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A Study on the Satellite Launch Vehicle Separation Detection Interface to Improve the Reliability of the Launch and Early Operation Phase

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Abstract

The launch vehicle (LV) separation detection interface of the satellite, which is designed to initiate the launch and early operation phase (LEOP) for S-band data transmission and the solar array deployment after the LV separation, is one of the hazard items at the launch site. Therefore, this interface should satisfy the single-fault tolerance requirement for the range safety. In this paper, we discuss the LV separation detection interfaces for two different satellite launch configurations and propose a method to guarantee for the satellite to start the LEOP even under the emergency case such as a partial separation from the LV. Furthermore, the proposed method meets the range safety requirement of the launch site. As this method only changes the external harness configuration of the satellite, it increases the reliability of the satellite early operation without any modification of the existing internal logics to detect the separation event.

Key Words : Satellite, Launch Vehicle, LV Electrical and Electronic Interface, LV Separation Detection Interface, Range Safety, Launch and Early Operation Phase

1. Introduction

The LV electrical and electronic interface (LVEEI) of a satellite is designed to ensure the range safety at the launch site while setting the satellite for the launch standby mode and to automatically initiate the LEOP after the LV separation. The LV separation detection interface is designed to enable the automatic operation of LEOP by detecting the mechanical motion of the LV connector separation [1-7]. In terms of the range safety, as the LV separation detection interface is directly linked to the deployment command schedule (DCS) of the solar panel, it should be designed to meet the single-fault tolerance requirement [5, 6]. The LVEEI design is dependent on the launch standby configuration, which is mainly related on the booting action of the onboard computer (OBC). The first type is for launching the satellite after its OBC is booted and the flight software (FSW) and internal electronics are set on the launch standby mode. The other type is designed for the launch standby configuration in which only essential units are powered on and the OBC is not booted. These two configurations are named Case 1 and Case 2, respectively. The overall electrical configuration between the satellite in the fairing and the satellite control room is shown in Fig.1. The satellite and the launch support test system (LSTS) are connected through the umbilical cables and two separation connector sets (SP1 and SP2). The LSTS and the satellite control center are connected via the long communication network [8, 9]. For the satellite of Case 1, the OBC is booted at the launch standby mode. Therefore, the FSW operation is working and all telemetry data of the satellite can be gathered in real-time at the satellite control room by the satellite commands [10-14]. Therefore, the satellite data related to the range safety can be obtained through the conventional LSTS communication interface. Meanwhile, the satellite of Case 2 is ready with power supplied only to the S-band receiver, the power control unit (PCU), and the internal board of the OBC to detect the separation from LV [1-3]. Therefore, its LSTS interface is design to communicate with the PCU instead of the OBC. For this reason, the limited telemetry and the status of the power relays in the PCU can be transmitted to the satellite control room. The satellite signals linked with the range safety should be directly gathered and processed by the dedicated circuit at the LSTS. Therefore, the pin number of the Case 2 LV channel increases compared with one of the Case 1 as each return signal should be assigned to protect the analog signals from the environment noise. Meanwhile, the harness configuration of the LV separation detection interface is designed as a loop-back type on the LV side connectors of the SP1 and SP2, as shown in Fig. 2. Once the SP1 and SP2 are separated, the loop-back signal is cut off and the output of the

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sensing circuit is changed and determine the separation from the LV. The LV separation detection interface of Case 1 is composed with three LV separation signals of loop-back configuration and their status are gathered at the independent sensing circuits in the OBC. Only when the LV separation signals are detected at two or more of these circuits, the initial stage of LEOP is started to power on the S-band transmitter and conduct the DCS [10-14]. This design satisfies the single-fault tolerance requirement for the range safety. From the perspective of the initiation of the LEOP, the OBC and the S-band receiver of the satellite are already working on the launch pad. Therefore, the ground station can communicate with the satellite and manually start the LEOP even if the LV connector partial separation occurs in orbit at the separation moment.

