SSC16-P2-09

Lean satellite Concept

Mengu Cho
Kyushu Institute of Technology, JAPAN

Filippo Graziani
G.A.U.S.S. Srl, Italy

In 2014, International Academy of Astronautics (IAA) initiated Study Group (SG) 4.18, "Definition and Requirements of Small Satellites Seeking Low-Cost and Fast-Delivery". Its objectives of the study group are to examine the definitions of small satellites, identify the requirements every satellite should follow and then reflect some of the findings to an ISO standard draft ISO/WD/20991, "Space systems — Requirements for Small Spacecraft" that is being developed recently at ISO/TC20/SC14. The purpose of the present paper is to present the latest findings in the SG activity especially in terms of small satellite definition.
During the SG meeting in 2014, a round-table discussion was held to discuss the terminology to describe small satellites. The majority of the opinions were that neither "mass" nor "size" is suitable for defining small satellites. Rather, philosophy of design, manufacturing, mission, program management, etc., should be used for the definition. The round-table discussion came to the conclusion that the term "Lean Satellite" is more suitable than "Small Satellite".
Historically, the word of "lean" originated from Toyota Production System (TPS). There are few things in common between satellites and automobiles. It is very difficult to apply lean concepts as they are to satellites. But some concept of "lean" is necessary for satellites. New types of customers are emerging today who want more value from satellites through lower unit prices and faster system delivery. Currently, mega-constellations consisting of hundreds or thousands of satellites are being proposed. Traditional satellite development philosophy cannot be applied to mega-constellations because the total cost would be prohibitively high. Small satellites and mega-constellations can benefit from the application of the lean satellite concept, although it must be modified to accommodate the differences between satellites and automobiles. Space systems engineering has put emphasis on delivering a perfectly working system. On the other hand, lean concept has put emphasis on delivering a high-quality product with the minimum cost and shortest time. Developing the lean satellite concept can be an interesting new subject for space systems engineering.
As a part of the SG activity, 16 questions were identified as good measures to scale the characteristics as a lean satellite. The 16 questions are made of 9 categories with different weighting. They are (1) total cost, (2) delivery time, (3) simplicity, (4) risk taking, (5) risk mitigation, (6) reliability requirement, (7) mission duration, (8) launch, and (9) waste minimization. Some categories are further divided to multiple questions. Each question has its weight. Each answer has its score. By adding the points of all the 16 questions, the total point is between 0 and 100.
The questionnaire made of the 16 questions was distributed in SG and answers by 35 existing satellites from all over the world were collected. At the conference, the lean satellite concept will be presented more in detail along with the analysis of answers made by the 35 satellites.

Table: Distribution of the answers to lean satellite scale questions given by 35 existing satellites

