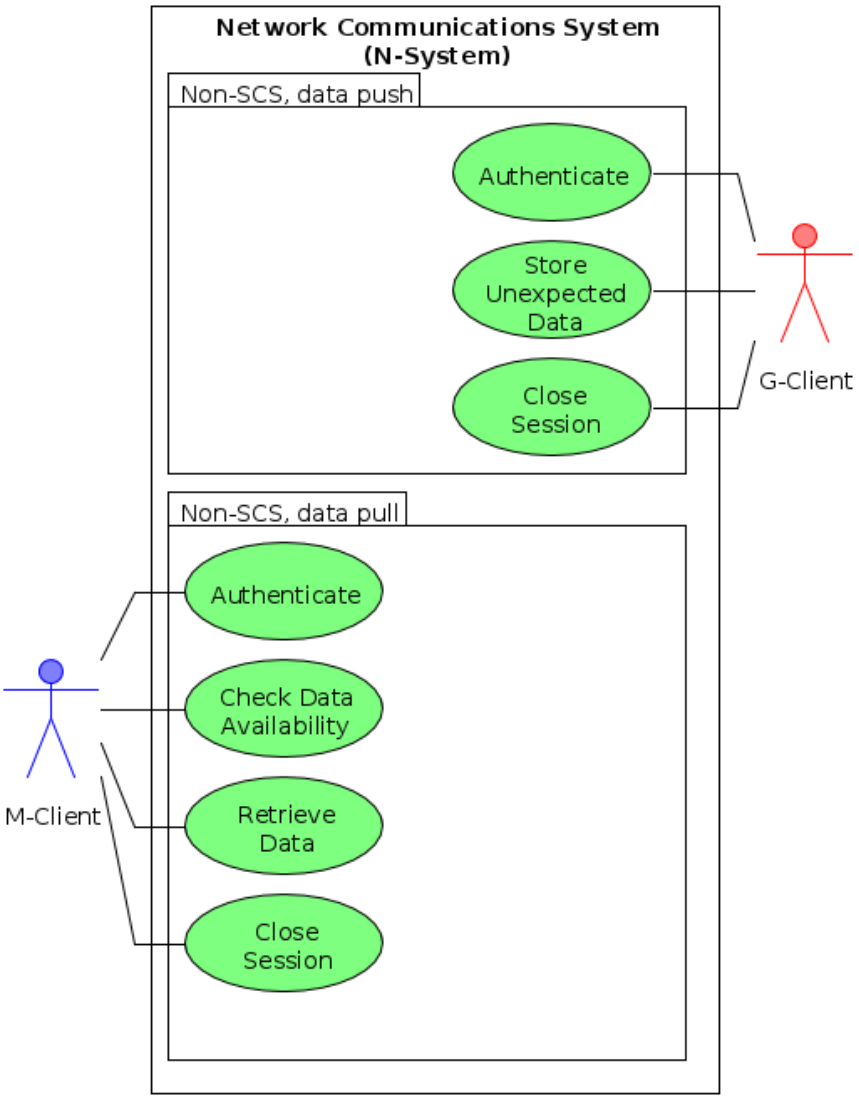
- **Use Case #2: Ground Station Operator Use Case.** This use case defines how ground station operators must use the system for sharing their ground station through this network. The operations that these operators carry out are pretty similar to the ones of the satellite operators: G-Client registration and unregistration, configuration of the parameters that define the capabilities of their ground station and the definition of their ASR rules set.



- **Use Case #3: Pre-Scheduled Satellite Operation Use Case.** This use case defines how network clients must use the central N-System for sending and receiving data to and from spacecraft, after they have reach an agreement about the operations plan to be executed. In this case, both clients have to be authenticated and check for the availability of the other one as a first step. After that, they start exchanging data messages either through the upstream or through the downstream. Once the remote operation of the spacecraft has finished, they close their communications sessions. In case any error occurs during the data messages exchange, there are mechanisms for reporting those incidents to the central N-System. This central system will provide coordination to solve this issue on both communication ends.



- **Use Case #4: Non-scheduled Satellite Operations Use Case.** In this case, a remote ground station client receives data from a spacecraft without having previously undergone a process of operation plan agreement after a SOR request. Ground station clients may report this data to the central N-System together with metadata that defines the context of the data reception.



