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Reverse engineering techniques to optimize facility location of satellite ground stations on building roofs

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ABSTRACT

The development of small satellites, called CubeSats, at universities gave rise to another concept of ground station and its location site on building roofs. As a facility project, conditioned by urban regulations, the agreement between the ground station engineers and the facility managers is necessary in the site selection process. This paper proposes the application of reverse engineering techniques, such as the laser scanning, to provide them 3D spatial information by the 3D digital reconstruction of the scenario. The main result obtained in the case study at the Technical University of Madrid was the proposal of the re-designed ground station site increasing the antenna performance and considering the established facility constraints. In these building roofs scenarios, the virtual simulation process of telecommunications antennas sites based on the created 3D digital scenario is very useful to optimize the location before the installation process.

1. Introduction

Within urban areas, the need of antennas installations on rooftops is well known to support telecommunications systems such as police and emergency services, radio and television services, and satellite communications. This paper analyzes the particular case of the GS (Ground Station) scenario on building roofs and proposes a methodology for the optimal site selection of telecommunication antennas. These scenarios of antennas on rooftops have increased considerably in order to track small satellites built by students and research teams at universities and research centers. As a communications sensor with satellites for transmitting and receiving radio waves, the FOV (Field of view) is the most relevant factor in the antenna site selection. As a facility location within urban areas, the GS site selection must also meet the established building regulations. In these scenarios a site selection process which includes the analysis of the antenna mission requirements and the facility constraints on building roofs is becoming more necessary.

This paper analyzes this case scenario of GS facilities installed on building roofs associated to a new generation of small satellites, called CubeSats, which were initially developed in the late 90s by a number of organizations and universities in an attempt to accelerate construction opportunities of small and low cost space experimentation platforms [1]. The need to support their own satellite projects as an educational challenge conditioned this new scenario for the earth-based point of communication with these space platforms within the University facilities. This scenario is based on the GS installed on a building top floor to track the first Stanford's amateur satellite built in 1998 [2]. Since the first CubeSat program created by the California Polytechnic State University in the 90s [3], these scenarios have increased in relation to the development of these programs at universities and organizations all over the world. To date, more than 1700 Nanosats and Cubesats have been launched [4]. This has been possible thanks to the rapid speed in the development of these space platforms [5], its approach to space access [6] and their capabilities for science missions [7]. The QB50 project, a network of 50 CubeSats (see Fig. 1(a)) built by universities including their respective GSs [8], is a current sample of the GS locations increase on building roofs. The QBito (see Fig. 1(b)) is one of the QB50 CubeSats, which will be tracked from the GS installed on a building roof at the Technical University of Madrid (see Fig. 1(c)). This is the typical GS configuration consisting of four main components: outdoor components which include the antennas system and the rotor-positioner (see Fig. 1(d)), and indoor components which include the

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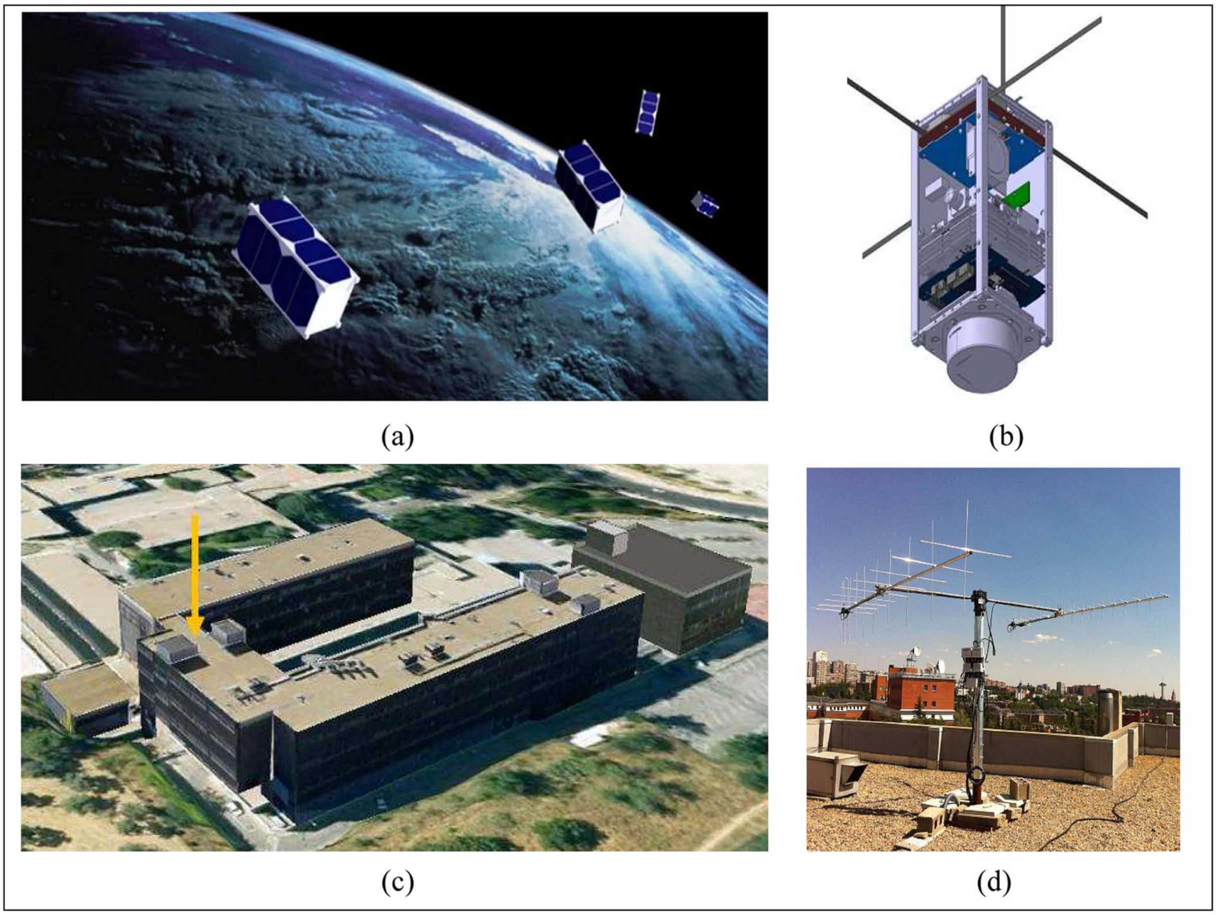