Meanwhile, the LV separation detection interface of Case 2 is shown in Fig. 3. The boards for processing the signals of LV separation are named Master (P) and Master (R) in this paper. The boards for the OBC booting and FSW operation are named Processor (P) and Processor (R). When all SP1 and SP2 are completely separated, power is supplied to Processor (P) and OBC is booted by R1 logic that determines the separation status of SP1 and SP2 using LV breakwire (B/W) signals [1-6]. T1 is an independent logic that verifies whether SP1 and SP2 are completely separated through the FSW Trigger 1-1 and FSW Trigger 1-2 signals, as shown in Fig. 3. Therefore, even if a malfunction occurs in the R1 circuit, the LEOP initiation can be suppressed by T1. If the LV connector partial separation error occurs, the OBC booting is not occurred since the separation detection harness is designed for the R1 logic only to work when all separation connectors are disconnected [4-6]. However, if the partial separation error occurs in orbit, as the OBC cannot be booted, it is hard to manually OBC to be booted and initiate the LEOP. As the S-band receiver is working on the launch pad, the DCS can be conducted through the command transmitted from the ground station. However, the OBC must be booted first. In order to guarantee the initiation of LEOP at the emergency case in orbit, it is necessary to take measures against the LV connector partial separation error.

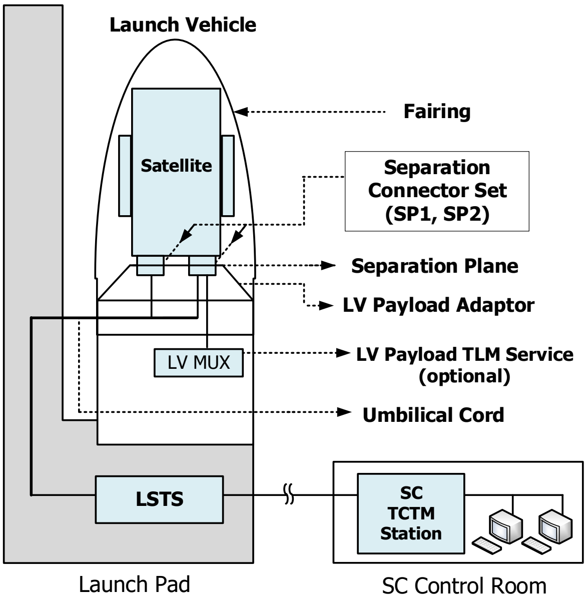


Fig. 1 Conventional Satellite-LV I/F

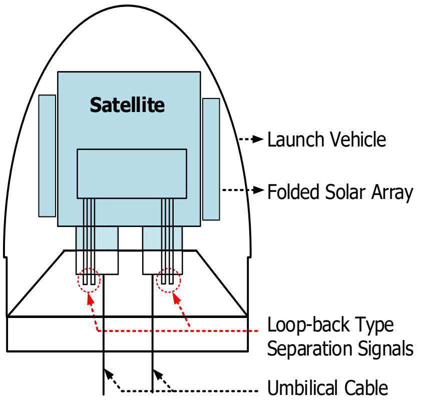


Fig. 2 Loop-back Type Separation Signals

In this study, the role and functions of LVEEI are described for the different satellite launch standby mode. Particularly, a new method is proposed to ensure highly reliable early satellite operation in case of the LV connector partial separation error after launch,

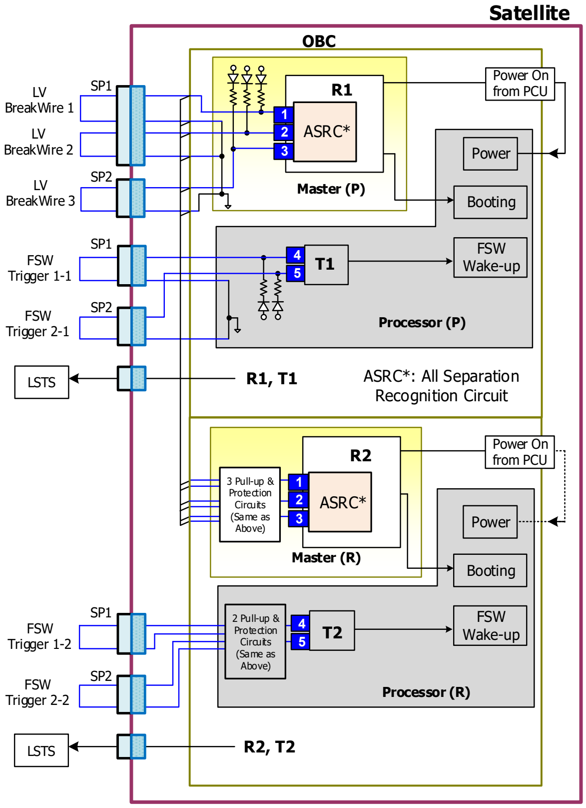


Fig. 3 Conventional Case 2 LV Separation Detection I/F

and also to satisfy the range safety requirements of the launch site after reviewing the existing LV separation detection interface of Case 2 satellite.

