SPACE MEMORY SYSTEM DESIGN FOR HIGHER DATA RATE

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ABSTRACT: No doubt that more vast data and precise values are required for the detailed and accurate analysis result. People's expectation for the output of space application goes higher, and consequently satellite memory system has to process massive data faster. This paper reviews memory systems of KOMPSAT (Korea Multi-Purpose SATellite) series and try to find a suitable memory system structure to process data more faster not at device level but at system level.

KEY WORDS: Space, Memory, System, Design

1. INTRODUCTION

As satellite data user demands more resolution and technologies for the payload instruments are developed, memory system has to record more massive data with faster speed. The resolution of the KOMPSAT-2 is 6.6 times better than the one of the KOMPSAT-1 but the input data rate of memory system increased about 54 times. The KOMPSAT-3 has 1.4 times better performance in resolution but has to face on about 4 times much data. Of cause more and more input data rate will be requested in the future projects.

Table 1. Minimum Input Data Rates of KOMPSATs

	KOMPSAT-1	KOMPSAT-2	KOMPSAT-3
Resolution	6.6 m	1 m	0.7 m
Dynamic Range	8 bits	10 bits	14 bits
Input Data Rate	22 Mbps	1.2 Gbps	4 Gbps

Some satellites use compression function to reduce data size recorded into memory system. And it's also effective to save time to send data to the ground station. But in case of lossy compression, user has to accept some data distortion and some side effects of the compression. Usually in higher compression rate JPEG compression algorism generates block effects on output image. In case of lossless compression, it does not compress much rate and it's hard to guarantee that how much compressed data will be generated. Lossless compression reduces small potion of data size but hard to operate memory system and we need more smart memory system. Smart system means hard to implement and its failure mode will be complex. To provide data for a scientific application the KOMPSAT-1 and the KOMPSAT-2 can transmit non compressed data. And the KOMPSAT-3 is able to send non compressed data to the ground station too.

One of the ways to increase data handling speed of the memory system is using more powerful device in the board. Yes, we can use DDR, DDR2 and DDR3 memory instead of SDRAM. But ironically sometimes space qualification process of a certain device is longer than the development period of new device. Space qualification process includes many kind of test and one of the tests is life time test. For the life time test the devices has to be at high temperature for couple of months. Sometimes that qualified device is obsolete. Finding qualified parts with good performance is one of big task in space business. Or the company have to make own qualification process and test the device by themselves with a lot of expense.

On this paper we tried to find out the solution to increase data handling speed of memory system not at device level but at system architectural level.

2. MEMORY SYSTEM

2.1 KOMPSAT-1

The main design target of KOMPSAT-1 memory system was flexibility. The memory system can expand their capacity easily by just plug additional memory board in a memory system. The manufacturer of the memory system was big company and they were making several memory systems for different space projects at the time. The system is configured modular basis so that they could only change interface boards and software for other project. By this approach they could reduce production schedule, development risk and cost.

Needless to say, this approach was based on their performance. For the internal data transfer they used flexible packet protocol and its data rate was about 2 Gbps. Considering that the KOMPSAT-1 data rate was only 45 Mbps, that memory system could satisfy almost every satellite requirement. Internal block diagram of the memory system is illustrated on the Figure 1.

BIF (Bus Interface) block receives image data from camera and store data to packet buffer. Frame Formatter reads the data from the packet buffer and packetizes input images by grouping. Source packet data are written in frame buffer by frame formatter. To store data ROF (Record Output Formatter) reads source packet data from frame buffer and packetizes the data into special packet for memory data chain with EDAC symbols. The memory system uses hamming code for EDAC function. And this code is also used for scrubbing function.

There is bypass path to send data without recording data into memory. This can be done because the input data rate is only 22 Mbps whereas the bandwidth of K-1 X-band transmitter is 45 Mbps.

