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Kent Ridge 1 - a hyper spectral micro satellite to aid disaster relieve

Tom Segert
Matthias Buhl
Björn Danziger
Berlin Space Technologies GmbH
Max-Planck-Str. 3, 12489 Berlin, Germany; Info@Berlin-Space-Tech.com

Prof. Goh Cher Hiang
Prof. Chua Kee-Chaing
Prof. Yeo Swee-Ping
National University of Singapore
21, Lower Kent Ridge Road, 119077 Singapore

ABSTRACT

Recent advances in Singapore based R&D in the field of Fourier transform recovery (FTR) enable micro satellites to carry hyper spectral payloads that work simultaneously in the VNIR (400-900) and SWIR (900-1700nm) bands. This will open path to multitudes of new applications in the monitoring of land, water & vegetation and thus will be useful to contribute towards the effort to prevent and manage such disasters in this region. The first satellite to carry a hyper spectral imager based on the FTR method is the Kent Ridge 1 satellite that is currently build as a collaboration between National University of Singapore and Berlin Space Technologies GmbH. The 80kg Kent Ridge 1 is based on the LEOS-50 platform of BST that has been upgraded to fit the specific needs of this mission such high internal data rate (2.2Gbit/s) and high speed data transmitter (100Mbit/s). Kent Ridge 1 is scheduled for launch in Q4 2015 will be flying in a near equatorial orbit of 550km altitude with around 15° inclination. This orbit has the added benefit of fast repeat cycles over the area a desired feature in disaster mitigation.

INTRODUCTION

National University of Singapore (NUS) has embarked in early 2013 a R&D micro-satellite program in partnership with Berlin Space Technologies (BST) for hyper-spectral imaging applications. This micro-satellite mission is called Kent Ridge 1.

Over the recent years, there have been a number of disasters in Asia Region (e.g. flood in Thailand, forest fires in Indonesia, tsunami, earth quakes & typhoons). Therefore significant interest from the local scientific community exists to have an increase in the available satellite data to mitigate the effects of disaster. A pathfinder mission for small satellites in this field is the X-Sat satellite by Nanyang University. Launched in 2011 and operated until today it carries a multi-spectral payload with 3 spectral bands (Landsat 2,3,4). Inspired by the success of this first Singapore satellite, other missions have been envisioned. Recent advances in Singapore based R&D in the field of Fourier transform recovery (FTR) techniques are in the center of interest as they enable micro satellites to carry hyper spectral payloads that work simultaneously in the VNIR (400-900) and SWIR (900-1700nm) bands. These sensors will open path to multitudes of new applications in the monitoring of land, water & vegetation and thus will be useful to contribute towards the effort to prevent and manage such disasters in this region. Figure 1 shows the Kent Ridge 1 Satellite

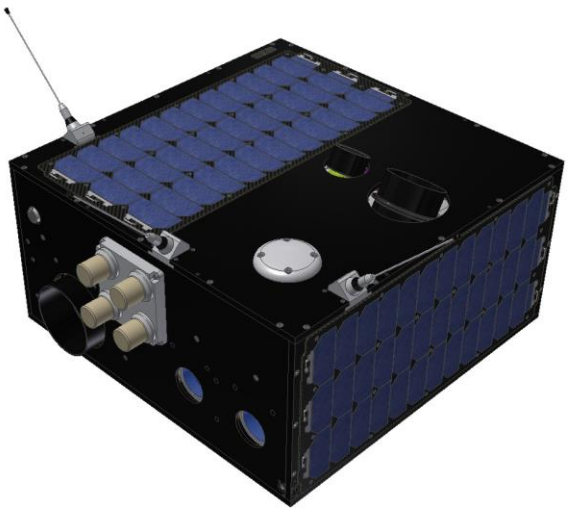

Figure 1: Kent Ridge 1 Satellite

FOURIER TRANSFORM SPECTROMETRY

The FTR method used a special filter element that generates fringes from which in post processing the spectral information can be established. The central image line acts as a quasi-scan line. In the fringes itself, their position and intensity the spectral information for each pixel of the image is coded.

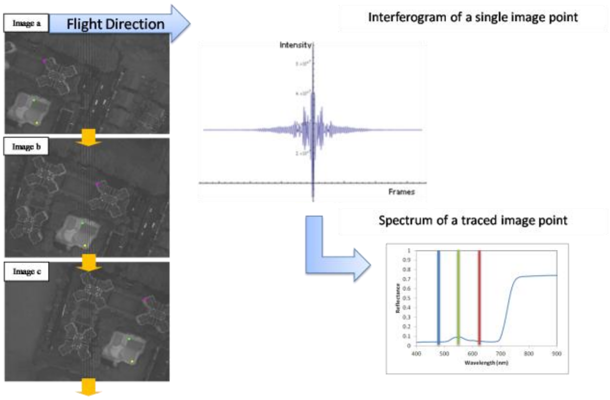

Figure 2: FTR Method

The camera is run in a high data rate (100 Hz) to get as many scan lines as possible while the satellite is progressing over the image. This is shown in Figure 2.