2. Roles and Functions of LV Electrical and Electronic Interface

2.1 Satellite Operations Support

(1) Satellite operations @ launch pad

The preparation for satellite operation at the launch pad includes setting the satellite to be on the launch standby mode and monitoring the data related to the safety of the launch site and controlling the satellite to prevent a malfunction. Therefore, LVEEI channels are designed to supply power and communicate with the satellite to set the launch standby mode and to receive the status of the deployment system as well as voltage, current, and power switch of battery [1, 7].

Table 1 SC LV Electrical Interface Summary

LV Electrical Interface Main Channels	
Power Line Analog TM	SC Power Supply Line Main Power Voltage/Current Sensing
Differential Type 1	LSTS-SC Serial Communication
Differential Type 2	SC PCU Setup Command (Only for Case 2)
Launch Site Safety Channels for Case 1 SC	
Differential Type 1	Battery Charge/Discharge Current and Temperature Deployment System Power and Output Status Propulsion Tank Pressure and Temperature
Loop-Back	Separation Indicators
Analog TM	Battery Voltage and Temperature
Launch Site Safety Channels for Case2 SC	
Differential Type 1	Deployment System Power and Output Status
Loop-Back	Separation Indicators FSW Wake-up Indicators
Analog TM	Battery Charge/Discharge Current and Temperature Propulsion Tank Pressure and Temperature
Bilevel TM	Separation Indicators Sensing FSW Wake-up Indicators Sensing
Differential Type 2	Battery Relay OFF Command OBC Power OFF Command
Differential Type 1: Serial Communication Rx/Tx all Differential Type 2: Serial Communication Tx only	

Furthermore, the channels for monitoring the critical satellite malfunctions and the channels for instantaneously cutting off the power of satellite and OBC operation should be defined. Also, the auto-alarm system should be designed to display the data based on each threshold level in real-time [15]. The launch preparations for Case 1and Case 2 differ from each other in the following ways. During the launch preparation for Case 1, the satellite OBC is booted, and the power state of the electrical units are set to be in the launch standby mode while the FSW is working at the LV separation determination phase. In Case 2, the satellite control center directly controls PCU instead of OBC via LSTS communication channels to set the power supply switches of the heater and the units based on its launch standby configuration [6, 7]. The LSTS collects the signals linked with launch site safety directly, which includes the signals for detecting LV separation to monitor malfunction of OBC and FSW, as shown in Fig. 3. Table 1 shows the detailed LVEEI channels for Case1 and Case2. Since the pin numbers of the separation connector is limited to either 37 or 61 [16, 17], the critical channels for the range safety and the essential communication and power channels are selected for the Case 2 LVEEI [1, 3].

(2) Satellite Operations after L/V separation

The LV separation detection interface is designed to detect the separation of the satellite from LV to automatically start the LEOP. The one of Case 1 is designed to acquire three loop-back signals by three independent sensing circuits inside the OBC, and to initiate the LEOP when two or more separation signals are detected [10-13]. For the satellite of Case 2, R1 logic to perform OBC booting and T1 logic to determine the LEOP using the 2 FSW trigger loop-back signals are independent of one another, as shown in Fig.4.

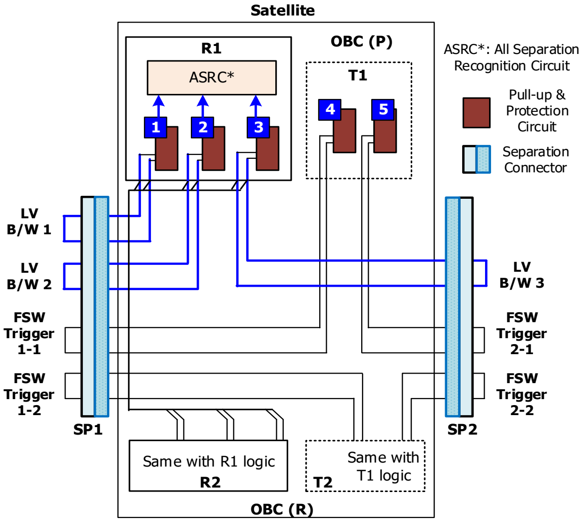


Fig. 4 Conventional Harness Configuration of the Case 2 LV Separation Detection I/F

