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Zea, L. et al. (2016): JoSS, Vol. 5, No. 3, pp. 483–511
(Peer-reviewed article available at www.jossonline.com)

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A Methodology for CubeSat Mission Selection

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Abstract

Over 400 CubeSats have been launched during the first 13 years of existence of this 10 cm cube-per unit standard. The CubeSat's flexibility to use commercial-off-the-shelf (COTS) parts and its standardization of interfaces have reduced the cost of developing and operating space systems. This is evident by satellite design projects where at least 95 universities and 18 developing countries have been involved. Although most of these initial projects had the sole mission of demonstrating that a space system could be developed and operated in-house, several others had scientific missions on their own. The selection of said mission is not a trivial process, however, as the cost and benefits of different options need to be carefully assessed. To conduct this analysis in a systematic and scholarly fashion, a methodology based on maximizing the benefits while considering programmatic risk and technical feasibility was developed for the current study. Several potential mission categories, which include remote sensing and space-based research, were analyzed for their technical requirements and feasibility to be implemented on CubeSats. The methodology helps compare potential missions based on their relevance, risk, required resources, and benefits. The use of this flexible methodology—as well as its inputs and outputs—is demonstrated through a case study. This tool may come in handy in deciding the most convenient mission for any organization, based on their strategic objectives.

1. Introduction

CubeSats are small satellites that are based on the CalPoly standard of 10 cubic centimeter units (1U) (CalPoly, 2014). The number of CubeSats launched to orbit has grown exponentially from one in 2002, to eight in 2008 to over 120 in 2015 (a complete list of CubeSats launched from 2002 and their respective missions can be found as Appendix A in this paper). By the time of publishing of this manuscript, the design and development of over 150 CubeSats have involved universities across the world; from those, less than half have reportedly carried a payload other than a commercial off-the-shelf (COTS) camera, radiometer, or beacon. The CubeSats that have limited their mission to these three options are sometimes referred to as being education-class or "beepsats" because their function is mainly to send back telemetry (Swartwout, 2013). However, non-"beepsapts" have demonstrated that university- or education-class CubeSats can also carry functional payloads that produce data of value to the home organization and country. In other words, universities can train their students and young engineers in satellite develop-

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Publication History: Submitted – 12/08/15; Revision Accepted – 09/16/16; Published – 10/27/16

ment while producing data that can be of benefit for a secondary purpose.

The objective of this article is to help organizations quantify the benefits of different CubeSat missions based on two segments: 1) a list of options and their respective technical feasibilities (section 2); and 2) a methodology to analyze each of these alternatives and calculate their benefit based on values that the organization may give to each variable, including programmatic risk (section 3). Finally, a case study is presented to exemplify how the methodology works and its inputs and outputs (section 4). The methodology and an eight-step procedure on how to use it are described in Appendix B. For recommendations on the steps to take after a mission has been selected, readers are referred to the work of Berthoud and Schenk (2016).

2. CubeSat Missions

Table 1 lists a series of satellite missions/ applications and for each of them the technical feasibility of having a CubeSat as its platform. It also lists examples of CubeSats that have already successfully operated a payload with that focus. Technical feasibility is based on the volume, mass, and power requirements of the sensors needed to acquire data relative to those that a 3U CubeSat can provide. Feasibility is described as "D" for demonstrated (i.e., CubeSats have already been successfully used for the given application); "LF" for likely feasible; or "~" if the current state-of-the-art sensors would place requirements that would be hard to fulfill with a CubeSat bus (but not necessarily impossible). There are no "unfeasible" scores, as the rate of sensor miniaturization is quickly increasing and there might be alternative ways of fulfilling a mission's requirements. Thus, a "~" score does not mean that a given mission should not be considered, but serves as a preliminary filter to inform of an even higher technical challenge to accommodate it using a 3U CubeSat. Furthermore, 1U or 2U CubeSats will place even more stringent power, mass, and volume constraints on the required sensors, so the options will be further reduced.

The missions/applications have been grouped under five different main groups. The first one is Earth Observation, which is further segregated under atmosphere, land, ocean, snow and ice, and global categories. The list of focuses and their respective feasibility scores are based on ESA (2014) and Selva and Krejci (2012), respectively. The latter reference goes into further details regarding the required sensors for each focus.

The second main group is Space Environment and is based on Prölss (2004). The third, fourth and fifth groups, Astronomy/Astrophysics, Basic Research, and Technology Demonstration are mainly based on Woellert et al. (2011) and several other sources, as indicated in Table 1.

3. A Methodology for Selecting a Mission and Payload

A review of research and development (R&D) project selection and evaluation methods was conducted to find approaches that could be applicable to the selection of a CubeSat mission. The methods that were studied presented different techniques, from simple screening procedures to complex mathematical models (Meade & Presley, 2002; Henriksen & Traynor, 1999). From the different options that were investigated, a scoring model was selected for CubeSat mission evaluation due to its simplicity, its ability to apply quantitative measures to qualitative parameters, and because it allows to compare alternatives with the same evaluation criteria. This methodology is customizable, as it allows organizations to provide values to each parameter, thus optimizing it for different users. This scoring model is based on aspects described in the decision framework for project evaluations proposed in (Coldrick et al., 2002), on criteria and measures mentioned on (Meade & Presley, 2002; Henriksen & Traynor, 1999; Linton et al., 2002), and was implemented with a trade study-like approach for CubeSat mission evaluation and selection in this work.

3.1. Determining the Evaluation Criteria

A usual first step of a review scoring process is to decide on the criteria against which the options will be evaluated (Henriksen & Traynor, 1999). Thus,

Table 1. CubeSat Missions

Mission / Application	Focus	Feasibility	Related CubeSats
Earth Observation – Atmosphere	Aerosols	D	BISONSAT
	Temperature and humidity fields	LF	
	Winds, cloud properties, liquid water, precipitation	D	SENSE SV-2
	Lightning detection (GHRC, 2007)	D	DELFI C3(DO-64)
	Ozone and trace gases	D	SWISS CUBE1, POPACS 1/2/3
	Radiation budget	~	
Earth Observation – Land	Topography	~	
	Soil moisture	LF	
	Surface temperature	LF	
	Vegetation Mapping	LF	
	Forest Health	LF	
	Animal population dynamics (Woellert et al., 2011)	~	
Earth Observation – Ocean	Color/Biology (Werdell, 2010)	LF	
	Surface salinity	LF	
	Surface winds	LF	
	Altimetry/Topography/Currents	~	
	Surface temperature	~	
Earth Observation – Snow and Ice	Ice sheet topography	~	
	Sea ice cover	~	
	Snow cover	~	
Earth Observation – Global	Gravity Field	~	
	Magnetic Field	D	ANTELSAT
Space Environment Observation	Ionosphere	D	GALASSIA, RAX1, DICE 1-2, SENSE SV-1, ZACUBE-1
	Radiation Belts	D	CSSWE, E1P2, FIREBIRD-I, -II
	Magnetosphere	D	CSSWE
	Solar activity	D	POPACS 1/2/3, MIXSS
	Magnetic storms	LF	
Astronomy / Astrophysics	Stellar oscillations (Deschamps et al. 2009)	LF	
	General astronomy	LF	
Basic Research	Space Life Sciences (Zea, 2014)	D	GENESAT-1, PHARMASAT, O/OREOS
	Space Physical Sciences	D	PSSC-TESTBED1
	Earthquake Research (Bleier & Dunson, 2005)	D	QUAKESAT
Technology Demonstration	Propulsion	D	LIGHT SAIL A, STU-2, POPSAT-HIP1
	De-orbiting	D	RAIKO

Key: “D”= demonstrated; "LF"= likely feasible, "~"= not likely feasible at this time. The latter indicates an even higher technical challenge to accommodating a focus using a 3U CubeSat. Further details for each of these CubeSats can be found in Appendix A.

five aspects were selected as the basis of the criteria that can be used by any organization to evaluate CubeSat missions: relevance, benefits, technical feasibility, required resources, and risks. Each of these aspects is further broken down into several parameters.

3.2. The Methodology

The methodology is based on seven steps that assess 28 different parameters. The first and third steps ("Overall feasibility" and "Technical feasibility") work as filters, reducing the number of missions being analyzed (Figure 1).

The output of this methodology is a numerical result for each mission being analyzed. This result is a function of two factors: 1) the score a mission is given in each of the 28 parameters (valued from 0 to 10); and 2) the "weight" or importance that each parameter is given (valued from 1 to 4). The user of this methodology assigns both values because something that for one group may be very important might not be for a second group. For example, the CubeSat mission "Snow cover measurement" might have a high value (*e.g.*, 9) for a group in Alaska, while it may rank low (*e.g.*, 0) for a group in the Caribbean. Similarly, each parameter's "weight" or importance will vary from group to group. For example, a commercial entity might assign a high weight value (*e.g.*, 4) to "Intellectual Property," whereas for other organizations the number of patents is not something as important. While Appendix B provides the Methodology and an eight-step procedure on how to implement it, details on how to utilize are provided in the following sections, starting with how to assign values. The user needs to follow these steps to be able to utilize the methodology:

1. Assign weights to each of the parameters;
2. For each mission being assessed, assign a normalized value for each parameter; and
3. Compare the results: the mission with the highest result is the best fit for the group using this methodology.

3.3. How to Assign Importance or Weight to each Parameter

Each parameter must be assigned a "weight" using Table 2.

3.4. How to Assign a Value to each Parameter for a Mission

It must be kept in mind that low values are given to undesirable outcomes, and high values are given to desirable outcomes. Values range from zero to ten, inclusive [0–10].

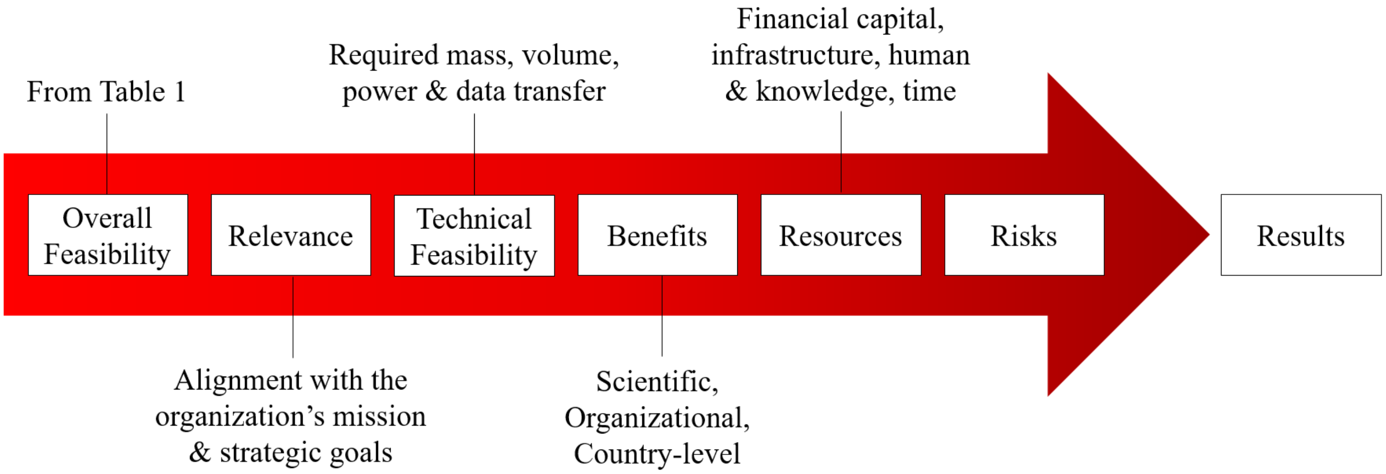

Figure 1. Flow chart describing the methodology to select a CubeSat mission.

