GIS PLATFORM FOR AUGMENTING SPACE SITUATIONAL AWARENESS

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ABSTRACT: Space launches have increased exponentially during this decade; hence Space Situational Awareness (SSA) has become one of the prominent activities due to increasing traffic in the air-space. In ASEAN, there are lots of reports and incidents of re-entry debris falling into the territories both land and sea. This can cause unintentional disastrous accidents, injuries as well as damage to properties. In general, the launch state will announce the area where the launch debris could potentially fall into, especially in their own territory. However, in several cases, the debris fall outside of the announced area due to uncertainty and system malfunction.
Therefore, to be able to spatially monitor space launch activity and to provide early warning for potentially dangerous area, the launch trajectory has to be determined. Generally, information about the launch trajectory is not publicly available. However, by grasping big data from various sources, for instance, civil aviation Notice to AirMen (NOTAM), information of launch site, and launch orbit, etc., and by assimilating this data, the launch trajectory could be reestablished, thus, situation awareness could be provided to local authority.
In this work, GIS platform for augmenting space situational awareness has been developed. This paper demonstrates the platform that is currently used in Thailand, its structure, workflows, some use cases including implementation examples.

1. INTRODUCTION

1.1 Space Traffic Management and Space Situational Awareness

Satellites have become one of the most important infrastructures that we rely on in our everyday lives. Utilization of satellites and its services, for example, navigation, remote-sensing applications, communication, etc. has been increasing drastically in the recent decade. This dues to the fact that satellite technology is more accessible for both public and private sectors. In addition, several breakthroughs and enabler technologies also lead to the reduction of the cost to build and put satellites into orbit, therefore, space industry become more attractive to the new players (PWC, 2019). From these reasons, population of space object (both satellites and space debris) has increased exponentially in the past decades. Currently, there are more than 5,000 space launches since 1957, these launches have made nearly one million space objects which includes satellites, launch vehicle parts, space debris size from 1cm (ESOC, 2019). The congestion has increased dramatically especially in the orbits with high utilization, this makes the satellites in those orbits even more vulnerable if no mitigation has been made.

In order to have safe and sustainable use of space, Space Traffic Management (STM), which is the measures to manage satellites to minimize the allocation conflict (Christopher, 2017), should be taken into consideration. However, in order to be able to manage satellites and space objects in high congestion area, Space Situational Awareness (SSA) which is the activities to determine information on the space environment and location of any flying objects must be implemented.

This could be done by ground-space surveillance (optical telescope, radar, etc.), space-space surveillance or data sharing among satellite operators.

In addition to the awareness of the objects in space, the safety during launch and re-entry operations should also be taken care of since the mishaps during these phases could cause harmful consequence to others that shares the same terrain or airspace with the launch or re-entry trajectories.

1.2 Space Situational Awareness Activities in Thailand

Thailand has been an active space user for nearly three decades, beginning from the operation of the first Thai communication satellite, Thaicom-1 which was launched and put into service in 1991. Space based remote sensing activity in Thailand even began earlier than that, where in 1982, the first satellite ground station was established in order to receive and utilize the data from space. Thailand has continuously developed its own capacity in space technology and space operations through Thaicom and THEOS missions ever since.

With the experiences from satellite operations, which raised issues of space debris mitigation, collision avoidance analysis into consideration, and due to the fact of the increasing number of space objects and global trend on fostering SSA and STM to maintain space sustainability as mentioned in 1.1. Thailand started its SSA activity in 2015 where the first satellite tracking observatory was put in operation under the collaboration between Royal Thai Airforce, Ministry of Digital Economy and Ministry of Science and Technology.

In addition to SSA for orbital management, satellite cataloging and satellite operation support, launch debris reentry is also one of the major issues in Thailand. Figure 1 shows the location of space launch sites in Asia. By plotting the historical data of launch trajectories from those sites, it can be observed that there were several launch trajectories that passed over ASEAN region and susceptible to have the re-entry debris falling onto Thai territory which might cause damage to property, injuries or even loss of life.

