Development Of KAISTSAT-4 Expanding The Role Of Small Satellite For Scientific Research

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Abstract

The fourth Korean small satellite, KAISTSAT-4, is under development by Satellite Technology Research Center (SaTReC) of the Korea Advanced Institute of Science and Technology (KAIST). The KAISTSAT-4 program was commenced on October 1998 with multiple mission objectives, which include exploring space science, deploying satellite-based data collection system and development of precision star sensor. Despite severe constraints on mass and size, these advanced science and engineering payloads are expected to deliver various useful results and exhibit the unique role of small satellite. We present an overview of the KAISTSAT-4 mission and describe its current status. Finally the prospect of future small satellite programs is briefly introduced.

Introduction

KAISTSAT-4 has a number of missions such as studying space science and exploring advanced space technology with the emphasis on the role of small satellites. The space science mission is aims at studying the evolution and spatial distribution of hot interstellar medium by performing spectral diagnostics in the Far Ultra Violet (FUV) ranges and investigating the space physics of the Earth's polar region. Korea Astronomy Observatory (KAO) and U.C. Berkley are involved as cooperating groups to develop the scientific payload called FIMS (Far ultra violet IMaging System). FIMS is now in a stage of integrating and verifying its interface with KAISTSAT-4 bus system.

KAISTSAT-4 shall also deploy a satellite-based Data Collection System (DCS) for environment monitoring, wildlife tracking and transportation monitoring purposes. DCS is being jointly developed through an international cooperation with CRCSS (Cooperative Research Center for Satellite System), Australia. KAISTSAT-4 also plans to conduct technology development and verification of a precision star sensor for precise attitude control required for high-resolution earth and space observation.

As a unique small satellite system, KAISTSAT-4 makes it a goal to minimize cost and maximize efficiency by employing small number of highly experienced engineers and to by integrating multiple payloads from independent organizations. As far as satellite bus-system is concerned, KAISTSAT-4 makes fully use of the heritage from KITSAT-3[1], which is still in successful operation carrying a multi-spectral camera.

Here, we present a general description of the KAISTSAT-4 system and its mission operation. After the current status of the KAISTSAT 4 program is described, a brief introduction of future satellite program is provided.

Mission Overview

The KAISTSAT-4 mission is designed to deploy various payloads which will conduct measurements for space science and perform various engineering tests. The KAISTSAT-4 program commenced at Oct. 1998 with the aim of expanding the role of previous KITSAT small satellite missions into scientific research fields. The project is fully supported by Korean MOST (Ministry of Science and Technology) with an initial budget of US$8 Million. KAISTSAT-4 exploits the similar bus structure as KITSAT-3 and targets to be an advanced small satellite with a mass budget around 100 kg.

KAISTSAT-4 is designed to meet the piggyback launch opportunities with volume and mass constraints. The orbit of the satellite will be near circular polar orbits with altitudes of about 800km. The launch schedule was initially planned to be around

[1] KITSAT series has been renamed as KAISTSAT from the current mission.

July 2002 but it is anticipated that there may be a marginal delay of about 6 months to 1 year. As of June 2002, the launch vehicle has not been confirmed yet.

Objective

KAISTSAT-4 symbolizes a continuing effort by SaTReC to develop small and cost-effective experimental satellites within moderately short development period. After the successful launch and operation of KITSAT-3 which has carried out Earth observation experiments, KAISTSAT-4 is intended to expand the role of micro-satellites into scientific research field. The scientific payload of KAISTSAT-4 will investigate the evolution and spatial distribution of hot interstellar medium. The space physics of the earth's polar region will also be investigated by simultaneously measuring the populations of charged particles precipitating into the earth's upper atmosphere.

In addition to the scientific purpose payloads, an engineering test payload will be deployed to implement a global data collection system. DCS payload is a satellite-based data collection system and provides a simple communication resource for collecting various types of data from remote sensors or moving vehicles. Its application areas include environment monitoring, fixed/mbile terminal access, data collection, personal mobile terminal, voice/mail messaging service and oceanographic research.

The attitude control system of KAISTSAT-4 is proposed to accommodate payloads requiring higher attitude accuracy and stability. To guarantee the successful operation of high-resolution Earth and Space observing missions, it is essential to adopt precise attitude determination and control schemes. A precision star sensor will be developed (10 arcsec) and verified to meet the required pointing accuracy for the operation of KAISTSAT-4 scientific payload.

System Overview

The overall system consists of the space segment, the ground segment and the user segment. The space segment will be a small LEO satellite, KAISTSAT-4, which carries various instruments for space science research, engineering tests, and practical applications.

While FIMS is the main scientific payload, there are other instruments performing various scientific research in space. Solid State Telescope (SST) will investigate plasma processes occurring in the low altitude auroral accelation region. SST is designed specifically to make measurements of energetic electrons and ions in this energy range with simultaneous measurement of FIMS. Langmuir Probe (LP) will measure electron temperatures, electron energy distribution functions, plasma densities and spacecraft potentials. Using LP, thermal energy and particle flows within the magnetosphere-ionosphere system willl be investigated. Scientific Magnetometer will detect the Earth's magnetic fields at improved sampling rate of about 20 vectos/s and at improved resolution of about 2 nT. Data Collection System (DCS) and NArrow field-of-view STar Sensor (NAST) are for engineering test and practical applications. Table 1 shows the system specification for KAISTSAT-4.

