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AUTOMATED IMAGE RECEPTION, PROCESSING AND DISTRIBUTION SYSTEM FOR HIGH RESOLUTION REMOTE SENSING SATELLITES

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ABSTRACT: This paper addresses the development work of image reception, processing and distribution system for the KOMPSAT-2 (KOrea Multi-Purpose SATellite-2), which 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 system under development is divided into three sub-systems: Receiving and Archiving Subsystem (RAS), Search and Processing Subsystem (SPS), and Value-added Product Generator (VPG). Big effort has been made to achieve maximum automation from image reception to generation of value-added products. In this paper, key factors used during design phase are addressed, and progress and lessons learned will be reported.

1. INTRODUCTION

The rapid progress of the technology of commercial remote sensing satellite and sensor development has made high-resolution satellite images available. Since the successful launch of IKOMOS satellite, which is capable of 1m panchromatic and 4m multi-spectral imaging, there have been growing demands on the high-resolution satellite images. To fulfill those need, many high-resolution earth observation satellites are to be launched, such as QuickBird-4, Orbview-2, etc. 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 very high-speed downlink rate and extensive amount of image data comparing conventional earth imaging systems. Table 1* shows a few examples of commercial system for data receiving, processing and distribution system (Hong, 1999). The table figures each system in terms of maximum data rate for reception, the type of main computers, and archive media. Most systems aimed the data rate at which 1m resolution satellite transmitted its image data There was a trend of using disk arrays for real-time storages and DLT or D1 tapes for permanent archives.

This paper will address the development work of image reception, processing and distribution system for a new high-resolution satellite, KOMPSAT-2 (KOrea Multi-Purpose SATellite-2), which to be launched in 2004 by the Korean Government. The specification of KOMPSAT-2 is given in Table 1. The development work is still undergoing and this paper will report the design of the system, lessons learned during the development work and future plan. The development work has been focused on automation, high speed, reliability, integrity, cost, expandability, accessibility and security of the system (Park, 2001).
The paper is organized as follows. Section 2 explains the image reception, processing and distribution system under development. Section 3 describes the progress and lesson learned.

Vendor (Nationality)	Max. Data rate	Main Computer	Archive media
DTi (USA)	320Mbps	SGI Dual processor R10000	Disk Array ->DLT
Vexcel (USA)	320Mbps	UNIX Workstation	Disk Array->DLT
MDA (Canada)	170Mbps	SGI Challenge 10000	Disk Array->DLT
Astrium (France)	160Mbps	Digital Symmetric Multiprocessing	Disk Array->Tape
ASC (Canada)	200Mbps	Unspecified	Tape
IAI (Israel)	85.5Mbps	Unspecified	D1

Table 1. Characteristics of commercial image receiving, processing and archiving systems

* Note that the information was gathered from product brochures, which may be incorrect or out-of-date.

Orbit	685Km Sun-synchronous
CCD	Linear push-broom
Band	1 Panchromatic: 500-900 nm 4 Multi-spectral: 450 – 520 nm, 520 – 600 nm , 630 – 690 nm, 760 – 900 nm
Radiometric resolution	10 bits
No. of pixels	15000 for panchromatic 3750 for multi-spectral
Pixel distance	1m for panchromatic 4m for multi-spectral
Downlink	320Mbps QPSK

Table 2. KOMPSAT-2 Specification

2. IMAGE RECEPTION, PROCESSING AND DISTRIBUTION SYSTEM FOR KOMPSAT-2

This section describes the overview of an image reception, processing and distribution system (hereby, the system) under development for KOMPSAT-2.

2.1 The System 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 catalog data and only authorized operators to system modules. For public data, user shall be able to access easily.

Many efforts have been made to realize maximum automation from image receiving to the generation of value-added products with minimum user intervention. Centralized order management and careful order management scheme made maximum automation of processing chain. High-speed data handling is achieved by using state-of-art technology in processing and storage equipment and appropriate redundancy, self-diagnosis and severe error check on user inputs are implemented to provide enough reliability. System integrity and security are realized by comprehensive management system with a high performance commercial database. WWW technology was used to increase user accessibility to image data.