Fig. 1. Case study of the Ground Station scenario at the Technical University of Madrid (a) Artist rendition of the QB50 CubeSats in space [11]. (b) Virtual 3D model of the Qbito CubeSat [12]. (c) Location site at the ETSIT (Escuela Tecnica Superior de Ingenieros de Telecomunicacion) (Source: Google Earth program). (d) Typical antennas system.

transceiver and the modem normally installed on the floor just below [9,10].

The approach of this paper is the analysis of the GS location site regarding its influence in the antenna performance as a communications sensor, and in the installation project as a facility location conditioned by building regulations. First, the presence of nearby obstacles and high buildings surrounding the GS site reduces the satellite FOV in its AOS (Acquisition of Signal) and LOS (Loss of Signal) in certain azimuth directions along the horizon visible from the antenna site. Second, facility constraints must be considered in the GS project design, as these relate to technical specifications such as the antenna maximum height and the required fastening and anchor systems and, safety systems during the installation and for future works of facility maintenance. In this context, the research focuses in the RE (Reverse Engineering) process to carry on the scenario analysis.

RE processes which create digital realities that represent real-world scenarios enable extracting missing information from anything which is man-made, by going backwards through its development cycle and by analyzing its structure, function and operation [13]. This is possible by applying 3D digital surveying techniques such as the laser scanning technology which can capture huge numbers of points with high accuracy in a relatively short period of time, obtaining surface free-forms and generating high density point clouds. This is an innovative solution for modeling objects without the need of physical contact which enables the representation of their complex architecture, and a realistic interpretation [14]. The application of these new 3D survey methods can be adapted to different needs and highlight the possibility to carry out reliable engineering processes [15,16]. In addition, 3D digital model generation of urban scenarios is useful for accurate 3D mapping of other man-made structures [17], especially in works related to data capture from in-situ based views of indoor and outdoor structures of buildings without there being physical contact [18,19]. RE process based on laser scanning technology has been revolutionary in specific applications such as deformation monitoring, interfering design, construction archiving, as-built surveys, and BIM (Building Information Modeling) [20–24]. In addition, these processes allow a swift relationship between different professionals from different disciplines thanks to its capabilities of simulation, multi-view representation, real time visualization and, digital data extracting in any project stage.

The research aim is to develop a methodology based on RE techniques for the digital reconstruction of the GS scenario providing those professionals involved in the site selection process with accurate spatial information to be analyzed, from the current state of a given antenna site to the virtual simulation of site proposals. The methodology, mainly based on laser scanning technology, also combines the application of specific hardware and software solutions to recreate the GS scenario from both points of view, antenna performance and facility location. Solutions such as the total stations (surveying instrument) to capture the FOV from the antenna rotor center, the STK (System Tool Kit) simulation software [25] to test the antenna performance and the CAD (Computer-Aided Design) software to process specific 3D Data. The expected goal is selection of the optimal site by the agreement between the GS engineers and the facility manager taking into account the antenna mission requirements and the facility constraints, respectively. The proposed methodology for the optimal site selection of telecommunications antennas on building roofs and main results obtained in the case study at the Technical University of Madrid, are described.

Table 1
Statistic for the duration of visibility passes for different satellite altitudes.

Satellite altitude	Raw data			
	Average pass duration	Longest pass	Number of passes	Daily coverage
380 km	4.72 min	6.02 min	470	1.88%
600 km	6.69 min	8.51 min	616	2.03%
800 km	8.31 min	10.60 min	712	2.70%

2. Case study at the Technical University of Madrid (Spain)

The GS is located at ETSIT (Escuela Tecnica Superior de Ingenieros de Telecomunicaciones) and it is installed on the building roof, right on top of the radiation group laboratory (40.26 N, −3.42 E). Its main mission will be that of tracking and acquiring the QBito nanosatellite. The development of this nanosatellite is the main aim of the TelCUBE Spatial Project [26], which is part of the QB50 Project devised to study the lower layer of the thermosphere (90–320 km) and to research the re-entry phenomenon.

2.1. Problem statement and available solutions

To introduce the antenna mission requirements in this scenario, the next table and figure show the statistics for the duration of visibility passes for different satellite altitudes (800, 600 and 380 km) by applying the STK program, where the mission duration is of five months, a minimum elevation constraint of 10° has been considered for the analysis, and the satellite orbits have been modeled as circular with an inclination of 98°. Table 1 shows the statistics for the duration of visibility passes for the different satellite altitudes without considering the time it takes to track the satellite and to establish communication. This duration of the pass was achieved for 28, 41 and 50% of the passes for 380, 600 and 800 km, respectively.

