The TripleSat constellation: a new geospatial data service model

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ABSTRACT
With the increase of different sensors, applications and customers, the demand from data providers and users is for a new geospatial data service model, which supports low cost, high dexterity, and which would provide a comprehensive service. Based on such requirements and demands, the 21AT TripleSat constellation terminal and data delivery and management system has been developed by a Beijing based high-tech enterprise, Twenty First Century Aerospace Technology Co., Ltd. (21AT). The company is the first commercial Earth observation satellite operator and service provider in China. This new geospatial data service model allows the user to directly access multi-source satellite data, manage the data order, and carry out automatic massive data production and delivery. The solution also implements safe and hierarchical user management, statistical data analysis, and automatic information reports. In addition, a mobile application is also available for users to easily access system functions. This new geospatial solution has already been successfully applied and installed in many customer sites in China, and is now available globally for international clients interested in fast geospatial solutions. It enables the success of customers’ operational services. Besides providing TripleSat Constellation images, the multi-source data access system also allows the users to access other satellite data sources, based on customized agreement. This paper describes and discusses this new geospatial data service model.

1. Introduction
Application of earth observation satellites plays a significant role in supporting national and international economies. So far, there are many Chinese land observation satellites in orbit and in operational service, including the CBERS-02B (China Brazil earth resource satellite), HJ, ZY, SJ, GF, and BJ series, and many others (Xu, Gong, and Wang 2014; Zhou, Huang, and Wang 2014). According to China’s Middle and Long-term Planning, in decade years, more than 10 land observation satellites will be developed and launched by China, thus forming an integrated land observation system, characterized by a multi-sale spatial resolution and diversified sensors (Yang and Chi 2011). In turn, these will obtain plentiful geospatial remote sensing data to apply in many industries such as agriculture, environment, forestry, traffic, and so on. While the number of remote sensing applications has increased greatly, the remote sensing data are still generally considered as a scientific data-set used by specialist organizations and government agencies. Currently, earth observation satellite data are certainly not as popular as data from global positioning satellites, communication satellites, and meteorological satellites. Moreover, the remote sensing satellites applications market is still typified by a lack of sufficient professional commercial services providers who can meet the needs and various demands from the end-users, like satellite planning, imaging, processing, obtaining, visualization, archiving, etc. Hence, it is clear that commercial remote sensing satellite enterprises who best understand the user demands by having close contact with their customers, provide more direct, convenient, and efficient services (Mantas, Liu, and Pereira 2015; Tan, Di, and Deng 2016).

The Twenty First Century Aerospace Technology Co., Ltd. (21AT) is a Beijing based high-tech enterprise and is the first commercial Earth observation satellite operator and service provider in China. In this paper, we present the 21AT TSCT and DDMS. The main satellite data source of the solution is the TripleSat Constellation operated by 21AT, which is a high resolution (<1 m) satellite constellation, consists of three identical satellites, launched on 10 July 2015. The constellation can provide daily targeting capability anywhere on Earth. Both space and ground segments have been designed to efficiently deliver guaranteed timely information. The TripleSat Constellation is the enabler for customers’ operational and sustainable geospatial applications. A diagram of
TripleSat constellation satellites in the same orbit is shown in Figure 1.

This new geospatial data service model allows the user to directly access multi-source satellite data, manage their data order, and carry out automatic massive data production and delivery. The solution also implements safe and hierarchical user management, statistical data analysis, and automatic information reports. In addition, a mobile application is also available for users to easily access system functions.

2. Review

In recent years, remote sensing data have become available from governmental agencies and enterprises because of the ever-increasing technological capabilities of the web (Ji 2013; Kang 2012; Zhou, Huang, and Wang 2014). Several web portals that provide comprehensive service opinions for data search, order, and download are presented below:

(1) NASA's earth observing system data and information system (https://earthdata.nasa.gov/data/near-real-time-data; http://gcmd.nasa.gov/index.html; http://reverb.echo.nasa.gov; https://earthdata.nasa.gov/echo/; https://earthdata.nasa.gov/data/data-tools) has a core capability for exploring and managing multi-source NASA's earth historical data, which is designed as a distributed system, with major facilities at distributed active archive centers (DAACs) located throughout the United States.