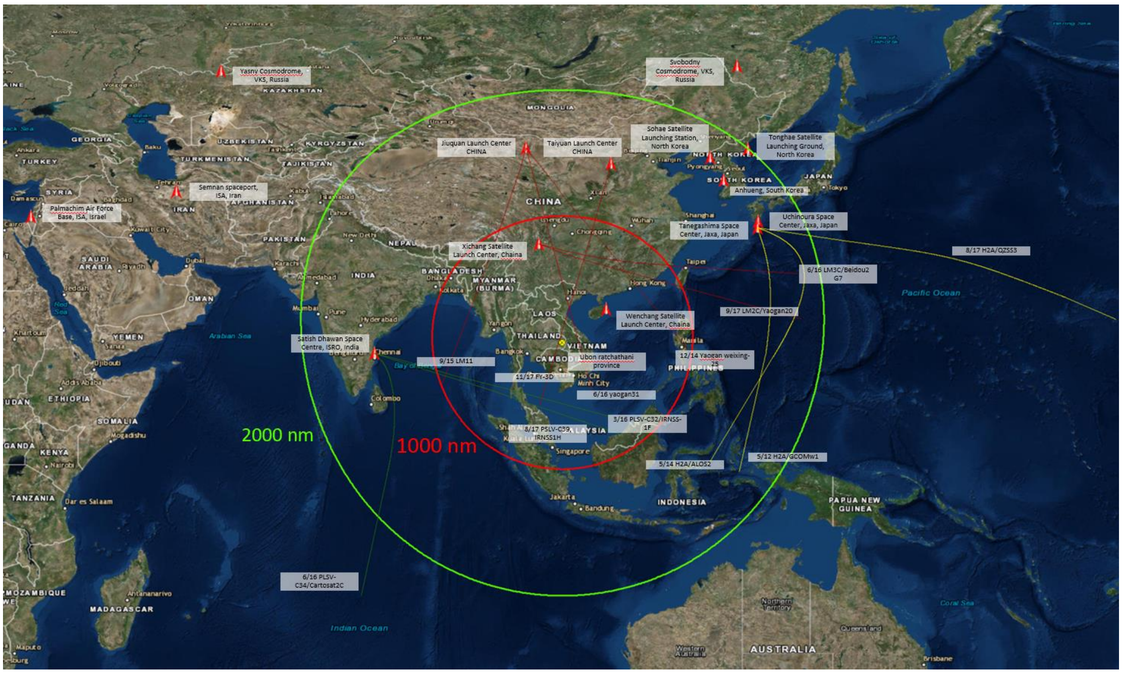

Figure 1: Space launch sites and historical launch trajectories around ASEAN region

Consider only between 2018-2019, there were more than 4 reports of debris re-entry over Thailand (see example in figure 2). Several news and reports showed that space launch debris were found in the vicinity of the residential zone and farmlands in the Northeastern part of Thailand. (Thagoon, 2019)

Figure 2 Launch re-entry debris near Ubonratchathani province 24/05/2019

From this reason, National Working Group for Space Debris Situational Awareness and Mitigation was setup in May 2019. (Boonchoob, 2019) The working group consists of Ministry of Defense, Department of Disaster Prevention and Mitigation under Ministry of Interior, Civil Aviation Authority of Thailand under Ministry of Transportation, Thailand aeronautical navigation service provider (AEROTHAI) and GISTDA under Ministry of Science and Technology. The objective of this working group is to provide support for space and space debris re-entry situational awareness and consolidate national plan for space debris mitigation.

2. IMPLEMENTING GIS FOR SPACE SITUATIONAL AWARENESS

To support the SSA activities in Thailand, Thai-SSA platform is developed by Strategic and Operations Aerospace Research center (SOAR), GISTDA as a tool to collect, analyze and visualize data from various sources. The aim of this tool is to allow the SSA stakeholders in Thailand and international partners to be able to collaborate and share the data among different users, operators and decision makers.

In this paper, the relevant data and methodology to develop GIS tool which is a part of Thai-SSA platform to provide launch debris early warning information is presented and demonstrated. In the following sub-sections, input data pre-processing and implementation of the tool is introduced, in the following sub-section the structure and the framework of the GIS platform to analyze and process the data was described. Then, case study of the launch debris re-entry over Thailand is shown and discussed.