The average pass duration is inversely proportional to the satellite altitude, and as can be seen the number of passes is reduced as the satellite altitude decreases. In addition, as the altitude of the satellite decreases the opportunities to track or communicate with it from a GS become more restricted further complicating satellite scheduling [27]. Despite the great advantage of LEO (Low Earth Orbit) orbits being the short distance, and thus the reduction in transmission power requirements and minimization of the propagation delay [28], the radio signal must pass through. Therefore, for science and communication missions it is becoming necessary to have a detailed analysis of the GS coverage that combines LEO orbit advantages with radio signal availability to profit from every single satellite pass. Taking into account that the communication time between the satellite and the GS is of 5–15 min, 6–8 min during the day [29,30], for those science missions that require a huge download data, satellite visibility duration of 8 min per pass was considered as a reference value for these missions. However, satellite orbits are imposed by mission and payload requirements, and thus affect visibility duration, so GS engineers must deal with this limitation to operate the mission efficiently. In this sense, connecting several GSs worldwide is a solution to give total coverage to these satellite projects along the mission by using GENSO (Global Educational Network for Satellite Operators) software which increases access to a particular satellite [31,32]. This fact has a great relevance in the amount of data download in each satellite pass in the QBito nanosatellite, since for the single GS located at the ETSIT campus the bit rate is of 9600 bits per second and the average pass duration is of 4.72 min. Despite this solution, a high percent of these operations depend on GS networks availability, and hence on the probability of the designed satellite communications system operating correctly throughout the mission [33].

GS locations in built-up areas are the most typical selection sites for ground segment facilities in these CubeSat projects, and signal obstructions caused by phenomena within these environments affect satellite communications at low elevation angles and hence the GS mission performance. In this sense, available solutions can be seen in satellite projects and research associated to these scenarios. These include: the use of azimuth-elevation pedestals to minimize tracking losses along the satellite passes [34,35,36], antenna size selection to achieve the desired gain margin to establish satellite communication links [37,38], the antenna positioning system using stepper motors and the design of software driver for this positioning system [39], and recent advances in optical and laser communication systems [40].

2.2. Further analysis from the location point of view

Despite the available abovementioned solutions, devised to increase the coverage of the satellite mission and in particular to increase the antenna performance, in most cases the location of the GS is conditioned by the available facilities within the complex at universities or research centers. Cases range from a limited area to a restricted location in both of which the best location must be selected. In addition, an installation project on a building roof requires considering the building rules as another specific critical point when determining the GS location site. In this sense, there are several examples of solutions that have been applied in engineering projects after location analysis and before the installation stage. These affect the GS components design during the installation stage, and can be seen; first, the first GENSO GS installation planned at the ESA (European Space Agency) ESTEC facilities (The Netherlands) [41] which was finally installed at International Space University in Strasburg (France) to solve the required area for equipment and antennas, and; second, in the antenna support design and safety systems at The University of Strathclyde (Glasgow) [42] to solve the non-penetrating roof requirement for the installation. In a few cases without a limited area or a restricted location, a previous analysis of the best antenna site is carried out, as can be seen: first, in the selection of the highest building to maximize the satellite FOV, such as the GS located at Eindhoven University of Technology (The Netherlands) for the Delfi-C3 satellite operations [43], and; second, in the antenna site selection with the best communication quality in the mission bands by comparing different sites using a modular antenna at California Polytechnic State University (US) for the ExoCube satellite operations [44].

By considering the worst case scenario such as in the case study which includes a given GS design located on a building roof and its mission of tracking a CubeSat unit in a LEO orbit, the antenna performance depends on the available communication times in each satellite pass visible from the spatial position of the antenna rotor center. In this scenario, in-situ physical obstacles and signal interference sources remain on the selected building roof when installing the GS antenna subsystem reducing the communication time between the satellite AOS and LOS (see Fig. 2(a)). These scenarios are not strictly analyzed from the spatial location of the antenna positioning system center. The tracking software with information of the satellite orbit is engaged to the antenna rotor controller to start the tracking process when the satellite is in view, to steer the antenna in the correct angular position along the satellite pass, and to stow its position once the satellite goes below the horizon. These programs such as the STK require a data set from the spatial location of the antenna positioning system center which is called antenna elevation mask that contains the geographic coordinates and height of the antenna location site, and the geographic information surrounding the GS location area that provides the altimetry profile (azimuth, elevation) surrounding the antenna site (see Fig. 2(b)) [45].

From the analysis of the problem statement, the antenna minimum elevation, which determines the satellite FOV from the GS site can be considered as the factor to be analyzed. This factor should be considered before the GS installation for an efficient use of the satellite visibility along the mission. Moreover, it is especially important for

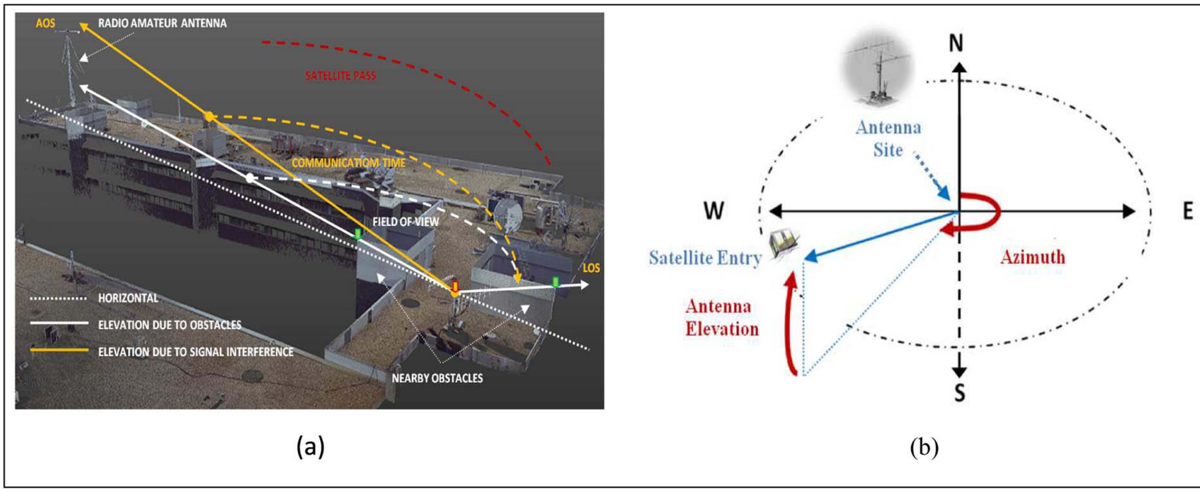

Fig. 2. Concept of the antenna elevation mask (a) Simulation of a single satellite pass from the ETSIT GS in the worst case scenario. (b) Graphic description of the required parameters from the antenna rotor center.

missions that require huge data download, such as the QB50 project, since having a detailed analysis of the GS coverage allows to take advantage of every single satellite pass. In this particular case, for a given GS, the proposed solution was the reconstruction of the GS scenario providing the GS engineers and the facility manager with accurate information of the data set required by the STK program to simulate the antenna performance from the current site and the 3D digital model of the building roof to analyze the impact of obstacles in the existing facility location.