Advantages of FTR based hyper spectral instruments

Dispersive hyper spectral instruments that rely on either filter or gratings have the disadvantage that the SNR is directly proportional to the number of channels in the spectral domain. Therefore the devices are either very large or have poor resolutions when installed on micro satellites. The advantage of FTR based spectrometers is the much higher SNR. In contrast to traditional hyper spectral imaging the spectral information is generated by Fourier transforming the image in the spectral domain. The overall transmittance for the DSO filter (PolarFour™) is 15% therefore a higher SNR at the same size instrument is achieved.

FTR Filters in Laboratory Tests

In Figure 3the development models of the PolarFour™ can be seen.

Figure 3: FTR Filter DM; Image DSO

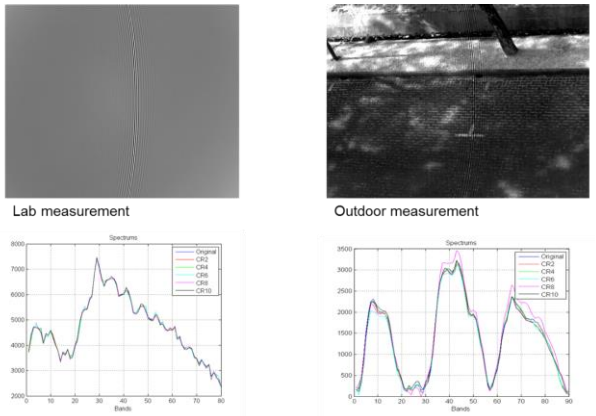

Figure 4: PolarFour™ ground campaign

The filter that has already been tested by DSO national labs in ground and balloon campaigns. The results can be seen in Figure 4 for the lab / ground campaign and in Figure 5 for the balloon campaign.

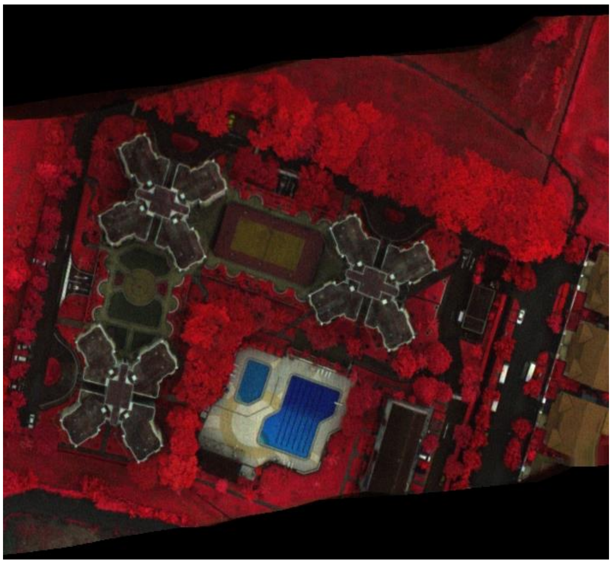

Figure 5: FTR balloon campaign; Image DSO

After proving the new imaging method to work on ground and on airborne campaigns a next step using them on a small satellite has been envisioned.

The centerpiece for Kent Ridge 1 is therefore to use FTR method in its COTS based two camera hyper-spectral payload. While implementing the mission there are many technical challenges both in the payload as well as the satellite bus. To address those NUS is working together with BST, a German small satellite specialist.

INTRODUCING KENT RIDGE 1

The Kent Ridge 1 satellite is an 80kg micro satellite that is jointly build by National University of Singapore (NUS) and Berlin Space Technologies (BST) as part of a training program. It carries three payloads including two hyper spectral cameras based on the FTR method developed by DSO national laboratories Singapore.

Mission

The mission Kent Ridge 1 is to test the FTR filters in space in a hyper spectral satellite mission. The training program will further enable NUS to independently build small satellites on system level based on the BST LEOS platform. The satellite operation as well as the science data processing will be done by the Center of Remote Imaging Sensing and Processing (CRISP) of NUS. The launch is foreseen in Q4 on PSLV alongside the Singapore mission TeLEOS-1 by ST-Electronics.

Schedule

The Kent Ridge 1 program of NUS has started in June 2013, passed three important milestones: Kick-Off meeting (July 2013), PDR (October 2013) and CDR (late February 2014). The next milestone is the start of Systems Integration and Test in Oct 2014 for the Flight Model of Kent Ridge. The progress is on track towards getting a flight readiness review in March/April 2015 so as to be ready for a pre-shipment review in July 2015 for a scheduled launch window in Q4 2015.