2.2 System Architecture

The system is divided into three subsystems, i.e. Receiving and Archiving Subsystem (RAS), Search and Processing Sub-system (SPS), and Value-added Product Generator (VPG) as shown in Fig. 1. RAS receives, displays, and archives raw data, which is downlinked from the satellite at 320 Mbps. SPS is responsible for generation, manipulation and distribution of image products. VPG produces value-added products from standard products. The hardware configuration is shown in Fig. 2. The RAS is hosted on the PC-base NT server and configured to have hot standby to improve the reliability as real-time receiving and storing is a very critical objective of the system. SPS and VPG are hosted on the same H/W, SGI server, to provide stable user services. High performance RAID was used for real-time image data storing and RAID, DLT jukebox and DLT are used to provide hierarchical storage management to handle large amount of image data.

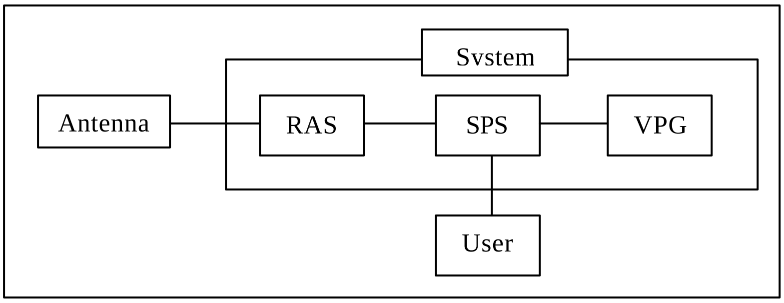

Fig.1 System block diagram

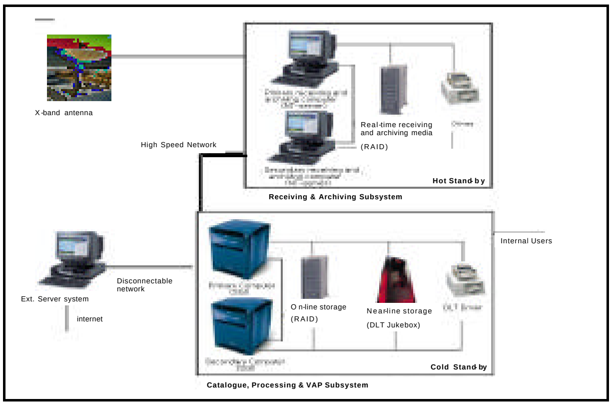

Fig. 2. System Configuration

2.2.1 <u>Receiving and Archiving Subsystem</u>

The RAS receives and archives image data transmitted at up to 320Mbps in real-time, performs moving window display (MWD) and provides antenna pointing data. The RAS subsystem consists of DRC (Direct Receiving Card), NT Server, RAID and DLT as shown in Fig. 3.

The DRC receives and convert high speed ECL data stream to parallel signal, and feed them into host computer. The PCI-based DRC was designed and manufactured to handle up to 400Mbps data rate. Pentium based NT server was selected as a RAS platform considering fast progress of CPU performance and relatively low price comparing high-performance workstation/server. 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. As a result, real-time receiving and archiving of up to 320Mbps has been achieved.

The RAS consists of two software modules: Pass scheduler and data processor. The pass scheduler can schedule antenna system for automatic down-link reception, handle multiple reception of work orders, maintain RAID capacity and perform RAID-to-DLT backup and restoration. Necessary is the efficient management of storage devices. The pass scheduler was designed to manage the storage devices with hierarchy and to perform the backup of data stored as requested. The data processor stores the data to RAIDs in real-time, performs real-time MWD after de-packetizing, decryption, decompression. Rather than using a special hardware to process downlink format, software implementation was adopted for system expandability and we pay extensive attention in parallel processing and code optimization to attain high performance. SIMD instructions are used for parallel processing to achieve high-speed data handling where applicable. Data processor also performs playback MWD of the data already stored in RAIDs.

