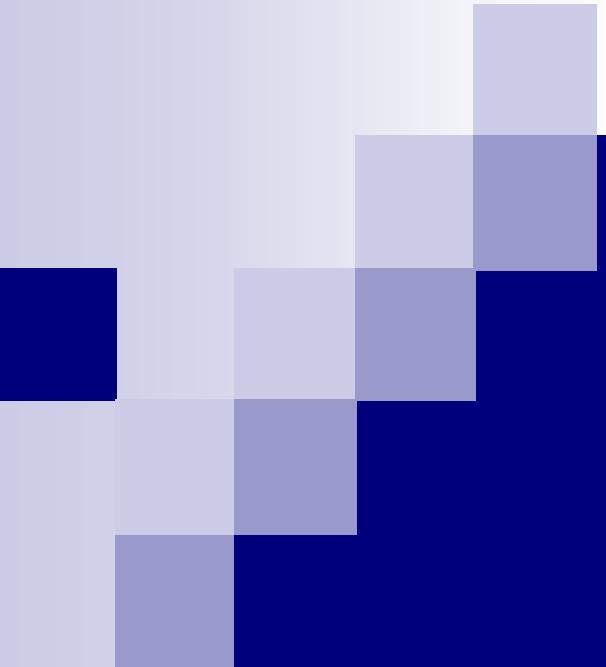


**Next Generation Microprocessors for Space Applications -
Round Table - 11 - 13 September 2006, ESTEC**



High-Performance Computing for Disaster Monitoring On Board Small Satellites

Tanya Vladimirova
Siti Yuhaniz
Guoxia Yu



Alex da Silva Curiel, Simon Prasad
David Cooke, Tim Plant
Adam Baker, Philip Davies



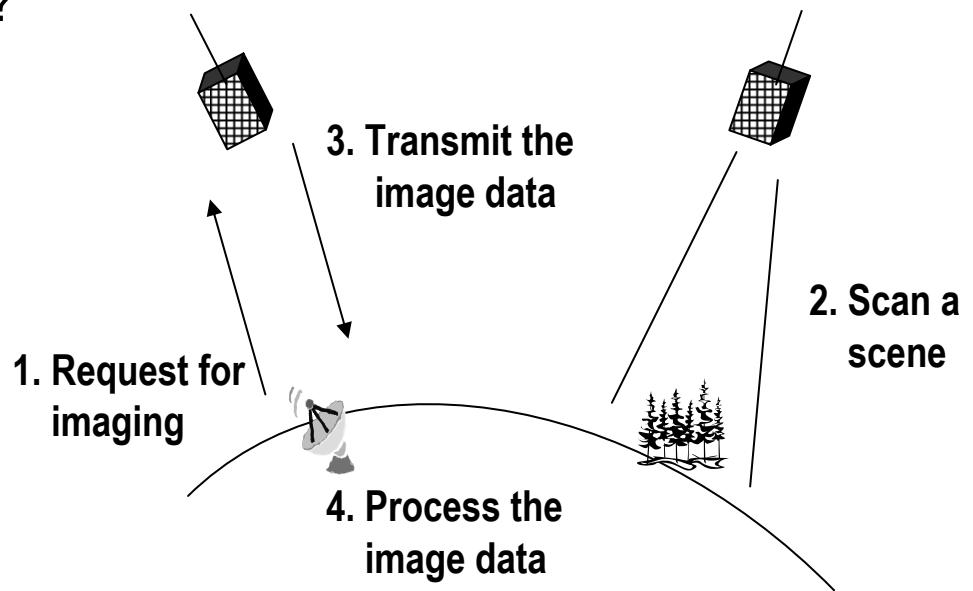
Department of Electronic Engineering, University of Surrey

Outline

- Introduction
 - A Typical Data Capture
- An Automatic Change Detection System
- Performance Evaluation
 - Registration
 - Change Detection Algorithms
 - Flood Detection Methods
 - Compression Algorithms
- Conclusions

Introduction

- What is involved in a data capture?
- How can we maximise on useful data?
 - Remove redundant information in an individual image
 - Do not transmit images with insignificant changes

