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DEVELOPMENT OF GROUND RECEIVING SYSTEM FOR KOMPSAT-2

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ABSTRACT:

This paper addresses the development work of ground receiving system for the Korea Multi-Purpose Satellite-2 (KOMPSAT-2), which is to be launched in 2004 by the Korean Government. KOMPSAT-2 is a new high-resolution earth observation satellite that is capable of 1m panchromatic and 4m multi-spectral imaging. The development is in its final year, and final system is expected by the end of October 2002. The development work ranges from manufacturing of high-speed interface card, so-called DRC (Direct Receiving Card), to integration of value-added processing, such as road and building extraction, to provide a complete ground receiving station. In this paper, key features of developed system are addressed, and lessons learned are reported.

1. INTRODUCTION

Since the successful launch of the first commercial high-resolution Earth observation satellite, IKONOS, there have been growing demands on the high-resolution satellite images. To meet such demands, Korea Government will launch its second Korean Multi-purpose Satellite (KOMPSAT-2) in 2004, which is one of such high-resolution Earth observation satellites. The payload of KOMPSAT-2 is the Multi-Spectral Camera (MSC), which consists of 1m resolution panchromatic camera and a 4 bands 4m resolution multi-spectral camera.

High resolution imaging satellites require drastic evolution of image reception, processing and distribution system to provide high-quality satellite images in a prompt and efficient manner due to the high-speed downlink rate and extensive amount of image data comparing conventional Earth imaging systems.

In this paper, we report development work of ground receiving system for KOMPSAT-2. The rest of this paper is organized as follows. Section 2 describes developed system including system objectives and design concepts. Section 3 emphasises key aspects of developed system. In section 4, conclusion and our future plan will be given.

2. SYSTEM OVERVIEW

2.1 System Objectives

The main objectives of the system are: 1) real-time receiving and processing of X-band downlink data, 2) generation of standard image products and catalogues, 3) integrated system management, 4) archive management, and 5) comprehensive user interface to provide easy access to satellite image data.

The first objective involves real-time archiving of satellite data and image generation from them for real-time display (Moving Window Display: MWD). This is a challenging task since high-resolution imaging satellite not only needs higher data rate but also requires more extensive real-time data processing. For

imaging satellites of less than 1m resolutions, the data rate between satellite and ground station is not enough to transfer all information obtained by the sensor, hence compression process is usually adopted. Also for security purpose, encryption process may be added to the processing for effective communication such as FEC and pseudo-randomisation. All such processing with high data rate requires higher processing power at the ground to recover image data. Moreover as satellite downlink is a very expensive process, the receiving system should be very reliable and have high availability. Summarizing all, real-time receiving process requires high performance, reliability and availability.

The second objective requires high performance due to extensive amount of data to process and high accuracy since higher resolution demands higher accuracy. To achieve this objective, efficient radiometric/geometric correction algorithms and accurate modelling are needed.

Third and forth objectives are more related with operation of system. Complete ground receiving system involves many components and operation requires various information and data to fulfil its objectives. Therefore system requires comprehensive management scheme for effectual operation. Also, enormous amount of data requires successful archive management. The operation of KOMPSAT-2 is expected to require at least 136T bytes storage for three years.

The last objective is to provide easy-to-use interface for inside and outside users to search, order and acquire satellite images of interest. As a ground receiving system is a service provider in a viewpoint, user interface as well as quality of processed images is very important.

2.2 Design Concepts

The system was designed to meet the following seven operational concepts.

- Maximum automation: The system shall be centralized and operated with minimum operator's interaction.

- High speed: The system shall handle up to 320Mbps image data and generate image products as fast as possible.
- High reliability: The system shall not fail to achieve system objectives by single point failure and/or operators' trivial mistake.
- Integrity: Operations and managements of system is integrated in the most efficient manner.
- Cost effectiveness: The system shall be operated economically so that it can save time, efforts and resources.
- Expandability: The system shall be upgraded for processing other satellite data with little change of the system.
- Security/Accessibility: Only authorized user shall have access to catalogue data and only authorized operators to system modules. For public data, user shall be able to access easily.

