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STUDY ON THE NEEDS AND PROPOSAL FOR HIGH AND VERY HIGH RESOLUTION SATELLITE REMOTE SENSING SYSTEMS IN VIETNAM

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ABSTRACT

The rapid development of remote sensing applications in Vietnam has resulted in high demands on satellite data, especially high and very high resolution images. It is the fact that, the country's existing remote sensing facilities are not adequate to satisfy its user's needs. Consequently, planning for new earth observation satellite systems is of a critical issue. This paper is firstly evaluating the requirements for high and very high resolution satellite images on various applications including land resource management, surveying and mapping, forestry, environment monitoring and agricultures. An assessment on data provision capabilities of existing Vietnamese Earth Observation systems VNREDSat-1 (Vietnam Natural resource, environment and disaster monitoring system) is also performed. Eventually, the authors suggest a newly planned remote sensing system for Vietnam, focusing on a high and very high resolution optical systems.

Keywords: remote sensing, high and very high resolution, satellite imagery

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I. INTRODUCTION

Currently, remarkable expansion of remote sensing applications in Vietnam, including natural resource management and monitoring, environment protection, surveying and mapping, agricultural management and disaster mitigation has led to sharp increase in demands of remote sensing data, particularly high and very high resolution satellite images. The Vietnamese government has already been aware the importance of remote sensing technology with a central role of satellite imagery and has made substantial investment in remote sensing infrastructures including the ground receiving station, the first Vietnamese Earth Observation satellite (VNREDSat-1) in order to supply satellite imagery for various applications. These investments have made significant contributions in promoting the remote sensing applications. However, current operating facilities are still not adequate for satisfying user's requirements on satellite imagery in Vietnam. Therefore, systematic and strategic planning for new remote sensing systems in the long-run is of high priority to effectively meet the increasing demands for satellite images in the country. This paper reviews the country's major applications and its requests of high resolution and very high resolution satellite images, capabilities of existing facilities and proposes future remote sensing systems for Vietnam.

2. APPLICATIONS OF HIGH AND VERY HIGH RESOLUTION OPTICAL REMOTE SENSING DATA IN VIETNAM

The following sections review key applications of remote sensing data in Vietnam, including high resolution (HR) and very high resolution (VHR) data.

2.1. Surveying and mapping

Surveying and mapping are very first applications of remote sensing technology in Vietnam. In 1980s, Remote Sensing Centre (RSC, former name of National Remote Sensing Department) of the State Department of Land Administration started using analog data, such as KFA-1000, KATE-200 provided by Soviet Union's space-crafts, to create and update maps, including topographic and thematic maps with scales of 1:500.000 and 1:200.000.

During the period from 1996 – 1998, RSC implemented the PRODIGE project with the French partner (SPOT Image) within the frame of French-Vietnamese Protocol 1995. This project provided a digital image processing system based on French-developed PRODIGEO software to RSC. This system allowed RSC to process SPOT 1/2 satellite images for producing and updating larger scale topographic and thematic maps at 1:100.000 or even at 1:50.000 scales. Thus, RSC has been assigned by the Government to procure satellite imagery, process and deliver satellite image products to Vietnamese users. Later, RSC has been equipped with more advanced and powerful satellite image production chain, namely SPACEMAT from the French IGN International (Chu 2005). The SPACEMAT system is capable of processing large blocks of multiple types of remote sensing data, such as SPOT 1-5, ERS 1/2 and ENVISAT/ASAR images.

Because of a large availabilities of satellite data, the range of maps to be produced are also enlarged from small scales (1:1.000.000, 1:500.000, 1:100.000), medium scales (1:50.000, 1:25.000) to large scales (1: 10.000, 1: 5.000 or larger) at different levels of details. Consequently, many organizations have utilized remote sensing data for generating, updating topographic and different types of thematic maps. In the past, aerial photograph were often used for generating topographic map at scale 1:25000 and larger. Currently, satellite images have gradually replaced aerial photography due to a rapid increase in their spatial resolution.