Table 2 OBC Booting and LEOP Operation Matrix of the Conventional Configuration for Case 2 Satellite

LV B/W 1	LV B/W 2	LV B/W 3	FT 1-1	FT 2-1	Booting (R1)	LEOP Operation (T1)
0	0	0	0	0	No	No
0	0	1	0	1	No *	No *
1	1	0	1	0	No *	No *
1	1	1	1	1	Yes	Yes

0: The loop-back signal harness is connected.
1: The loop-back signal harness is disconnected.
*: It means the LV connector partial separation case happens but it doesn't cause the OBC booting.

As shown in Fig. 4, three signals from LV B/W 1 to LV B/W 3 are connected to the all separation reconfiguration circuit (ASRC), which is designed to verify whether SP1 and SP2 are separated through these signals in the R1 logic. The T1 logic verifies the separation of the SP1 and SP2 using FSW trigger 1-1 (FT 1-1) and FSW trigger 2-1 (FT 2-1) harness. Table 2 shows the OBC booting and LEOP operation matrix for Case 2 LV separation detection interface. The asterisk (*) symbol in Table 2 shows the OBC booting and LEOP operation of Case 2 are inhibited in the case of the LV connector partial separation.

2.2 Launch Site Safety Provision

The hazard items at the launch site are categorized as the catastrophic one and the critical one, as listed in Table 3. The catastrophic hazard should not be caused by two independent faults, and the critical hazard should not be caused by the single fault [4-6]. The monitoring and safety measures at the launch site are established as follows.

(1) Monitoring the hazard items at the launch site

For the satellite mechanical operation before mating on the LV payload adaptor, all safety plugs should be always installed in the SP1 and SP2 of the satellite side to shut down the OBC. These plugs are designed to have only launch separation signals to complete the loop-back configuration of the LV separation detection interface. Moreover, other safety plugs should be also installed to short the output signals of the solar panels and X-band antenna deployment system, and the propulsion valves, which will serve as an effective double safeguard at a zero-current state of the satellite along with shut down measures for satellite battery power relay [1]. At the stage of mating the satellite on the LV payload adaptor in Fig. 1, the safety plug is replaced with the flight model connectors and all shorted output signals of the satellite are ultimately connected to the propulsion and pyro valves and deployment device.

Table 3 Launch Site Hazard Operation

Item	Hazard Description	Category
Propulsion	Tank and Lie Explosion	Catastrophic
Power	Battery Explosion	Catastrophic
Structure	Solar Array Deployment Malfunction	Critical
RF	Transmitter Malfunction RF Emission	Critical

(2) Safety measures on the launch pad

The non-ionizing radiation regulation stated in Table 3 limits the EMC radiation level of the satellite within the LV EMC requirement. It is verified by the EMC radiation and conduction tests during the satellite development and test phase before delivering the satellite to the launch site [18-22]. Meanwhile, on the launch day, the critical satellite data in the launch pad are reported to the satellite control center and the LV mission control center in real time, and the emergency procedures are put in place to control the satellite in case of OBC malfunction or abnormal data generation.

(3) Monitoring the hazard items after the LV lift-off

Through the RF communication channels provided by launcher companies, the vital signals of the satellite can be transmitted to the satellite control center even after the lift-off. This function consists of the LV RF communication function and the analog conversion circuit in the LV named as "LV MUX" in Fig.1. The characteristics of the satellite output signals for the LV MUX should meet the requirements, and the analog conversion formula should be verified before and after connecting with the LV MUX system [23, 24]. Fig. 5 is the LV MUX telemetry examples which displayed on the launch day of the satellite and was used to monitor the key status inside the satellite for a certain period of time after the lift-off.