Table 1 KAISTSAT-4 satellite specification

Item	Specification
MASS	~ 130 kg (Margin of 10 %)
SIZE	664 x 800 x 600 mm
Power Consumption	94 W
Solar Panel Capacity	150 W
Attitude Control	3-axis stabilization 0.1 degree pointing accuracy
Mass Memory	2 Gb SDRAM 1 Gb SDRAM + 0.5 Gb SRAM
Communication	S-Band, VHF/UHF
High rate Payload Data link	X-band transmitter

The ground segment will include Mission Control Station (MCS), Data Receiving Stations (DRS) and Mobile Terminals (MT) for Data Collection System (DCS). The MCS will be located at SaTReC, KAIST in Taejon, Korea. Primary DRS will be located at SaTReC and archive all payload and bus telemetry data for post processing and distribution. Additional DRS shall be located close to the data users for direct data receiving.

Mobile Terminal (MT) is a part of the ground segment for DCS operation. Its functions and size may vary depending on application areas. For instance, MT for animal tracking is supposed to be as light as 20 grams while one for environment monitoring at remote site could be about several kilograms or even heavier up to several hundred kilograms.

Current Status

The Engineering Model (EM) of KAISTSAT-4 has been developed and tested at the end of 2000. Currently SaTReC is developing Qualification Model (QM), of which Assembly and Integration Test will be conducted before the end of 2001.

Unlike KITSAT-3 which was developed and tested entirely within SaTReC, the KAISTSAT-4 program involves other organizations comprising domestics and foreign research institutes. This implies that bus system and payload developments should be coordinated with a great care while each development process may be considered as an independent sub-program. Contrary to the original plan, we found that incorporating several sub-programs requires extra efforts and time-consuming processes. It has further complicated the overall mission management and may have contributed to the delay of the program.

User Groups

Primary groups of the user segment will be national and international Earth science research communities, various users of DCS, and the satellite development group at SaTReC. SaTReC will be the primary organization to provide data to users. It is expected that there will be a large number of small research groups interested in the space science mission of the K-4. A great interest has been already drawn from domestic organizations such as Korea Ocean Research and Development Institute (Kordi), Korea Meteorological Administration (KMA) and National Fisheries Research and Development Institute (NFRDI).

SaTReC will establish effective links to space science research communities including University of California, Berkeley and University of Washington, Seattle. The Institute of Telecommunication Research (ITR) of University of South Australia will be one of the DCS users. All spacecraft telemetry data will be made available to the satellite development group at SaTReC since it will be valuable information for the following missions.

Mission Operation

The operation of NAST test does not require particular maneuvering of the satellite attitude and may be executed during normal modes. Similar to NAST, DCS does not require a precise pointing accuracy and its operating performance will not be significantly degraded as long as DCS antenna points downward to the Earth.

For the operation of space science payloads including FIMS which require high level of pointing accuracy of satellite attitudes, a number of observation scenarios have to be organized. The satellite system shall enter the observation mode by stored command from the MCS. The observation mode shall include all the necessary procedures to deploy and operate the space science payloads.

Bus System

KAISTSAT-4 satellite bus system is being developed based on proven technologies from KITSAT-3. The KAISTSAT-4 spacecraft has three solar panels, one fixed and two deployable. The fixed solar panel is attached to the negative Z-axis side of the spacecraft, and two deployable solar panels are located at the positive and negative X-axis sides. Deployable solar panels are attached to the spacecraft by deploy mechanisms such as hinges and holding devices. They will be deployed by the command from the ground station. The launch adapter is attached to the bottom surface of the spacecraft.

For the successful operation of scientific payload, it is required to point the FIMS at various celestial targets with 0.5 degree of pointing and 5 arc minutes of attitude knowledge accuracy. A star tracker is necessary since highly accurate attitude information is required and the target direction is almost uniformly distributed around the whole celestial sphere including the Earth.

The star trackers provide inertial reference attitude to within 10 to 60 arc seconds (1σ) while scanning at rates up to 1.0 degree/second. Blocking stray light from the Earth or the Sun by using optical baffle is critical for the stable operation of the star tracker. There are four fiber optic gyros (FOGs). Three of them are aligned with the orthogonal satellite body axes and the fourth one's disposition is in skewed manner as a redundancy. The spare gyro backups any single point failure in the rest three of them by linear