The system design emphasizes full automation from image receiving to the generation of standard products with minimum user intervention. High-speed data handling is achieved by using state-of-art technology in processing and storage equipment and appropriate redundancy is considered to provide high reliability and availability. System integrity and security are realized by comprehensive management system with a high performance commercial database. PC based receiving system contribute for low cost system and web-based user interface increase data accessibility. The whole system is based on the open architecture for easy upgrade of software and hardware.

2.3 System Architecture

Fig. 1 shows system hardware architecture for each subsystem. In design process, system was divided into two subsystems: receiving and archiving subsystem (RAS) and search and processing subsystem (SPS). Former is responsible for the real-time receiving and processing of X-band downlink data and latter for other objectives such as product generation, User interface and system managements.

We also developed value-added product generation software (VPG) as a part of the system based on the idea that complete system should provide *information* not only *data*. There are many value-added products that can be defined. We selected a few of them to develop such as DEM generation from stereo pair, road network extraction, and building extraction from high-resolution satellite images.

To achieve high reliability and availability, redundancy was considered. As a result, RAS, which was a mission critical subsystem, was designed to have hot redundancy and SPS to have warm redundancy.
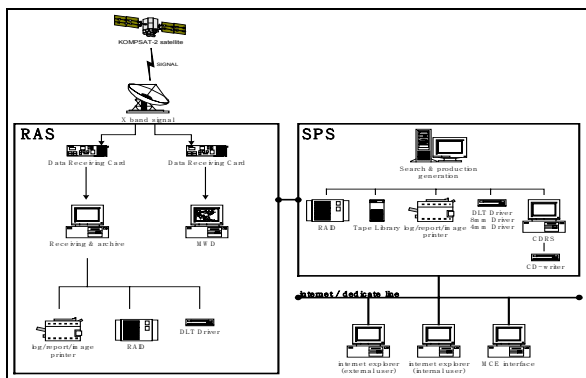

Figure 1. System architecture

2.3.1 Receiving and Archiving Subsystem

The RAS receives and records image data transmitted from satellite in real-time. Developed RAS supports sustainable data rate up to 320Mbps in real-time. It also performs moving window display (MWD) in real-time and playback mode and provides processing functions to handle satellite specific downlink formats. Block diagram of RAS is given in Fig. 2.
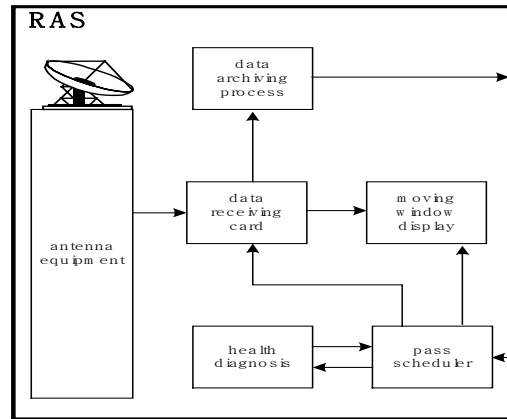

Figure 2. Block diagram of RAS

The RAS consists of two software modules: Pass scheduler (PS) and data processor (DP). The PS supports system management functions such as initiation of automatic downlink reception based on work orders either remotely or locally ingested, maintaining RAID capacity, monitoring connected hardware and backup and restoration of raw data using DLT. The DP is responsible for data capturing to RAID in real-time, real-time and playback MWD, error control and satellite specific processing such as deciphering and decompression. Rather than using a special hardware to process downlink format, software implementation was adopted for system expandability and we pay extensive attention in code optimisation to attain high performance.

The hardware of RAS comprises DRC (Data Receiving Card), Intel™ server, RAID and DLT. The DRC receives and converts high speed ECL data stream to parallel signal, and feeds them into host computer. The PCI-based DRC was designed and manufactured to support data rate up to 400Mbps. With careful selection of hardware and development of software, real-time ingestion and recording of sustainable data rate up to 320Mbps was achieved. Since real-time receiving and recording is a very critical objective of the system, the RAS consists of two fully redundant units in hot standby to accomplish high reliability and availability.