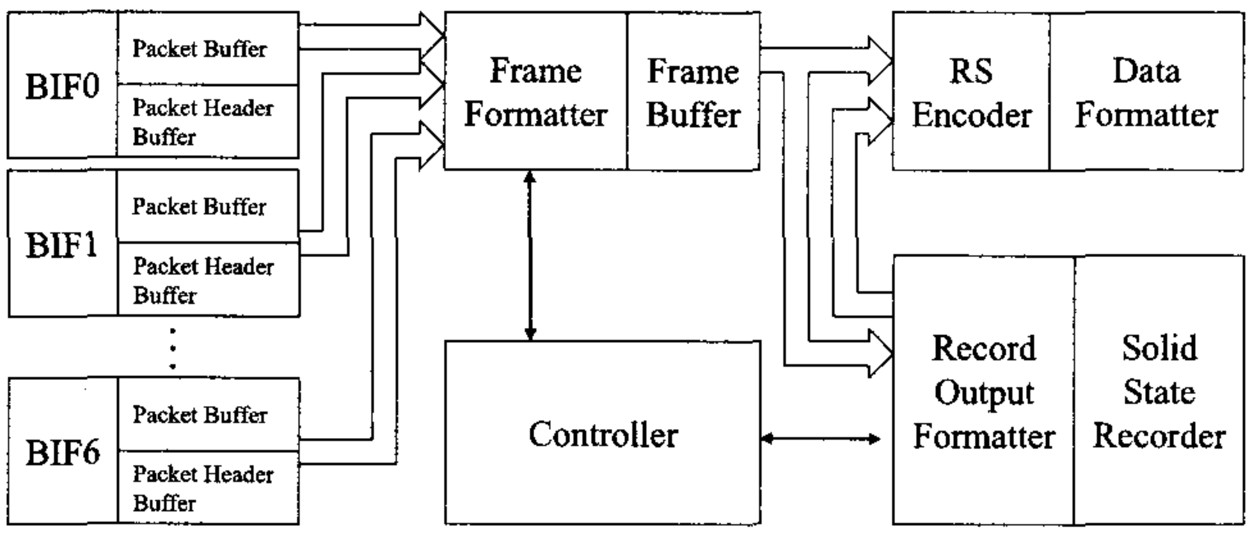

Figure 1. K-1 Memory Unit

Read data through ROF or direct data from frame buffer have to RS encoded and CCSDS formatted by Data Formatter to send to X-band transmitter.

Most impressive design of K-1 memory system is memory data chain. Figure 2. illustrates memory data chain. Data chain forms a circular structure. All write and read operations are start from the ROF and end at the ROF. The ROF initiates data transfer with packet and the packer travels all memory modules one by one until they found right position (address) then the MC (Memory Controller) transfers the result of operation to the ROF. The interface between memory modules has a full cross-strap and one MC sends a packet to two MCs of next stage. Scrubbing function can be done by sequential operations of read, EDAC and write operation. MC controls read/write operation with 2-port DRAM and refreshes the memory.