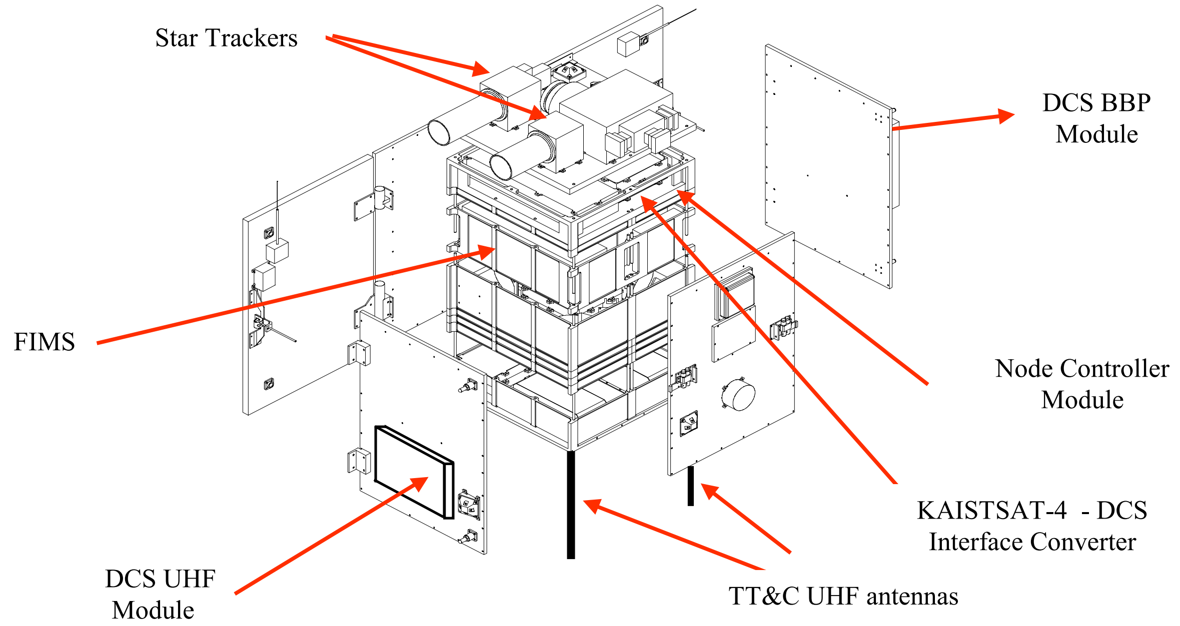

Figure 1 Exploded view of KAISTSAT-4 and indication of its payloads

combination of the readout data. One analog sun sensor and three coarse sun sensors are employed to estimate the coarse three-axis attitude information with the help of the magnetometer. Four reaction wheels are arranged in a pyramid shape. Each wheel is tilted 45 degrees from the pitch axis to provide high pitch control torque. Each reaction wheel is capable of producing a torque of 5mNm and storing 0.12Nms of angular momentum.

One GPS receiver is used to provide a spacecraft position, velocity and UTC time clock. The attitude control processor, an i80960 based computer, can handle 2 MIPS. Its reliability has been proven after several years of successful operation of KITSAT-2 and 3. Each subsystem is connected to the node controller to share communication, telecommand and telemetry information. The shared bus structure is a modification of MIL-STD-1553B bus for micro-satellite use.

Payload Data Transfer Link

Various scientific payloads as well as DCS system will be continuously collecting a large amount of data everyday and therefore a high speed data transmitter will be installed which is similar to the one in KITSAT-3. The requirements for the KAISTSAT-4 payload data transmitter will be less stringent compared to KITSAT-3 case, in which multi-spectral Earth image data has been produced. Since only scientific sensors and low data-rate communication payloads are employed, the rate of daily data generation will be kept below a moderate level.

It is estimated that the main scientific payload (FIMS) will produce around 0.5 Gbits/day. Assuming normal operation modes are maintained for all other payloads, space science packages comprising SST, LP and SMAG will produce similar amount of data. Although DCS payload is expected to deal with a large number of MTs ranging from a few to hundreds of buoys per day, the data link capacity with one single terminal is restricted within a few Kbytes for each contact and therefore data flow from DCS payload will not exceed several Mbytes per day. Assuming the frequency of guaranteed contact between satellite and ground station is twice per day with average contact duration of 5 minutes, it is estimated that the minimum payload data downlink speed of KAISTSAT-4 is required to be over 1.6Mbps. In the actual system design, link speed requirement is set to 3.0Mbps to assure that there will be no loss of collected data during any operation modes.

As in KITSAT-3, X-band is chosen for downlink frequency. A microstrip patch antenna will be installed to transmit stored data to SaTReC ground station. The ground station is equipped with a 13m dish antenna and complete data processing facilities. The required pointing accuracy of the X-band antenna should be within 5 degrees. The specification for payload data link is shown in Table 2.

Table 2 KAISTSAT-4 payload data transmitter specifiation

Item	Specification
Frequency	8.125 ~ 8.329 GHz
Link Speed	> 3.0 Mbps
Link Margin & BER	3 dB at 10E-6
Output Power	33 dBm (2W)
Power Consumption	< 30W

Engineering Model Test

Engineering Model (EM) for KAISTSAT-4 was developed and tested. Collected payload data will be stored in Mass Memory System (MMS) and transferred to the payload transmitter for downlink. QPSK modulation will be employed before passing the payload data to solid-state power amplifier. The typical gain of the power amplifier is 47dB. Figure 2 shows the preliminary measured result of the power level at the output of the QPSK modulator.