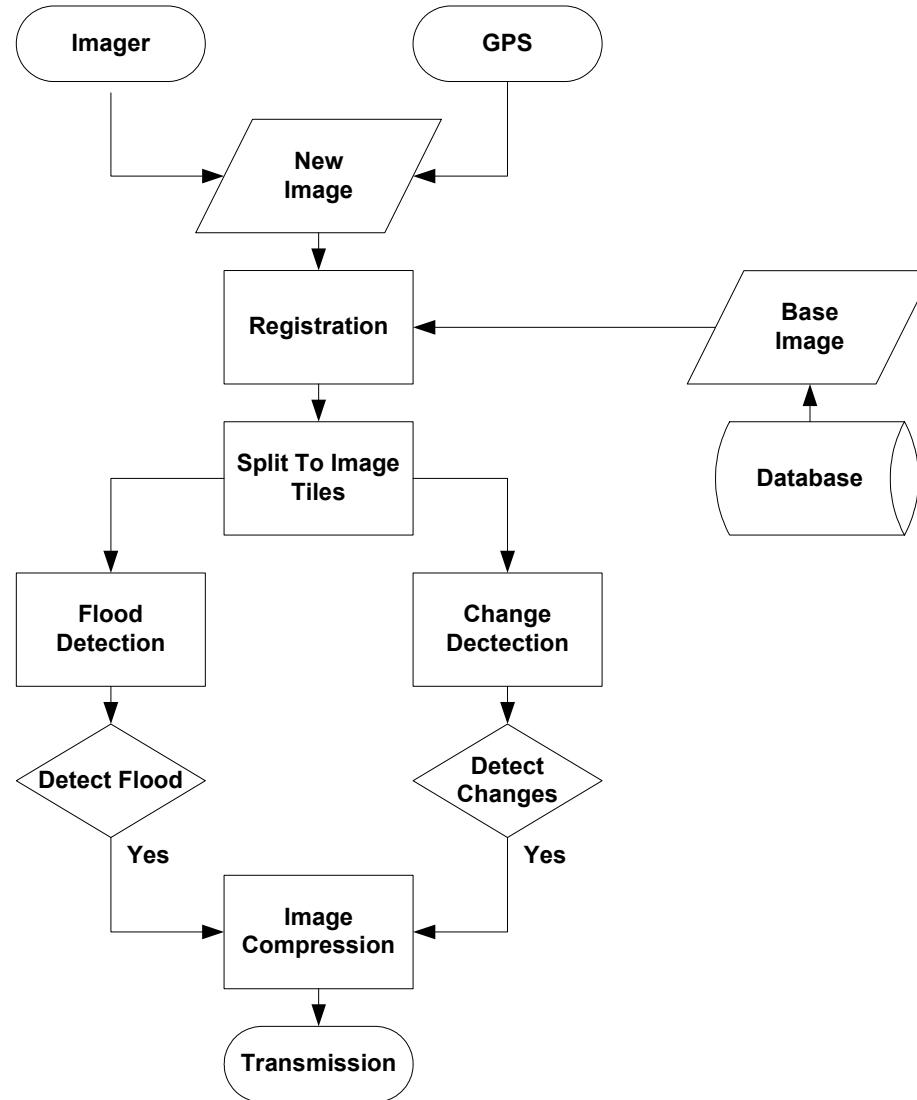


How Can We Detect Change?

Automatic Change Detection System (ACDS)