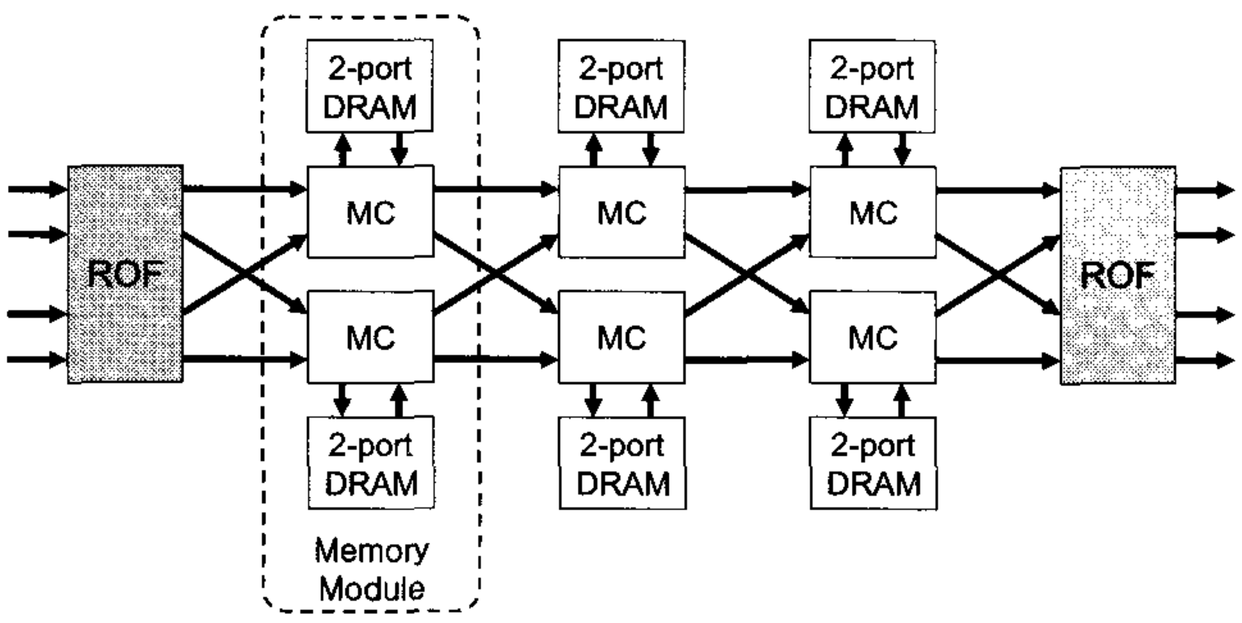

Figure 2. K-1 Memory Data Chain

By using this memory data chain it's easy to increase the storage capacity of the memory system. Put the more memory module without changing hardware design.

Disadvantages of this structure are read/write timing delay will be increased by the number of memory module and there is no cold redundant memory module.

From the point of software K-1 memory system has simple memory mapping algorism. It divides 4 partitions of memory space by the source of instruments. Each partition has consecutive memory address space and mission is controlled by read/write pointer. The size of each partition can be adjusted by memory format command. The allocation of each mission data is responsible to the ground station. The ground station has to know where the start point of a mission was and where the end point of a mission was.

2.2 KOMPSAT-2

The main design target of K-2 memory system was easy handling of mission data in memory system. The memory system has a file system. Each input image is stored into one file and one mission data is stored into one folder. Recording image mission and replay image mission can be achieved by folder name. The ground station no longer needs to memorize the pointers and no needs to worry about the write point of current mission cross over the area of another mission data is stored. The ground station has to know only remained free sector size to initiate new mission. Due to the data rate difference, there is no bypass path to skip recording data into memory even in real-time transmission mode. The memory system uses memory space as a buffer in real-time transmission mode. As the buffer acts like a circular buffer, real-time transmission can be done with very small free sectors.

The memory system manages the entire memory space by a sector. One sector means 2 Mbits. Any file size can be multiplex of 2 Mbits. For file memory allocation linked list of sector is used. Main processor performs logical address to physical address translation and distributes next physical address to input interface boards and output interface boards for write and read operation.

The simplified hardware configuration of K-2 memory system is illustrated on Figure 3.