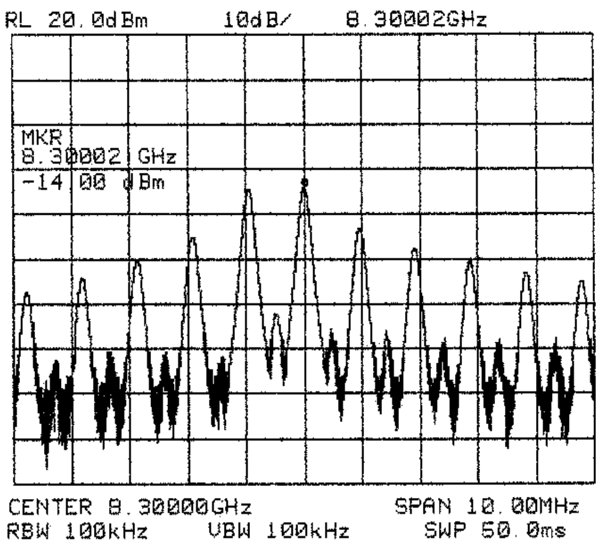

Figure 2 Power level of payload data transmitter measured at the output of QPSK modulator prior to power amplifier stage

The measured power level is –14dBm at 8.3GHz and the final output level of the payload data transmitter becomes 33dBm with 47dB power gain, which satisfies the requirement listed in Table 2.

Ground Station

SaTReC has its own ground station in which all the necessary mission operation and management such as LEOP, TT&C link and payload data downlink will be performed. In KITSAT-3, only VHF link has been adopted for TT&C uplink purpose. It is planned that a new 3 m S-band dish antenna will be installed on the ground station to replace the previous VHF uplink and provide an enhanced TT&C capability. The specification of SaTReC ground station is shown in Table 3.

Table 3 SaTReC ground station specification

Items	Specification
Receive RF bands	2000 ~ 2400 8020 ~ 8400 MHz
Receive G/T	25 dB/k, 35 dB/k
Modulation	QPSK, PM, FM
Receive Data Rate	~ 180 Mbps

Scientific Payload

The main scientific objective of KAISTSAT-4 is to study the diffuse hot interstellar matter, for which Far-ultraviolet Imaging Spectrograph (FIMS) is currently under development. The instrument employs a dual bandpass (900-1175 Å and 1335-1750 Å), high resolution (1.5 Å and 2.5 Å, respectively) imaging spectrograph with a 8^{o}X 5‘ field of view and 5’ spatial resolution. FIMS is sensitive to emission line fluxes an order of magnitude fainter than any previous detection and allows us to determine the thermal and ionization equilibrium state in hot Galactic plasmas. Scientific goals of FIMS are 1) to map the spatial distribution of hot Galactic plasmas through a one-year sky survey, 2) to determine physical states of hot interstellar matter such as superbubbles and supernova remnants with pointed observations, and 3) to test the models presently available for the Galactic evolution. The scientific objectives of the space plasma instrumentation can be summarized as 1) detection of directly penetrating solar wind plasmas and up-flowing, cold ionospheric electrons, 2) investigation of sub-kilometric scale structures of the Earth‘s polar regions, and 3) comparisons of the *in-situ* measurements with the spectrographic images ($\Delta\lambda/\lambda$

~ 500) of the Earth's Aurora in the far-ultraviolet ranges

Operation Modes

The operation of scientific payload is divided into the following modes: an aurora observation mode, two airglow modes, and two astrophysical observation modes. The aurora observation will be done over the North and South polar regions. Figure 3 illustrates these operations as the satellite orbits around the earth. During the aurora observation mode, the field of view direction of the Far Ultraviolet imaging Spectrograph (FIMS) is to be pointed to the nadir direction. During the airglow observation, the FIMS is to be pointed to an inertial or the nadir direction. The astrophysical observation is to be performed during the eclipse, and the selected extended galactic sources will be observed during the pointing observation mode. During the sky survey operation, all the sky will be surveyed. The spacecraft should spin around the axis parallel to the slit of FIMS during this mode

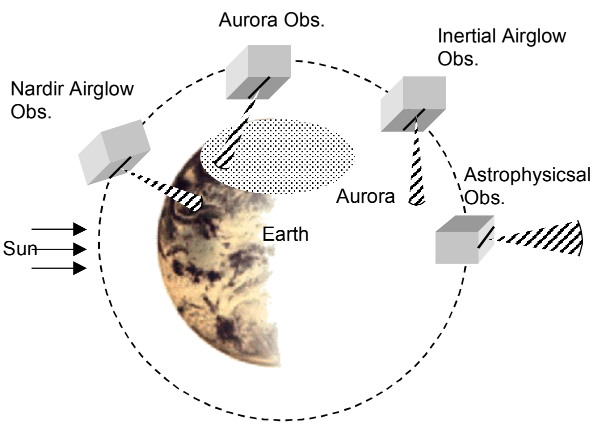

Figure 3 Operational modes of the payload

Data Collection System

There are two main trends in Low Earth Orbit (LEO) satellite communication systems, namely "big LEO" and "little LEO". The big LEO supports the real time communication and hence it requires the satellite constellation covering the whole Earth. On the other hand the little LEO mainly focuses on the non-real time communication with a small number of satellites. DCS will be a good candidate demonstrating an attractive potential of low cost micro-satellite for little LEO applications,.