Table 2. Weight Assignment to Each Analyzed Parameter

Weight	Meaning
1	Unimportant
2	Slightly unimportant
3	Slightly important
4	Important

3.4.1. Overall Feasibility

Table 1 can be used as a guide for overall feasibility. The missions ranked with an "D" or "LF" can be assumed feasible and may be further analyzed in the subsequent steps. Since the rate of sensor miniaturization is high, missions currently ranked with "~" or "not likely feasible at this time" may indeed become feasible with time. As mentioned earlier, "Overall Feasibility" works like a filter and there is no scoring in this step.

3.4.2. Relevance

The alignment between the mission(s) being analyzed and the organization's mission and strategic objectives is quantified as "Relevance" (Henriksen & Traynor, 1999). Table 3 briefly indicates how to score each mission.

Table 3. Relevance Scoring

Normalized Score	Relevance
0	Not aligned at all
3	Mostly not aligned
7	Mostly aligned
10	Highly aligned

Note: High values are given to the desirable outcomes.

3.4.3. Technical Feasibility

This step requires some investigative effort to further analyze the missions being assessed. For each of the missions being analyzed the relevant sensors must be identified. For that purpose, the work published by Selva & Krejci (2012) is recommended as a starting source. For example, for "measuring ocean surface salinity," one or more of these sensors may be needed: L-band passive radiometer; GNSS receiver; TIR sensors; and/or microbolometers. After the required sensors/equipment have been identified, their respective mass, volume, power, and data bandwidth should be determined. Finally, these values should be compared with what is available in a CubeSat, depending on whether it is a 1-, 2-, or 3-U. In other words, these steps need to be conducted for each mission:

1. Identify required onboard sensors/equipment;
2. Determine the mass, volume, power, and data up/downlink requirements of said sensors; and
3. Compare the values from the previous step with what is available in a CubeSat.

This last step works as a filter to further reduce the number of missions that will be assessed through the rest of the methodology.

3.4.4. Benefits

"Benefits" help quantify the impact the project would have if the mission were successful. The potential benefits a mission may produce can be quantified through three groups of parameters: scientific; organizational; and country-level. Each of these parameters should be scored with "0" for "undesirable" and "10" for "desirable." Table 4 shows the criteria used for scoring in the following aspects:

3.4.5. Required Resources

The organization contemplating development of a CubeSat should make sure to identify the resources needed by each of the missions being assessed. Resources are here described through the following parameters, as shown in Table 5. "Budget" and "Time" are considered key parameters in that, if a given mission requires more of them than what is available, it is automatically disqualified from further analysis. An alternative approach can be a re-design to decrease the estimated cost and/or time needed for completion, and thus increase the score of these key-parameters. Using COTS components and sharing infrastructure with other groups is recommended to

Table 4. Benefits Scoring

Parameter	*0*	*1…4*	*5*	*6…9*	*10*
Benefits					
Scientific					
New technologies	No new tech developed		Some new technologies		Significant amount of new technologies
Basic Research	No new knowledge developed		Some new basic knowledge developed		Significant new basic knowledge developed
Applied Research	No new applied knowledge developed		Some new applied knowledge developed		Significant new applied knowledge developed
Organizational					
Impact on personnel	No impact on personnel capabilities and loyalty to the organization		Some impact on personnel capabilities and loyalty to the organization		High impact on personnel capabilities and loyalty to the organization
Intellectual Property	Low probability of new patents and/or publications		Some probability of new patents and/or publications		High probability of new patents and/or publications
Marketing	Low impact on image or public relations		Some impact on image or public relations		High impact on image or public relations
Products / services	No new products/services, no improvement in current products/services or performance		Some new products/services, some improvement in current products/services or performance		New products/services, new improvement in current products/services or performance
New customers	Low probability of new customers		Some probability of new customers		High probability of new customers
New markets	Low probability to participate in new markets		Some probability to participate in new markets		High probability to participate in new markets
Return of Investment	More than 10 years		5 or 6 years		Less than 2 years
Country-level					
Health	Low impact on food security or disease prevention		Some impact on food security or disease prevention		High impact on food security or disease prevention
Education	Low impact on new careers or student curricula improvement		Some impact on new careers or student curricula improvement		High impact on new careers or student curricula improvement
Natural resources	Low impact on resource monitoring, climate change data acquisition		Some impact on resource monitoring, climate change data acquisition		High impact on resource monitoring, climate change data acquisition
Natural disasters	Low impact on event prediction, disaster monitoring, post-disaster assessment and resource management		Some impact on event prediction, disaster monitoring, post-disaster assessment and resource management		High impact on event prediction, disaster monitoring, post-disaster assessment and resource management

Note: High values are given to the desirable outcomes.

Table 4. Benefits Scoring (continued)

Parameter	*0*	*1…4*	*5*	*6…9*	*10*
Technology development	Low impact on creation of new technological capabilities		Some impact on creation of new technological capabilities		High impact on creation of new technological capabilities
Economic productivity	Low impact on manufacturing, agriculture or other sectors' productivity		Some impact on manufacturing, agriculture, or other sectors' productivity		High impact on manufacturing, agriculture or other sectors' productivity
Job creation	No impact on new industries or job creation		Some impact on new industries or job creation		High impact on new industries or job creation
Exports	No impact on new exporting products/services and/or exports volume		Some impact on new exporting products/services and/or exports volume		High impact on new exporting products/services and/or exports volume

Note: High values are given to the desirable outcomes.

Table 5. Required Resources Scoring

Parameter	*0*	*1…4*	*5*	*6…9*	*10*
Required Resources					
Budget*	Project cost higher than available budget		Project cost same as available budget		Project cost lower than available budget
Time*	Time for completion longer than available		Time for completion same as available		Time for completion less than available
Alignment with other projects	No symbiosis with other projects		Some symbiosis with other projects		Significant symbiosis with other projects
Technical / Infrastructure	Necessary equipment and facilities unavailable and/or difficult to obtain		Necessary equipment and facilities can be attained		Necessary equipment and facilities readily available and easy to obtain
Human					
In-house knowledge	High in-house knowledge acquisition needed		Some in-house knowledge acquisition needed		Low in-house knowledge acquisition needed
Team leadership	Team leadership expertise required is higher than available		Team leadership expertise required is same as available		Team leadership expertise required is lower than available
Human resource retention	Indispensable that all the members of the team stay for the whole lifetime of the project		Indispensable that some members of the team stay for the whole lifetime of the project		It is not indispensable that any member of the team stays for the whole lifetime of the project
External alliances	Highly required for project success		Some required for project success		Not required for project success

Note: High values are given to the desirable outcomes. * = key parameters for which a score of "0" automatically disqualifies a given mission from further analysis unless an alternative approach can be designed that would increase these values above "0."

find alternative approaches in reducing estimated financial and time budgets.

3.4.6. Risks

Risk may be seen as a counter-indicator of the probability of success. Some parameters, *e.g.*, those under technical feasibility and resources, are directly related to it. However, there are other parameters not yet assessed, that vary from project to project. One way of assigning a normalized score of risk is to develop a risk matrix. To do a risk matrix, the most signification risks need to be identified and for each of them, likeliness and consequence values have to be given (scored from 1 to 5), as indicated in Table 6.

Table 6. Risk Scoring

Normalized Score	Relevance
0	High risk of mission failure identified
5	Acceptable risk of mission failure identified
10	Low risk of mission failure identified

Note: High values are given to the desirable outcomes.

For example, a mission may have a risk *X* described as “Data output rate larger than available communication downlink” (as seen in Figure 2), describing that it is expected that the payload sensors will produce more data than the satellite is capable of sending to the ground station. It could be determined that this risk is very unlikely, a *1* in a scale from *1* to *5*, where *5* is very likely (i.e. 1 indicates a (0%–20%) probability). On the other hand, the consequence of this risk actually occurring could be determined to be very high, a *4* in a scale from *1* to *5*, where five is loss of mission or loss of spacecraft. By doing this, this step also helps consider the programmatic risks that arise from the readiness level of the technologies (TRL) that are planned on being used. A sensitivity analysis may or may not be conducted after this point, as these types of assessments help study the uncertainty in the methodology’s output but are not necessarily required. Wertz et al. (2011) and Garvey & Lansdowne (1998) explain risk matrices in further detail, and Brumbaugh and Lightsey (2013) describe risk management strategies specifically for CubeSat missions. Based on this analysis, a relevance value can be assigned to each mission (per Table 6) for its use in the methodology.

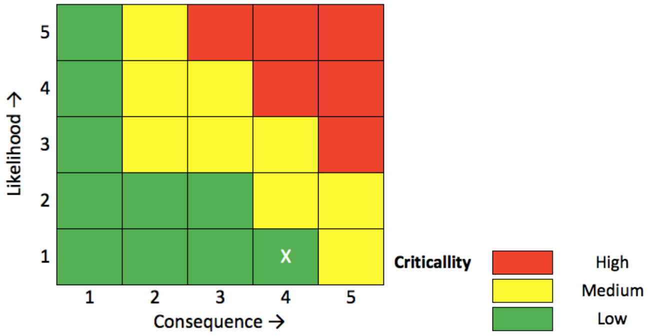

Figure 2. Example of a Risk Matrix with "Risk *X*" on the (4,1) coordinates.

3.5. Calculating the Result

This methodology assesses 28 different parameters (*i*), each with a weight *W*. Each mission has been given a normalized value from zero to ten (*V*). *A* describes the result mission “A” receives and is the sum of the product of each parameter’s weight and normalized value, assigned by the user, as follows:

$$\mathrm{A} = \sum_{i}^{i=28} w_i \cdot V_i$$

The mission with the highest results is the one that should be considered as the best option to choose for the CubeSat’s mission. It must be stressed that missions that score “0” on the “Budget” and/or “Time” key parameters (Required Resources) cannot be further analyzed as options.

4. Case Study: Guatemala’s First CubeSat

The motivation to create this methodology was Universidad del Valle de Guatemala (UVG) School of Engineering’s work on developing the first Guatemalan CubeSat. The goal was to select a payload for the country’s first satellite in an objective and systematic fashion. Therefore, it is fitting that Guatemala's first CubeSat is used as a case study and example on the use of this methodology.