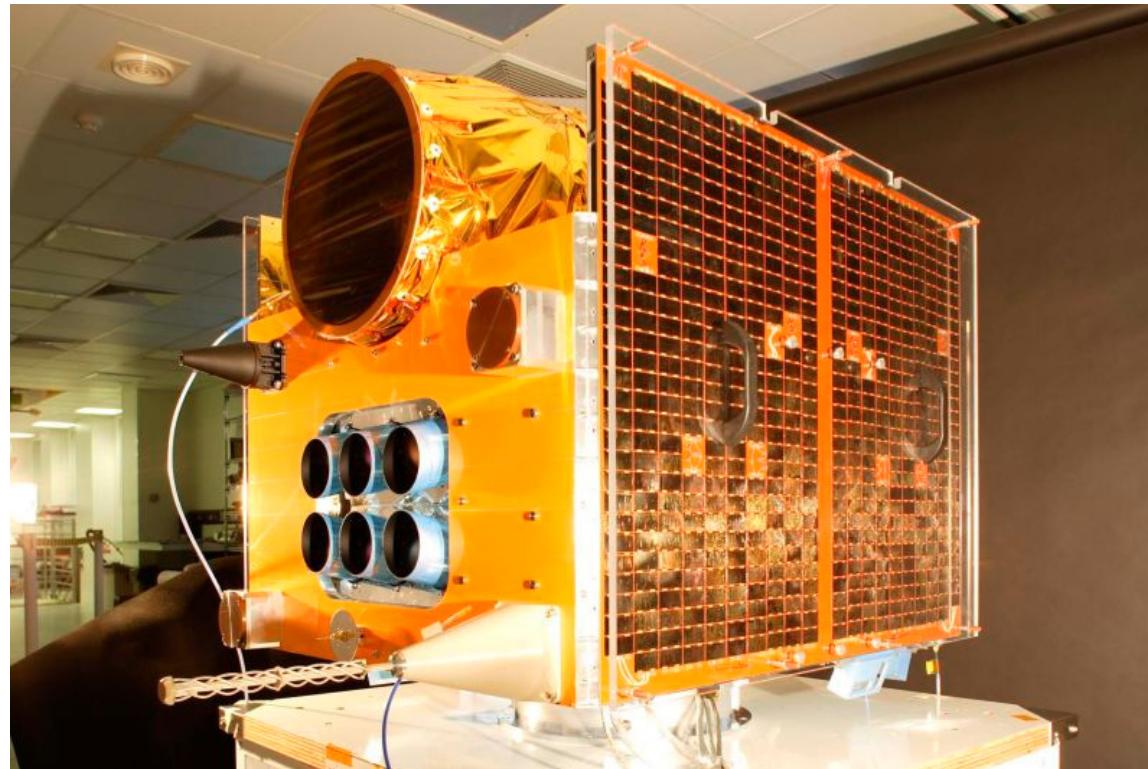
- Image is captured and time stamped.
- Pre-processing is carried out
 - Radiometric correction.
 - Registration with reference image.
- Image is tiled.
- Flood / Change Detection
- Image Compression
- Transmission

What about the hardware and software in these blocks?



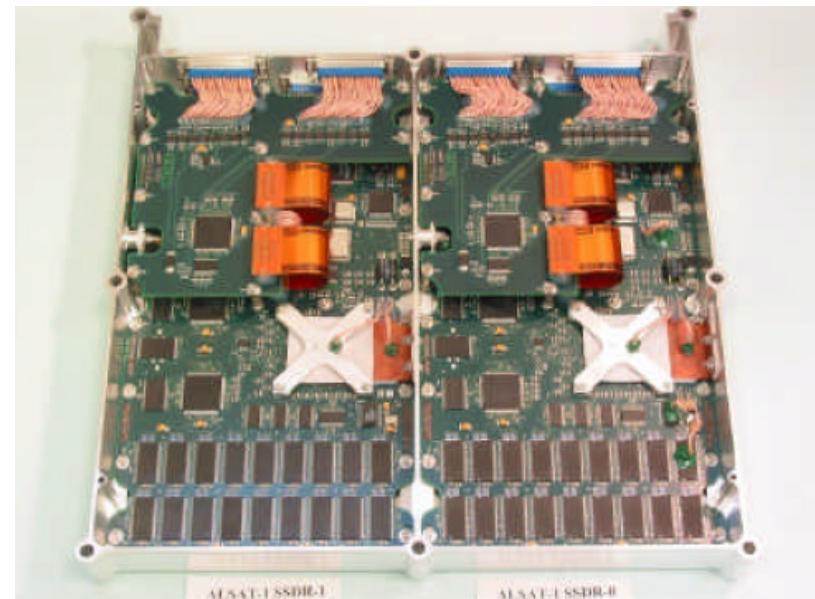
SSTL – In orbit units

- Data Storage
 - 120 Gbytes Non-volatile
- High performance processing
 - 3840 MMAC Processor



DMC Standard Data Recorder

- SSDR (MPC8260) - 280 MIPS at 200Mhz



Solid State Data Recorder (MPC8260)
of the SSTL DMC Satellite Platform

What is SSC's role?

- Develop and analyse an automatic change detection system for the purpose of flood monitoring
- Investigate possible algorithms.
- Test the **fault tolerance** and **error resilience** of software and develop methods to prevent faults.