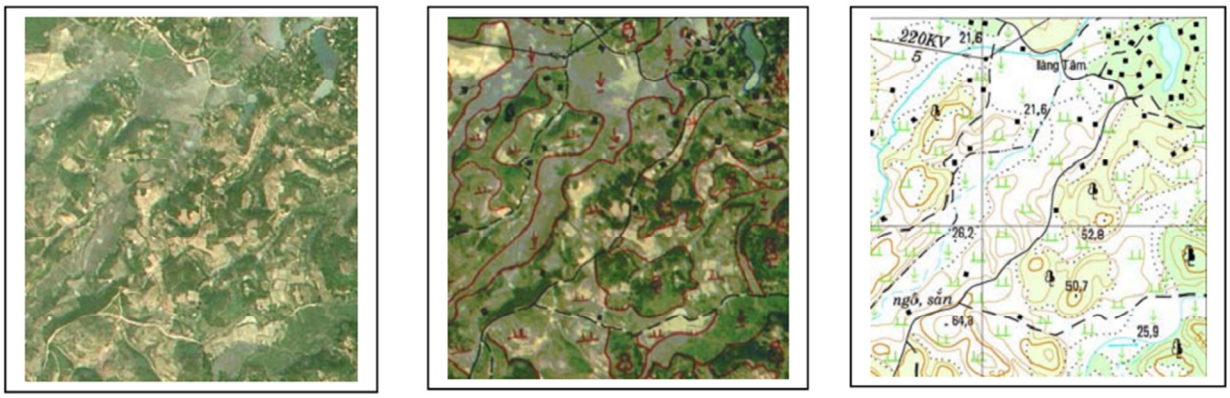

Figure 1 Interpretation and updating topographic map in mountainous area using SPOT 5 satellite images (Source: Chu, 2005).

Figure 2 interpretation and updating topographic map in plan area using SPOT 5 satellite images (Source: Chu, 2005).

VHR satellite imagery, such as IKONOS, QUICKBIRD or WorldView 1-4, Pleaides, has also been used for detail mapping at 1:10.000, 1:5.000 or larger scales, particularly in urban areas (Lu et al. 2011, Mustapha et al. 2015). This kind of data is an important data source for topographic and cadastral mapping, updating (Jacobsen, 2008) and spatial database development. For instance, the project "Development of a basic topographic – hydrographic information system database for flood prevention and protection and social – economic development in Cuu Long River's Delta" implemented from 2004 to 2008 used a large amount of Quick Bird satellite images for detail mapping in some urban areas and developing a spatial database.

2.2. Land management

Satellite images are considered as an important data source for land use/land cover mappings, survey and planning. Satellite imagery, such as Landsat TM, had been utilized for generating land use map with scale of 1:1.000.000 for nation-wide level since 1990s. HR satellite images, such as SPOT 5, VNREDSat-1, SPOT 6, IKONOS, QuickBird or WorldViews have been used for the provincial level, larger scale land use maps at 1: 25.000, 1:10.000 or even larger scales.

Since 1990s, Vietnam has been implementing a national land inventory program every 5 years. In these programs, uses of satellite images have gradually increased. In the year 2000 of land inventory program, SPOT 2, 4 satellite images were introduced to users in 13 provinces and achieved positive results. In the following Land Inventory programs (2005, 2010), high resolution SPOT 5 imagery (2,5m in PAN) had played a crucial role in producing

large scale image-maps. These image-maps were then provided to local provinces to map land-use features at 1:10.000 scale. During the program in 2005, RSC has produced thousands of high quality image maps at 1:50.000, 1:25.000 and 1:10.000 scales and delivered to various provinces from North to South of the country. Recently, HR and VHR remote sensing data, such as SPOT 6/7 and Pleiades, with resolution from 1,5m to 0,5m are being employed more often for producing large scale land use maps of 1:10.000 and 1: 5.000 scales. For example, in the 2015 Land Inventory program, large scale image maps generated from these satellite images had been provided to 13 provinces in the Cuu Long river delta and for identifying coastal mud flats.

Furthermore, satellite images are also an effective tool for evaluating of planning implementation and utilization of land resources.

It is clear that demands for satellite images for land resource management are significant increase. Satellite images are not only applied for large areas for overall views and monitoring but also for applications at much higher level of details. Therefore, multiple levels of satellite imagery, particularly HR and VHR remote sensing data are highly requested.

2.3. Forestry

Since 1990s, Landsat MSS and Landsat TM data had been employed by the Forest Inventory and Planning Institute (FIPI) for updating forest maps over changed areas at nation-wide scale (Nguyen, 2016). Landsat MSS and Landsat TM images were also utilized for producing ecological vegetative forest maps at a scale of 1: 250.000 over numerous areas.

During the period from 1996 – 2005, Landsat TM, + ETM and SPOT 2, 3, 4 images had played indispensable roles in forest mappings, assessments and monitoring. The SPOT data with higher resolution has allowed mapping forest features at a scale of 1: 100.000.