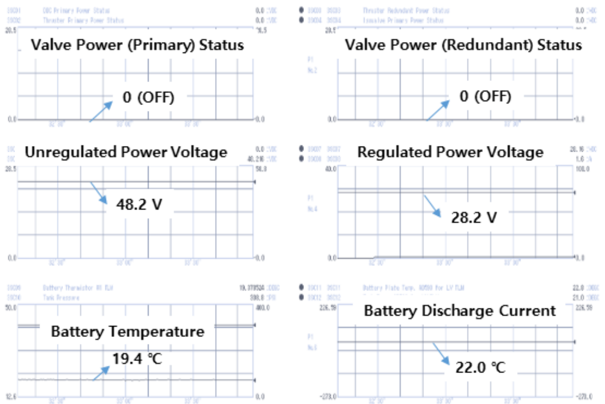


Fig. 5 LV MUX Telemetry Example

2.3 Discussion on LV Separation Detection I/F

At the launch site, the LV separation detection interface, which is defined as a critical hazard for the range safety , should meet a single-fault tolerance requirement. It should also be designed to assure the launch and early operation after the LV separation in orbit. The existing LV separation detection interface of Case 2 satellite shown in Fig. 4 cannot perform the OBC booting in case of the LV connector partial separation as described in Table 2. Therefore, the method to make sure the starting of the LEOP even in the emergency case in orbit should be prepared in the LVEEI. This study proposes to increase the LV B/W signals that determine OBC booting as six signals from LV B/W 1-1 to LV B/W 3-2, and connect them between the SP1 and SP2 and the R1 logic, as described in Fig.6.

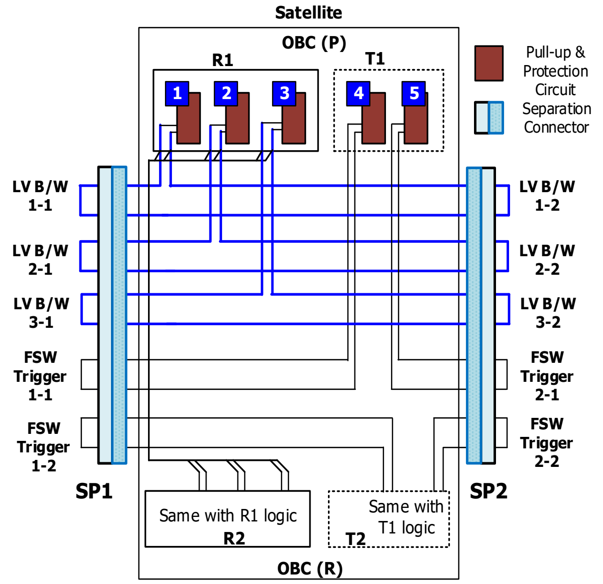
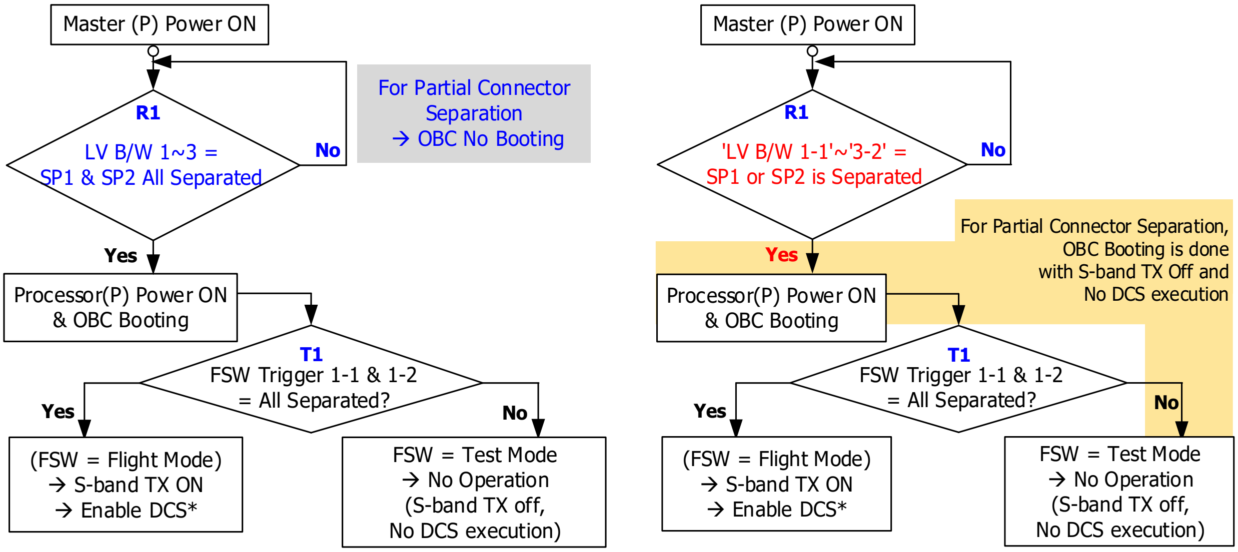