Like most developing countries, Guatemala is located in the Tropics. It is one of the Central American nations and has a territorial extension of 108,889 km^2 and a population of 15 million people. Its economy is based in agriculture, and due to its location and geography, which includes 33 volcanoes, mountains and valleys, is very vulnerable to the effects of climate change.

4.1. User Characteristics

To understand how each of the potential satellite missions fit into the reality of the methodology user, it is important to understand the characteristics of said user—in this case, Guatemala. As reported in INE (2013) in 2011, 13.3% of the population lived in extreme poverty and 53.7% in poverty; in 2012, the illiteracy rate was 16.6%. With an economy based in agriculture, 22% of total exports for 2012 corresponded to green coffee, 19% to sugar and 13% to silver (INE, 2013). In terms of natural resources, in 2012, 34% of the national territory was covered with forest (INAB et al., 2012); in the same year, an area of 70.61 km^2 was affected by forest fires (INE, 2013). With regard to land use, according to INE (2013), 10,000 km^2 (representing 14% of the total agribusinesses area) are used for permanent crops (coffee, sugar cane, African palm, rubber, and cardamom), 8,900 km^2 (12%) for annual crops (corn, beans, fruits and vegetables, rice) and 16,000 km^2 (23%) for pasture. Guatemala has 38 river basins, 7 lakes, and 49 lagoons (BID & SEGEPLAN, 2006). Although Guatemala has high hydric resources that represent 8,000 m^3 of water per capita per year (BID & SEGEPLAN, 2006), two of its lakes (Lake Amatitlán and Lake Atitlán) have contamination problems. Lake Atitlán contamination comes from wastewater and represents a bacteriological risk for humans. This contamination provides nutrients, especially nitrogen and phosphorous, which contribute to algae and other plant growth (Castellanos & Girón, 2009). Lake Atitlán is economically important for the country and the surrounding communities, not only in terms of human health but also because it is one of the country's main touristic places, making it the source of livelihood for many people. Guatemala is often struck by natural disasters. In 1998, tropical storm Mitch caused economic losses of US$948.79 million. In 2005, Tropical Storm Stan, cost the country US$1,000 million and in 2010, tropical storm Agatha and the Pacaya Volcano eruption had a financial cost of US$7,855.7 million (GG, 2010). Beyond financial values is the human cost of these disasters. In 2008, 241,582 people were affected, while in 2012, this value grew to 4,669,064 (INE, 2013). Additionally, from 2008 to 2012, an average of 1,064 earthquakes per year were registered (INE, 2013).

4.2. Relevant Missions

For developing countries such as Guatemala, the development of a CubeSat is already a national technology demonstrator. In addition to having that benefit, having a functional payload could increase the return of investment. Here, this study briefly analyzes five missions that passed the first three steps of this methodology (Figure 1).

4.2.1. Soil Moisture

Soil Moisture refers to monitoring the water held in the spaces between soil particles. It can be classified in surface soil moisture (water that is in the upper 10 cm of soil) and root zone soil moisture (water available for plants, upper 200 cm of soil) (James, 1999). There are several techniques to remotely estimate soil moisture: optical, thermal infrared, and microwave radiometers (passive and active measurement) (Wang & Qu, 2009). However, to accomplish an appropriate spatial resolution at low band frequencies from space, antennas significantly larger than a CubeSat (on the order of several meters) are needed (Kerr et al., 2001).

4.2.2. Vegetation Mapping and Forest Health Monitoring

Vegetation mapping consists in quantifying and qualifying the amount of plants located in a specific area. It can be used for vegetation species identification, vegetation (forest) health monitoring, forest inventorying, etc., and it plays an important role in nature preservation and in climate change adaption strategies (TRS, 2012).

4.2.3. Earthquake Research

A hypothesis suggests that before an earthquake takes place, the earth's magnetic field is affected by the electrical activity between the tectonic plates (Bleir & Freund, 2005). This hypothesis sustains that low-orbit satellites could potentially predict earthquakes by detecting the electromagnetic fluctuations on the magnetic field. It is also believed that earthquakes could be predicted by the use of an Interferometric-Synthetic Aperture Radar, which detects any changes in ground motion at the earth's surface (Fox et al., 1989).

4.2.4. Water Color/Biology

Water Color/ Biology is usually referred to as Ocean Color Monitoring. Satellites can measure phytoplankton concentration on the upper layers or water bodies (*i.e.*, oceans and lakes) (Flores, 2013; Lowe et al., 2012; Trescott, 2012). Phytoplankton is a key factor in aquatic life and ecosystems because it is at the bottom of the food chain and serves as a proxy to assess an ecosystem's health and overall contamination (Charlson et al., 1987).

4.3. Methodology Operation

Although the steps described before were implemented on all five relevant missions, one of them—Water Color Monitoring—is described here. As depicted in Figure 1, "Benefits" is the next step after the filtering that produced the five mission options described above. A weight was given to each of the eighteen parameters in Table 4. For example, impact on "Health" was given a weight of four (very important) due to the health crisis lived in Guatemala, while a weight of one (mostly unimportant) was given to "Exports," as this is an academic project. Because the Water Color Monitoring option was scored with 9 for the Health parameter (high impact on food security, disease prevention, as described in Table 4) the total value for this variable and for this option is 4 x 9 = 36. The final score for a given option is the summation of the total value for all 28 parameters.

4.4. Outputs from the Methodology

After evaluating the five missions under the categories described in this paper, the methodology yielded a score of 642 to water monitoring, 555 to forest health, 540 to vegetation mapping, 466 to soil moisture, and 381 to earthquake research, as seen in Figure 3. The difference between water monitoring and forest health, the two top-scored missions, is 87 points, or a 14% of the top score's value. The model output is very clear, concise, and straightforward. These results allow the organization using the methodology to make objective decisions in a systematic and scholarly fashion.

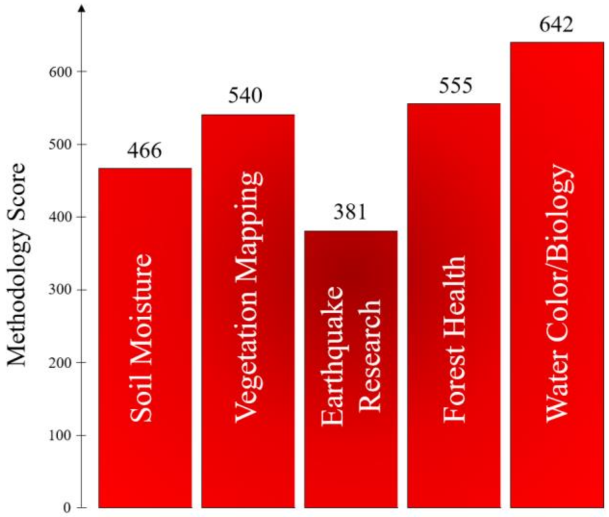

Figure 3. The results of the methodology for the case study indicate that water monitoring is the most suitable mission for Guatemala's first CubeSat.

5. Discussion

As Universidad del Valle de Guatemala started considering developing its first CubeSat, the definition of the satellite's mission became a task of paramount importance. This is because the mission creates and places requirements and constraints upon all of the CubeSat's subsystems. To conduct the mission selection in an academic fashion, a literature survey was conducted to find a methodology for this purpose. However, that search was futile, as it seems that such methodology has not yet been published. With that in mind, this systematic approach to mission selection was developed. Furthermore, this methodology was designed such that each user can provide its own level of importance to the different parameters used to assess the missions.

Five payload options (soil moisture, vegetation mapping, earthquake research, forest health, and water monitoring) were analyzed as options for Guatemala's first satellite's payload. The use of this methodology brought up several aspects about these missions to light as well as allowed to come to several conclusions. For example, it is not recommended to implement a soil-moisture sensing payload on a 1U CubeSat. At this time, the space required for such a payload can only be provided by a 3U or larger CubeSat. Another issue that this type of payload faces is the fact that no L-band radiometers for passive sensing were found on the market. For this reason, any radiometer for a soil moisture payload must be built in-house. Additionally, radiometers are limited by dense vegetation, clouds contamination, soil roughness, and penetration depth.

Earthquake research was found to be a viable payload because of the simplicity of the required instruments, such as those used by the QuakeSat (Bleir & Dunson, 2005). However, the benefits of this mission could only be seen in the long term, as it is focused on basic research. Learning how to predict earthquakes would be invaluable as it could save thousands of lives; however, the data points produced by one CubeSat would be limited in proving or disproving related hypotheses. It is considered that this mission could best be served by a swarm of CubeSats, versus a single free flyer.

Although vegetation mapping and forest health scored highly, water monitoring proved to be the best option. It was found that the mass, volume, and power required by the instruments may fit in a 1U CubeSat. Preliminary research on the sensors, suggest that there is a possibility of fulfilling more than one of the previous researched functions with these same devices. Based on the fact that two of the main lakes in Guatemala have had serious contamination problems, frequent and focused monitoring may enable better and faster reactions to changes in these aquatic ecosystems.

This methodology's flexibility, which stems from the fact that each user can designate different levels of importance to each parameter, allows it to be of use to multiple parties. This is also supported by the diverse fields covered with the 28 parameters of assessment, from export quantification to intellectual property production. This tool may come in handy in deciding the most convenient mission for any organization, based on their strategic objectives.

Acknowledgments

The authors would like to thank Michael Swartwout (Saint Louis University), Gunter Krebs (Gunter's Space Page), and the eoPortal Directory (European Space Agency) for maintaining comprehensive and freely-available databases online.

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Appendix A: List of Cubesats 2002-August 2016

The starting point to develop this table was the lists presented in (Swartwout, 2013) and (Swartwout, 2016), from which the year, name, size and organization and result (S-success, F-failure, RF-rocket failure) were taken in part, as well as NASA's Space Science Data Center (NSSDC) Database (NASA, 2014) and the eoPortal (eoPortal, 2016). The other fields were identified in a CubeSat-by-CubeSat basis. The mission type was identified as one of the following: A-astronomy/astrophysics, BR-basic research (to conduct life or physical sciences experiments, earthquake prediction research, etc.), C-commercial (to develop a product or provide a service commercial in nature), CM-communication, E-education (to train students and/or engineers), S-science, SE-space environment, or T-technology demonstration (to increase the technology readiness level TRL of a specific technology). Some CubeSats have had more than one of these mission types, for example university missions that not only have the purpose of training its students but also conduct a scientific mission.