3 User Requirements Baseline

3.1 General Requirements

- This section contains a set of high-level requirements that define the general aspects of the system.

USR-GEN-010	**System Objective** The SATNet network shall provide a system for interconnecting ground stations with satellite operators through the Internet.
USR-GEN-020	**Satellite Data** The SATNet network shall not access to the data either transmitted from the spacecraft or from the mission operation facilities.
USR-GEN-030	**System Monitoring** The SATNet network shall permit a monitoring of its execution, performance and user access.
USR-GEN-040	**Hardware and Software Support** The SATNet network shall neither provide hardware nor software support to ground station operators or to satellite operators.
USR-GEN-050	**Commercial Uses** The SATNet network shall not have commercial uses.
USR-GEN-060	**Software Development License** The software developed for the SATNet network shall be licensed in accordance with the version 2.0 of the Apache Software License. *NOTE 1:* The usage of this software license will guarantee: 1) the preservation of the rights of the original author of the code without concern for royalties, 2) the free distribution of the original software code for its subsequent modification, 3) the possibility of linking from code regardless of its development license, and 4) further license modifications in derivative works. *NOTE 2:* For more details about the version 2.0 of the Apache Software License, see [http://www.apache.org/licenses/].

USR-GEN-070 **Design evolution**

The design of the SATNet network shall evolve as new user needs and/or requirements are identified.

USR-GEN-080 **System Implementation**

The implementation of the SATNet network shall permit a continuous evolution of the system.

USR-GEN-090 **System Development**

The development of the SATNet network shall follow a software engineering process that implements an evolutionary implementation of the required features.

USR-GEN-100 **Design Justification**

All design and implementation assumptions shall be dully justified.

USR-GEN-110 **Security Measures**

The security measures implemented for this network shall not preclude potential user groups.

USR-GEN-120 **Exploitation Time**

The exploitation time for the SATNet network shall be 2 years (**TBC**).

USR-GEN-130 **Releases Schedule**

The releases for the network shall follow the schedule defined in section **Roadmap** of document AD-00.

NOTE: On this date, the SATNet system shall not be fully operational but shall, at least, permit a regular operation of a CubeSat with a remote compatible Ground Station.

USR-GEN-140 **Network Validation**

The implementation of each of the releases of the SATNet network shall be validated in accordance with an Integration and Validation Plan.

3.2 System Access and Security Requirements

- This section contains a definition of the access mechanisms that the network enables for users to access to its services.

USR-ACC-010	**User Access** The design of the SATNet network shall allow users to access the services provided through tools developed by themselves.
USR-ACC-020	**User Access - Medium** The SATNet network shall provide access to the services of the network through the Internet.
USR-ACC-030	**User Access - API** A public definition of the API shall be released for users to access to the services of the network.
USR-ACC-040	**User Access - API updates** The public definition of the API shall be updated as changes in the access services are required for accessing the network.
USR-ACC-050	**User Access - API changes** Future changes in the API of the network services shall be announced in advance together with the correspondent API update. *NOTE:* This guarantees that users will have time enough for adapting their access tools before the network itself implements those changes.
USR-ACC-060	**User Authorization** The SATNet network shall provide access only to users who have previously registered and whose registration had been approved.
USR-ACC-070	**User Identification** The SATNet network shall provide access only to users whose identity had been unambiguously verified.
USR-ACC-080	**Network Authentication**

	The SATNet network shall implement a mechanism for unambiguously identifying itself to the users of the network.
USR-ACC-090	**Network Authentication**
	The SATNet network shall implement a mechanism for unambiguously identifying itself to the users of the network.
USR-ACC-100	**Data Privacy - Storage**
	The SATNet network shall guarantee the privacy of the data stored within the network.
USR-ACC-110	**Data Privacy - Communications**
	The SATNet network shall guarantee the privacy of the data exchanged through the communications carried out along the network.
USR-ACC-120	**Data Integrity - Storage**
	The SATNet network shall guarantee the integrity of the data stored within the network.
USR-ACC-130	**Data Integrity - Communications**
	The SATNet network shall guarantee the integrity of the data exchanged through the communications carried out along the network.
USR-ACC-140	**Data Authenticity - Storage**
	The SATNet network shall guarantee the authenticity of the data stored within the network.
USR-ACC-150	**Data Authenticity - Communications**
	The SATNet network shall guarantee the authenticity of the data exchanged through the communications carried out along the network.