3. Methodology

This section describes the proposed methodology for the optimal site selection of telecommunications antennas on building roofs locations. The developed procedures are based on the adequate selection of the data capture technologies to provide 3D spatial information of the antenna scenario, and the application of data processing software to analyze the antenna optimal site by considering the antenna mission requirements and the facility constraints. Fig. 3 shows the required data set and the applied technologies to obtain it, and the expected results to achieve the objective of the analysis of the antenna scenario taking into account the antenna performance and the facility location.

Fig. 4 shows the implementation of the proposed procedures in the methodology for the antenna site selection, including the designed processes to be applied from the analysis of the antenna scenario to the optimal site selection. The following subsections describe these processes through their implementation in the case scenario of the GS's antenna located at the Technical University of Madrid.

3.1. Geographic study I

This procedure has been designed to provide, in the antenna site selection process, 3D spatial information of the current state of the antenna and the optimal site selection by considering the antenna mission requirements. By applying the first process, *Data Capture*, the antenna elevation mask or geographic mask is obtained. Establishing the orthometric height of the antenna rotor center as the center of the coordinate reference system, the first step is to target its coordinates by applying GNSS (Global Navigation Satellite System) technology (see Fig. 5(a)). The next step is the data capturing of the altimetry profile surrounding the antenna site by topographic equipment, such as the Trimble S6 [46] used in the case study, taking into account the required measurement data (azimuth, elevation) to determine the available FOV surrounding the antenna site (see Fig. 5(b)). The second process, *Virtual Simulation*, simulates the antenna mission performance by applying the geographic mask calculated from the antenna site. When establishing the satellite parameters (orbit altitude and inclination) and the calculated mask to create the scenario, the first step is to simulate the mission to estimate the satellite coverage from the selected antenna site by applying specific simulation software such as the STK program used in the case study. Fig. 5(c) shows the orbit length visible from the antenna site in each satellite pass, which means the satellite contact times to mission operations. The second step is to analyze the antenna performance between the selected site and proposals which maximize the satellite FOV. Fig. 5(d) shows the 3D view of a single satellite pass affected by obstacles near the selected antenna site in the case study which reduces the contact time with the satellite. By applying this

Procedures	Data Set	Technologies	Results
Geographic Study I	**Antenna Rotor Center Coordinates** **Altimetry Profile from the Selected site**	**Topographic Equipment with integrated GNSS System**	**Geographic Mask**
	Objective: Analysis of the antenna performance by applying the antenna simulation software		
Geographic Study II	**3D Point cloud of the Building Roof Platform**	**Laser Scanner Equipment**	**3D Digital Scenario**
	Objective: Analysis of the facility location by applying 3D viewer program		

Fig. 3. Main concepts and objectives of the designed procedures to reconstruct and to analyze the antenna scenario.

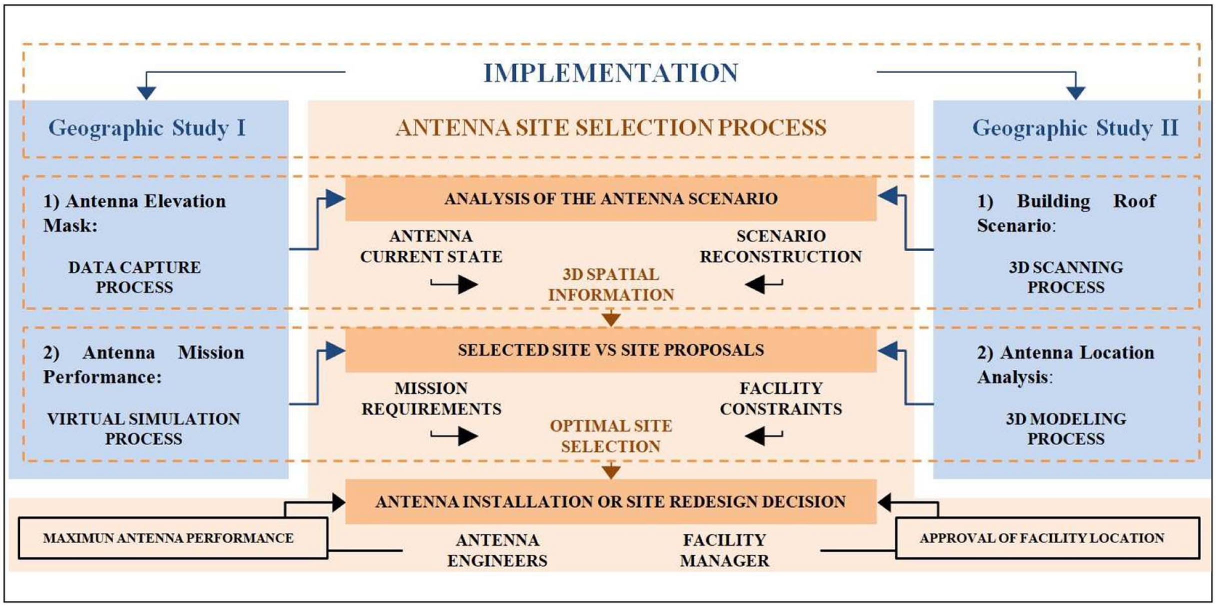

Fig. 4. Methodology of the antenna selection site process by implementing the designed procedures.

procedure from different sites the optimal site is selected taking into account the antenna mission requirements.