Areas of Interest

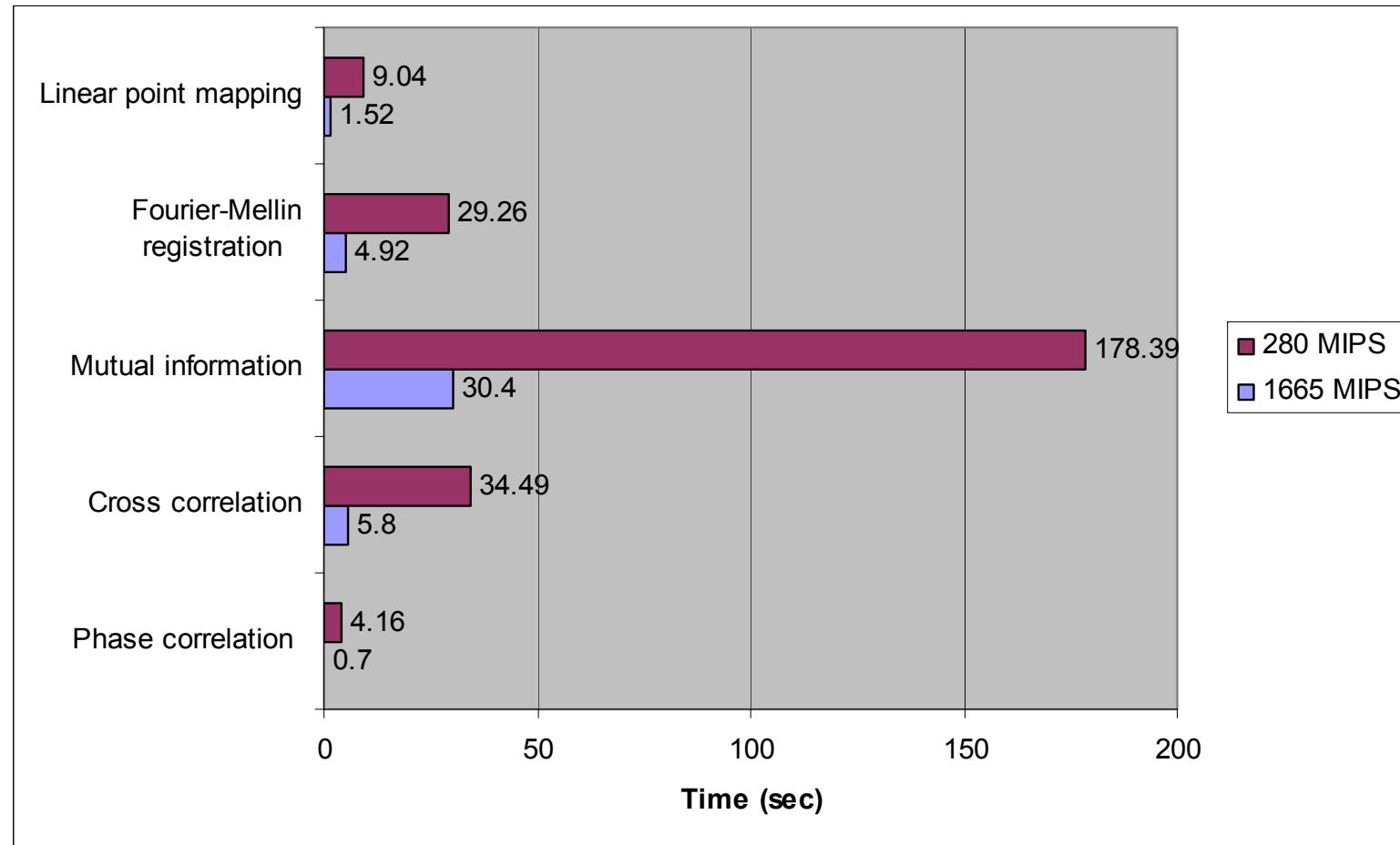
- Radiometric and geometric on-board correction of sensor signals
- Bi-temporal change detection so that only specified change data are transmitted
- Thematic on-board classifiers for disaster warning and monitoring
- Data compression
- Encryption

On-Board Image Registration

- Several image registration algorithms were selected as the candidate methods for this processing block:
 - phase correlation,
 - cross correlation,
 - mutual information and
 - point mapping.
- The first three image registration methods (**phase correlation, cross correlation and mutual information**) are based on the pixel information.
 - They have the advantage of being automatic but very limited in terms of recovering geometric distortions.
- **Point mapping** is a good way to do image registration but finding suitable control points can be a problem.