(2) China center for resources satellite data and application (CRESDA) has established a “three-in-one network” data distribution service system to ensure that the rapid growth of satellite data can meet users’ requirements. The data distribution system was transitioned from a single CD-ROM (magnetic media)-based distribution to network-based distribution, followed by a transition from single network to multiple networks, including a special network, the e-government network, and the Internet, at different levels and for different users.

(3) The European space agency’s (ESA) earthnet online portal: this provides services for search and request of EO data from ESA EO Missions (ERS-1, ERS-2, Envisat, GOCE, SMOS, CryoSat, SENTINEL-1, SENTINEL-2, SENTINEL-3), third party missions (TPMs), ESA campaigns, the GMES space component (GSC), as well as sample and auxiliary data from a number of missions and instruments. The data browsing can be performed by mission and instrument, or by earth topic, typology, and processing level (https://earth.esa.int).

(4) The Canadian space agency provides capabilities of searching and downloading open access data which consists of EO data over Canada, such as Landsat imagery. The data search can be performed through free text form and filters by organization, data type, and subject, etc. (http://data.gc.ca/eng).

(5) The national remote sensing center (NSRC) of the Indian space research organization (ISRO) distributes open EO data archive of ISRO's satellite products (Resourcesat-1: OrthoAWiFS and LISS III data; IMS-1: HySISpectralBinnedData) for India via the Bhuvan geoportal. (http://bhuvan.nrsc.gov.in).

(6) Argentina’s national commission on space activities (CONAE) provides catalog imagery data search under different states of access and download. (http://www.conae.gov.ar/index.php/es/catalogo-de-imagenes).

(7) Brazil’s national institute for space research (INPE) has a catalog search for imagery products (CEBERS, Landsat, MODIS TERRA, MODIS/AQUA, Resourcesat-1) and also provides the capability of imagery data acquisition after registration (http://www.dgi.inpe.br/CDSR/).

In summary, many government organizations and agencies have been providing multi-data products and services for a very long time. However, systems’ service methods place restrictions on historical imagery data or catalog search, order, and download processes. Additionally, such traditional services often lack low cost, high dexterity, and comprehensive application and distribution services, to specifically meet the user’s interest in subscription, independent processing and 3D visualization needs. In particular, remote sensing data distribution is a key component of the whole service, as this directly bridges the gap between the user and the remote sensing data.

The traditional data sales and services of satellite operators in the market are through local partners or resellers. For instance, in 2014, DigitalGlobe had 60% of the world remote sensing data sales market (Wang and He 2015). DigitalGlobe has 2 subsidiary companies, 7 sole agents, and 116 international distribution partners. Airbus has about 20% of the market of world remote
sensing data sales (Wang and He 2015). It has 7 subsidiary companies, 4 sole agents, and 102 international distribution partners. However, as is well known, the disadvantage of this method of selling Earth observation data by means of distributors, is associated with high costs and low efficiency. Nowadays, with the web technology development, users can access the remote sensing data in a faster, more flexible, simple, and cheap way.

When Earth observation spatial data distribution is by means of the web, customers should log into the data service website supported by the data provider, and search data by specific attribute parameters (Ji 2013; Mantas, Liu, and Pereira 2015; Qian, Sun, and Xu 2012; Wang, Li, and Jia 2007). Once the relevant data have been found in the database, customers can order the data, which can then be delivered to them by disks, CDs, or direct download from the Internet. Currently, nearly all the leading remote sensing data service platforms around the world implement this model to distribute remote sensing data and provide data services, such as the multi-satellite data service platform operated by the institute of remote sensing and digital earth, Chinese academy of sciences (http://eds.ceode.ac.cn/); the TERRA-MODIS platform from the institute of geographic sciences and natural resources research Chinese academy of sciences; the scientific data platform from the computer network information center (http://www.csdb.cn/), data service platform from the China center for resources satellite data and application (http://218.247.138.121/DSSPlatform/index.html#/); the data service website from US geological survey (USGS)/EDC (http://landsat.usgs.gov/), data service platform from Remote Sensing Technology Center of Japan (http://www.restec.or.jp/english/satellite/index.html), and data service platform from geo-informatics to space technology development agency of Thailand (http://www.gistda.or.th/gistda_n/en/index.php?option=com_content&view=article&id=17&Itemid=27).