While other scientific payloads are for observing outer space and studying space physics, DCS payload is designed to apply for Earth environmental monitoring purposes. Although there have been already numerous satellite missions and communication networks before, most of them have relied on heavy and expensive satellite system or an extensive commercial satellite constellation. KAISTSAT-4 will exploit a simple and cost-effective implementation of global data collection strategy. It is expected to provide an alternative choice with enhanced features distinguished from conventional systems.

Background

In the UN ESCAP (Economic and Social Commission for Asia and the Pacific), SaTReC proposed a 'simple common payload' program among the nations in Asia-pacific region. According to the proposal, the selected payload shall be deployed by the spacecraft owner countries and shared by Asia-pacific nations. DCS has been considered as a good candidate for this program and SaTReC intends to promote the DCS project as a 'simple common payload' program in Asia-pacific region. As a part of implementing the "Simple Common Payload" scheme, SaTReC and Institute of Telecommunication Research (ITR) of University of South Australia have worked together to operate this `Data Collection System' in each of their own satellites. The DCS payload, called as ADAM (Advanced Data Acquisition and Messaging) in FedSaT-1, aims at collecting various scientific and environmental data from the Earth and will contribute to a better understanding of ocean dynamics. It will demonstrate the efficiency of LEO satellite communication technology by adopting new protocols for bi-directional messaging, on-board modem algorithms and architectures. A bi-directional communication will be established between DCS and several (>5) buoys simultaneously.

In the KAISTSAT-4 mission, the primary application of DCS will be oceanographic research which is associated with ARGO (Array for Real-time Geostrophic Oceanoraphy) environmental monitoring project. This project will be distinguished from the previous ARGO missions by several advanced features. Higher data transfer capability will be achieved by using a custom multiple access method involving two-way communication. With the efficient control of power consumption of mobile terminals, the lifetime of each buoy can be highly increased.

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System Overview

DCS payload consists of UHF electronics and a baseband processor (BBP). The baseband processor for KAISTSAT-4 is identical to the one for FedSat-1. The complete BBP hardware module is manufactured by ITR, while the UHF module is integrated and tested in SaTReC. SaTReC is responsible for installing DCS in KAISTSAT-4. This also includes a provision of “Interface Converter” Module to adopt the DCS payload for KAISTSAT-4 and installation of necessary UHF antennas to communicate with MTs. The collected DCS data will be received and distributed by SaTReC ground station facility.

The BBP module is for data processing during packet data communication between satellite and MTs. Two identical modules will be prepared for both KAISTSAT-4 and FedSat-1 respectively. The UHF electronics for KAISTSAT-4, unlike FedSat-1, does not require Ka-band operation. and hence significant design changes and modification have been made before DCS payload is adopted for KAISTSAT-4.

SaTReC is developing an extra “Interface Converter Module” to relay collected DCS packets and telemetry data to KAISTSAT-4 and control the overall operation of DCS.

Operation Plan

It is envisaged that a number of buoys will be distributed around Korean peninsula and Australia operating in conjunction with KAISTSAT-4 and FedSat-1 respectively. The buoys will record various ocean

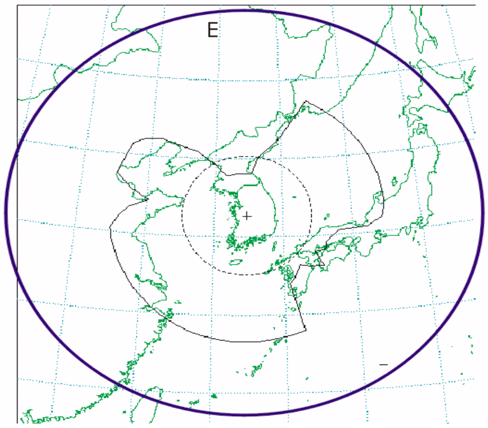


Figure 4 DCS operational region around Korean peninsular

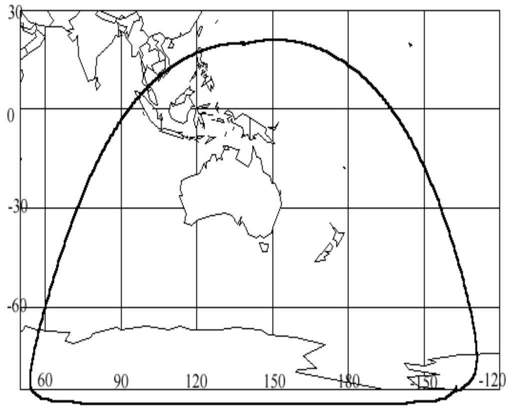


Figure 5 DCS operational region around Australia, South-East Asia and Antarctica

environmental data including temperature and salinity up to depth of 2000m below sea level. The proposed program will introduce an enhanced type of buoy and demonstrate successful operation for ARGO project using cost effective small satellites. It is anticipated that the simultaneous operation of two satellites of KAISTSAT-4 and FEDSAT-1 and ground stations from both countries will certainly enhance the efficiency of ocean data acquisition scheme. Figure 4 and Figure 5 illustrate DCS operational region over Korea and Australia region respectively. It is a matter of available frequency bands rather than technical problems that restrict the extension of DCS operational region. There are some meteorological uses of the UHF spectrum that may need to be coordinated. Care must be take that transmissions do not interfere with satellite transmissions in neighbor countries.