2.4 Search and Processing Subsystem

Four main functions of SPS are as follows: 1) imaging acquisition plan, 2) standard product and catalogue generation, 3) catalogue search and order ingestion from users, and 4) system managements. Block diagram of SPS is given in Fig. 3.
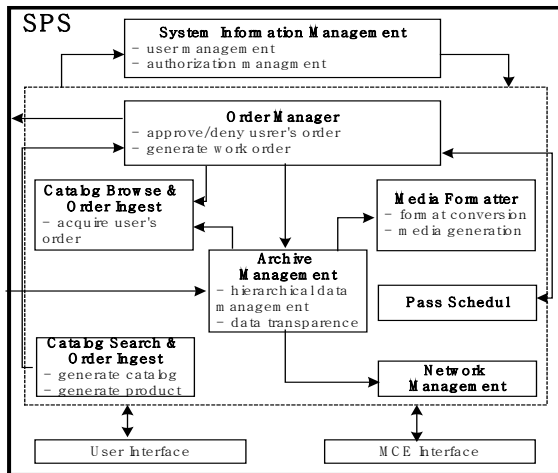
Figure 3. Block diagram of SPS

The pass schedule s/w (PSS) is developed to support for operators to plan image acquisition and to make satellite-programming request to a mission control centre.

The catalogue and product generation component (CAP) generates catalogue and standard level image products. Main functionalities are systematic correction, radiometric correction, and geometric correction using GCP or DEM. It also provides automatic geometric correction and accuracy assessment of product if relevant GCP chips are available in a database. Cloud assessment can be done automatically, semi-automatically or manually. CAP provides very flexible configuration. User can pre-define standard level of product, the order of product generation and area of interest to be processed. CAP generates image products automatically or with minimum user intervention if necessary according to pre-defined configuration. Running instance of CAP is shown in Fig. 4.
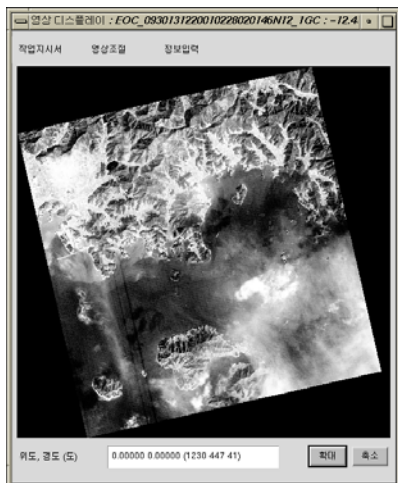

Figure 4.   Running instance of CAP

Catalogue browse and order ingest component (CBI) is a web-based software that provides easy access on the image data for users of image products. The main functions of CBI are catalogue searching, order ingestion from users and user access

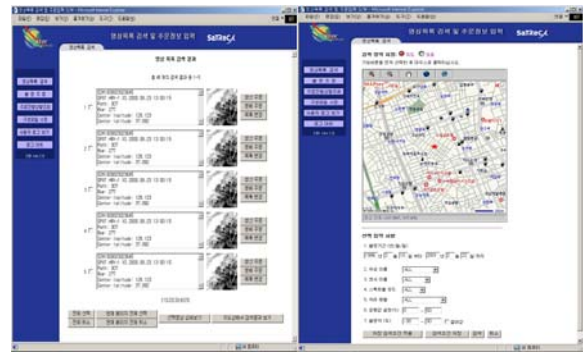control. The example of user interface is shown in Fig. 5.

Figure 5.   Running instance of CBI

Three key modules are developed to realize a comprehensive management of the system: order manager, system information manager and archive manager. The order management component (OM) controls flow of data and processing. It analyses orders from users and operators, makes a sequence of execution, generates *work orders (sub-orders)*, and transfers *work order* to the responsible components in appropriate sequence to guarantee automatic processing of given order. It also monitors system resources and produces reports and statistics. The system information management component (SIMS) manages accounts of users and operators, controls their access to data and system components, and monitors system resources to keep system integrity and security. Archive management component (AMS) is to provide enhanced archiving management for raw data, generated products and catalogues and any other data necessary for system operation. In our system, storage space is divided into three layers, namely, online (RAIDs), near-line (DLT library) and off-line (tape shelves) in a hierarchical way. AMS monitors available storage space and data, and moves and restores data between storage equipments to maintain storage space to support successful operation of system.

The SPS resides on Unix based servers and configured in warm standby status.