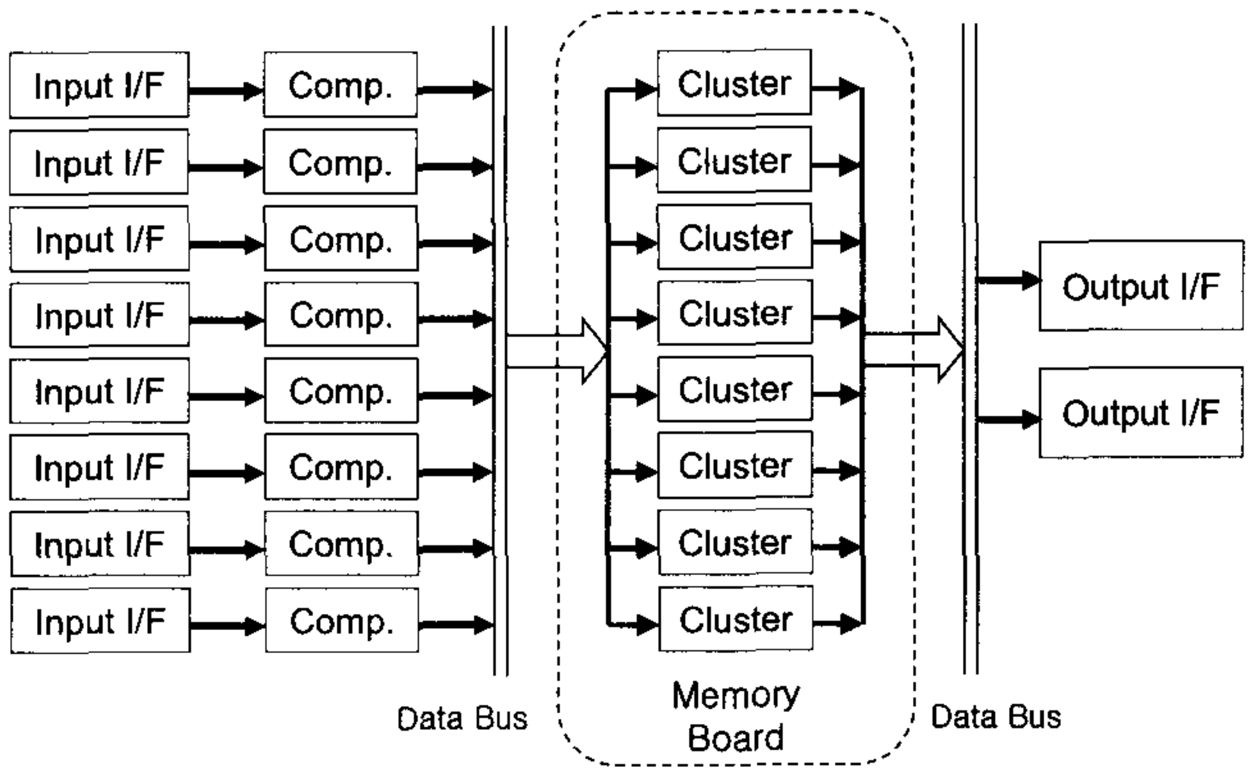

Figure 3. K-2 Memory Unit

Input image data are compressed by dedicated compression unit per channel. It was the first design that performs compression function and storage function in one box. Compression boards have their own SRAM devices for alignment function and working memory. Normally all panchromatic image and multi-spectral image come together. Relatively high power consumption occurs at a certain timing of compression process. That propagates noise to entire unit through ground.

Input data bus acts like a data train. It provides several time windows and loads channel data with fixed sequence. To increase recording speed, data is written into memory with parallel working of 8 clusters. If some part of a cluster memory is failures, relative column will be fail. That sector has to be removed by memory selftest initiated by the ground station. After selftest faulty sectors will be automatically removed. In this case entire usable memory space will be reduced as same as the size of faulty sectors. All memory boards have a cold redundant memory cluster as a backup. Faulty cluster can be removed by memory configuration command and can use spare one. The configuration of the memory board is shown in Figure 4. Memory controller MING ASIC controls 4 memory modules which has 2 Gbits memory capacity. Each memory boards have 9 MING ASICs. 8 of them are working together and one is for cold redundancy. The memory system has two memory boards and each board is powered on and off independently.