2.1 Input Data for Launch Debris Early Warning System

Within the scope of this paper, as a matter of facts that launching trajectories and the detailed information on the launching event usually is proprietary or confidential information, in this case, only the data available to the public is used for the analysis. The following information is required;

2.1.1 Notice to Airmen (NOTAM) which is the information which is distributed to the airspace users to announce the change, interruption or any special activities/occurrences that happens in any specific area that will concern civil aviation authority. This information is available for civil aviation airspace users and could be retrieved from state civil aviation authority. For our objective to provide launch activity early warning, this messages which should be collected for the entire world on a daily basis or more frequent. The format and guidelines to interpret NOTAM message is defined in (ICAO, 2016). Example of NOTAM message is shown in figure 3.

2.1.2 Space launch sites locations for example, this information could be retrieved from (Wikipedia, 2019) or from any other available sources.

2.1.3 Tentative launch schedule could be retrieved from any available sources, for example (SPACEFLIGHT, 2019)

```
id : A1582/19
Area : Navigation Warnings
Condition : Limitations
Created : 2019-07-18T11:10:00.000Z
Modifier : Will take place
Qcode : WMLW
StateCode : IND
StateName : India
SubArea : Warnings
Subject : Missile, gun or rocket firing
entity : WM
isICAO : true
key : A1582/19-VOMF
location : VOMF
startdate : 2019-07-22T08:30:00.000Z
enddate : 2019-07-31T10:00:00.000Z
status : LW
type : airspace
_id : 5d33ee73ab233e8499920693
all : A1582/19 NOTAMN Q) VOMF/QWMLW/IV/NBO/W/000/999/ A) VOMF PART 1 OF 3 B) 1907220830 C) 1907311000 D) BTN 0830-1000
ON 22-31 JUL E) GSLV- MKIII- M1 CHANDRAYAAN-2 ROCKET LAUNCH FM SHAR RANGE, SHRIHARIKOTA WILL TAKE PLACE AS PER FLW
DETAILS. THE LAUNCH WILL BE ON ANY ONE OF THE DAY DRG THIS PERIOD.ACTUAL DATE OF LAUNCH WILL BE INTIMATED 24 HR IN
ADVANCE THROUGH A SEPARATE NOTAM. LAUNCH PAD COORDINATES : 134312.00N 0801348.00E NO FLT IS PERMITTED OVER THE
DNG ZONES DANGER ZONE -1: IS A CIRCLE OF 10 NAUTICAL MILES AROUND THE LAUNCH PAD. DANGER ZONE -2: I. 1230N 08240E II.
1315N 08250E III.1245N 08410E IV. 1200N 08400E DANGER ZONE -3 I. 1135N 08500E II. 1225N 08510E III.1145N 08715E IV. 1055N
08705E DANGER ZONE 4 I. 0810N 09420E II. 0900N 09440E III.0825N 09615E IV. 0735N 09555E END PART 1 OF 3 CREATED: 18 Jul 2019