2.5 Value-Added Product Generation Subsystem

The VPG generates value-added products such as digital elevation models (DEM), road network and building extraction from high-resolution satellite images. Fig. 6 shows the digital elevation model derived from IKONOS stereo pair (Kim, 2002a). The running instance of developed road network extraction software is shown in Fig. 7 (Kim, 2002c). VPG software is developed as stand-alone software to be used as required.
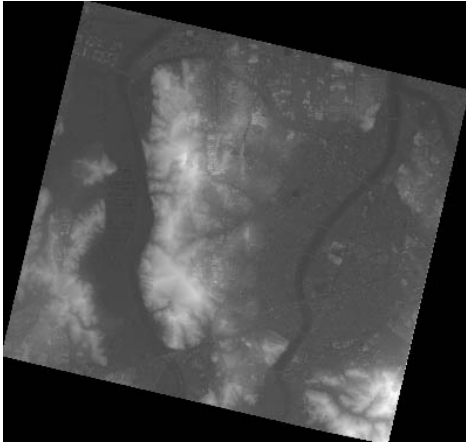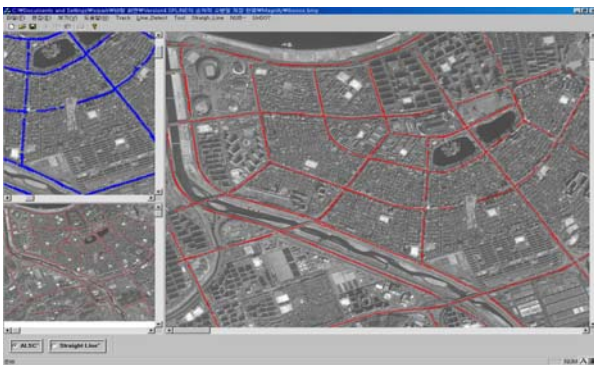
Figure 6.   DEM derived from IKONOS stereo pair

Figure 7.   Running instance of road network extraction s/w

3.   KEY ASPECTS OF SYSTEM

In this section, the key aspects of system developed are explained in detail.

3.1 Low Cost, High Performance Receiving and Archiving Subsystem

Real-time receiving and storing of satellite image data is the most important operation in ground receiving system. It requires very high speed in processing, and high reliability and availability since satellite imaging and RF downlink are high cost operations. To achieve such characteristics, both of careful selection of hardware and precise programming are required.

Our objective in designing receiving and archiving subsystem was to keep performance, reliability and availability high enough while reducing cost.

Key hardware components of RAS are DRC, a host computer and RAID. DRC is required to convert serial data input from demodulator to parallel data for storing. DRC was built in-house to have 400Mbps bandwidth. This is the only special hardware in the whole system. Host computer is needed to receive parallel data from DRC and store them onto RAID. Intel [TM] Pentium 4 or Xeon server was selected considering their high bandwidth and processing power. Fast progress of CPU performance and relatively low price in comparison with high-performance workstation/server also played important roles in

decision process. While selecting RAID system, the performance and reliability of a dozen of major RAID systems were tested using our own benchmarking program to choose reliable real-time storage equipment.

While programming RAS software, careful attention had been paid in optimisation. We utilized multi-processors to obtain consistent processing power to maintain sustainable data rate. Also careful buffer management was implemented to handle instant slow-down of RAID. Single instruction multiple data (SIMD) instructions are used for parallel processing to achieve high-speed data handling where applicable.

Our efforts in selection of hardware and implementation of software achieved sustainable data rate of 320Mbps while reducing cost compared with commercial system.

3.2 Hierarchical Standard Product Generation

In designing and implementing product generation component, CAP, we believed that it is a very important constraint for user to acquire image products of required level and of region of interest in limited time in some applications. Besides, for the sake of archiving, whole data should be processed and managed. Thus the CAP was developed to provide three processing order for product generation, namely, *primary product generation, primary passdata processing and secondary passdata processing* according to their processing order. In primary product generation, specific scenes explicitly defined by order are generated in specified standard product level. This is to provide scenes of region of special interests for such as fire damage assessment and flood assessment. Secondly, during primary passdata processing, scenes defined in *standard processing options* in terms of latitude and longitude, and cloud coverage are processed to provide standard products of region of general interests. For example, primary passdata processing defines Korean peninsula with less than 30% of cloud coverage. Lastly, CAP generates rest of scenes for archiving purpose: secondary passdata processing. In such processing order, system can satisfy various requirements in time of product generation.