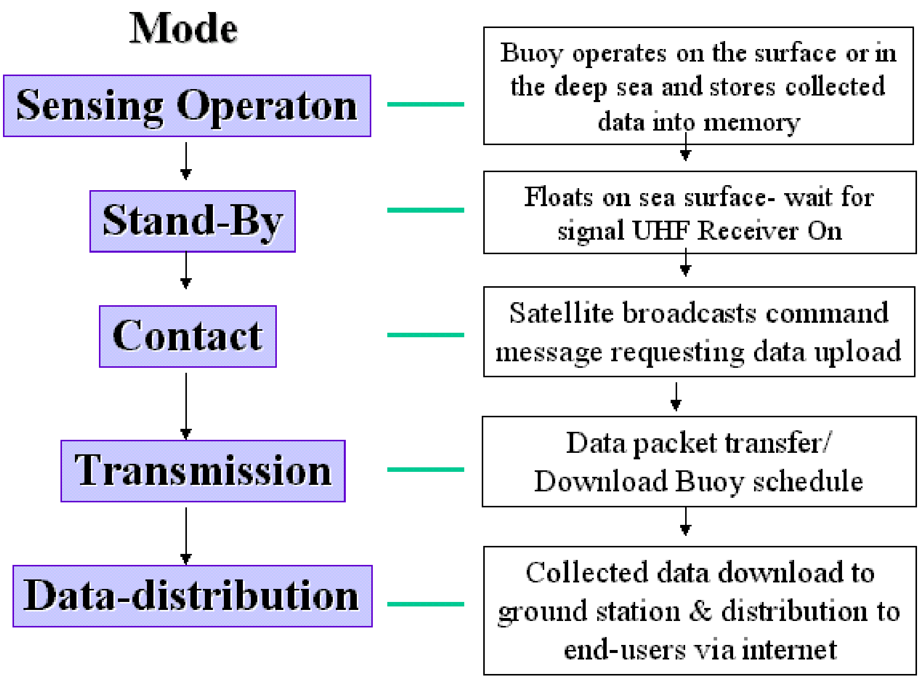


Figure 6 Operation mode of DCS during data collection from MTs

The operational duration will be pre-scheduled by TT&C control. The contact time with MTs are expected to be around 15 minutes over Australian region and 10 minutes over Korean region. The actual contact time will be adjusted to be less than planned schedule to avoid any conflict with other payload operation. Figure 6 is a flow diagram describing the operational plan of DCS. Initially mobile terminals or buoys on the sea surface wait for signals from satellite during stand-by mode. Once a communication link is established between MT and the satellite, bi-directional data transmissions are executed. The collected data will be stored in the mass memory system until they are forwarded to ground station, where they are processed and distributed to end-users. Part of them will be made available to public via Internet.

Technical Aspects

During DCS operation, a two-way Earth-Satellite-Earth communication link will be established in UHF band. DCS uses two-way UHF communications for both up- and down links of packet data. Table 4 shows the characteristics of UHF links between KAISTSAT-4 and MTs on the Earth. QPSK modulation is employed to improve data transfer rate. In addition, it is expected that Turbo code scheme will provide a further 3-dB gain in the link margin.

Table 4 DCS up & down link communication specification

	Uplink	**Downlink**
Frequency	313.55 MHz	400.4 MHz
Link Speed	4000 bps	1000 bps
Multiple Acess	TDMA	TDM
Modulation	QPSK	BPSK

Since the downlink frequency corresponds to the TT&C UHF downlink of KAISTSAT-4, although TT&C UHF link is only for backup of S-band TT&C link and will be seldom used during normal operation, still a great care must be taken to avoid any overlap of DCS with other operations.

The complete set of BBP and UHF electronics has been manufactured and tested in ITR, University of South Australia which is remotely placed from SaTReC. Since the payload design, test and verification have been performed in remote site, a separate design scheme has been adopted dedicated for DCS payload.

In KAISTSAT-4, all the subsystems including scientific payload and DCS are connected to Node Controllers (NCs) to communicate with each other through Modular Command and Data Handling (MCDH) network. Since the final design and specification of DCS had not been confirmed in the design stage of NC, it is decided that a separate interface converter should be installed between DCS and so that any data transfer between DCS and KAISTSAT-4 shall be done through the interface converter. The purpose of interface converter is to minimize any physical hardware modification later and it is envisaged that communication links between NC and interface card should be made as simple as possible. Only two serial lines have been installed through which all the data packets and telemetry information will be transferred from DCS to NC. The frame structure of data and packets produced by DCS are designed to meet FedSat-1 specification and it is the function of interface converter to translate different data protocols to be understood by KAISTSAT-4 NC.

Antenna Design

Two monopole UHF antennas are installed on FedSat-1 for DCS operation. Monopole antenna has been favored due to its design simplicity and broad radiation pattern. However it is found that it is not straightforward to adopt the same type of antenna for KAISTSAT-4 due to several problems incurred. First of all, there are already installed four UHF antennas that are exactly the same type of UHF antennas used for FedSat-1. This leads to difficulty in choosing appropriate location for DCS UHF antennas. The surface of KAISTSAT-4 is already too crowded and the only available space is susceptible to damages during launch procedure. Secondly, since the same frequency spectrum is shared with TT&C link, electromagnetic couplings between antennas arise as a serious concern. As a result, a new design strategy has been considered, where the monopole antenna will be replaced by a microstrip patch type antenna.