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2002	MEPSI	2U	T	Technology Demonstrator	Design Testing	DARPA & Aerospace Corp.	USA	Deployed	(Krebs, 2016) (NASA, 2016)
2003	QuakeSat 1	3U	E - BR	Eartquake research	Earthquake Prediction	Stanford & QuakeFinder	USA	Success	(Bleier, 2005) (eoPortal, 2016)
2003	DTUSat 1	1U	E	Educational	De-orbiting	Technological University of Denmark	Denmark	Deployed	(Technical University of Denmark, 2016)
2003	CUTE 1	1U	E	Educational	Design Testing	Tokyo Institute of Technology	Japan	Success	(NASA, 2016)(eoPortal, 2016)
2003	AAU CUBESAT 1	1U	E	Educational	Earth imaging	Aalborg University	Denmark	Deployed	(NASA, 2016)
2003	CanX 1	1U	E	Educational	Design testing	University of Toronto	Canada	Success	(NASA, 2016) (eoPortal, 2016)
2003	XI-IV	1U	E	Educational	Nano-technology testing	University of Tokyo	Japan	Partial Success	(NASA, 2016) (University of Tokyo, 2016)
2005	UWE-1	1U	E	Educational	Internet protocols testing	University of Wurzburg	Germany	Success	(Krebs, 2016) (NASA, 2016) (eoPortal, 2016)
2005	XI-V	1U	E	Educational	Nano-technology testing, Solar Cells	University of Tokyo	Japan	Success	(NASA, 2016) (University of Tokyo, 2016)
2005	Ncube 2	1U	E	Educational	Ship Tracking, Animal Population Dynamics	Multiple universities	Norway	Failed to Launch	(Krebs, 2016) (eoPortal, 2016)
2006	CUTE 1.7	2U	E	Educational	Design Testing	Tokyo Institute of Technology	Japan	Established Communications	(NASA, 2016) (eoPortal, 2016)
2006	AeroCube 1	1U	T	Technology Demonstrator	N/A	Aerospace Corporation	USA	Launch Failure	(Krebs, 2016)
2006	CP 1	1U	E	Educational	ADCS (Magnetorquer), Power (Sun sensors)	CalPoly	USA	Launch Failure	(Krebs, 2016)
2006	CP 2	1U	E	Educational	Power (Energy Dissipation)	CalPoly	USA	Launch Failure	(Krebs, 2016)
2006	HAUSAT 1	1U	E	Educational	GPS, Deployable Solar Panels, Sun Sensors	Hankuk Aviation University	South Korea	Launch Failure	(Krebs, 2016) (Chang et al., 2006)
2006	ICECube 1	1U	E - SE	Educational	Ionosphere	Cornell & California Polytechnic State University	USA	Launch Failure	(Krebs, 2016)
2006	ICECube 2	1U	E - S	Educational	Ionosphere	Cornell & California Polytechnic State University	USA	Launch Failure	(Krebs, 2016)

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2006	ION	2U	E - S	Propulsion and Earth Observation	Propulsion, Ozone and trace gases	University of Illinois & Alameda Applied Sciences Corp.	USA	Launch Failure	(Krebs, 2016)
2006	KUTESat Pathfinder	1U	E - S	Educational	Radiation Budget	University of Kansas	USA	Launch Failure	(Krebs, 2016)
2006	Mea Huaka'i	1U	E - T	Educational	Communications and data capabilities	University of Hawaii	USA	Launch Failure	(Krebs, 2016)
2006	MEROPE	1U	E - S	Educational	Radiation Belts	Montana State University	USA	Launch Failure	(Krebs, 2016)
2006	Ncube 1	1U	E	Educational	Ship Tracking, Animal Population Dynamics	Multiple universities	Norway	Launch Failure	(Krebs, 2016)
2006	Rincon 1	1U	E	Educational	Communications and data capabilities	University of Arizona	USA	Launch Failure	(Krebs, 2016)
2006	SACRED	1U	E / C	Educational & Commercial	COTS components test	University of Arizona, Montpellier University and AlcaTel Space Systems	USA / France	Launch Failure	(Krebs, 2016)
2006	SEEDS	1U	E	Educational	Communications	Nihon Universities	Japan	Launch Failure	(Krebs, 2016)
2006	HIT-Sat	1U	E	Educational	Design Testing (Bus)	Hokkaido Institute of Technology	Japan	Success	(Krebs, 2016) (NASA, 2016) (eoPortal, 2016)
2006	GeneSat-1	3U	S	Space Life Sciences	Space Life Sciences (effects of gravity on biological cultures)	NASA Ames	USA	Success	(NASA, 2010) (Kitts et al., 2006) (Kitts et al., 2006)
2006	MEPSI 2	2U	T	Technology Demonstrator	Design Testing	DARPA & Aerospace Corp.	USA	Success	(NASA, 2016)
2007	AeroCube 2	1U	T	Technology Demonstrator	De-orbiting	Aerospace Corporation	USA	Failed	(Krebs, 2016)
2007	CAPE 1	1U	SE	Technology Demonstrator	Ionosphere	University of Louisiana	USA	Success	(Grayzeck, 2016)
2007	CP3	1U	T	Technology Demonstrator	ADCS (Magnetorquer)	Cal Poly	USA	Failed	(Grayzeck, 2016), (Krebs, 2016)
2007	CP4	1U	T	Technology Demonstrator	Power (Energy Dissipation)	Cal Poly	USA	Failed	(Grayzeck, 2016), (Krebs, 2016)
2007	CSTB 1	1U	BR-CM	Techical Research	Communications	Boeing	USA	Failed	(Grayzeck, 2016), (Krebs, 2016)
2007	LIBERTAD 1	1U	E	Educational	Communications (Telemetry)	University of Sergio Arboleda	Colombia	Failed	(Grayzeck, 2016)
2007	MAST	3U	T	Technology Demonstrator	Space Technology testing	Tethers Unlimited. Inc.; Pumpkin. Inc. (bus)	USA	Failed	(Grayzeck, 2016)
2008	AAUSAT 2	1U	E	Educational	ADCS, X-Ray measurments	University of Aalborg	Denmark	Success	(Grayzeck, 2016), (Krebs, 2016)
2008	CanX 2	3U	T	Technology Demonstrator	ADCS, GPS, Propulsion	UTIAS (University of Toronto)	Canada	Success	(eoPortal, 2016)
2008	COMPASS-1	1U	T	Technology Demonstrator	GPS, Earth imaging, ADCS	Fachhochschule Aachen	Germany	Failed	(Grayzeck, 2016)
2008	Delfi C3	3U	T	Technology Demonstrator	Lighting Detection	Technical University of Delft	Netherlands	Success	(eoPortal, 2016)
2008	SEEDS 2	1U	T	Technology Demonstrator	Communications and data capabilities (Protocols)	Nihon University	Japan	Success	(eoPortal, 2016)
2008	NanoSail D	3U	T	Technology Demonstrator	Propulsion	NASA Ames	USA	Failed	(Grayzeck, 2016), (Krebs, 2016)
2008	PreSat	3U	T-BR	Technology Demonstrator	Space Life Sciences	NASA Ames	USA	Failed	(Krebs, 2016)
2008	PSSC-Testbed 1	2U	T	Technology Demonstrator	Space Physical Sciences (radiation degradation of solar cells)	Aerospace Corporation	USA	Success	(eoPortal, 2016)

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2009	KKS 1 (Kiseki)	1U	T	Technology Demonstrator	Propulsion, Earth imaging, ADCS	Tokyo Metropolitan College of Industrial Technology	Japan	Established Communications	(Grayzeck, 2016), (Krebs, 2016)
2009	AeroCube 3	1U	T	Technology Demonstrator	Bus performance, photograph launch vehicle	Aerospace Corporation	USA	Success	(eoPortal, 2016)
2009	CP 6	1U	T	Technology Demonstrator	ADCS (Magnetometers)	Cal Poly	USA	Failed	(Grayzeck, 2016), (Krebs, 2016)
2009	HawkSat 1	1U	civ	Technology Demonstrator	Space Physical Sciences	Hawk Institute for Space Sciences	USA	Deployed	(Grayzeck, 2016) (Krebs, 2016)
2009	PharmaSat	3U	T	Technology Demonstrator	Space Life Sciences	Stanford University	USA	Success	(eoPortal, 2016)
2009	Bevo 1	1U	T	Technology Demonstrator	GPS	University of Texas	USA	Failed	(Krebs, 2016)
2009	AggieSat 2	1U	T	Technology Demonstrator	GPS	Texas A&M University	USA	Success	(Grayzeck, 2016)
2009	BeeSat-1	1U	T	Technology Demonstrator	ADCS (Micro-reaction wheels)	Technical University of Berlin	Germany	Failed	(NASA, 2016)
2009	ITUpSAT-1	1U	E	Technology Demonstrator	ADCS, Capture images	Istanbul Technical University	Turkey	Success	(NASA, 2016) (eoPortal, 2016)
2009	SwissCube 1	1U	S	Space Environment	Ozone and trace gases (airglow phenomena)	EPFL	Switzerland	Success	(eoPortal, 2016)
2009	UWE-2	1U	E	Technology Demonstrator	ADCS, GPS	University of Wurzburg	Germany	Deployed	(NASA, 2016)
2010	Hayato (K-SAT)	1U	CM	Educational	Communications and data capabilities	Kagoshima University	Japan	Failed	(Krebs, 2016)
2010	Negai-Star (Negai-Boshi)	1U	E-T	Technology Demonstrator	Design Testing (FPGA)	Soka University	Japan	Success	(Krebs, 2016)
2010	Waseda-SAT2	1U	E-T	Technology Demonstrator	Earth imaging	Waseda University	Japan	Failed	(Krebs, 2016)
2010	StudSat-1	1U	E	Earth Observation-Land	Earth imaging	Indian University Consortium	USA	Failed	(eoPortal, 2016)
2010	TISat-1	1U	E	Educational	Electronics Degradation (Degradation in space environment)	Scuola universitaria della Svizzera italiana	Switzerland	Success	(eoPortal, 2016)
2010	O/OREOS	3U	S	Basic Reasearch	Space Life Sciences	NASA Ames	USA	Success	(eoPortal, 2016)
2010	RAX 1	3U	S	Earth Observation	Ionosphere	University of Michigan	USA	Success	(eoPortal, 2016)
2010	Mayflower-Caerus	3U	E-T	Technology Demonstrator	Design Testing	University of Southern California	USA	Success	(Krebs, 2016)
2010	Perseus 000	1.5U	T	Technology Demonstrator	Design Testing	Los Alamos National Laboratory	USA	Success	(Krebs, 2016), (Grayzeck, 2016)
2010	Perseus 001	1.5U	T	Technology Demonstrator	Design Testing	Los Alamos National Laboratory	USA	Success	(Krebs, 2016), (Grayzeck, 2016)
2010	Perseus 002	1.5U	T	Technology Demonstrator	Design Testing	Los Alamos National Laboratory	USA	Success	(Krebs, 2016), (Grayzeck, 2016)
2010	Perseus 003	1.5U	T	Technology Demonstrator	Design Testing	Los Alamos National Laboratory	USA	Success	(Krebs, 2016), (Grayzeck, 2016)
2010	QbX 1	3U	T	Technology Demonstrator	Communications	Naval Research Laboratory	USA	Success	(eoPortal, 2016)
2010	QbX 2	3U-C1	T	Technology Demonstrator	Communications	Naval Research Laboratory	USA	Success	(eoPortal, 2016)
2010	SMDC ONE	3U	CM	Technology Demonstrator	Communications and data capabilities (Data relay)	MilTec	USA	Success	(eoPortal, 2016)
2011	NanoSail-D2	3U	T	Technology Demonstrator	Propulsion	NASA Ames	USA	Failed	(eoPortal, 2016)
2011	E1P (Explorer 1 Prime)	1U	E-T	Technology and Software Demonstrator	Radiation Belts	Montana State University	USA	Failed	(Krebs, 2016)