Image Registration

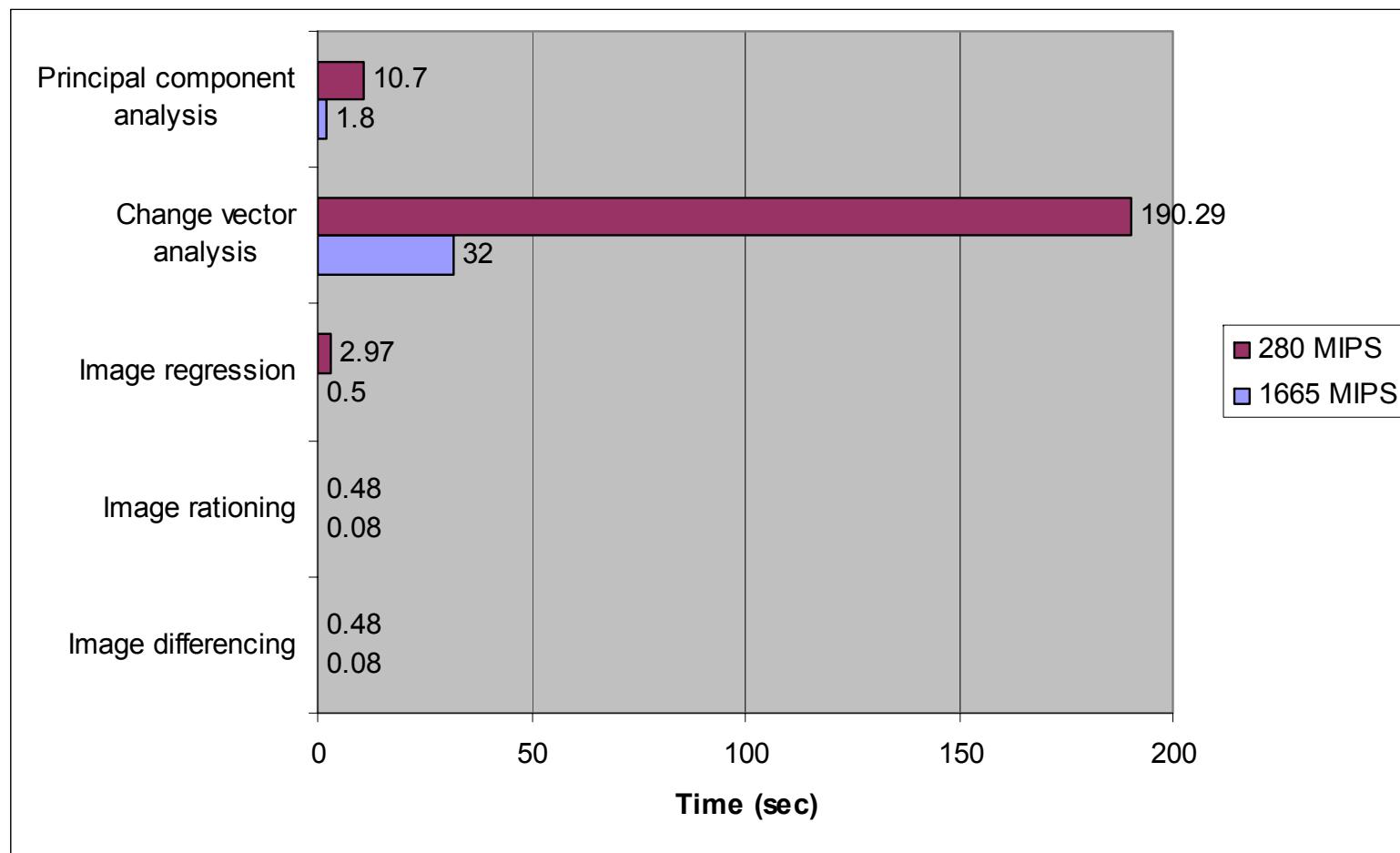


Estimated processing time on a pair of 500x500 pixels image on the test processor (1665 MIPS) and targeted processor (280 MIPS)

Algorithms for Change Detection

- **Image differencing** - this method subtracts each pixel value in one image to another pixel value in the second image to get the change image.
- **Image ratioing** - the change image is generated by dividing one image by the other
- **Image regression** - image regression adheres to the general regression formula.
- **Change vector analysis (CVA)** - a multivariate change detection technique, which processes spectral and temporal aspects of the image data.
- **Principal component analysis (PCA)** - the purpose of PCA is to define the number of dimensions present in the data set and to fix coefficients which specify the positions of the set of uncorrelated orthogonal axes pointing in the directions of greatest variability in the data.