2.2.2 <u>Search and Processing Subsystem</u>

The SPS provides a tool for catalog searching to users and generates pre-processed products. The SPS performs radiometric and geometric correction of KOMPSAT-2 image data, and is capable of image data processing and standard image product generation. It also provides orbit, attitude, and sensor models to support data correction and processing.

The SPS subsystem consists of a number of software modules: catalog browse and order ingest module, catalog and product generation module, order manager, system information manager, network manager, media formatter, physical device manager, archive manager, pass scheduler, etc..

Catalog browse and order ingest module is to provide users catalogue searching and order generation. This module was designed using WWW technology to provide easy access on the image data. User can apply a search condition using any web browser with a help of 1:25,000 digital map DB for visualization. Catalog browse and order ingest module provide catalogue searching, ingests acquisition, product, and distribution orders and control user access. The example of user interface is shown in Fig. 4.

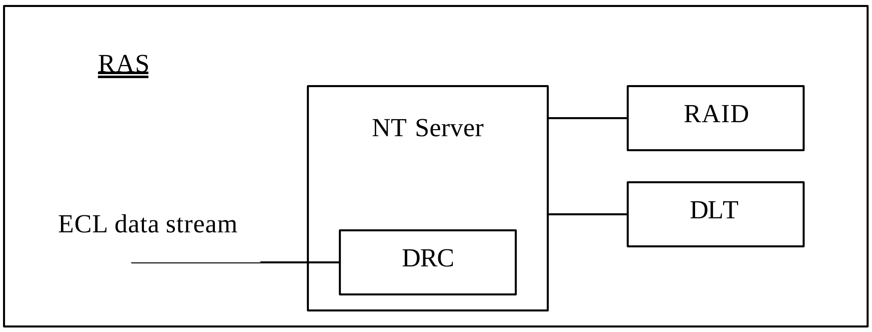

Fig. 3 Receiving and archiving system

Fig. 4 Running instance of Catalogue Browse and Order Ingestion module (left) and Catalogue and Product Generation module (right)

The catalog and product generation module generates catalog and pre-processed products. An operator can select the product level for automated processing. Cloud assessment can be done automatically, semi-automatically and manually. Also user can configure browse image level.

The order manager analyzes user's orders, makes a plan of execution, monitors system resources and produces reports and statistics. As a result of order analysis, order manager generates and transfers *work order* to the responsible modules in appropriate sequence while monitoring system resources to guarantee automatic processing of user order. Reports are also generated after the completion of order execution or for any possible error.

The information manager is implemented as a comprehensive management system using a high performance commercial database to keep system integrity and security. It manages DB for operators, users and system configuration to control and monitor user access and system integrity.

The network manager sends and receives message with the RAS. The media formatter reads data from input media and writes to output media, which include 4mm, 8mm, compact disks and DLT tapes. Also this module outputs label and product list, and handles various data formats, including EOSAT Fast Format, HDF, GeoTiff, Raw, etc..

The physical device manager exists as a part of other modules. This diagnoses a status of physical drivers. The archive manager archives satellite data to a storage device and manages data. The pass scheduler provides a tool to plan image acquisition and to help satellite-programming request to a mission control center.

2.2.3 Value-Added product generator subsystem

The VPG generates value-added products such as precision-correction image, ortho-corrected images, digital elevation models, road and building network from KOMPSAT-2 image data. These data are fed to the SPS for distribution to users. The VPG receives orders from the SPS for automatic execution or operators for manual.

An emphasis was put to the integration of value-added processing modules into the whole system. With this, we intended to fully automate the processing chain from image reception to the generation of value-added information. Fig. 5 shows two examples of VPG subsystem.