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2011	Hermes	1U	E	Educational	Communications and data capabilities (S-band)	Colorado Space Grant Consortium	USA	Failed	(Krebs, 2016)
2011	KySat-1	1U	E	Educational	Communications and data capabilities	Kentucky Space	USA	Failed	(Grayzeck, 2016)
2011	PSSC-2	2U	T	Technology Demonstrator	Ionosphere, Vehicle Tracking	Aerospace Corporation	USA	Success	(Hinkley & Hardy, 2012)
2011	Jugnu	3U	E	Educational	Imaging IR	Indian Institute of Technology Kanpur	India	Not found	(Grayzeck, 2016)
2011	AubieSat-1	1U	E-T	Technology Demonstrator	Power (Solar cell coatings)	Auburn University	USA	Success	(Krebs, 2016)
2011	DICE 1	1.5U	E-SE	Educational	Ionosphere	Utah State University	USA	Success	(eoPortal, 2016)
2011	DICE 2	1.5U	E-SE	Educational	Ionosphere	Utah State University	USA	Success	(eoPortal, 2016)
2011	E1P-2 (Explorer-1 Prime)	1U	E	Educational	Radiation Budget (Van Allen)	University of Michigan	USA	Success	(Krebs, 2016)
2011	M-Cubed	2U	E	Educational	Imaging	Montana State University	USA	Failed	(Krebs, 2016)
2011	RAX-2	3U	E	Educational	Ionosphere	University of Michigan	USA	Failed	(Grayzeck, 2016)
2012	E-ST@R	1U	E-T	Technology Demonstrator	ADCS	Politecnico di Torino	Italy	Failed	(Grayzeck, 2016)
2012	GOLIAT	1U	E-SE	Educational	Earth imaging, Electronics Degradation, Radiation Budget	University of Bucharest	Romania	Failed	(Grayzeck, 2016)
2012	MaSat-1	1U	E-T	Technology Demonstrator	Imaging	Budapest University of Technology and Economics	Hungary	Success	(eoPortal, 2016)
2012	PW-Sat 1	1U	E-BR	Educational	De-orbiting	Warsaw University of Technology	Poland	Failed	(Grayzeck, 2016)
2012	Robusta	1U	E-BR	Educational	Electronics Degradation (Radiation)	University of Montpellier II	France	Failed	(Grayzeck, 2016)
2012	UniCubeSat-GG	1U	E-T	Technology Demonstrator	ADCS	University of Rome "La Sapienza"	Italy	Failed	(Grayzeck, 2016)
2012	XaTcobeo	1U	E-T-BS	Technology Demonstrator	Ionosphere, Communications	University of Vigo	Spain	Not Found	(Grayzeck, 2016)
2012	Aeneas	3U-C	E-T	Technology Demonstrator	Vehicle Tracking	University of Southern California	USA	Established Communications	(Grayzeck, 2016) (Swartwout, 2016)
2012	AeroCube 4A	1U	T	Technology Demonstrator	N/A	Aerospace Corporation	USA	Failed	(Grayzeck, 2016)
2012	AeroCube 4B	1U	T	Technology Demonstrator	N/A	Aerospace Corporation	USA	Failed	(Grayzeck, 2016)
2012	AeroCube 4C	1U	T	Technology Demonstrator	De-orbiting, Launch conditions (Vibrations)	Aerospace Corporation	USA	Failed	(Grayzeck, 2016)
2012	CINEMA 1	3U	A-SE-T	Technology Demonstrator	Space Weather observations	CINEMA consortium	USA	Established Communications	(Grayzeck, 2016) (Swartwout, 2016)
2012	CP5	1U	T	Technology Demonstrator	De-orbiting	Cal Poly	USA	Failed	(Grayzeck, 2016)
2012	CSSWE	3U	SE-T	Technology Demonstrator	Solar Activity, radiation belts, magnetosphere	University of Boulder Colorado	USA	Success	(Grayzeck, 2016)
2012	CXBN	2U	A- SE-T	Technology Demonstrator	X-Ray measurments	Kentucky Space	USA	Failed	(Grayzeck, 2016)
2012	Re (STARE)	3U	T	Technology Demonstrator	Space Objects detection	Lawrence Livermore National Laboratory	USA	Failed	(Grayzeck, 2016)
2012	SMDC ONE 2.1	3U	CM- T	Communications	Communications and data capabilities (Data relay)	MilTec	USA	Success	(eoPortal, 2016)
2012	SMDC ONE 2.2	3U	CM- T	Communications	Communications and data capabilities (Data relay)	MilTec	USA	Success	(eoPortal, 2016)
2012	F1	1U	E	Educational	ADCS, Earth imaging	FPT Technology Research Institute	Vietnam	Failed	(Pe0sat, 2016)

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2012	FITSat-1 (Niwaka)	1U	T	Technology Demonstrator	Communications and data capabilities	Fukuoka Institute of Technology	Japan	Success	(eoPortal, 2016)
2012	Raiko	2U	E-T	Educational and Technology Demonstrarion	Imaging, Communications, deorbit	Tohoku University	Japan	Success	(eoPortal, 2016)
2012	TechEdSat	1U	E-CM	Educational	Communications, Design testing	San Jose State University	USA	Success	(Grayzeck, 2016) (eoPortal, 2016)
2012	WE WISH	1U	CM	Communications	Surface Temperature	Meisei Electric Co	Japan	Failed	(Grayzeck, 2016), (Krebs, 2016)
2013	AAUSAT 3	1U	E	Educational	Vehicle Tracking	University of Aalborg	Denmark	Success	(eoPortal, 2016)
2013	STRaND-1	3U	T	Technology Demonstrator	Design Testing (OBC design using a cellphone)	University of Surrey	England	Success	(eoPortal, 2016)
2013	BeeSat-2	1U	T	Technology Demonstrator	ADCS, GPS	Technical University of Berlin	Germany	Success	(eoPortal, 2016)
2013	BeeSat-3	1U	T	Technology Demonstrator	Communications, new S-Band Transmitter	Technical University of Berlin	Germany	Success	(eoPortal, 2016)
2013	Dove 2	3U	T	Technology Demonstrator	Imaging, design testing	Planet Labs	USA	Success	(eoPortal, 2016)
2013	OSSI-1	1U	CM-T	Communications	Communications and data capabilities	Hojun Song	South Korea	Failed	(Grayzeck, 2016), (Krebs, 2016)
2013	SOMP	1U	E-T	Educational, Technology Demonstration	Ozone and trace gases	Technical University of Dresden	Germany	Established Communications	(Grayzeck, 2016), (Krebs, 2016) (Swartwout, 2016)
2013	PhoneSat-1a	1U	T	Technology Demonstrator	Design Testing (OBC design)	NASA Ames	USA	Success	(eoPortal, 2016)
2013	PhoneSat-1b	1U	T	Technology Demonstrator	Design Testing (OBC design)	NASA Ames	USA	Success	(eoPortal, 2016), (Krebs, 2016)
2013	PhoneSat-1c	1U	T	Technology Demonstrator	Design Testing (OBC design)	NASA Ames	USA	Success	(eoPortal, 2016), (Krebs, 2016)
2013	Dove 1	3U	T	Technology Demonstrator	Imaging, design testing	Planet Labs	USA	Success	(Grayzeck, 2016), (Krebs, 2016)
2013	CubeBug-1	2U	T	Technology Demonstrator	Earth imaging, Design testing	Ministry of Science Technology & Productive Innovation	Argentina	Established Communications	(Grayzeck, 2016), (Krebs, 2016) (Swartwout, 2016)
2013	NEE-01 Pegasus	1U	T-E-BR	Educational, Technology Demonstration	Design Testing, Earth imaging (Real-time video transmission)	EXA	Ecuador	Failed	(Grayzeck, 2016)
2013	TurkSat-3USat	3U	CM	Communications	Communications and data capabilities (Data relay)	Istanbul Technical University	Turkey	Failed	(Grayzeck, 2016), (Krebs, 2016)
2013	ESTCube-1	1U	T	Technology Demonstrator	Propulsion	University of Tartu	Estonia	Failed	(ESTCUBE, 2016) (eoPortal, 2016)
2013	POPACS (1, 2 & 3)	3U	SE	Scientific Research	Ozone and trace gases	Utah State University	USA	Success	(eoPortal, 2016)
2013	ArduSat 1	1U	T	Technology Demonstrator	Earth imaging, Design testing (Amateur arduino experiments)	NanoSatisfi	Japan	Established Communications	(eoPortal, 2016)
2013	ArduSat X	1U	T	Technology Demonstrator	Earth imaging, Design testing (Amateur arduino experiments)	NanoSatisfi	Japan	Not Found	(eoPortal, 2016)
2013	PicoDragon	1U	T	Technology Demonstrator	Imaging	Vietnam National Satellite Center	Vietnam	Partial Success	(Krebs, 2016) (VNSC, 2015)
2013	Black Knight-1	1U	T	Technology Testing	ADCS	US Military Academy	USA	Failed	(Spaceflight Now, 2013)