Change Detection Performance

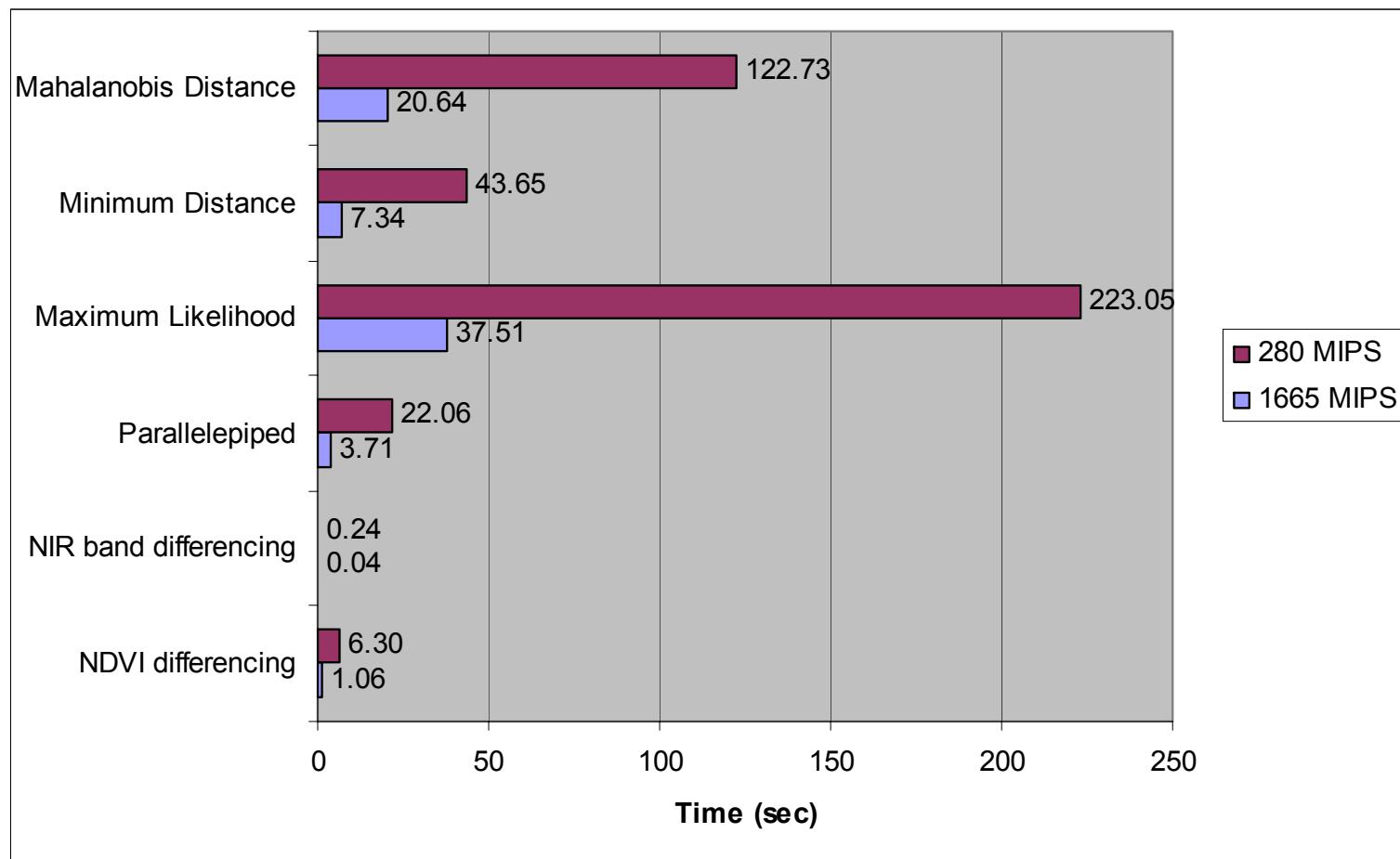


Estimated processing time on a pair of 500x500 pixels image on the test processor (1665 MIPS) and targeted processor (280 MIPS)