3.2. Geographic study II

This procedure has been designed to provide, in the antenna site selection process, 3D spatial information of the building roof scenario and the optimal site selection by considering the facility constraints. The first process, *3D Scanning*, consists in the laser scanning of the building roof taking into account the GS site and the obstacles located on the roof. Before the scanning process it is necessary to establish the optimal site of the scan stations maximizing the scan resolution, and to place the required control points to later join the point clouds obtained from the scans. Fig. 6(a) shows the Trimble TX5 laser equipment [47] used in the case study, placed at the first scan station. This process allowed, in few minutes, the massive data capture in a range up to 120 m with centimeter accuracy from the 9 established scan stations which are represented in different colors in Fig. 6(b). The point cloud

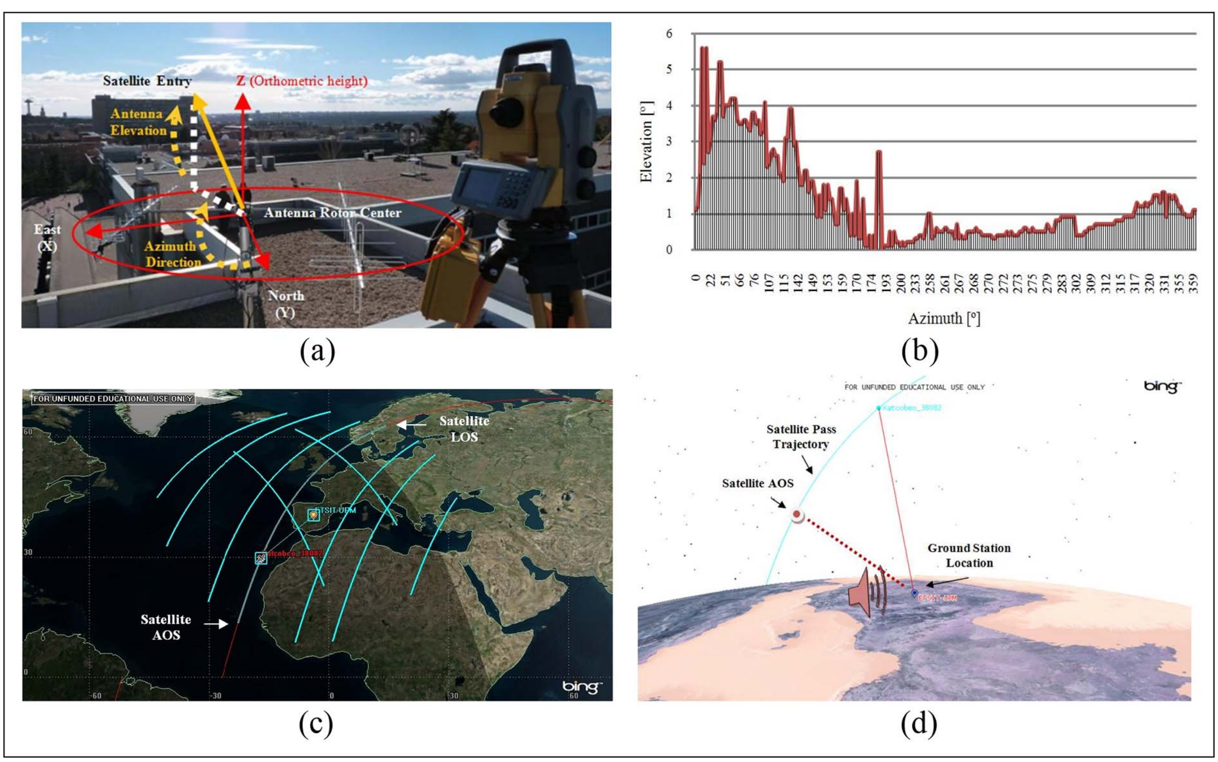

Fig. 5. Geographic Study I (a) Spatial position of the coordinate reference system targeted in the antenna rotor center by GNSS technology. (b) Graphic representation of the available satellite FOV limited by the calculated geographic mask. (c) 2D view of the orbit lengths visible from the antenna site by applying the STK program which determe the AOS and LOS in each satellite pass. (d) Simulation of the visible trajectory in a single satellite pass due to the presence of obstacles nearby the antenna site which increase the antenna elevation to start communication with the satellite.