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2013	CAPE-2	1U	BR	Technology Demonstrator	Power (Deployable Panels), Communications	University of Louisiana	USA	Not Found	(eoPortal, 2016)
2013	ChargerSat-1	1U	T	Technology Testing	Power, ADCS, Communications	University of Alabama-Huntsville	USA	Failed	(Krebs, 2016)
2013	COPPER	1U	T	Technology Testing	Surface Temperature, Electronics Degradation	Saint Louis University	USA	Failed	(Krebs, 2016)
2013	DragonSat-1	1U	SE	Scientific Research	Radiation Budget	Drexel University	USA	Failed	(Krebs, 2016)
2013	Firefly	3U	SE	Scientific Research	Lightning Detection	NASA Goddard	USA	Not Found	(NASA,2009)
2013	Ho'oponopono-2	3U	T	Technology Testing	General Astronomy (Ephemeris data), Space Objects Detection	University of Hawaii	USA	Failed	(Krebs, 2016)
2013	Horus (STARE)	3U	T	Technology Demonstrator	ADCS, Space Objects detection	Lawrence Livermore National Laboratory	USA	Failed	(Krebs, 2016)
2013	KySat-2	1U	T	Technology Demonstrator	Space Imaging	Kentucky Space	USA	Partial Success	(eoPortal, 2016)
2013	Lunar	1U	T	Technology Testing	General Astronomy (Lunar orbit)	Vermont Technical College	USA	Not Found	(Grayzeck, 2016)
2013	NPS-SCAT	1U	E - T	Technology Testing/Educational	Power (Solar cell testing)	Naval Postgraduate School	USA	Established Communications	(eoPortal, 2016)
2013	ORS Tech 1	3U	T	Technology Demonstrator	Design Testing	Johns Hopkins APL	USA	Success	(Krebs, 2016) (eoPortal, 2016)
2013	ORS Tech 2	3U	T	Technology Demonstrator	Design Testing	Johns Hopkins APL	USA	Success	(Krebs, 2016) (eoPortal, 2016)
2013	ORSES	3U	T	Technology Testing	Communications and data capabilities	MilTec	USA	Failed	(Krebs, 2016)
2013	PhoneSat 2.4	1U	T	Technology Development	Design Testing	NASA Ames	USA	Established Communications	(PhoneSat, 2014)
2013	Prometheus 1.1	1.5U	T	Technology Development	Communications and data capabilities (Data relay)	Los Alamos National Laboratory	USA	Not Found	(Krebs, 2016)
2013	Prometheus 1.2	1.5U	T	Technology Development	Communications and data capabilities (Data relay)	Los Alamos National Laboratory	USA	Not Found	(Krebs, 2016)
2013	Prometheus 2.1	1.5U	T	Technology Development	Communications and data capabilities (Data relay)	Los Alamos National Laboratory	USA	Not Found	(Krebs, 2016)
2013	Prometheus 2.2	1.5U	T	Technology Development	Communications and data capabilities (Data relay)	Los Alamos National Laboratory	USA	Not Found	(Krebs, 2016)
2013	Prometheus 3.1	1.5U	T	Technology Development	Communications and data capabilities (Data relay)	Los Alamos National Laboratory	USA	Not Found	(Krebs, 2016)
2013	Prometheus 3.2	1.5U	T	Technology Development	Communications and data capabilities (Data relay)	Los Alamos National Laboratory	USA	Not Found	(Krebs, 2016)
2013	Prometheus 4.1	1.5U	T	Technology Development	Communications and data capabilities (Data relay)	Los Alamos National Laboratory	USA	Not Found	(Krebs, 2016)
2013	Prometheus 4.2	1.5U	T	Technology Development	Communications and data capabilities (Data relay)	Los Alamos National Laboratory	USA	Not Found	(Krebs, 2016)
2013	SENSE SV-1	3U	SE	Scientific Research	Ionosphere	Boeing	USA	Success	(Krebs, 2016)
2013	SENSE SV-2	3U	SE	Scientific Research	Weather observation	Boeing	USA	Success	(Krebs, 2016)
2013	Trailblazer (SPA-1)	1U	T	Technology Demonstrator	Design Testing, Design testing (Bus)	University of New Mexico	USA	Failed	(eoPortal, 2016)
2013	SwampSat	1U	T	Technology Development	ADCS (Gyroscope)	University of Florida	USA	Failed	(eoPortal, 2016)
2013	TechEdSat-3	3U	T	Technology Demonstrator	De-orbiting	San Jose State University	USA	Not Found	(eoPortal, 2016)
2013	TJ3Sat	1U	T	Technology Demonstrator	Communications (Telemetry)	Thomas Jefferson High School	USA	Failed	(eoPortal, 2016)
2013	CINEMA 2	3U	SE	Scientific Research	Space Weather observations	KyungHeeUniversity	South Korea	Failed	(eoPortal, 2016)
2013	CINEMA 3	3U	SE	Scientific Research	Space Weather observations	KyungHeeUniversity	South Korea	Failed	(eoPortal, 2016)

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2013	CubeBug-2	2U	T	Technology Demonstrator	Design Testing (COTS components)	Ministry of Science Technology & Productive Innovation		Not Found	(Krebs, 2016)
2013	Delfi-n3Xt	3U	T	Technology Demonstrator	Propulsion	Technical University of Delft	Netherlands	Failed	(Krebs, 2016)
2013	Dove 4	3U	T	Technology Demonstrator	Earth imaging	Planet Labs	USA	Failed to Deploy	(Krebs, 2016)
2013	First-MOVE	1U	T	Technology Testing	Earth imaging	Technical University of Munich	Germany	Failed	(eoPortal, 2016)
2013	FUNcube 1	1U	E	Educational	Communications	Amsat-UK	UK	Success	(FUNcube, 2013)
2013	GATOSS (GOMX 1)	2U	T	Technology Testing	Vehicle Tracking	GOMSpace	Denmark	Success	(Hinkley & Hardy, 2012)
2013	HiNCube	1U	E	Educational	Earth imaging	Narvik University College	Norway	Failed	(Krebs, 2016)
2013	HumSat-D	1U	T	Technology Testing	Communications and data capabilities (Data relay)	University of Vigo	Spain	Not Found	(eoPortal, 2016)
2013	iCube-1	1U	T	Technology Testing	Space Life Sciences	Institute of Space Technology Islamabad	Pakistan	Failed	(Krebs, 2016)
2013	NEE 02 Krysaor	1U	SE	Scientific Research	Space Objects detection, Communications and data capabilities (Data relay)	EXA	Ecuador	Success	(Krebs, 2016) (Agencia Espacial Civil Ecuatoriana, 2015)
2013	OPTOS	3U	T	Technology Demonstrator	Design Testing	INTA	Spain	Established Communications	(Krebs, 2016)
2013	PUCP-Sat 1	1U	T	Technology Demonstrator	Surface Temperature	Pontifical Catholic University of Peru	Peru	Established Communications	(eoPortal, 2016)
2013	Triton 1	3U	T	Technology Testing	Vehicle Tracking	ISIS-BV	UK	Not Found	(Krebs, 2016)
2013	UWE-3	1U	T	Technology Development	ADCS	University of Würzburg	Germany	Not Found	(eoPortal, 2016)
2013	VELOX-P2	1U	T	Technology Testing	ADCS, sun sensor	Nanyang Technological University	Singapore	Success	(eoPortal, 2016)
2013	ZACUBE 1	1U	SE	Scientific Research	Ionosphere	Cape Peninsula University of Technology	South Africa	Success	(eoPortal, 2016)
2013	AeroCube 5a	1U	T	Technology Demonstrator	Point and track capabilities, De-orbiting	Aerospace Corporation	USA	Not Found	(Krebs, 2016)
2013	AeroCube 5b	1U	T	Technology Demonstrator	Point and track capabilities, De-orbiting	Aerospace Corporation	USA	Not Found	(Krebs, 2016)
2013	ALICE	3U	T	Technology Testing	Propulsion	Air Force Institute of Technology	USA	Not Found	(Krebs, 2016)
2013	CUNYSAT-1	1U	SE	Scientific Research	Ionosphere	City University of New York	USA	Failed	(Krebs, 2016)
2013	FIREBIRD IA	1.5U	SE	Scientific Research	Radiation Belts	Montana State University	USA	Success	(FIREBIRD, 2013) (eoPortal, 2016)
2013	FIREBIRD IB	1.5U	SE	Scientific Research	Radiation Belts	Montana State University	USA	Success	(FIREBIRD, 2013) (eoPortal, 2016)
2013	IPEX	3U	T	Technology Testing	Communications and data capabilities	Cal Poly	USA	Success	(Krebs, 2016) (eoPortal, 2016)
2013	MCubed-2	1U	BR	Educational	Weather observation	University of Michigan	USA	Success	(Krebs, 2016) (eoPortal, 2016)
2013	SMDC ONE 3.1	3U	T	Technology Demonstrator	Communications and data capabilities (Data relay)	MilTec	USA	Not Found	(eoPortal, 2016)
2013	SMDC ONE 3.2	3U	T	Technology Demonstrator	Communications and data capabilities (Data relay)	MilTec	USA	Not Found	(Krebs, 2016)
2013	SNAP-1	1U	T	Technology Demonstrator	Space Objects detection	Naval Postgraduate School	USA	Success	(eoPortal, 2016)

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2013	TacSat-6	3U	T	Technology Demonstrator	Communications and data capabilities	AFRL	USA	Not Found	(eoPortal, 2016)
2014	Perseus-M 1	6U	BR	Scientific Research	Vehicle Tracking	Canopus Systems US	Russia/USA	Not Found	(Krebs, 2016)
2014	Perseus-M 2	6U	BR	Scientific Research	Vehicle Tracking	Canopus Systems US	Russia/USA	Not Found	(Krebs, 2016)
2014	ANTELSat	2U	E	Educational	Imaging	Universidad de la Republica	Uruguay	Success	(AMSAT, 2016) (Ruggiero,2014) (UDELAR, 2015)
2014	ArduSat 2	2U	E	Educational	Earth imaging, Design testing (Amateur arduino experiments)	NanoSatisfi	USA	Deployed	(Krebs, 2016)
2014	Chasqui 1	1U	E	Technology Demonstrator	Earth imaging, Surface temperature	Universidad Nacional de Ingeniería del Perú	Peru	Deployed	(Martínez,2015) (Krebs, 2016)
2014	Duchifat 1	1U	E	Educational	Communications and data capabilities (Data relay)	Space Laboratory of the Herzliya Science Centre	Israel	Success	(Heller,2012) (Krebs, 2016)
2014	IFT-1	1U	E	Educational	Communications (Telemetry)	University of Tsukuba	Japan	Deployed	(AMSAT-UK, 2016)
2014	INVADER	1U	E	Educational	Artistic Missions	Tama Art University	Japan	Success	(ARTSAT, 2014)
2014	LitSat-1	1U	E	Technology Demonstrator	Earth imaging, Communications	Kaunas University of Technology	Lithuania	Success	(LitSat-1,2014)
2014	LituanicaSAT-1	1U	E	Technology Demonstrator	Communications and data capabilities (Data relay), Design Testing, Earth Imaging	University of Vilnius	Lithuania	Success	(Lithuanica,2014) (eoPortal, 2016)
2014	PACE	2U	E	Educational	ADCS	National Cheng Kung University	Taiwan	Deployed	(Krebs, 2016)
2014	PolyITAN 1	1U	E	Educational	ADCS, GPS, Communications	National Technical University of Ukraine	Ukraine	Not Found	(AMSAT, 2016)
2014	UAPSat-1	1U	E	Educational	Communications (Telemetry)	Pontifical Catholic University of Peru	Peru	Deployed	(Krebs, 2016)
2014	SkyCube	1U	BR	Scientific Research	Earth imaging	Southern Stars Group LLC	USA	Deployed	(Krebs, 2016)
2014	AeroCube 6A	0.5U	T	Technology Demonstrator	Radiation Budget	Aerospace Corporation	USA	Not Found	(Krebs, 2016)
2014	AeroCube 6B	0.5U	T	Technology Demonstrator	Radiation Budget	Aerospace Corporation	USA	Not Found	(Krebs, 2016)
2014	ALL-STAR/THEIA	3U	BR	Scientific Research	Earth imaging	Colorado Space Grant Consortium	USA	Deployed	(All-Star,2014) (Krebs, 2016)
2014	DTUSat-2	1U	BR	Scientific Research	Animal population dynamics	Danmarks Tekniske Universitet	Denmark	Deployed	(Fléron,2013)
2014	NanoSatC-Br1	1U	BR	Scientific Research	Magnetic Field	INPE Southern Regional Space Research Center	Brazil	Established Communications	(Krebs, 2016)
2014	SporeSat	3U	BR	Scientific Research	Space Life Sciences	NASA Ames and Department of Agricultural and Biological Engineering at Perdue University	USA	Failed	(NASA,2014)
2014	TigriSat	3U	BR	Scientific Research	Dust storm detection	La Sapienza University of Rome	Italy	Not Found	(Krebs, 2016)
2014	Arkyd 3	3U	T	Technology Demonstrator	Space Object detection (Asteroids)	Planetary Resources, Inc.	USA	Failed	(Krebs, 2016)
2014	GOMX 2	2U	T	Technology Demonstrator	De-orbiting	GOMSpace	Denmark	Failed	(Krebs, 2016)
2014	KickSat 1	3U	T	Technology Demonstrator	Communications and data capabilities, Design testing	Cornell University	USA	Established Communications	(Krebs, 2016)
2014	KSAT-2	1U	T	Scientific Research	Weather observation	Kagoshima University	Japan	Established Communications	(Krebs, 2016)