At present, due to the rapid increase in the number and types of Earth observation data sources, and the rapid development and prevalence of mobile terminals and wireless networks, these traditional data distribution models have been exposing constraints that hinder the development of remote sensing applications. The institute of remote sensing and digital earth (CAS-RADI) was one of the first organizations to present a location-based instant satellite image service (LBISIS) system which provides LBISIS. By means of this system, users can subscribe to data, based on their location of interest, and subsequently the satellite image data received by the ground receiving station's antenna will be distributed to the customer's terminal devices (Liu, Yang, and Chen 2014). LBISIS provides instant image services adjoining remote sensing application downstream demands. The main drawback of this system is the lack of instant observing services.

### 3. User requirements

Based on traditional image storage and management, search and query, order and distribution service methods, a new generation of remote sensing service system is needed, with a structure that will meet higher user demands. From the data provider's point of view, there are two aspects to take into consideration about developing this new system at low cost (Tan, Di, and Deng 2016). Firstly, the new system should have the capability of integrating satellite operations, data receiving, data processing, data dispatch, and other services. Traditionally, the management of satellite observations, processing and distribution are separate issues, and treated separately. This mode of management reduces service efficiency, and is not suitable to meet the need for efficiency. Furthermore, the cost will increase exponentially for the management of mass imagery products, various application requirements, and connect and balance between different departments. Secondly, the new system has a core capability of pliability and expansability to multi-satellite sources, imagery products, and application users. With spacecraft technology development (Hastings, Putbrese, and Tour 2016; Kang 2012), more quantity and type of satellites will be available. For taking full advantage of satellites sources, it is a requirement for remote sensing data service systems to support satellite dynamic increase and overall management. Then different sensor satellites produce new standard imagery other than existing product, therefore, the design of structure must have the ability to extend other sensor standard product. The increase in quantity and type of product attract application users, and then the size of system, which is the core of sharing data, can be extended.

From a data user's perspective, there are three important aspects of the system that users really need, namely: it should be real time, enable multi-terminals to be used simultaneously, and provide a personalized service. Because of the ever-increasing number of satellites, products and number of customers, the system should support custom-made business workflows and execution capabilities. As Earth observation satellites play a significant role in supporting the action of quick responders in case of emergency events (Denis, Boissezon, and Hosford 2016), more and more both professional and non-professional data application users need instant or near real-time services about satellite imaging and “area of interest” imagery. Recently, mobile devices have become very popular, as they provide convenient and shortcut methods to recognize and understand geospatial data products. Hence, mobile services have become a significant part of the system. Many users like to understand remote sensing data by means of 3D visualization, in order to study the environment.

Hence, in order to meet these user requirements, this paper presents a new integrated and instant geospatial data service model which establishes an integrated
various data sources in one catalog and make the data available to its subordinates. 21AT DDMS comprises seven subsystems, which can be combined in a very flexible manner based on customer needs. These seven subsystems are: (i) TSCT; (ii) data management system, (iii) data distribution system, (iv) 3D display and conference system, (v) Multi-satellite mission simulation system, (vi) Multi-source data access system, and (vii) mobile terminal system. The solution system diagram is shown in Figure 2.

4. Solution description

21AT DDMS is a total solution for a customer who needs to receive TripleSat Constellation images, as well as other satellite data, manage the mass data from multi-source remote sensing product database and geospatial information platform. It centralizes all these processes in one place, giving users a very comprehensive way to use the satellite data supporting their applications.
The data purchase module includes both archiving data and tasking data procurement. The module allows users to have a real-time tracking of the submitted order forms, including the approval status, production, and the delivery status. The function of order form consultation also enables users to communicate directly with the data administrators.

The data reception module realizes a real-time interface to the TripleSat Constellation database. The data downloading is automatic, which consists of the data ordered by the users or pushed by the system. The users are able to select the download path and to connect with the Data Management System, sequentially realizing the closed-loop management from data downloading to storage.

The personal center allows the users to check the data order forms and modify the registration information. The submitted order can be searched in the system in different ways (Song 2015).