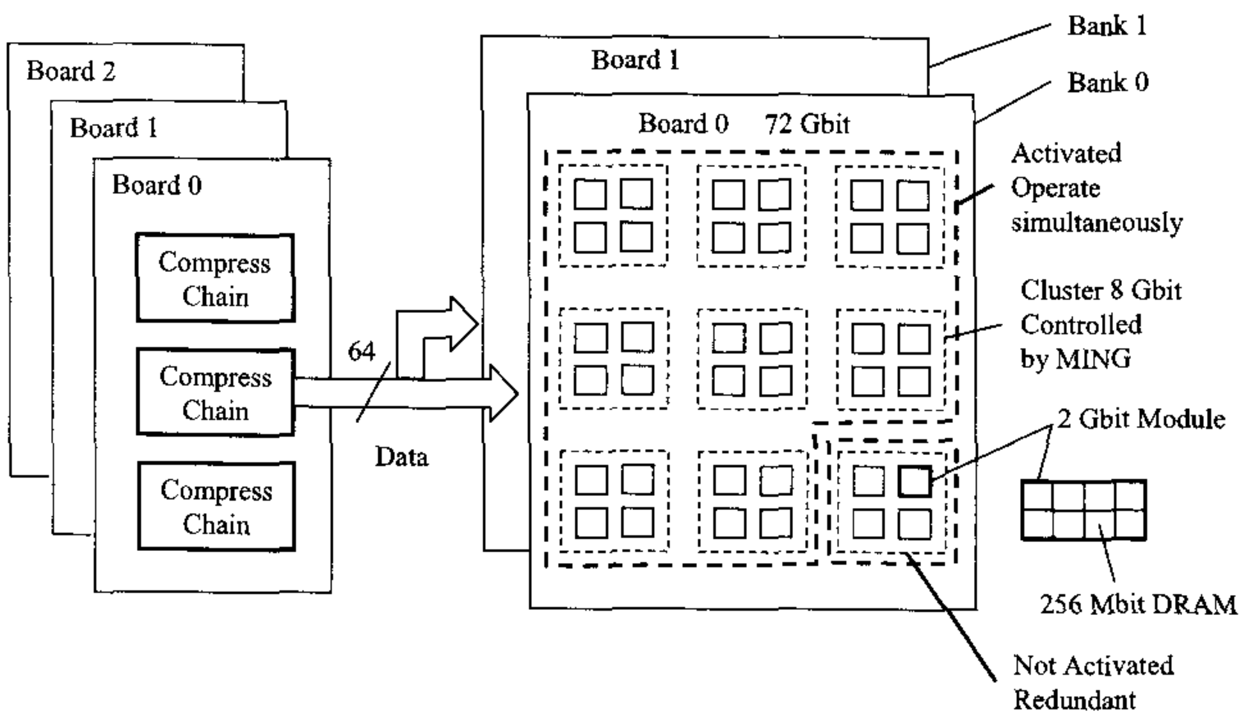

Figure 4. K-2 Data Writing

The most weak point of K-2 memory system is that always the micro-processor controls entire read/write operation. Micro-processor performs logical to physical address translation and gives next write address or read address to input interface boards or output interface boards. Without real-time support of micro-processor input and output functions will be stop.

One thing that makes the problem more difficult is the size of sector. It's true that smaller size of sector makes possible to use memory space with more efficiency. But in the other hand, it means the number of address for read and write operation will be increased as the potion of decreasing the size of sector. The input data rate is about 1.2 Gbps. So when using nominal compression rate (PAN 5.08:1, MS 3.80:1), 139 sectors are generated per second. The ground station normally plans a mission with second time base. Before recording mission the ground station has to assign each file size per image data and unfilled sectors of the recorded file are not released automatically. There is no way to free that unused sectors but only erase the entire file.

Another requirement making much traffic on the communication between micro-processor and peripheral ASICs is progress report. It's nice to look how much or what percentage of work has been done. We can guess there is some anomaly or wrong behaviour when the values are suddenly stopped or irregularly increase. But there is nothing can do while a mission. Only after mission we can get the final result value of mission and treat some actions accordingly. To know the progress of a mission, micro-process has to send progress check commands to all input and output ASICs through communication lines while they are busy to handling the address for a mission. Actually K-2 memory system does not provide the real value of progress. Micro-processor reports a virtual value by calculating time with input data rate and requested data sector size. It's not wise deign to waste the resources just for visual entertainment.