The main concern on new microstrip patch antenna is to minimize occupied space in order to overcome mechanical interface problem. Figure 7 compares the mechanical structure of two different antenna types and Figure 8 compares their simulated radiation patterns. The required specification of radiation beamwidth is 120 x 90 degrees. The preliminary investigation shows that the performance of microstrip patch antenna satisfies this requirement.

Applications

Little LEO communication finds an extensive applications in various areas of industry, environmental monitoring, remote site control & management and personal data communication. Accordingly the market value concerning LEO communication has been increasing consistently in the past and will continue to grow in the future. Table 5 summarizes predicted market value of LEO Store-and-Forward Market comprising diverse application areas ranging from E-mail service to stolen cars. The table indicates that expected market value will be increasing rapidly.

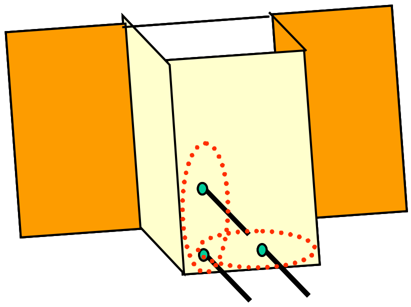
Table 5 Little LEO communications Store-and-Forward Market Prediction

	1996	**2000**	**2005**
E-Mail	N/a	564.4	715.9
Hard-to-Read Meters	N/a	342.0	690.0
Two-Way Messaging	16.4	82.4	505.0
Fleet monitoring	48.0	212.6	350.2
Management		26.7	
Intranet	N/a	5.39	106.4
Stolen Cars	N/a		15.08
Total	**64.4**	**1233**	**2382**

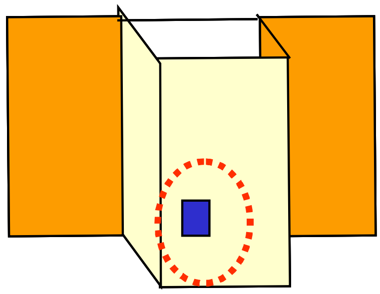
Oceanographic Application

Conventionally remote environmental data telemetry from oceans has been dominated by the Argos systems. Although there have been several attempts to challenge the Argos, it has remained as a preferred choice for oceanographic application due to simple user interfacing of transmitters, low cost and convenient data dissemination.

The Array for Real-time Geostrophic Oceanography (ARGO) project is part of the World Ocean Circulation Experiment.

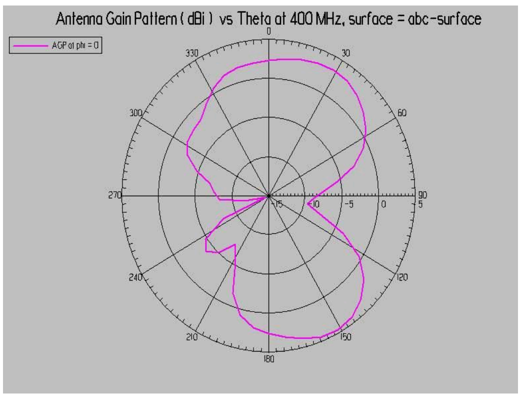


(a) Monopole type UHF antenna

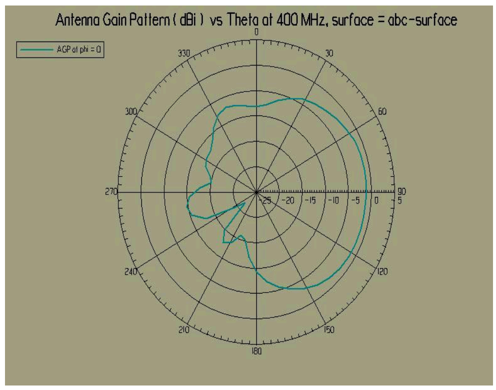


(b) Microstrip patch antenna design

Figure 7 UHF antenna design for DCS payload; a comparison between monopole and microstrip patch antenna



(a) Radiation pattern of monopole antenna



(b) Radiation pattern of microstrip patch antenna

Figure 8 Comparison of simulated antenna radiation pattern between monopole and microstrip patch antennas

In this project, Profiling Autonomous LAgrangian Circulation Explorer (PALACE) floats will be deployed to record temperature, salinity, pressure and other scientific measurements. These floats will drift for several days at 1 ~ 2 km down below sea levels and then record temperature, salinity and ocean circulation before they rise to surface. Figure 9 illustrates the interaction and data relay between satellites and ocean buoys. It is planned that up to 3000 ARGO buoys will be deployed in global scale by 2005.

Unfortunately, conventional Argo floats have limitations on the amount of data that can be collected per pass. DCS payloads carried by KAISTSAT-4 and FedSat-1 will be distinguished from conventional ARGO system by advanced data processing capability which enables to increase communication data rate by significant level. Multiple channels will be established simultaneously between satellite and MTs in order to increase the data capacity.