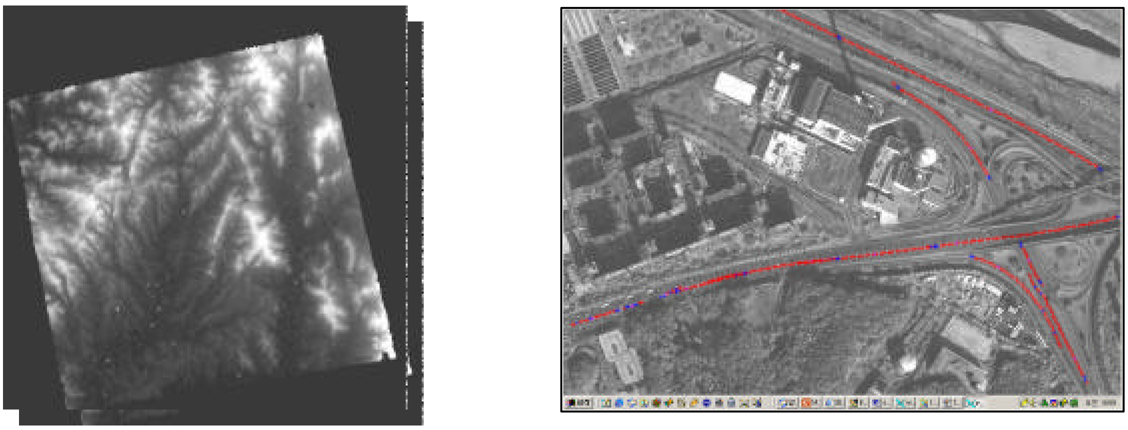

Fig. 5 Example of Value-added Product Generation: Left image shows DEM extracted from KOMPSAT-1 (6.6m resolution) with height accuracy of about 15m. Right image shows semi-automatic road extraction.

3. PROGRESS AND LESSONS LEARNED

Currently, the system development stage is a system integration phase. Development model we adopted was a mixture of prototyping and iterative models. As a prototype of the system, a SPOT image receiving and processing system had been developed. From the prototype, the system has been upgraded for the KOMPSAT-2 specification. Development of each module has been completed and system integration and tests are on-going. The system integration will be finished by August 2002. The system will be finally verified in real operation when the KOMPSAT-2 is launched in 2004.

Throughout the on-going development, we have found several very important issues. First issue is selection of appropriate devices and platforms. The major difference between the prototype (for the SPOT) and the complete system (for the KOMPSAT-2) is the amount of data the system should handle. It was difficult to select reliable and fast enough disk storage devices at an affordable price range. Often the devices did not perform as specified by vendors. Also handling of some 100s terra bytes of data does require very special treatments. We invested enormous time and efforts to select adequate storage system by performing our own benchmarking tests.

While selecting the platform for image receiving and archiving subsystem, PCs and UNIX-based platforms were considered. We chose PCs for their rapid performance upgrade, low cost and developmental convenience. We believe the choice was valid and cares were taken to achieve reliability and to keep high performance.

Since the system handles image data of very high speed, special care should be made to prevent bottleneck in overall processing chain from hardware selection to software implementation.

A trade-off study between system performance and cost was also important. For example, the configuration of host PCs for RAS was closely related to the requirement of disk storage devices and hence to the overall system cost. The choice of platforms for the SPS and VPG was also related to this issue.

The other issue was the level of automation and system performance. Cloud assessment, for example, was designed to work in three modes: automatic, semi-automatic and manual. It was difficult to make cloud assessment work well automatically in all cases. Instead, we found a very simple but robust semi-automatic technique that could be applied for fast execution as well as in good accuracy.

The last issue to discuss here, but not the least, is the image resolution. Preprocessing, ground control point acquisition, value-added processing, etc. were designed accordingly. In the design of catalogue search and display, order generation and pass scheduling, the image resolution was also taken into account.

As many high-resolution remote sensing satellite programs are being carried out and more will start in near future, the development of ground stations for those satellites has become more and more important. The development work stated here, we hope, can be of any help when making such ground stations.

4. REFERENCES

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