2.3 Memory System for Higher Data Rate

K-3 memory system has to store 4 Gbps up to 5 Gbps data. Using common data bus like K-2 memory system is quite challenging design. To avoid design risk, in stead of design new high speed data bus distributed memory module system is proposed on Figure 5.

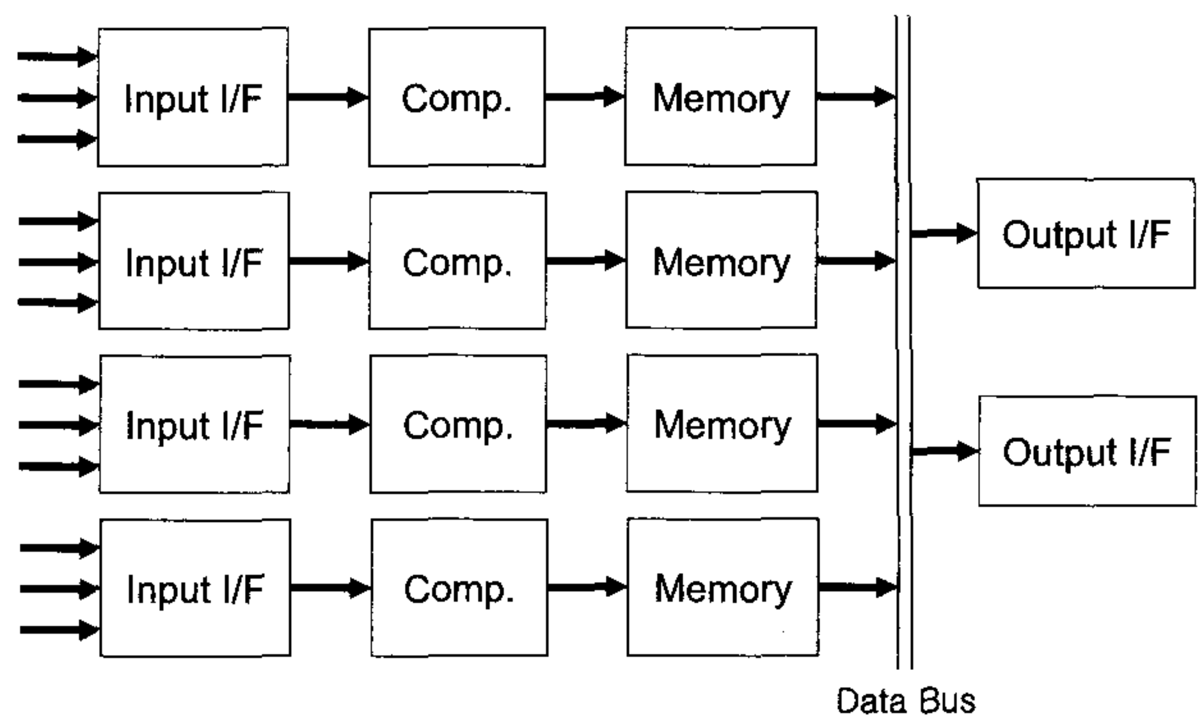

Figure 5. Distributed Memory System

The distributed memory system has own memory storage space for certain input channels. It's a similar concept that each instrument has own recorder except one thing that grouping of input channels is done at design phase. To assign input channels to a group, information about data rate per each channel, overall operational plan and compression ratio to be used per each channel should be checked to prevent data concentrated on one memory module. The ground station is responsible to balance the level of stored file size too.

Nowadays the bottle neck of satellite data transmission system is RF component. Normally total downlink data rate depends on the performance of downlink transmitter. So the requirement of output scream is not high, one data bus can be used to transmit all output data to the transmitter.