During the period from 2005 -2010 (the fourth national program on inventory, assessment and monitoring forest resource), the high resolution SPOT 5 imagery 2,5m (PAN) and 10 m (MS) has been used broadly to produce forest resource maps at a 1: 25,000 scale for 1000 communes; current forest maps at a 1: 50.000 scale for districts, a 1: 100.000, 1: 250.000 and 1: 1000.000 for provinces, regions and the whole country, respectively.

The role of HR satellite images has been highlighted in the project “General nation-wide forest survey, inventory for a period 2013 – 2016”. In this project, a large range of remote sensing data at different spatial resolution were considered, including SPOT 5, VNREDSat-1, SPOT 6 and other images. These higher resolution data has made larger scale of 1: 10.000 forest maps become predominate products.

Generally, it is apparent that remote sensing data has become essential for forested application. This leads to strong demand on satellite images, especially, HR data for forest management and monitoring.

2.4. Environment monitoring

Satellite images are crucial inputs for environment management and monitoring. NOAA-AVHRR, MODIS, OceanSat-2 data are very effective for operational assessment and monitoring of air quality, particularly for urban and industrial areas (Savtchenko et al. 2004). These kinds of images are also employed for producing Sea Surface Temperature and Ocean Color products. Landsat TM, OLI, SPOT 1-5, 6/7, Sentinel-2 and other remote sensing data can be used for detecting and monitoring of air pollution (Tran et al. 2012), water pollution in rivers or lakes (Gholizadeh et al. 2016). HR images are ideal tools for detection of discharged waste and assessment of environment impacts by mineral exploitation, operation of industrial plants.

2.5. Agriculture

In Vietnam, Landsat TM and SPOT 1-4 satellite imagery has been employed for crop identification and monitoring since early 1990s. They are being used by the Vietnam National Institute of Agricultural Planning and Projection (NIAPP) for implementing different types of agricultural practices. These diverse tasks includes crop area mapping and estimation, crop yield prediction, crop growth monitoring, early warning and detection of stress, diseases, impact of drought, soil moistures estimation. In Vietnam, rice is most important crop and occupies largest proportion of cultivated land (around 3.8 million ha). Therefore, rice related activities are main targets of remote sensing application. Navalgund et al. (1996) suggested that three layers of remote sensing data are requested for comprehensive rice monitoring on national or regional levels, provincial or district levels and field (parcel) levels. The low spatial resolution data (>100m) with high revisit capability (several days) can provide a quick general view over regional levels. For crop area estimation, crop product forecasting, disease/stress detection, uses of medium resolution satellite imagery (Landsat TM, ETM+, Landsat 8 OLI, SPOT 1-4, Sentinel 2) would be appropriate. In a case of detail monitoring at a field (parcel) level, particularly in complex areas with multiple or mixing of different types of crops, the HR and VHR satellite imagery such as SPOT 5/6/7, VNREDSat-1, LISS-4, KOMPSAT-3, IKONOS, QuickBird, WorldView 2,3,4 or Pleiades are most suitable.

3. CAPABILITIES OF EXISTING SATELLITE REMOTE SENSING SYSTEM IN VIETNAM

3.1. Remote sensing data supply prior to the launch of VNREDSat-1 satellite

Before having its own satellite, commercial satellite images were bought from foreign suppliers such as SPOT Image (now it belongs to the AirBus), Digital Globe, or RadarSat International. The National Remote Sensing Department (NRSD) was authorized by the Vietnamese government to purchase and process remote sensing data to generate value added products at different levels and re-distribute to local users.

Since 2009, with the normal operation of the Vietnamese Ground Receiving Station (VNGS), satellite images, including SPOT 2, 4, 5; Envisat/ASAR and Envisat/MERIS data have been directly acquired and processed by this Station. The VNGS has successfully received several hundreds of thousands SPOT scenes, of which many tens of thousands scenes with less than 10% of cloud covered. Satellite image products received and processed at the VNGS have played major roles in supporting remote sensing applications in Vietnam. Unfortunately, none of these satellites and sensors is in operation to date.

3.2. VNREDSat-1 system

The Vietnam Natural Resource, Environment, Disaster monitoring small Satellite (VNREDSat-1) was launched in May 7, 2013 and providing HR optical satellite images in one Panchromatic (PAN) band and four multispectral (MS). Its specifications is described in the Table 1.