Prospectus of Future Programs

A long-term plan for Korea's space development has been recently revised and confirmed in Dec. 2000. Korea aims to join the group of advanced countries in the field of space development and application. In order to achieve this goal, according to the revised report, a number of satellite mission programs will be initiated within next 15 years during which multi purpose satellites such as remote sensing satellites as well as communication and weather satellites will be developed and launched into space. In parallel to space programs for multi-purpose satellites, a special attention has been paid to a series of small satellite development. Due to a relatively short history in space program, it is widely acknowledged that a strategic plan should be set up to acquire core space technologies and to assure that the long term space program should continue in the future. In this sense, small satellite development programs provide excellent opportunities to pursue advanced technology development and raise human resources.

For the success of the national space program, it is as important to raise highly skilled engineers as to acquire space related core technologies. SaTReC has a number of experiences to develop small satellites and it is said that SaTReC set up its own history for Korean small satellite industry along with the national space program. While previous missions were oriented to show the feasibility of small satellite development, future programs will be focused on demonstrating the acquired advanced space technologies that will be essential for future space programs. Similar to DCS, payloads for future small satellites shall be developed as parts or subsystems of main payloads, which is demanding and needs previously unavailable technologies. These payloads may include microwave

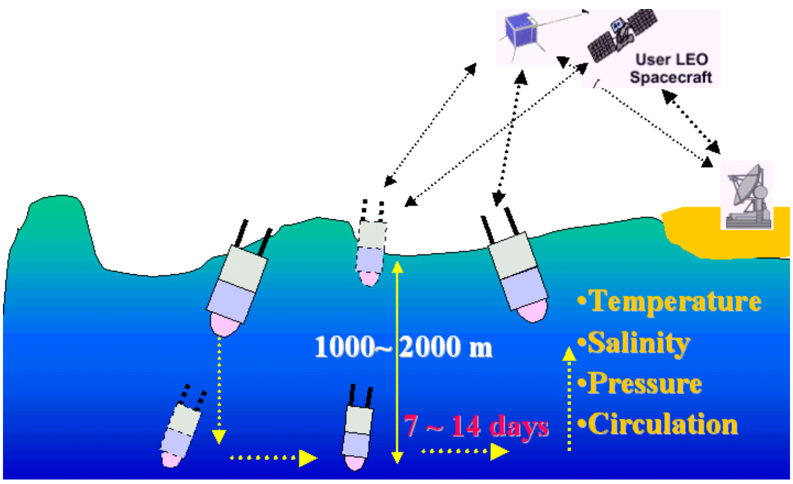


Figure 9 Operational plan of KAISTSAT-1 DCS and mobile buoys floating over ocean.

sensors, IR & optical sensors, advanced control and propulsion system, antennas, active imaging sensors and high rate space communication systems. As far as the future space program is concerned, the fact that small satellite system is limited in total mass, size and available power may be a driving force to achieve cheaper and more efficient technologies.

Conclusion

KAISTSAT-4 program of the Satellite Technology Research Center has been initiated in Oct. 1998. The payloads consist of Far Ultra Violet Imaging Spectroscope, Solid State Telescope, Data Collection System, Narrow Angle Star Sensor. It will perform space science experiments by measuring far ultra violet (FUV) radiation with an FUV imaging spectrograph (FIMS).

The DCS communication payload will introduce a new type of packet data service which are well suited to environmental data acquisition by LEO micro satellites. It will demonstrate LEO satellite communication technologies by adopting new protocols for bi-directional messaging and on-board modem algorithms and architectures. Multi-channel, bi-directional communication links will be established between DCS and MT.

Although it was planned to launched KAISTSAT-4 in the middle of 2002, a marginal delay is expected in the schedule.

SaTReC shall take a major role in yielding highly educated and skilled engineers to meet the need of human resources in the course of future Korean space program.

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References

1. J. Seon, K.I. Seon, S.H. Kim, K.W. Min, B. J. Kim, R. C. K. Yong, L. F. Leong, H. J. Chun, H. S. Chang, J. S. Bae, Y.W. Choi, S. R. LEE, Y. H. Shin, K. S. Ryu, "Brief Reports On Kaistsat-4: Mission Analysis", Journal of Astronomy and Space Sciences, vol. 17, no. 2, Dec., 2000
2. Ryu, K.-S.; Seon, K.-I.; Yuk, I.-S.; Seon, J.-H.; Nam, U.-W.; Lee, D.-H.; Min, K.-W.; Han, W.; Edelstein, J.; Korpela, E. J. , "Tolerance Analysis of FIMS Optical System"
3. W.G. Cowley, W.N. Farrel and D.A. Powell, "Baseband Processor for FedSat", Sixth International Mobile Satellite Conference, OTTAWA, June 1999
4. Jean-Pierre Prost, Christophe Levisage, "Oceanographic Data Collection System", Proceedings, OCEANS `94, Vol. 3, pp. 51 ~ 62
5. K.A. Gamache and P.E. Fogel, "Oceanographic Datalink", Proceedings, OCEANS '99, Vol.3 pp. 1395 – 1403
6. Hyun-Woo Lee, Buyung-Jin Kim, "Attitude determination and control fo KAISTSAT-4 satellite", 3rd Asian Control Conference, July 4-7, 2000, Shanghai, China