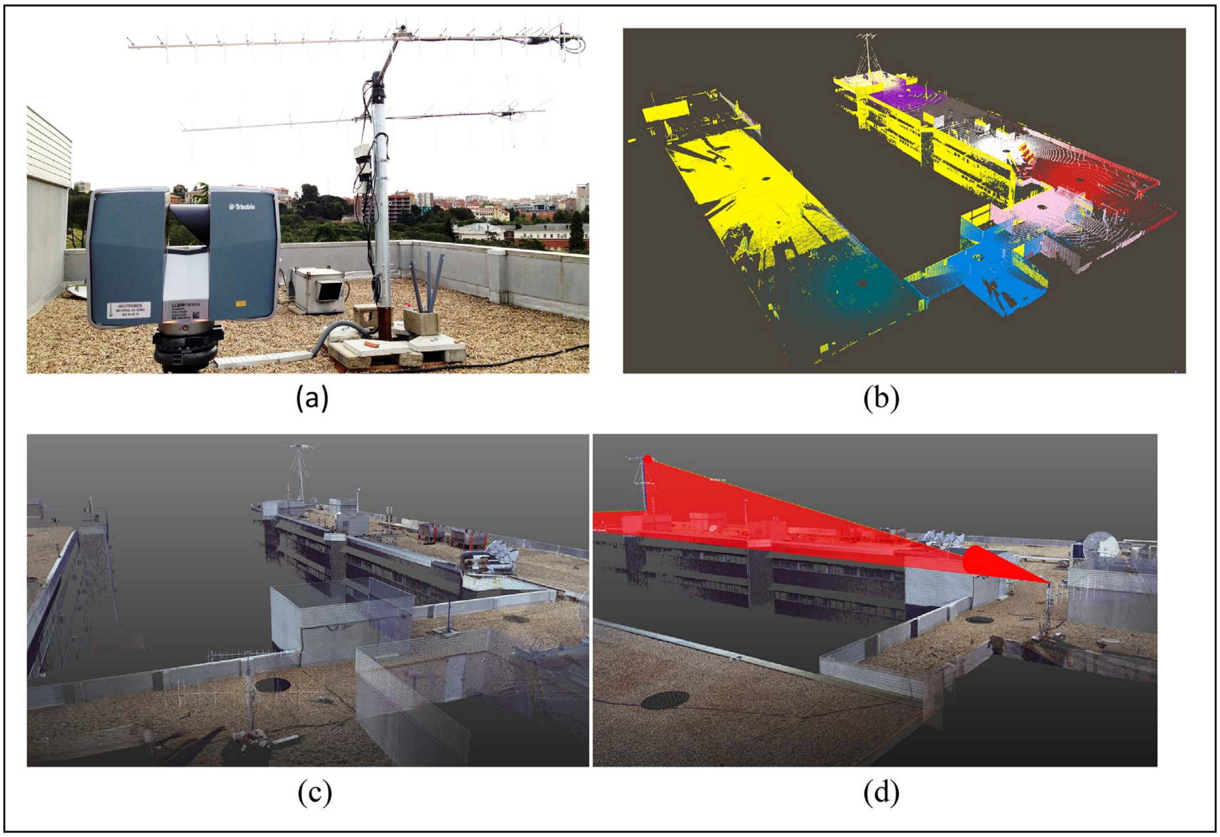

Fig. 6. Geographic Study II (a) Laser scanning process of the GS outdoor components. (b) 3D point clouds joined from the different scan stations by using the Real Works program. (c) 3D view of the digitalized scenario which is managed by the 3D viewer program. (d) 3D view of one the measurement tools available in the viewer program.

joined by applying the Real Works program [48,49] provides the real 3D view (see Fig. 6(c)) of the spatial position (x,y,z) and pixel of each analyzed point such as in the case study with a data processing accuracy of 7 mm [50]. The next step consists in extracting specific geometric information by applying the 3D viewer tool in order to check the constraints for installation imposed by the facility manager. Fig. 6(d) shows measurements taken from the antenna site in the case study, regarding the maximum antenna height from the antenna rotor center and regarding the available area surrounding the antenna site to fulfill building rules.

The second process, *3D Modeling*, allows to simplify the digital scenario built in the previous process by creating solid elements. The 3D solid tool included in the Real Works program allows selecting the point clouds of a figure and to model them by applying geometric elements which are determined by surfaces. Fig. 7(a) shows this process applied in the case study where the cylindrical figure has been used to model the antenna system. Before the modeling process, the first step is the selection of the entities to create the 3D scenario to be analyzed. Fig. 7(b) shows the result of the modeling process in the case study where the antenna system and the main obstacles over the roof platform were selected. This 3D model allowed the GS engineers and the facility manager respectively, a swift and real analysis of the impact of the obstacles in the satellite FOV and the available areas without constraints for facility location.

The main application of the proposed methodology is the virtual simulation of the antenna scenario to make a decision regarding the location site before the installation process. In addition, the implemented procedures, and particularly the designed processes, take into account possible case scenarios when technical specifications of the antenna system are changed or new facility constraints are imposed. This methodology can be applied even for an installed antenna such as that in the case study. If needed, to improve the antenna performance, solutions will be proposed either in the redesign or relocation of the antenna.

4. Results and discussion

To discuss the usefulness of the proposed methodology for the antenna site selection process, the obtained results in the case study of the satellite GS are described by following the stages of the methodology.

4.1. Analysis of the antenna scenario

In this stage the available 3D spatial information was analyzed taking into account the current state of the antenna performance and the reconstruction of the location site. To discuss the selection of the antenna elevation mask as a relevant factor in the analysis of the antenna location site within the proposed procedure, *Geographic Study I*, the Xatcobeo nanosatellite mission [51] simulation by the STK program on a specific day (15th May 2013) was analyzed. Establishing a standard mask of 5° and applying the calculated mask (see Table 2), results by applying the calculated mask evidenced a new pass and the increase of the visibility times in each satellite pass along this day, from its AOS and LOS. This fact is of great relevance in the amount of data download in each satellite pass. Since there is new pass, and there is an increase of the time duration of each satellite pass, the bit rate of 9600 bits per second can be translated into an increase of 10.633 Megabyte in data download thus solving the problem in the QBito pico-satellite mission.

Hence, the calculated mask provides the antenna minimum elevation in each azimuth direction and opens a discussion, from the point of view of the satellite communications in built-up areas, regarding the application of a standard mask which reduces obstacles [52] but also the satellite FOV. However, the calculated mask should not be considered in the satellite link analysis but in the telemetry operations