11:10:00 SOURCE: VOMMYNYX
message : GSLV- MKIII- M1 CHANDRAYAAN-2 ROCKET LAUNCH FM SHAR RANGE, SHRIHARIKOTA WILL TAKE PLACE AS PER FLW
DETAILS. THE LAUNCH WILL BE ON ANY ONE OF THE DAY DRG THIS PERIOD.ACTUAL DATE OF LAUNCH WILL BE INTIMATED 24 HR IN
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DNG ZONES DANGER ZONE -1: IS A CIRCLE OF 10 NAUTICAL MILES AROUND THE LAUNCH PAD. DANGER ZONE -2: I. 1230N 08240E II.
1315N 08250E III.1245N 08410E IV. 1200N 08400E DANGER ZONE -3 I. 1135N 08500E II. 1225N 08510E III.1145N 08715E IV. 1055N
08705E DANGER ZONE 4 I. 0810N 09420E II. 0900N 09440E III.0825N 09615E IV. 0735N 09555E END PART 1 OF 3 CREATED: 18 Jul 2019
11:10:00 SOURCE: VOMMYNYX
coordinates : [13.72 , 80.23] [12.5 , 82.66666666666667] [13.25 , 82.83333333333333] [12.75 , 84.16666666666667] [12 , 84]
[11.583333333333334 , 85] [12.416666666666666 , 85.16666666666667] [11.75 , 87.25] [10.916666666666666 , 87.08333333333333]
[8.166666666666666 , 94.33333333333333] [9 , 94.66666666666667] [8.416666666666666 , 96.25] [7.583333333333333 ,
95.91666666666667]
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Figure 3 example NOTAM message for GSLV launch for Chandrayaan-2 on 22th July 2019

2.2 Framework of the SSA Platform for Launch Debris Warning

Information from 2.1 can be processed by the launch trajectory determination module in order to find the area for launch activity early warning. The structure of this module can be expressed in figure 4. After NOTAM messages are recursively fetch by API, text mining is processed thanks to regular expression patterns so as to extract key information, which are time (start date and duration), set of coordinates (lat, lon) and description message from the NOTAM, this data is then validate and store in the database.

Extracted coordinates from NOTAM message, launch site locations and launch schedule could be linked together by time window and the line relations that connect coordinates. This process is performed under the launch trajectory finder module, where the approximate launch trajectory could be obtained.

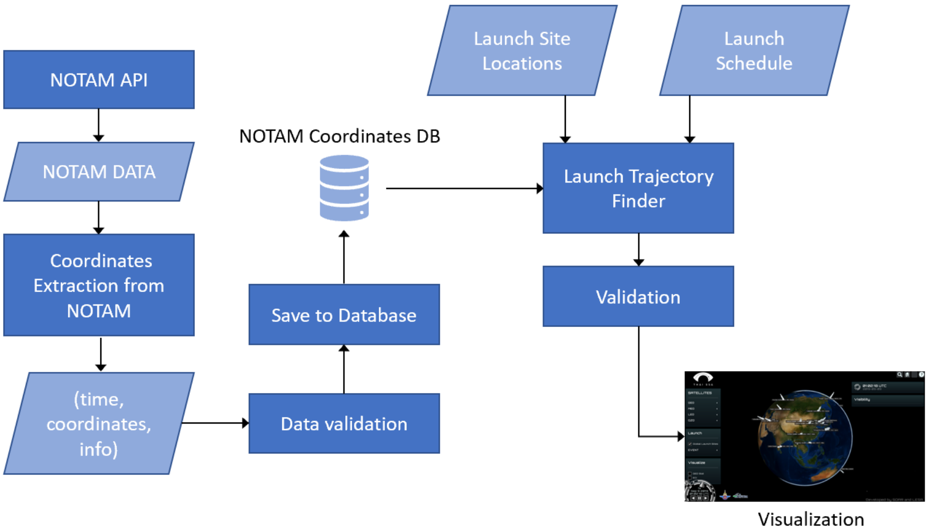

Figure 4 Launch re-entry debris area determination work flow

2.3 Case Study of Implementing the Platform

Early warning information is provided to the related government organizations and local entities thanks to the Thai-SSA platform. Several cases of the launch activities and debris re-entry incidents were able to automatically detected and early warning information was provided. Examples can be shown in figure 4.