3.3 Service Provision Requirements

- This section contains a definition of the requirements that define how the network provides its services, in terms of availability, general functionality and performance.

USR-SRV-010	**Network Communications Services**
	The SATNet network shall provide the following services: 1. Non-Scheduled Communications Service *'(Non-SCS service)'* and 2. Pre-Scheduled Communications Service *'(Pre-SCS service)'*
USR-SRV-010	**Pre-SCS service - Definition**
	The Pre-SCS service shall permit the remote operation of spacecraft through a bi-directional message exchanges service in real time.
USR-SRV-010	**Pre-SCS service - SOR request**
	M-Clients shall place a SOR request and undergo the process for arranging a spacecraft operation before they can utilize the Pre-SCS service.
	NOTE: Therefore, spacecraft operators shall take into account when it comes to plan an operation that this process may not be automatic and may take some time.
USR-SRV-010	**Pre-SCS service - G-Client and ASR rules**
	The usage of a ground station is subjected to the ASR rules set defined by the ground station operator.
USR-SRV-010	**Pre-SCS service - transmission delay (1)**
	The maximum time for a message to arrive at its destination (either a M- or a G- Client) once its origin (either a M- or a G-Client) has transmitted it, must be smaller than 100 miliseconds. (TBC)
USR-SRV-010	**Pre-SCS service - transmission delay (2)**
	The real time requirement on communications delay shall be met regardless of the load of the network.
USR-SRV-010	**Non-SCS service - Definition (1)**

The Non-SCS service shall permit G-Clients to store data gathered from spacecraft without an scheduled operation to had been arranged beforehand.

USR-SRV-010 **Non-SCS service - Definition (2)**

The SATNet network shall only permit the storage of this data by G-Clients whenever they can also provide the additional metadata required for the identification of the spacecraft that transmitted that data.

NOTE: This metadata is composed of information about the reception of the data from the G-Client such as frequency, contact time, antenna elevation... etc. Therefore, it enables the automatic retrieval of this data only by the owners of the satellite that originated it.

USR-SRV-010 **Pre-SCS service - Definition (3)**

The Pre-SCS service shall permit M-Clients to retrieve data gathered from their spacecraft, only if the origin of the data can be unambiguously determined and attributed to that satellite operator.

USR-SRV-010 **Pre-SCS service - Data Storage**

Spacecraft data temporary stored at the central N-System shall be deleted from the system after 7 days. (TBC)

USR-SRV-010 **Backwards Compatibility**

The implementation of new definitions or updates of the network services shall preserve the compatibility with previous versions.

3.4 Implementation Requirements

- This section contains all the requirements that restrict the implementation process of the SATNet network.

USR-IMP-010	**Satellite Protocol Agnostic** The data transport carried out by the SATNet network shall be independent of the protocol utilized for the communications in between the mission operation facilities and spacecraft.
USR-IMP-020	**Network Scalability** The design of the SATNet network shall permit the scalability of the service provision. *NOTE:* This way, increases in the network load can be solved without the need of carrying out a redesign of the architecture of the network.
USR-IMP-020	**M-Client Implementation (1)** The implementation of the M-Client shall be carried out by each satellite operator.
USR-IMP-030	**M-Client Implementation (2)** The implementation of the M-Client shall meet the requirements to access the services of the SATNet network, as per document TBD.
USR-IMP-040	**G-Client Implementation** The implementation of the G-Client shall be carried out by each ground station operator.
USR-IMP-050	**G-Client Implementation (2)** The implementation of the G-Client shall meet the requirements to access the services of the SATNet network, as per document TBD.
USR-IMP-060	**Central N-System Implementation** The implementation of the central N-System shall meet the requirements for implementing the access interfaces of the services, as per documents TBD and TBD.

3.5 Use Case Requirements

USR-USC-010	**Use Case Implementation** G-Clients, M-Clients and the central N-System shall implement the use cases as defined per section “Use Cases” of this document.