At the point of software, followings items are proposed for the implementation of higher data rate memory system:

1. Separation File_Create command with recording command

The K-2 memory system has no File_Create command. On receiving the command of start recording, memory system performs the synthetic check, validation check and then memory segment allocation for that file. After successive file creation any recording mission can start. The small problem is the memory system takes some time to create a file. Normally it can be covered by changing operational concept or mission script which is a batch code for a mission. It's better to create file before a mission.

2. The Reasonable Size of the Segment

The memory is divided by segment which is minimum amount for read/write operation. In K-2 memory system the segment had small size to save a memory as much as possible. But that made a lot of traffics internal communication line and gave a lot of burden to micro-processor. The micro-process had to translate and send hundreds of segment address to input/output devices through internal communication line per each second.

The size of segment should be determined by considering the design architecture of memory, the input data rate and imaging plan. The memory system for K-3 has 4 panchromatic image channels and 8 multi-spectral image channels. There are 4 input interface boards and 4 memory module working at a time. At normal line rate each memory board will receive about 1 Gbps image data. The K-2 ground station plans imaging schedule by the unit of second. So the proposed size of segment is 1 Gbits. Of cause we can define smaller size for a segment like 512 Mbits. In that case we can save only 512 Mbits (512 M x 2 (pan, ms) x 1/2 (probability of saving)) per mission. Then how many operations are needed to perform additional mission with saved segment? Theoretically it's needed 2 Gbits in a pan + ms mission for 1 sec. and normally the ground station takes image before 3 sec. and after 3 sec. to have a margin to overcome miss-location of the satellite at worst case. So we need total 14 Gbits per 1 sec. pan + ms recording in a UFM. To save 14 Gbits more than 28 files should be recorded in a UFM. That means about 14 missions has to be stored to get space for 1 sec. pan + ms mission.

Another thing to know is that there is no automatic memory release system for unused segment after recording mission. The waste of memory space is mainly due to bad calculation of file size at the mission planning phase.

3. Continuous File Management System

File management System is the manner of segment allocation to a file. There are two kind of file management system. One is continuous memory allocation and the other is distributed memory allocation.

The continuous memory allocation regards entire memory space as a linear memory. A file can be located from anywhere of that linear memory but without any break-up. So a file bigger than maximum continuous block size is not able to be stored even though total free memory space is bigger than the file size. To create a file the ground station has to define the start point of the file and the length of the file. The ground station has to know occupation map of entire memory space, so that new create file command shall not going to be rejected.

The distributed memory allocation makes a file with linked list structure. In addition to start point of file and the length of file, micro-processor has to manage a file allocation table which indicates next segment location of the current segment for a file. To create a file the ground station only has to indicate the length of file. Rest operations will be done by the micro-processor. The execution time for a Creat_File command relatively takes more time in distributed memory system. The processor has to find free segment and link the segment to the file until the end of the file. But this file system guarantees that all unused segment can be used by user.

How to allocate the segments into a file is important subject not only at file creation phase but also in a mission phase. In distributed memory system peripheral devices have no way to know the next address for record or replay mission. So while a mission, the micro-processor has to send new address to input and output interface boards in real-time. That increases internal communication traffic. If the communication is broken or interfered then the mission will be stopped. In continuous memory system peripheral devices can guess the next address easily without any support of the micro-processor.

Table 1. Continuous Memory vs. Distributed Memory

Segment Allocation	Continuous Memory	Distributed Memory
File Structure	A Linear Memory Block	A Linked List
Arguments for File Creation	File ID, Start Point, Length	File ID, Length
Utilization of Entire Memory	No	OK
Ground Station Responsibility	High	Low
Internal Communication while Imaging	Low	High

3. CONCLUSION

For the better quality of output, we need to enhance the performance of data handling process or we need to gather more detailed more massive input data. The demands of earth observation satellite gets higher, the more data has to be handled by memory system. On this paper hardware and software concept to process higher data rate by succeeding strong points of KOMPSAT-1 and KOMPSAT-2 design and by overcoming their weak points.

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Acknowledgements

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