Another key aspect of CAP is automatic precision correction using automatic GCP matching algorithm (Kim, 2002b). If relevant GCP chips are in the database, CAP finds the positions of GCP chips on the newly acquired image using GCP matching algorithm, and apply random sample consensus (RANSAC) algorithm to exclude outliers, namely false matches, from camera modelling. In this way, CAP can generate precision corrected scenes without operator's intervention.

3.3 Redundancy of System

Handling satellite imaging needs very high reliability and availability. To meet these requirements, redundancy is considered and implemented besides improving reliability and availability of each component.

For the RAS, we adopted hot redundancy since real-time data receiving and recording is the most critical step. RAS has a hot-standby system keeping data consistency between them. During unplanned downtime standby system is changed to primary and the system continue its functions without any break.

Database also designed to have hot redundancy so that even if one database server is down, system can continue its operation. The SPS is designed in slightly different way. We considered

the functions of SPS and concluded to minimize overhead due to redundancy. Therefore, we designed SPS subsystem to have warm redundancy. If primary or secondary SPS goes down, we reconfigure SPS to run without the host out of order and continue reduced operation if whole recovery is not possible. In this case, system status is conserved and system can restart operation continuing stopped operations.

3.4 Access Control on Data and Functions

System was developed to be capable of managing priority level through users, operators, data and even each function of components. Purpose of this concept is to keep system integrity from unauthorized accesses and mistaken operations.

SIMS manages priority level of operators, users, data, components, and important functions of each component. This information is provided for system to control accessibility. For example, if *approval* of *imaging request order* has higher priority than certain operator he/she cannot access this function. This capability allows sophisticated accessibility control. Carefully configuration of priority levels can permit only authorised people with enough knowledge and training to have an access to certain functions and data to maintain system integrity.

3.5 Hierarchical Archive Management

The objective of AMS is to manage storage space and data to minimize operators' effort to maintain storage space and data. For this purpose, AMS divide system's storage space into three hierarchically: online, near-line and offline. Online storage is implemented with a RAID and near-line storage with DLT library physically. Concept of online storage is to store data most recently acquired and provide them to system quickly as requested. Near-line storage is used for back-up storage and to store data considered to be used.

Newly acquired X-band raw data are passed to SPS and stored on the online storage. Products generated from them also stored on the on-line storage. During non-working hour, AMS makes copies of them to near-line storage for the sake of backup. AMS also secure predefined storage space on the online by deleting data files that are already copied to near-line storage. In this manner, the system maintains enough free space for operation on the online.

AMS also manages near-line storage space and data. For required space for near-line, upper and lower limits are needed. Upper limit indicates minimum near-line free space required for system operation and lower limit indicates minimum space can be used for near-line data to provide data service to the system without operators' intervention. AMS monitors near-line data and space during working hour. If amount of near-line data exceeds the upper limit, AMS secure free space required by dropping the used DLTs automatically in chronological order until the used data space reaches the lower limit. Operators are required to locate new DLTs as AMS requests. For dropped tapes, i.e. offline data, AMS maintains a database of their ID and contents of data on the tape. So if required, AMS requests operator to insert specific DLT to restore off-line data.

When certain component requests specific data to AMS, AMS looks for the database and finds the location of data: online, near-line, or offline. If requested data are on the offline, AMS requests operator to supply offline DLT to near-line. Near-line data are automatically restored to online. AMS informs the location of data on the online storage to the component that requested data. In this manner, AMS can service requested data to system with minimum user involvement.

4. CONCLUSION

In this paper, we reported the development of ground receiving system for KOMPSAT-2. The most principal design concept of system was cost effective system in terms of money and human efforts. The system was developed to have maximum automation including hierarchical archive management scheme to save time, efforts and resources. Access control, redundancy and highly flexible, expandable system design contribute to cost down for maintenance and system upgrade. Careful hardware selection and implementation of software play a part in reducing the cost while keeping system performance. All those new concepts accomplished a new competitive ground receiving system.

Currently developed system is under integration test and expected to have final acceptance test in 2004 when KOMPSAT-2 will be launched. For system itself, we consider introducing more distributed processing to achieve further scalable system.

We hope our work stated here would be any help to developing future ground receiving systems.

ACKNOWLEGEMENTS

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