PAYLOAD

Kent Ridge 1 carries three payloads, two medium resolution hyper spectral payloads based on the FTR method (PPL1 & PPL2) and one high resolution video payload (SPL). In Table 1 an overview on the capabilities of the different payloads is given.

Table 1: Payload Overview of KR1

Margin	PPL1	PPL2	SPL
GSD	44m	110m	6m
Swath	47.5km	56.3km	5.75 x 4.75km
Spectral Band	500-900nm	900-1500nm	450-630nm
Channels	20-30	20-30	3 RGB Bayer
MTF @ NQ.	>0.2	>0.2	0.1
SNR	>200	>300	>100
Bit Depth	8/**10**/12	12/**16**	**8**/12
Frames per second	100	100	30
Raw Data Rate	1.41 Gbit/s	525 Mbit/s	340 Mbit/s
Compression	JPEG2000	JPEG2000	H.264
Compression Rate	4	4	40

As it can be seen especially the high data rate of the primary payloads is a demanding requirement for the KR1 satellite. Thus a complex DPU developed by BST is used. It allows storing the raw data rate of all three cameras simultaneously (2.2Gbit/s) and transmitting them via 100Mbit/s X-Band to the ground.

Primary Payload

Figure 6 shows the hyper spectral cameras PPL1 and PPL2 payloads. As it can be seen PPL1 and PPL2 share one unified platform.

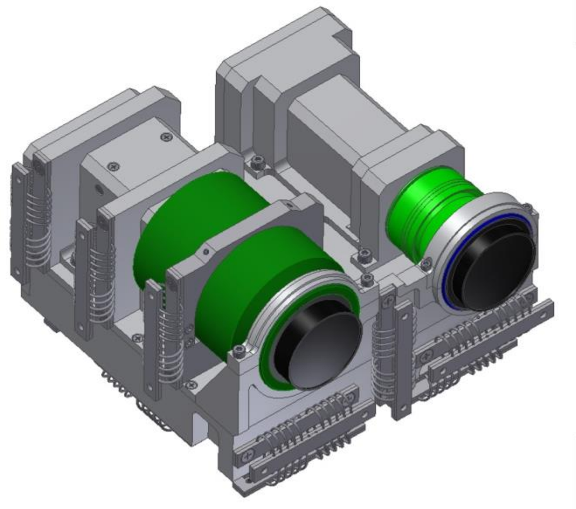

Figure 6: PPL1 and PPL2 hyper spectral camera

Secondary Payload

In addition the KR1 satellite carries a high resolution video camera as a secondary payload (SPL). The SPL has a resolution of 6m and can be seen in Figure 7.

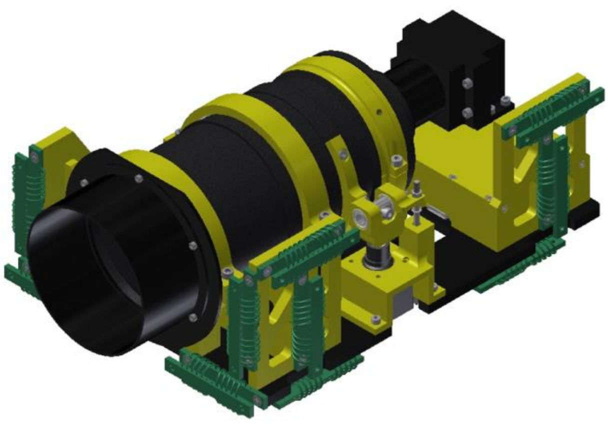

Figure 7: SPL Video Camera

Payload Block Diagram

Many satellites route the payload data via the OBC. This leads to an ever increasing demand for faster on board computers and ultimately redevelopment of the OBC for every new mission. As it can be seen BST has chosen a different approach where Payload and Bus are strictly separated and only connected via low data rate serial connection. This enables to reuse the bus for many mission and adapt only the payload and its DPU to each mission. To achieve this a direct data transfer from image data (via DPU) to the transmitter is realized.

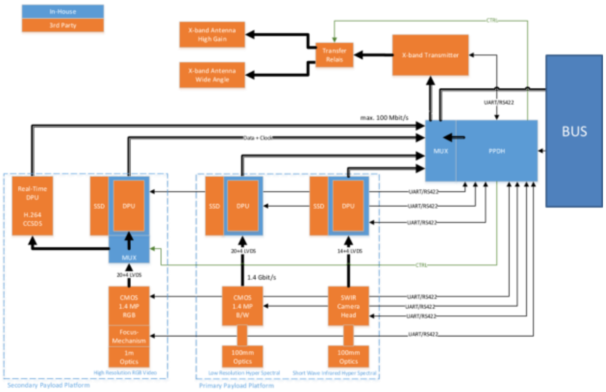

Figure 8: Payload Block Diagram

This can be seen in the block diagram of KR1 payload in Figure 8

SATELLITE BUS

The Kent Ridge 1 is based on the LEOS-50 platform of BST. A 3D view of the inside of the satellite based on the CDR that was successfully passed in February 2014 can be seen in Figure 9.