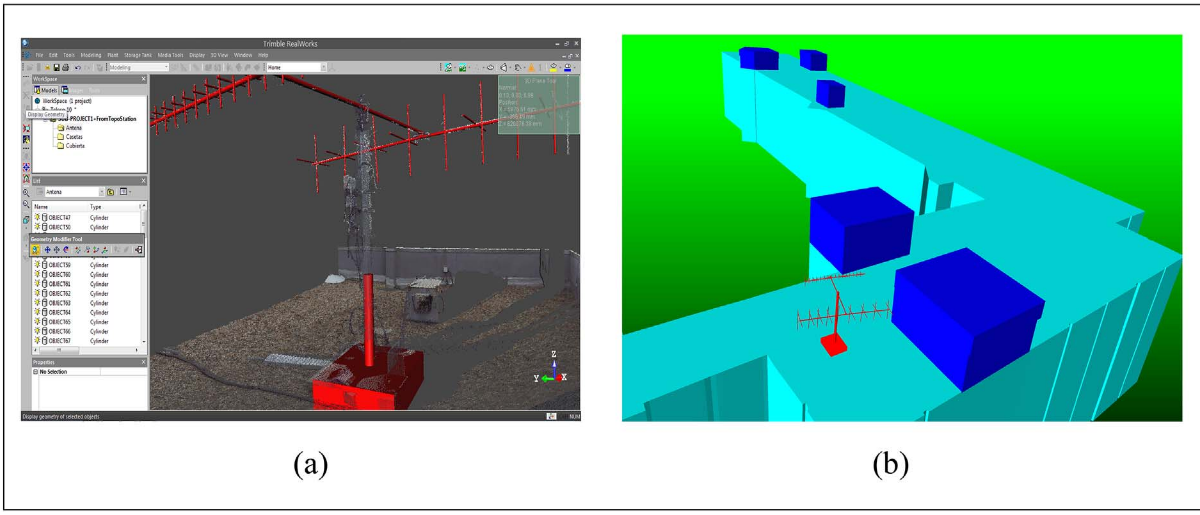

Fig. 7. Geographic Study II (a) Antenna modeling process. (b) 3D digital model of the building roof scenario which includes the selected obstacles nearby the antenna to analyze its impact in the satellite FOV.

Table 2
Duration times comparison between satellite passes on a specific day of the satellite mission applying an antenna standard mask of 5° and the calculated mask.

Pass	Standard mask			Calculated mask		
	Start time	Stop time	Duration	Start time	Stop time	Duration
1	00:46:50.543	00:52:49.190	**5.99 min**	00:45:36.009	00:53:40.558	**8.71 min**
2	02:22:31.243	02:37:44.495	**15.22 min**	02:20:59.724	02:38:04.221	**17.07 min**
3	04:05:11.145	04:18:55.506	**13.74 min**	04:03:36.514	04:19:20.517	**15.73 min**
				05:51:30.166	**05:59:38.571**	**8.14 min**
4	11:07:43.955	11:13:26.970	**5.72 min**	11:06:23.965	11:13:54.037	**7.50 min**
5	12:48:36.040	12:56:15.401	**7.66 min**	12:47:38.370	12:57:16.857	**9.64 min**
Total passes duration			**48.33 min**			**66.79 min**

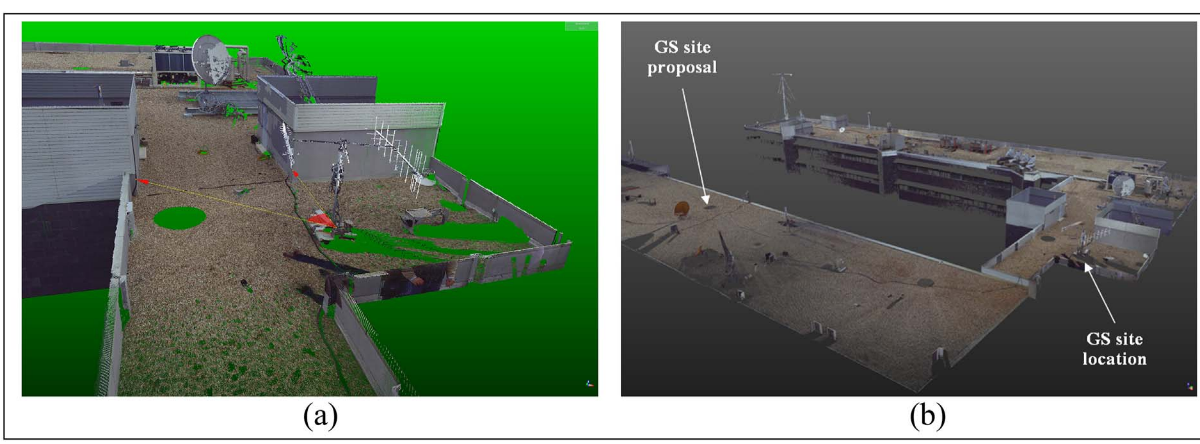

Fig. 8. Analysis of the antenna scenario (a) Analysis of the antenna current state based on the digital reconstruction of the building roof scenario. (b) Analysis of the provisional site selection by using the 3D viewer program.

along the mission to maximize the data download per day [53].

From the point of view of the analysis of the facility location, the proposed digital reconstruction of the building roof scenario opens a discussion about the usefulness of the laser scanning technology. This process, within the proposed procedure, *Geographic Study II*, provided GS engineers and the facility manager with the 3D digital scenario in order to select the provisional site. The 3D Viewer program enables the real visualization of the scene which even allowed; first, to extract accurate data such as measurements in order to establish the GS spatial position regarding the range to the existing facilities (see Fig. 8(a)) and; second, to generate deliverables from the site proposal which will allow installing the fastening and anchor systems taking into account the required safety perimeter for installation and future works of maintenance. The GS site re-design was the proposed solution which considers: constraints for installation established by the facility manager and, maximization, in this particular case, of the satellite FOV established by the GS engineers (see Fig. 8(b)).