No	Category	Weight	Question	Scale	Mark	Number of satellites answered: Academic	Non-academic	Total	Your satellite
1	Total cost	5	If your satellite program is a single satellite program, answer this question. Total cost including a satellite, non-recurring cost (e.g. infrastructure investment, etc), launch and operation, A	A ≥ 15 MUSD	0	0	0	0	
				10 MUSD ≤ A < 15MUSD	1	0	1	1	
				5 MUSD ≤ A < 10MUSD	2	2	3	5	
				3 MUSD ≤ A < 5MUSD	3	1	0	1	
				A< 3MUSD	4	21	3	24	
1'	Total cost	5	If your satellite program contains multiple satellites, answer this question. Total cost including satellites, non-recurring cost (e.g. infrastructure investment, etc), launch and operation divided by the number of satellites, A'	A' ≥ 10 MUSD	0	0	0	0	
				5 MUSD ≤ A' <10MUSD	1	0	0	0	
				2 MUSD ≤ A' < 5MUSD	2	0	1	1	
				1 MUSD ≤ A' < 2MUSD	3	0	2	2	
				A'< 1MUSD	4	0	1	1	
2	Satellite delivery time	5	Time from the program start to delivery, B	B ≥ 3 years	0	8	4	12	
				2 ≤ B < 3 years	1	8	2	10	
				1 ≤ B < 2 years	2	6	3	9	
				6 months ≤ B < 1 year	3	2	2	4	
				B < 6 months	4	0	0	0	
3	Simple satellite	1	Number of mission payloads, H	5 ≤ H	0	3	5	8	
				3 ≤ H < 5	1	5	1	6	
				H ≤ 2	2	16	5	21	
4	Simple operation	1	Number of persons needed to operate per satellite pass, AE	5 ≤ AE	0	0	1	1	
				3 ≤ AE < 5	1	5	0	5	
				AE ≤ 2	2	19	10	29	
5	Simple management	2	Number of people engaged in satellite development, C	C ≥ 30 persons	0	3	0	3	
				20 ≤ C < 30 persons	1	1	4	5	
				10 ≤ C < 20 persons	2	12	2	14	
				C < 10 persons	3	8	5	13	
6	Simple handling	1	No hazardous/explosive alternative is chosen to make satellite handling easier	NO	0	0	4	4	
				YES	1	24	7	31	
7	Risk taking	1	Screening and management of individual parts based on test results (e.g., radiation) is done	ALL Parts	0	1	1	2	
				All non-space qualified COTS parts	1	4	5	9	
				Only mission critical parts or no screening and management	2	19	5	24	
8	Risk taking	2	Percentage of non-space qualified COTS parts/material usage, D	D ≤ 10 %	0	0	2	2	
				10 < D ≤ 50%	1	3	3	6	
				50 < D ≤ 90%	2	3	3	6	
				90 % < D	3	18	3	21	
9	Risk taking	2	Use of non-flight proven technology, non-space qualified manufacturing, procurement of components via Internet from unknown manufactures are allowed and encouraged to the achieve the required specification with less cost and/or less schedule	NO	0	2	8	10	
				YES	1	22	3	25	
10	Risk taking	2	Single-point-of-failure is allowed in satellite design to make satellite simple or comply with launch provider's requirement, etc	NO	0	2	2	4	
				YES	1	21	9	30	
11	Risk mitigation	5	Risk is evaluated and managed based on collective experience and knowledge of team members rather than expensive and/or time-consuming testing and/or analysis with heavy documents.	NO	0	2	2	4	
				YES	1	22	9	31	
12	Reliability requirement	4	Failure of single satellite jeopardise the overall satellite program (replenishing satellite can be built and launched fairly easily)	YES	0	14	8	22	
				NO	1	10	3	13	
13	Reliability requirement	2	Consecutive mission down time until recovery is allowed up to F	F≤ 90 minutes	0	1	0	1	
				90 minutes < F ≤ 1 day	1	1	1	2	
				1 day < F ≤ 1week	2	6	6	12	
				1 week < F	3	16	4	20	
14	Mission duration	1	Satellite Mission Duration, E	E ≥ 5 years	0	0	1	1	
				3 ≤ E < 5 years	1	2	0	2	
				2 ≤ E < 3 years	2	4	1	5	
				1 ≤ E < 2 years	3	9	6	15	
				E < 1 years	4	9	3	12	
15	Launch	5	Access to space is prioritized by designing launcher compatibility (i.e.POD) or having mission less dependent on orbit	NO	0	1	1	2	
				YES, either launch compatibility or non-strict orbit requirement	1	14	5	19	
				YES, both launch compatibility and non-strict orbit requirement	2	9	5	14	
16	Waste minimization	8	Waste associated with transportation time (satellite hardware, human) and communication delay (e-mail exchange) is minimized by conducting the satellite development/integration/testing activities in one place with all the team members located within close proximity as much as possible.	NO	0	5	2	7	
				YES	1	19	9	28	

Majority of satellites cost less than 3MUSD

Many satellites take 2 years or longer to build (not fast-delivery!) Non-academic satellites faster. Due to more experience.

Simple satellite, simple operation

Team size is still large?

Simple handling

Academic satellites take more risk

Allow single point of failure

Risk evaluation and management is based on experience

Allow significant mission down time

Short mission time. Make parts selection (radiation tolerance) easy

Waste minimization is tried