Fig. 6 Proposed Harness Configuration of the Case2 LV Separation Detection I/F

The conventional ASRC in the R1 logic for sensing three LV B/W status can be applied in the proposed method. The key point is to configure the LV B/W signals to the R1 in the way shown in Fig. 6. The ASRC processes three pairs of LV B/W signals to determine whether the SP1 or SP2 is separated. According to the proposed harness configuration, both cases of “either SP1 or SP2 is separated” and “SP1 and SP2 are both separated” result in the status of “1 (separation)”. Finally, the R1 logic in Fig. 6 confirm “LV separation” when two or more LV B/W status circuits show “1 (separation)”. This means that the R1 logic is same with the conventional one and satisfies the single-fault tolerance requirements for the OBC booting determination. The main characteristics of the proposed method is that the OBC booting is performed in the LV connector partial separation case. Since the T1 logic in the proposed configuration to initiate the LEOP operation is same with the conventional one of Case 2, the LEOP operation in the proposed configuration is executed only when all the SP1 and SP2 are completely separated, meeting the range safety requirements.

Fig. 7 (a) and (b) summarize the LEOP determination flows of the Case 2 satellite for the conventional configuration and the proposed one, respectively. Under the conventional configuration, when the LV connector partial separation occurs, the OBC booting is cut off by the R1 logic, as explained in Fig. 7 (a). Whereas under the proposed configuration, the OBC booting is performed by modified LV B/W harness configuration, as shown in Fig.7 (b). The LEOP operation of the proposed method is inhibited as the FSW operation is at “Test mode” instead of “Flight mode” by the T1 logic. Accordingly, even if the OBC booting is performed in the launch site and launch pad, the S-band transmitter is not powered and DCS execution is prevented by the T1 logic.



(a) (b)

Fig. 7 Case 2 LEOP Determination Flows (a) of the Conventional Method and (b) of the Proposed Method

Table 4 OBC Booting and LEOP Operation Matrix of the Proposed Configuration for Case 2 Satellite

R1 1	R1 2	R1 3	FT 1-1	FT 2-1	Booting (R1)	LEOP Operation (T1)
0	0	0	0	0	No	No
1	1	1	0	1	Yes*	No
1	1	1	1	0	Yes*	No
1	1	1	1	1	Yes	Yes
‘R1 1’=0: LV B/W 1-1 & LV B/W 1-2 are connected. ‘R1 1’=1: LV B/W 1-1 or LV B/W 1-2 is disconnected. ‘R1 2’=0: LV B/W 2-1 & LV B/W 2-2 are connected. ‘R1 2’=1: LV B/W 2-1 or LV B/W 2-2 is disconnected. ‘R1 3’=0: LV B/W 3-1 & LV B/W 3-2 are connected. ‘R1 3’=1: LV B/W 3-1 or LV B/W 3-2 is disconnected.						
*: If any separation connector is in the partial separation, SC OBC will be in booting mode but LEOP not be executed.						

For the case that the LV connector partial separation occurs in orbit, in the proposed method, the ground station can take the urgent measures to communication with the satellite since the OBC is booted and the S-band receiver is powered-on.

Table 4 shows the OBC booting and LEOP operation matrix of the proposed configuration for Case 2 satellite. Since the T1 logic is the same as the conventional one, it detects the separation of SP1 and SP2 independently from the R1 logic. As described in the asterisk (*) of Table 4, in the case of LV connector partial separation, the OBC is booted by the R1 logic but the LEOP operation is cut off by the T1 logic, thereby it satisfies the single-fault tolerance requirement for the range safety. Meanwhile, under the proposed configuration, the number of LV B/W harnesses increases compared with the conventional configuration. Therefore, it can increase the chances of the harness open failure. The satellite harness is fully verified at the electrical and environmental test stage and also verified again at the satellite level electrical test after delivered at the launch site. Since, open fails can occur even from the verified harness, the single failure on the hazard interface should be prevented. For the proposed method, the LEOP operation errors are analyzed for the harness open failure cases. Tables 5 (a), (b) and (c) represent the error cases of LV B/W harness and the FT 1-1 and 2-1 harness, and the total number of errors of (a) and (b) combined, respectively. Table 5 (a) indicates that the OBC booting is caused when two or more open failures occur from the LV B/W harness. Only when the open failure occurs on both FT 1-1 and FT 2-1, the OBC booting and LEOP are performed, as shown in Table 5 (b). Meanwhile, when single harness open failure at LV B/W signal and the T1 logic failure occur at the same time, it causes the LEOP operation. But this failure case is due to a double failure. Therefore, the harness open failure case analysis described in Table 5 can conclude that the proposed method meets the requirements for a single fault tolerance.