4.2. Selected site versus site proposals

In this stage the optimal site selection was analyzed taking into account the mission requirements and the facility constraints imposed

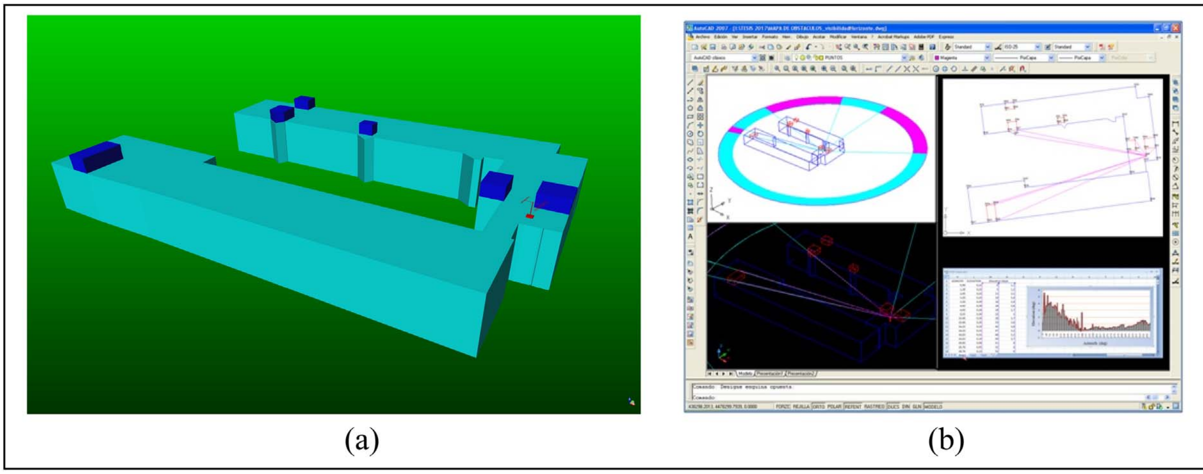

Fig. 9. Selected site versus site proposals (a) 3D digital model of the building roof scenario including the 3D model of the antenna system. (b) Simulation process of the site proposals using the CAD program.

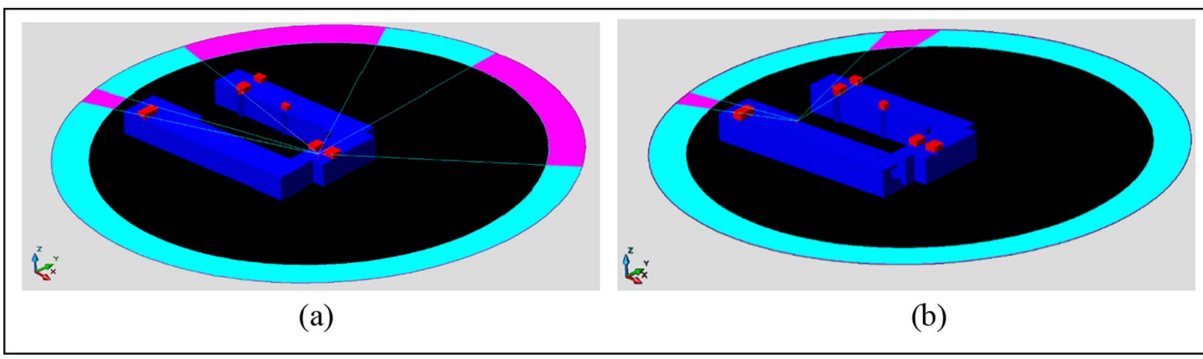

Fig. 10. Antenna installation or site redesign decision: visibility perimeter from the spatial position of the antenna site (a) Current site. (b) Proposed site.

by the GS engineers and the facility manager, respectively. The 3D model obtained from the proposed procedure, *Geographic Study II*, provided a swift analysis of the future antenna location thanks to the modeling process being applied just to the selected entities which affected the GS scenario. In this particular case, the main facilities on the building roof were selected (see Fig. 9(a)). In order to analyze the site proposals versus the selected site, the antenna mission simulation obtained by applying STK software provided the antenna site with the maximum satellite FOV. This is a swift process included in the proposed procedure, *Geographic Study I*, based on the comparison between the geographic masks calculated from the site proposals. Fig. 9(b) shows the graphic concept of this process. In this particular case, the geometric information regarding the antenna orthometric height and the obstacles over the roof was exported from the 3D model in the specific extension file required to be imported from the CAD program.

To discuss the proposed solution, based on the antenna elevation mask and the digital reconstruction of the GS scenario, the limitation of the antenna height was established as the main facility constraint. The new antenna site of the GS was proposed to fulfill those constraints, site which also reduced the impact of obstacles in the satellite FOV by 85% (see Fig. 10(b)) more than from the current GS site (see Fig. 10(a)) [53].

This result opens a discussion around the proposed methodology for the antenna site selection process regarding the available budget associated to the low-cost concept applied in these projects, in order to avoid over costs and optimize the available resources, in particular, the usefulness of the virtual simulation of the antenna site scenario before the installation stage by considering the mission requirements and the facility constraints required by the professionals involved in the GS project design.

5. Conclusions

3D digital surveying techniques, and in particular the laser scanning technology, are an innovative solution to analyze GS scenarios on building roofs: first, by capturing massive information about the GS location; second, creating the digital scene which contains the spatial position and the pixel of each analyzed point, and; third, modeling objects without physical contact to create the 3D model of the particular scenario to be analyzed. The developed procedures, based on RE tools and techniques, and implemented in the antenna selection site process are very useful in order to create the virtual scene of the GS site on the real scenario before the installation stage, to analyze the in situ constraints in built-up areas, to provide accurate measurements of great importance in the analysis of the GS components configuration and, finally, to test the requirements of the GS mission taking into account the antenna elevation mask as a relevant factor in the site selection, especially in CubeSat-LEO missions.

The main conclusion drawn from the research experience in the case study of the ETSIT GS at the Technical University of Madrid was the successful interaction with GS engineers providing them with another approach, that from the geographic engineering scope, to solve the data download problem in the future QBito nanosatellite mission.

The main conclusion drawn from the developed methodology is its application for the installation of telecommunications antennas on buildings roofs where the antenna performance depends on the available FOV and the facility location depends on building regulations.

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Conflicts of interest

The authors declare no conflict of interest.

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