Table 1 Specification of the VNREDSat-1 system (Source: *www.sti.vast.vn*)

Orbit	Type of orbit: Sun-synchronous Orbit parameters: 14+18/29 Altitude: 680km Inclination: 98.7o
Instrument type	Push-broom imager
Optics	Korsch telescope with a TMA design
Spectral bands	Panchromatic (PAN): 0.45-0.75 µm Multispectral bands (MS): B1: 0.45-0.52 µm (Blue) B2: 0.53-060 µm (Green) B3: 0.62-0.69 µm (Red) B4: 0.76-0.89 µm (Near-Infrared - NIR)
Ground Sample Distance (GSD)	2.5m for PAN 10m for MS
Detectors	7000 pixels (PAN), 1750 pixels (MS)
Swath width	17.5 km at nadir
Quantization level	12 bit (10 bit coding for downlink)
Designed lifetime	5 years

3.3. Imaging capabilities of the VNREDSat-1 system

Results of analyzing technical properties of the VNREDSat-1 system and experiences in operating this system since May 2013 has revealed that:

- It takes 3 to 4 days for acquiring qualified images over various regions in Vietnam;
- Although theoretical period for taking images over land areas in Vietnamese territory is 337 seconds it is not feasible in reality since the system need time for changing and stabilizing while implementing different imaging requests. These time periods are depended on changing of imaging angles and ranges from 30 second to 120 seconds.
- The longer imaging strip the more effective in acquiring data since the system need less time for changing imaging angles.

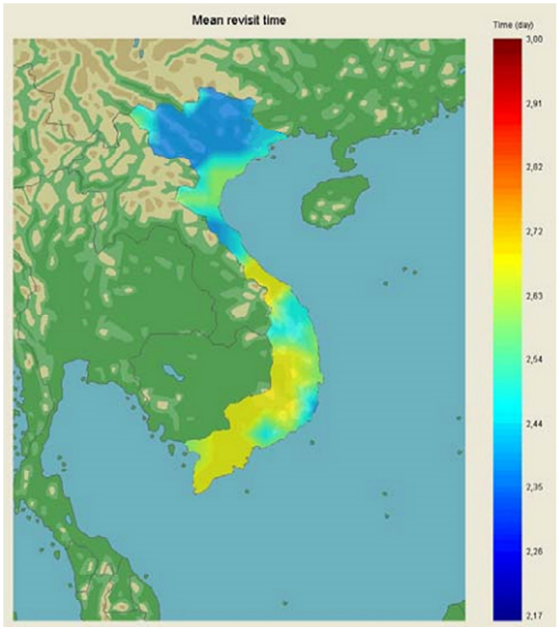

Figure 3 VNREDSat-1's mean revisit time over Vietnamese territory with agility of ±35o (Source: www.sti.vast.vn)

As using optical imaging sensors the VNREDSat-1 system has been severely affected by weather condition, particularly for Vietnam which locates in monsoon tropical region. In Vietnam, it is estimated that clear sky time only occupy 10%. Therefore, it is very difficult to acquire cloud free images (cloud cover <10%). The small swath is another major disadvantage. Eventually, in rarely good weather days, it cannot take image strips with larger than 17.5 km (at nadir). This causes an enormous difficulty for fulfill requests of covering relatively large areas, such as provinces, regions or nation-wide, in acceptable time period. It is very often that there are many holes in a data requested areas. In a case that the satellite can fully cover the projected areas, the data are often different in acquiring dates which leads to inconsistent of datasets and make it hard to use, particularly with automatic processes.

Experiences of 4 years exploiting the VNREDSat-1 satellites has shown that due to weather condition of Vietnam and limitations of VNREDSat-1 satellite, the Vietnamese satellite can only satisfy approximately 40% of demand on remote sensing data. However, actual amount of data has been used are even much lower since it cannot satisfy customer's requirement for completed covering ordered areas.

4. DATA REQUIREMENTS AND PROPOSAL OF HR AND VHR OPTICAL SATELLITE SYSTEMS

4.1. Proposing for HR and VHR systems

Based on above discussion it is clear that in near future Vietnam should plan for new remote sensing systems in order to satisfy requirements of remote sensing data, particularly HR satellite images. In the following sections the HR and VHR systems are discussed and proposed.

1) HR optical remote sensing systems

To date, it is obvious that demands on HR optical remote sensing data (resolution from 1m to 10 m) are increasing. There are many applications using this kind of satellite images. These includes producing and updating topographic and various types of thematic maps, land

resource management and monitoring, forests, environment, agriculture, disaster prevention and mitigation, developing of spatial database. The HR satellite imagery is used as a major data source for implementing national inventory programs such as National Land Inventory Program (every five years) or General Forest Resource Inventory Program. Moreover, using HR satellite imagery for creating, updating topographic and thematic map at a scale of 1: 50.000 and 1:25 000 or even larger scale has become operational and require large amount of remote sensing data.