4.2. Data management subsystem

The data management subsystem allows the users to effectively manage multi-source remote sensing data, including the storage, management, searching, browsing, and exporting. These functions are illustrated in Figure 5.
The data storage function provides support for the bulk data operations of both automatic manner and manual manner. Varieties of remote sensing data and derived information products could be put in storage uniformly, providing a real-time review of the schedule and statistical information (Wang et al. 2016).

The data management function enables the users to manage the mass data, meanwhile providing multiple searching manners. Moreover, the map-based display, extraction and exportation of data resource are also supported (Lv, Cheng, and Gong 2011).

The data migration function realizes the immigration and emigration of the stored data, contributing to the exchange among different network architectures and equipment.

The statistical analysis function consists of multiple subfunctions, and the user-concerned statistical information could be displayed directly with the visual diagrams and tables (Jiao, Ma, and Deng 2015).

4.3. Data distribution subsystem

The data distribution subsystem is established to be service provider-oriented, centralizes the searching and delivery of multi-source remote sensing data, and supports both online and offline services, as depicted in Figure 6.

To support information management of data distribution subsystem, a separate operation management system has been developed. This subsystem implements the safe and hierarchical user authorization management, order approval, statistical data analysis, and information publishing, etc. The subsystem is responsible for providing robust safety and technical support to the whole platform operation, as shown in Figure 7, which shows the various geospatial functions involved in the operational management of the subsystem.

4.4. 3D display and conference subsystem

The 3D display and communication subsystem is an integrated 3D remote sensing data visualization system, which displays multi-satellite source imagery, thematic information, geostatistical reports, and typical application cases, etc. With this module, users are able to visit the data management system, subsequently realizing the display of the data information on the 3D platform. Meanwhile, the module provides the custom tools to display the multi-satellite source imagery and thematic information synthetically. In addition, the 3D display and communication subsystem supports the management of long-time series data, providing a convenience for data comparison. (Guo, Chen, and Han 2016; He et al. 2011) Figure 8 illustrates the capabilities of the subsystem.
forward, and rewind the orbit. Furthermore, the orbit plane could be fixed, in order to view the status of the Earth’s rotation (Guo, Chen, and Han 2016).

The satellite task simulation function makes use of orbit tracks, payload operation, and off-pointing parameters of a selected satellite to simulate the imaging mission over a targeted area. Users are able to decide the time needed, the selection of satellite track, and the number of scenes (He et al. 2011; Song 2015).

Satellite resource management means that users can manage varieties of satellite resources, and set the initial information of orbits and sensors. Moreover, the ground station resources can be managed, including the setting

4.5. **Multi-satellite mission simulation subsystem**

The multi-satellite mission simulation subsystem consists of three primary subfunctions, including the satellite tracking, task simulation, and satellite resource management.

The satellite tracking function provides the real-time monitoring of satellite position and operation status, meanwhile displaying to users the combination of 2D&3D. With this module, the users are able to track the real-time position of the satellites, and to check the status information of satellites. At the same time, the users can make predictions about the orbit positions of the satellites, so as to view, fast forward, and rewind the orbit. Furthermore, the orbit plane could be fixed, in order to view the status of the Earth’s rotation (Guo, Chen, and Han 2016).

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**Figure 6.** Functions of the data distribution system.

**Figure 7.** Typical information management functions of the data distribution system.
Figure 8. 3D display and conference system.

Figure 9. Multi-satellite mission simulation system.
5. Conclusions

Having described the seven subsystems of the 21AT TSCT and DDMS, it can be clearly seen that worldwide users are now able to access the strong TripleSat Constellation satellite data source in the fastest and simplest manner. All users can watch the satellite status in real time, submit tasking requests, and track their orders, even via a mobile device from home. Subject to the customized service agreement and multiple data channels provided by 21AT, all users may access multiple satellites and other remote sensing data sources. This geospatial information solution gives all users maximum flexibility to choose modules that fit their preference in order to solve their geospatial information needs.

Therefore, this new 21AT DDMS solution combined with its core system, TSTC allows its users to obtain maximum benefit from the TripleSat Constellation. The comprehensive solution provided to users has exhibited an efficient approach on how to use and manage remote sensing data to support their geospatial applications and projects.

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