Table 5 OBC Booting & LEOP Operation Matrix for Harness Open Failure in the Proposed Case2 LV Separation Detection I/F

(a) R1 harness Error		(b) T1 harness Error		(c) Total Fault No. ‘(a)+(b)’
6 LV B/W signals	Booting (R1)	FT 1-1 FT 2-1	LEOP Operation (T1)	-
(1 Fault) Any 1 LV B/W @ SP1 or SP2 is open-failure.	No	1 Fault	**No***	**2 Faults**
	No	2 Faults	No	3 Faults
(2 Faults) Any 2 LV B/W @ SP1 are open-failure.	Yes	1 Fault	No	3 Faults
	Yes	2 Faults	Yes	4 Faults
(2 Faults) Any 2 LV B/W @ SP2 are open-failure.	Yes	1 Fault	No	3 Faults
	Yes	2 Faults	Yes	4 Faults
(2 Faults) Any 1 LV B/W @ SP1 and Any 1 LV B/W @ SP2 are open-failure.	Yes	1 Fault	No	3 Faults
	Yes	2 Faults	Yes	4 Faults
*** : Double Fault Tolerance**				

Moreover, the proposed method can be applied in the already developed LVEEI without the modification of the internal logic circuit, since it only changes the external harness configuration to improve the reliability of the satellite early operation. Furthermore, the proposed method can make the design of the ASRC simpler than the one of the conventional R1 logic for the newly development of the LV separation detection interface.

3. Conclusion

In this paper, the detailed characteristics of LVEEI were discussed for two different satellite launch configurations. As the LV connector separation detection interface is closely linked with the range safety and also with the satellite early operation in orbit, this study investigated the conventional design to determine the OBC booting and the LEOP in detail and proposed the method to improve the reliability of the satellite early operation. This proposed method follows the existing design concept to satisfy the range safety requirements. The method only changes the external harness configuration of LV separation detection interface to ensure the OBC booting in case of the LV connector partial separation in orbit. Therefore, the proposed LV connector separation detection interface is advantageous as it can be applied in the already developed LVEEI without the modification of the internal logic circuit to meet the range safety requirements and also to improve the reliability of the satellite early operation in orbit.

References

[1] N. Y. Lee, D. Y. Kim, J. H. Im, D. Y. Kwon, M. J. Jeon, and G. S. Kim, "Electrical interface design of launch vehicle for an low earth orbit satellite," *Proc. of the Autumn Conf. of the Korean Society for Aeronautical & Space Sciences*, pp. 1005-1007, Nov. 2010.

[2] M. J. Jeon, D. Y. Kwon, and D. Y. Kim, "Spacecraft bus initial activation and checkout of a LEO satellite," *Aerospace Engineering and Technology*, vol. 11, no. 2, pp. 33-38, 2012.

[3] G. S. Kim, D. Y. Kim, H. B. Kim, H. S. Kim, J. H. Im, N. Y. Lee, M. J. Jeon, D. Y. Kwon, and H. J. Choi, "Summary of the KOMPSAT-3 launch campaign and Early operation," *Proc. of the Autumn Conf. of the Korean Society for Aeronautical & Space Sciences*, pp. 839-845, Nov. 2012.

[4] J. H. Im, H. Y. Moon, and S. R. Lee, "KOMPSAT-2 design from the viewpoint of range safety," *Proc. of the Autumn Conf. of the Korean Society for Aeronautical & Space Sciences*, pp. 259-262, Nov. 2003.

[5] J. H. Im, S. C. Lee, and J. Y. Suk, "Range safety design and verification for the low earth orbit observation satellite," *Current Industrial and Technological Trends in Aerospace*, vol. 11, no. 2, pp. 90-100, 2013.