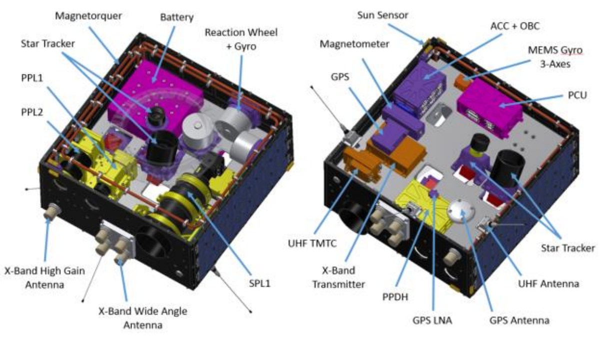

Figure 9: KR1 System Layout

As it can be seen the satellite uses the box design of the LEOS-50 platform that has been increase in size to fit all components. The solid aluminum structure simplified mechanical design, integration and testing. It further more supports the passive thermal control regime and provided good radiation protection.

Capabilities

For the mission the satellite has upgraded to the specific needs of this mission. *Table 2* shows the capabilities of the Bus.

Table 2: Overview on KR1 Bus

Parameter	Value	Comment
Pointing	1 arcmin	
Pointing Knowledge	15 arcsec	Star tracker
Bus Voltage	24 V	
Power	120 / 30 / 20 W	Peak / Orbit Average / payload average
Downlink rate	100 Mbit/s	X-Band Transmitter

As can be seen KR1 is able to generate more than 20W average for the payload, host a high performance payload computer (1.4 Gbit/s raw data rate) and a 100Mbits/s X-Band down link.

Bus Block Diagram

The satellite bus of Kent Ridge 1 is a complex device. It is composed of a number of BST in-house developments as well as equipment from partner companies. As it can be seen in Figure 10 KR1 follows a star topography for the Bus. Furthermore the payloads and the bus function of the satellite is strictly separated.

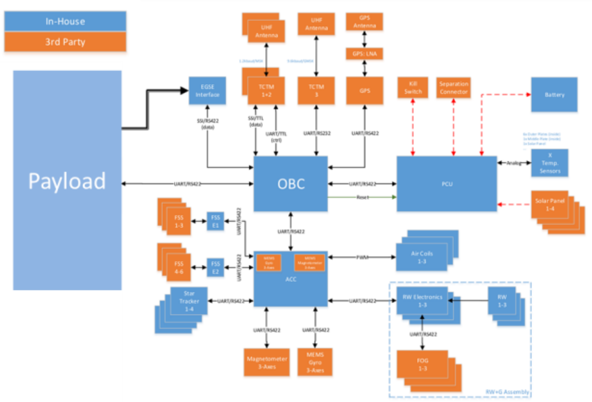

Figure 10: Bus Block Diagram

TRAINING PROGRAM

Kent Ridge 1 is build alongside a comprehensive training program that will enable NUS to build small satellites on system level based on the LEOS platform after the completion of the program. Seven Trainees from NUS currently undergo training both by BST and its educational partner the TU Berlin. In a first step basic space training is given by online lectures of TU Berlin. Afterwards, starting in October 2014 the trainees will join the BST team for integration of the KR1 satellite. In parallel satellite design courses and hands on training will be given. In parallel to the delivery of KR1 a second satellite in parts and pieces will be delivered to NUS. These satellite components have FM level and can be used to build the second satellite based on KR1 in Singapore.

Figure 11: NUS Trainees and BST Key Personnel

The trainees of the KR1 program can be seen in Figure 11.

OUTLOOK

Kent Ridge 1 is an advanced micro satellite carrying hyper spectral payloads. It is jointly built by a team of National University of Singapore and Berlin Space Technologies, leveraging on FTR technique developed by DSO National Laboratories. KR1 has three mission aspects: environmental monitoring, technology demonstration and small satellite system training. The special filter that enables the mission was designed by DSO National Laboratories of Singapore and was already successfully tested on ground and air based campaigns. After the launch, the mission operation and data processing will be handled by the Centre of Remote Imaging, Sensing and Processing (CRISP) of NUS. The mission has successfully passed CDR in End Feb 2014, and its progress is on-track towards scheduled launch window in Q4 2015. It will be piggyback to a PSLV rocket from ISRO for the launch.

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