Unlike lower resolution remote sensing data, HR remote sensing data are not free but users have to purchase from the foreign satellite suppliers or pay fees for data received and processed from the Ground Receiving Station in Vietnam.

HR satellite images such as SPOT 5, 6/7, VNREDSat-1 have been used broadly and become very familiar with the Vietnamese user community. Thus, continuing to maintain the supply for this kind of satellite imagery is essential.

On the other hand, as the Vietnamese VNREDSat-1 satellite are getting closer to its end of design life time, in 2018, though it is expected that the system will work for longer period, it is critical for developing and launching more HR remote sensing satellite.

Moreover, since the current VNREDSat-1 satellite can provide approximately 40% of data demands, in order to meet requirements for this kind of satellite imagery, it is not only one but 2 or even three satellites should be planned. These remote sensing satellites have to work in constellation to optimize data supplying capability to users.

2) VHR optical remote sensing systems

The demand on VHR satellite images has been increased rapidly and is continuing to increase, particularly with optical data. In Vietnam, there is a large requirement on VHR satellite image for such an application which requires high level of detail. For instance, management and monitoring of changes, urban planning, detail construction and transportation monitoring, land use mapping, creating and updating large scale map from 1: 10.000, 1: 5000 and larger, cadastral mapping and generating highly detail spatial database. Currently, Vietnam has not yet had any VHR remote sensing system. All of VHR satellite images are bought from foreign supplier, mainly Airbus and Digital Globe. The VHR optical remote sensing systems are also depended on sun illumination and weather conditions. Consequently, it is more difficult to acquire cloud free images, since Vietnam is tropical country where cloudy sky is very often. For these reasons it is necessary for Vietnam to develop their own VHR remote sensing system in order to be more active in satisfy user's requirement for this kind of satellite images.

In many cases, the VHR remote sensing system can be used more effectively together with other type remote sensing data, particularly, HR image. For examples, firstly, using lower resolution data with larger coverage and shorter revisit time for overall assessment or monitoring. After that, uses VHR systems to focus on detected or suspected areas for monitoring related features at higher level of detail. This approach allows utilization of resource from remote sensing systems more effective and better satisfying needs from users.

4.2. Selections of technical properties based on experience from the VNREDSat-1 system

According to the Strategy for Research and application on Space Technology in Vietnam until 2020, Vietnam will continue to develop and launch several small Earth Observation satellites. It mean that, our proposed HR and VHR remote sensing systems should be fitted for platform of small satellites (weight<500 kg).

In order to reduce cost of building small satellite systems the most common and accepted approach is to select already designed and tested components which are ready available in the market.

Regarding the technical properties of the proposed systems, based on experiences gained from operating the VNREDSat-1 system, it is necessary to develop remote sensing systems with numerous features inherited from the VNREDSat-1's design and some improved features.

Inherited features

- Sun-synchronous orbit;
- High spatial resolution (from 2,5m to >1,0 m – for HR systems and <1m for VHR system);
- Can change its postures (tilt, pitch, roll) for acquiring image at different position on Earth surface;

Improved features

- Large swath width;
- Reduced time for changing position and stabilization.

The swath width is depended on many factors, including design of the payload (telescope's aperture, focus length, a number of detectors) and the height of satellite orbit. In fact, for small satellite the swath width is often around 20 km or less. However, as the case of Formosat-5 satellite from Taiwan the swath width can reach to 24 km (Hsu et al. 2016). Therefore, we also recommend that the newly planned HR and VHR remote sensing systems should have similar swath width of 24 km or even larger. This larger swath width could significantly improve the efficiency of the system in comparing with the VNREDSat-1 system.

In order to reduce time for changing position and stabilization of the satellite the designed system should be equipped with the 3 –axis stabilization attitude control system based on modern Control Moment Gyros as the case of SPOT 6/7 or WorldView 2,3,4 satellites.

5. CONCLUSION

There is a great demand of HR and VHR optical satellite images for sustainable development in Vietnam and it is continued on increasing. The existing Vietnamese Earth Observation satellite VNREdSat-1 can partly satisfy user's needs. Hence, it is necessary to plan and propose new HR and VHR remote sensing systems in near future for Vietnam. Based on evaluations of main application and requirements on satellite imagery as well as data supplied capabilities of VNREDSat-1 system and other source we have proposed new HR and VHR optical remote sensing systems. It is revealed that Vietnam should prepare for 2 HR optical remote sensing system which is a twin satellites working as a constellation and a VHR optical remote sensing system. In order to avoid limitations of the VNREDSat-1 system, the authors make a recommendation to design larger swath width and reducing time for changing positions and system's stabilization.

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