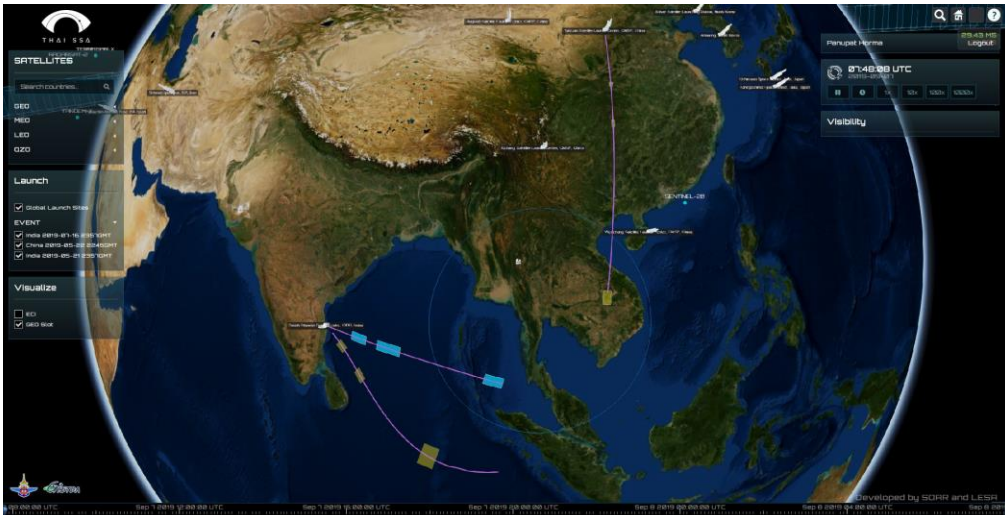

Figure 4 Warning message and visualization of launch debris re-entry by Thai-SSA platform

After the debris re-entry incidents had occurred, information from social media posted by the people in affected area was collected. The results showed that civilians in the affected area were well informed and aware about the situation. (example as in figure 5) With good precaution, local authorities were able to perform situation assessment with mitigation plan and be ready to manage if there is any hazardous object from the launch vehicle.

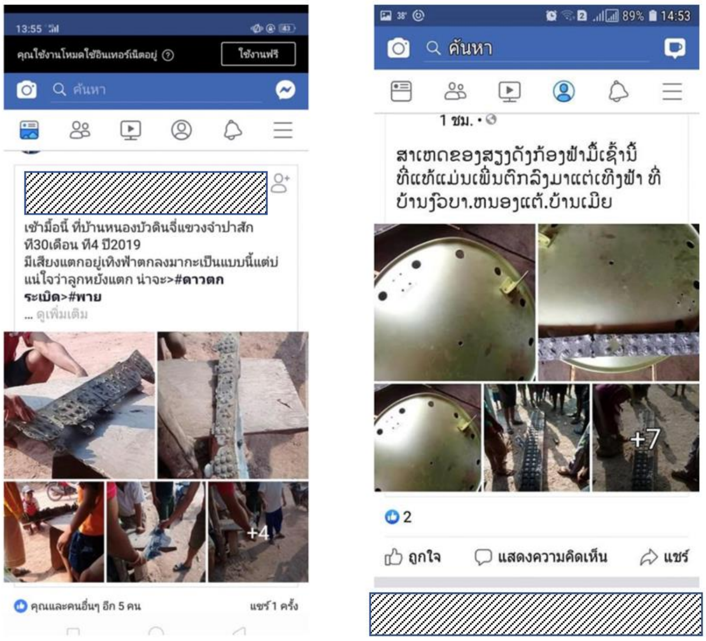

Figure 5 Responses in social media after the launch debris re-entry had fallen. 30/4/2019

3. CONCLUSION

Launch debris re-entry is one of the manmade incidents/disasters which can be intentionally avoid, or at least, prevent from causing damage, injuries or loss of life if caution is well taken. However, space launching is an activity that intervenes large area and usually concerns several territories under the launch trajectory. Hence in some cases, it is difficult to manage and to get the necessary precaution information when such kind of event occur.

In order to have the awareness of the impact from launch debris re-entry and to be able to provide the early warning information to the relevant governmental organizations and the locals in the affected area, publicly available information which are NOTAMs, space launch site locations and potential launch schedule is collected and analyzed by the proposed platform. Potential hazard zone and warning interval can be determined from the publicly available information. This early warning message is then provided to the National Working Group for Space Debris Situational Awareness and Mitigation in order to prepare for the debris re-entry event in the affected area. From several launch debris re-entry incidents over Thailand that occurs recently, it is obvious that the early warning information helps and raise the awareness of the local authorities and civilians in the affected area. This also increase preparedness to mitigate the re-entry debris accident if the situation shall occur. More importantly, the collected information on launch events and the affected area can be used to identify and manage the situation with the launch providers for future launch activities.

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