[6] N. Y. Lee, J. H. Im, D. Y. Kim, and G. S. Kim, "Launch site safety review summary for the KOMPSAT3," *Proc. of the Autumn Conf. of the Korean Society for Aeronautical & Space Sciences*, pp. 2143-2146, Nov. 2012.

[7] Y. S. Youn, "Satellite system test at launch site," *Proc. of the Autumn Conf. of the Korean Society for Aeronautical & Space Sciences*, pp. 693-696, Nov. 2015.

[8] J. H. Park, S. W. Cho, Y. Y. Kim, D. C. Chae, Y. G. Huh, and J. Y. Choi, "Development trend of electrical ground support equipment for space program," *Current Industrial and Technological Trends in Aerospace*, vol. 11, no. 2, pp. 62-70, 2013.

[9] N. E. Sitter, "Gemini titan II booster electrical system," *Journal of IEEE Transactions on Aerospace and Electronic Systems*, vol. AES-2, no. 4, pp. 310-318, July 1966.

[10] Y. H. Cho, D. Y. Kwon, J. H. Won, and S. K. Lee, "Design of on board computer for data handling system in GEO-Satellites," *Proc. of the Information and Control Systems Conference*, pp. 293-294, Oct. 2015.

[11] D. Y. Kwon, J. H. Won, Y. J. Cho, Y. H. Cho, and Y. J. Cheon, "Result of data handling system operation on GK2A LEOP," *Proc. of the Spring Conf. of the Korean Society for Aeronautical & Space Sciences*, pp. 494-496, April 2019.

[12] H. K. Shin, S. E. Yang, and Y. J. Cheon, "A glance at flight software for geo-stationary satellite with GK2A development and early operation," *Proc. of the Spring Conf. of the Korean Society for Aeronautical & Space Sciences*, pp. 497-499, April 2019.

[13] Y. H. Cho, K. J. Park, B. K. Park, and Y. J. Cheon, "LEOP operation for bus system on GEO-KOMPSAT-2A satellite," *Proc. of the Spring Conf. of the Korean Society for Aeronautical & Space Sciences*, pp. 470-471, April 2019.

[14] Y. H. Cho, "Overview of LEOP operation on GEO-KOMPSAT 2A," *Proc. of the Information and Control Symposium*, pp. 172-173, Oct. 2019.

[15] N. Y. Lee, "Development of satellite telemetry display system for GK2A launch preparation," *Proc. of the Spring Conf. of the Society for Aerospace System Engineering*, pp. 89, July 2019.

[16] Arian5, User's Manual, issue 5 rev. 2, 2016.

[17] H-II A, User's Manual, ver. 4.0, 2015.

[18] S. R. Lee and J. D. Lee, "Electromagnetic environments of launch vehicle," *Journal. of the Korean Society for Aeronautical & Space Sciences*, vol. 31, no. 2, pp. 108-117, 2003.

[19] J. C. Koo and E. C. Kim, "Electromagnetic environments of launch vehicles for GEO Satellite," *Proc. of the Spring Conf. of the Korean Society for Aeronautical & Space Sciences*, pp. 717-720, April 2005.

[20] E. C. Kim, J. C. Koo, and S. W. Ra, "The preliminary EMC analysis between GEO satellite and the delta 4 launch vehicle," *Proc. of the INTELEC 2009 - 31st International Telecommunications Energy Conference*, Incheon, Korea, pp. 1-2, 2009.

[21] H. H. Lee, T. B. Chae, and S. Y. Oh, "COMS LV interface analysis considering RF compatibility," *Journal of Aerospace System Engineering*, vol. 1, no. 3, pp. 1-6, Dec. 2007.

[22] E. C. Kim and H. H. Lee, "Preliminary EMC analysis between the COMS and the GEO launch vehicles," *Journal of the Transactions of The Korean Institute of Electrical Engineers*, vol. 57, no. 3, pp. 439-445, 2008.

[23] D. Y. Kwon, N. Y. Lee, and D. Y. Kim, "Development and test of launch vehicle MUX interfaces simulator for LEO satellite," *Proc. of the Autumn Conf. of the Korean Society for Aeronautical & Space Sciences*, pp. 2162-2165, Nov. 2012.

[24] N. Y. Lee, J. H. Im, and G. S. Kim, "Summary of the KOMPSAT-3 launch campaign," *Proc. of the Autumn Conf. of the Korean Society for Aeronautical & Space Sciences*, pp. 2131-2134, Nov. 2012.