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2014	Lemur 1	3U	T	Technology Demonstrator	Imaging	NanoSatisfi	USA	Success	(eoPortal, 2016)
2014	OPUSat	1U	T	Technology Demonstrator	Power (Hybrid battery system, Deployable panels), ADCS	Osaka Prefecture University	Japan	Established Communications	(Krebs, 2016)
2014	PhoneSat 2.5	1U	T	Technology Demonstrator	Design Testing (OBC design)	NASA Ames	USA	Success	(eoPortal, 2016)
2014	POPSAT-HIP1	3U	T	Technology Demonstrator	Earth Imaging, Propulsion	Microspace Rapid Pte Ltd	Singapore	Success	(Krebs, 2016) (eoPortal, 2016)
2014	QB50p1	2U	T	Technology Demonstrator	Systems testing	von Karman Institute	Belgium	Not Found	(AMSAT, 2016)
2014	QB50p2	2U	T	Technology Demonstrator	Systems testing	von Karman Institute	Belgium	Not Found	(AMSAT, 2016)
2014	RACE	3U	T	Technology Demonstrator	Radiometer testing	University of Texas	USA	Failed	(eoPortal, 2016)
2014	TSAT (TestSat-Lite)	2U	T	Technology Demonstrator	Communications	Taylor University	USA	Success	(Krebs, 2016) (Voss et. Al., 2014)
2014	Ukube-1	3U	T	Technology Demonstrator	Test space technologies	ClydeSpace	UK	Success	(Krebs, 2016) (UK Space Agency, 2015)
2014	VELOX I-NSAT	3U	T	Technology Demonstrator	Inter-satellite communication	Nanyang Technological University	Singapore	Established Communications	(eoPortal, 2016)
2015	DCBB	2U	CM	Educational	Amateur radio communication	Shenzhen Aerospace Dongfanghong HIT Satellite Ltd.	China	Deployed	(Krebs, 2016)
2015	ExoCube	3U	SE	Scientific Research	Ozone and trace gases	Cal Poly	USA	Established Communications	(CalPoly,2015)
2015	FIREBIRD-2A	1.5U	SE	Scientific Research	Radiation Budget (Van Allen)	Montana State University	USA	Success	(Boswell,2015) (eoPortal, 2016)
2015	FIREBIRD-2B	1.5U	SE	Scientific Research	Radiation Budget (Van Allen)	Montana State University	USA	Success	(Boswell,2015) (eoPortal, 2016)
2015	MicroMAS-1	3U	T	Technology Demonstrator	Weather observation	MIT	USA	Deployed	(eoPortal, 2016)
2015	AeroCube 8A	1.5U	T	Technology Demonstrator	Propulsion, Power (Solar cells)	Aerospace Corporation	USA	Deployed	(NASA,2016)
2015	AeroCube 8B	1.5U	T	Technology Demonstrator	Propulsion, Power (Solar cells)	Aerospace Corporation	USA	Deployed	(NASA,2016)
2015	AESP-14	1U	T	Scientific Research	Ionosphere (Plasma bubbles)	Aeronautics Technological Institute	Brazil	Deployed	(Krebs, 2016)
2015	Arkyd 3-Reflight	3U	T	Technology Demonstrator	Design Testing (Asteroid prospecting)	Planetary Resources, Inc.	USA	Established Communications	(O'Keefe,2015)
2015	BRICSat-P	1.5U	T	Technology Demonstrator	Communications and data capabilities, Propulsion	US Naval Academy	USA	Established Communications	(Krebs, 2016)
2015	Centennial-1	1U	T	Technology Demonstrator	Earth imaging	Booz Allen Hamilton	USA	Failed	(Krebs, 2016)
2015	DeOrbitSail	3U	T	Technology Demonstrator	De-orbiting	University of Surrey	UK	Failed	(ARRL,2015) (eoPortal, 2016)
2015	GEARRSAT 2	3U	T	Technology Demonstrator	Communications and data capabilities	NearSpace Launch	USA	Deployed	(Krebs, 2016)
2015	GEARRSAT	3U	T	Technology Demonstrator	Communications and data capabilities	NearSpace Launch	USA	Deployed	(Krebs, 2016)
2015	GRIFEX	3U	T	Technology Demonstrator	Ozone and trace gases	NASA JPL	USA	Not Found	(eoPortal, 2016)
2015	LambdaSat	1U	T	Technology Demonstrator	Design Testing (Bus)	Greek Silicon Valley folks	USA/Greece	Established Communications	(eoPortal, 2016)
2015	LightSail	3U	T	Technology Demonstrator	Propulsion	Planetary Society	USA	Success	(eoPortal, 2016)

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2015	NJFA	3U	T	Technology Demonstrator	Communications and data capabilities (Satellite network)	Shanghai Engineering Center for Microsatellites	China	Success	(Krebs, 2016) (AMSAT-UK, 2016)
2015	NJUST 2	2U	T	Technology Demonstrator	Communications and data capabilities (Satellite network), Vehicle Tracking	Nanjing University	China	Success	(Krebs, 2016) (AMSAT-UK, 2016)
2015	OptiCube 1	3U	T	Technology Demonstrator	Space Objects detection	Cal Poly	USA	Deployed	(Krebs, 2016)
2015	OptiCube 2	3U	T	Technology Demonstrator	Space Objects detection	Cal Poly	USA	Deployed	(Krebs, 2016)
2015	OptiCube 3	3U	T	Technology Demonstrator	Space Objects detection	Cal Poly	USA	Deployed	(Krebs, 2016)
2015	ParkinsonSat	3U	T	Technology Demonstrator	Communications and data capabilities (Data relay)	NearSpace Launch	USA	Partial Success	(Krebs, 2016) (ARRL, 2015 May)
2015	S-CUBE	3U	T	Technology Demonstrator	Space Objects detection	Tohoku University	Japan	Deployed	(Krebs, 2016)
2015	SERPENS	3U	T	Technology Demonstrator	Weather observation	SERPENS	Brazil	Deployed	(AMSAT-UK, 2016)
2015	Shankeda 2	2U	T	Technology Demonstrator	Communications and data capabilities (Satellite network)	Shanghai Engineering Center for Microsatellites	China	Deployed	(Krebs, 2016)
2015	TechEdSat-4	3U	T	Technology Demonstrator	De-orbiting	San Jose State University	USA	Deployed	(Krebs, 2016)
2015	USS Langley	3U	T	Technology Demonstrator	Communications and data capabilities (Data relay)	US Naval Academy	USA	Deployed	(Krebs, 2016)
2015	STU-2A	3U	T	Technology Demonstrator	Ice Sheet Imaging	Shanghai Engineering Center for Microsatellites	China	Success	(Wu, Chen, & Chao, 2016)
2015	STU-2B	2U	T	Technology Demonstrator	Vehicle Tracking	Shanghai Engineering Center for Microsatellites	China	Success	(Wu, Chen, & Chao, 2016)
2015	STU-2C	2U	T	Technology Demonstrator	Propulsion, Communications and data capabilities, ADCS	Shanghai Engineering Center for Microsatellites	China	Success	(Wu, Chen, & Chao, 2016)
2015	GOMX-3	3U	T	Technology Demonstrator	Vehicle Tracking, Communications and data capabilities	GOMSpace	Denmark	Success	(Spaceflight 101, 2015) (eoPortal, 2016)
2015	AAUSAT 5	3U		Technology Demonstrator	Vehicle Tracking	Aalborg University	Denmark	Success	(ESA, 2015)
2015	Aerocube 5c	1.5U	T	Technology Demonstrator	Vehicle Tracking, Communications and data capabilities	Aerospace Corporation	USA	Launch Failure	(Krebs, 2016)
2015	AeroCube 7	1.5U	T	Technology Demonstrator	Communications and data capabilities (Laser communications)	Aerospace Corporation	USA	Failed (ADCS Failure)	(Krebs, 2016)
2015	Fox-1A	1U	T	Technology Demonstrator	Communications and data capabilities (Data relay), ADCS, Radiation budget	AMSAT	USA	Success	(AMSAT, 2016)
2015	BisonSat	1U	E	Educational	Cloud Properties, Aerosols	Salish Kootenai College, Montana	USA	Success	(Krebs, 2016)
2015	ARC 1	1U	T	Technology Demonstrator	ADCS, Communications and data capabilities, Snow Cover	University of Alaska Fairbanks	USA	Not Found	(Krebs, 2016) (Swartwout, 2016)
2015	SNAP-3 Alice	3U	CM	Communications	Communications and data capabilities (Data relay)	United States Army Space and Missile Defense Command	USA	Not Found	(NASA, 2016) (Swartwout, 2016)
2015	LMRST-Sat	3U	T	Technology Testing	Design testing (Deep-space navigation), Gravity Fields	Jet Propulsion Laboratory	USA	Not Found	(Krebs, 2016) (Swartwout, 2016)
2015	SNAP-3 Eddie	3U	CM	Communications	Communications and data capabilities (Data relay)	United States Army Space and Missile Defense Command	USA	Not Found	(Krebs, 2016)
2015	PropCube Merryweather	1U	E	Earth Observation-Atmosphere	Ionosphere	Naval Postgraduate School	USA	Not Found	(Krebs, 2016)

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2015	SINOD-D 1	3U	T	Technology Demonstrator	Communications and data capabilities	SRI International	USA	Deployed	(Krebs, 2016) (Swartwout, 2016)
2015	SNAP-3 Jimi	3U	CM	Communications	Communications and data capabilities (Data relay)	United States Army Space and Missile Defense Command	USA	Not Found	(Krebs, 2016)
2015	PropCube Flora	1U	BR	Earth Observation-Atmosphere	Ionosphere	Naval Postgraduate School	USA	Not Found	(Krebs, 2016) (Swartwout, 2016)
2015	SINOD-D 3	3U	T	Technology Demonstrator	Communications and data capabilities	Tyvak Nano-Satellite Systems Inc.	USA	Deployed	(Krebs, 2016) (Swartwout, 2016)
2015	Supernova-Beta	6U	T	Technology Demonstrator	Design Testing	Pumpkin Inc.	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	EDSN 1	1.5U	T	Technology Demonstrator	Communications and data capabilities (Satellite network)	NASA Ames	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	EDSN 2	1.5U	T	Technology Demonstrator	Communications and data capabilities (Satellite network)	NASA Ames	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	EDSN 3	1.5U	T	Technology Demonstrator	Communications and data capabilities (Satellite network)	NASA Ames	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	EDSN 4	1.5U	T	Technology Demonstrator	Communications and data capabilities (Satellite network)	NASA Ames	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	EDSN 5	1.5U	T	Technology Demonstrator	Communications and data capabilities (Satellite network)	NASA Ames	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	EDSN 6	1.5U	T	Technology Demonstrator	Communications and data capabilities (Satellite network)	NASA Ames	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	EDSN 7	1.5U	T	Technology Demonstrator	Communications and data capabilities (Satellite network)	NASA Ames	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	EDSN 8	1.5U	T	Technology Demonstrator	Communications and data capabilities (Satellite network)	NASA Ames	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	STACEM	3U	BR	Earth Observation	Environmental analysis and monitoring	Space Dynamics Laboratory	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	Argus	2U	BR	Space Environment Observation	Electronics Degradation (Radiation)	Saint Louis University	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	PrintSat	1U	T-BR	Technology Demonstrator	Design Testing (3D printed structure)	Montana State University	USA	Launch Failure	(Krebs, 2016) (Swartwout, 2016)
2015	Bevo 2	3U	T	Technology Demonstrator	Proximity Operations	University of Texas	USA	Established Communications	(Krebs, 2016) (Swartwout, 2016)
2015	CADRE	3U	BR	Earth Observation-Atmosphere	Space Weather observations	University of Michigan	USA	Deployed	(Krebs, 2016) (Swartwout, 2016)
2015	MinXSS	3U	BR	Space Environment Observation	Solar activity	University of Colorado LASP	USA	Success	(Krebs, 2016) (eoPortal, 2016)
2015	STMSat-1	1U	T	Earth Observation	Earth imaging	St. Thomas More Cathedral School	USA	Deployed	(Swartwout, 2016)
2015	Nodes 1	1.5U	T	Technology Demonstrator	Test network capanilities for multiple spacecraft, Radiation Budget	NASA Ames	USA	Partial Success	(Swartwout, 2016)
2015	Nodes 2	1.5U	T	Technology Demonstrator	Test network capanilities for multiple spacecraft, Radiation Budget	NASA Ames	USA	Partial Success	(Swartwout, 2016)

Launch	Name	Size	Mission	Application	Application Details	Institution	Country	Note	Ref.
2015	Athenoxat 1	3U	T	Earth Observation	Night time optical data acquisition	Microspace Rapid Pte Ltd	Singapore	Success	(Krebs, 2016) (Swartwout, 2016)
2015	Galassia	2U	E	Earth Observation-Atmosphere	Ionosphere	National University of Singapore	Singapore	Success	(Krebs, 2016) (eoPortal, 2016)
2016	VELOX 2	6U	CM-T	Technology Demonstrator	Communications and data capabilities	Nanyang Technological University	Singapore	Success	(Krebs, 2016) (Swartwout, 2016)
2016	Tomsk-TPU-120	3U	T	Technology Demonstrator	Design Testing (3D printed structure)	Tomsk Polytechnic University	Russia	Not Found	(Krebs, 2016) (Swartwout, 2016)
2016	OUFTI-1	1U	CM-T	Technology Demonstrator	Communications and data capabilities	Université de Liège	Belgium	Established Communications	(Krebs, 2016) (Swartwout, 2016)
2016	e-st@r 2	1U	E-BR	Scientific Research	ADCS	Politecnico di Torino	Italy	Partial Success	(Krebs, 2016) (Swartwout, 2016)
2016	AAUSAT 4	1U	E	Technology Demonstrator	Vehicle Tracking	Aalborg University	Denmark	Not Found	(Krebs, 2016) (Swartwout, 2016)
2016	SamSat-218/D	3U	T-BR	Technology Demonstrator	ADCS (Aerodynamic forces)	Samara Aerospace University	Russia	Established Communications	(Krebs, 2016) (Swartwout, 2016)
2016	Sathyabama-Sat	2U	BR	Earth Observation-Atmosphere	Ozone and trace gases	Sathyabama University	India	Not Found	(Krebs, 2016) (Swartwout, 2016)
2016	Swayam	1U	CM	Technology Demonstrator	Communications and data capabilities	College of Engineering, Pune	India	Not Found	(Krebs, 2016) (Swartwout, 2016)
2016	BeeSat-4	1U	T-BR	Technology Demonstrator	ADCS	Technical University of Berlin	Germany	Not Found	(Krebs, 2016) (Swartwout, 2016)

Appendix B: Methodology for Cubesat Mission Selection

Instructions to utilize the Methodology for CubeSat Mission Selection:

1. Select all of the text in gray and copy (CTRL+C)
2. Open a new excel workbook and place the cursor on cell A1
3. Paste (CTRL+V)
4. Change the “0” in columns Q, S, U, W and Y for the product of the parameter weight and the parameter’s normalized value. For example, in cell Q5 enter “+B5*P5”, in cell S5 enter “+B5*R5”, and so on. Expand these calculations from Row 4 all the way down to Row 38 (i.e. cell Y38’s content should be “+B38*X38”).
5. Change the “X” in Row 39 for the summation of the values above each “X”. For example, in cell Q38 enter “+SUM(Q4:Q38)”.
6. For each parameter indicated in Column A (rows 4 to 38), enter the desired weight value from 1 to 4 in Column B. Note: the rows that have zeroes on columns Q, S, U, W and Y are parameters; the rows without zeroes on those columns are category headers (e.g. Row 5 is the header for the “Benefits” category). Only enter values for parameters and not for category headers.
7. For each parameter indicated in Column A (rows 4 to 38), enter a value from 0 to 10 in Columns P, R, T, V, and X (each of these columns represent a different option being analyzed) according to the scales given in Columns D to N.
8. Select the mission with the highest score (shown in Row 39).

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Undesired
Desired Option 1 Option 2 Option 3 Option 4 Option 5
Parameter Weight (1-4) 0 1 2 3 4 5 6 7 8
9 10 Normalized Total Normalized Total Normalized Total
Normalized Total Normalized Total
Relevance

Relevance Not aligned Mostly not aligned
Mostly aligned Highly aligned 0 0 0
0 0
Benefits

Scientific

New technologies No new tech Some new techs
Significant amount of new techs 0 0
0 0 0
Basic Research Not significant Somewhat significant
Highly significant 0 0 0
0 0
Applied Research Not significant Somewhat significant
Highly significant 0 0
0 0 0
Organizational

Impact on personnel No impact on personnel capabilities and loyalty to the institution
Some impact on personnel capabilities and loyalty to the institution
High impact on personnel capabilities and loyalty to the institution 0
0 0 0 0
Intelectual Property No possibility of new patents and/or publications
Some possibility of new patents and/or publications High possibility of new patents and/or publications 0 0 0 0
0
Marketing "Low impact in image, promotion or public relations"
"Some impact in image, promotion or public relations"
"High impact in image, promotion or public relations" 0 0
0 0 0
Products / services "No new products/services, no improment in current products/services performance"
Somewhat significant new products/services or improvement on current products/services performance New products/services or improvement on current products/services performance 0 0 0
0 0
New customers No new customers Some possibility of new customers
High possibility of new customers 0
0 0 0 0
New markets No possibility to participate in new markets
Some possibility to participate in new markets High possibility to participate in new markets 0 0 0 0 0
Return of Investment More than 10 years 5 or 6 years
Less than 2 years 0 0 0
0 0
Country-level

Health No impact on food security or disease prevention
"Some impact on food security, disease prevention" "High impact on food security, disease prevention" 0 0 0 0

0
Education No impact in new careers or student curriculum improvement
Some impact on new careers or student curriculum improvement
High impact in new careers or student curriculum improvement 0
0 0 0 0
Natural resources "Low impact in resource monitoring, climate change data acquisition"
"Some impact in resource monitoring, climate change data acquisition"
"High impact in resource monitoring, climate change data acquisition" 0
0 0 0 0
Natural disasters "No impact in events prediction, disaster monitoring, post-disaster assessment and resource management" "Some impact in events prediction, disaster monitoring, post-disaster assessment and resource management" "High impact in events prediction, disaster monitoring, post-disaster assessment and resource management" 0 0
0 0 0
Technology development No impact in creation of new technological capabilities
Some impact in creation of new technological capabilities
High impact in creation of new technological capabilities 0 0
0 0 0
Economic productivity "Low impact in productivity, manufacturing, agriculture or other sectors"
"Some impact in productivity, manufacturing, agriculture or other sectors"
"High impact in productivity, manufacturing, agriculture or other sectors"
0 0 0 0 0
Job creation No impact on new industries or job creation
Some impact on new industries or job creation High impact on new industries or job creation 0 0 0 0
0
Exports No impact on new exporting products/services and/or exports volume
Some impact on new exporting products/services and/or exports volume
High impact on new exporting products/services and/or exports volume 0
0 0 0 0
Required Resources

Budget Project cost higher than available budget Project cost same as available budget Project cost lower than available budget
0 0 0 0 0
Time Time for completion longer than available Time for completion same as available Time for completion less than available
0 0 0 0 0
Alignment with other projects No symbiosis with other projects
Some symbiosis with other projects Significant symbiosis with other projects
0 0 0 0 0
Technical / Infrastructure Necessary equipment and facilities unavailable and/or difficult to obtain
Necessary equipment and facilities available and/or attainable
Necessary equipment and facilities readily available and easy to obtain 0
0 0 0 0
Human

In-house knowledge High in-house knowledge needed
Some in-house knowledge needed Low in-house knowledge needed
0 0 0 0 0
Team leadership High expertise in team leadership required
Some expertise in team leadership required Low expertise in team leadership required
0 0 0 0 0
Human resource retention Indispensable that all the members of the team stay for the whole lifetime of the project
Indispensable that some members of the team stay for the whole life-

time of the project It is not ndispensable that any member of the team stay for the
whole lifetime of the project 0 0 0
0 0
External alliances Highly required for project success
Some required for project success Not required for project success
0 0 0 0 0
Risk

Risk High risk of mission failure identified Acceptable risk
of mission failure identified Low risk of mission failure identified
0 0 0 0 0

FINAL SCORE: X X X X X

Choose Highest Value