Flood Detection Methods

- Two flood detection methods and four classification methods have been investigated for the purpose of designing a flood-monitoring ACDS
- Near Infrared (NIR) differencing method
- Normalised Difference Vegetation Index (NDVI) differencing method
- Classification methods
 - Parallelepiped,
 - Maximum Likelihood,
 - Minimum Distance and
 - Mahalanobis Distance

Flood Detection



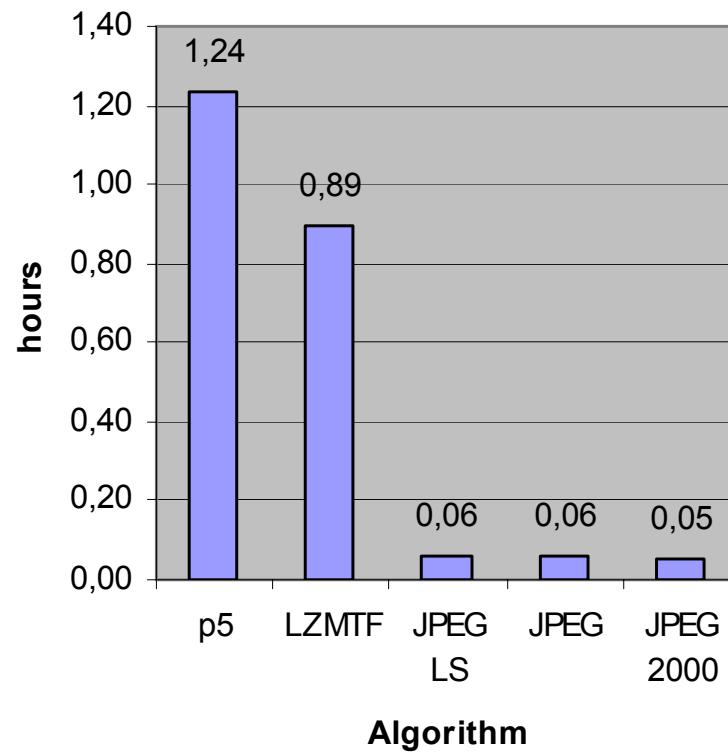
Estimated processing time on a pair of 500x500 pixels image on the test processor (1665 MIPS) and targeted processor (280 MIPS)

Compression Algorithms

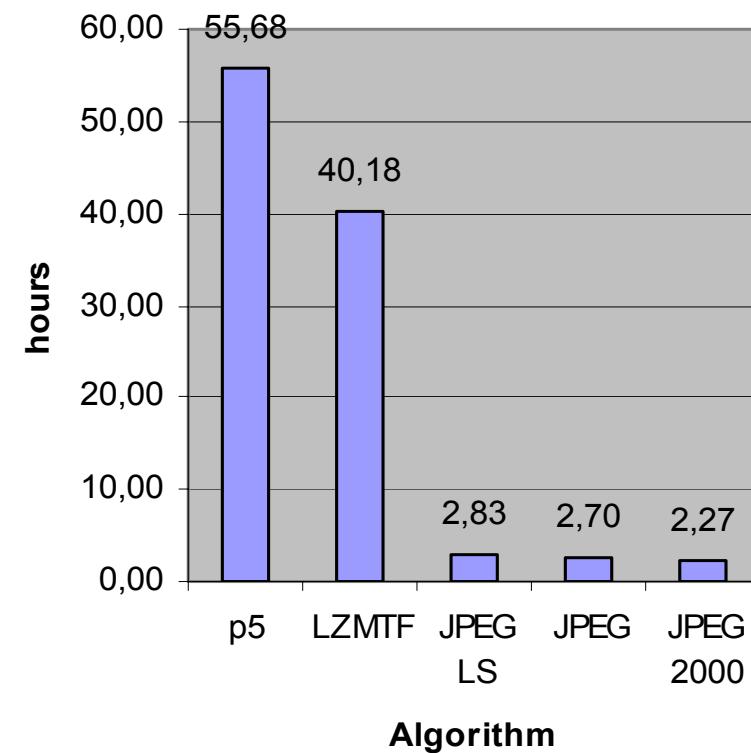
- The p5 program - a text compression program that interprets the entire incoming data as a bit stream. It employs a Neural Network (NN) to predict pixel probability.
- The move-to-front Lempel-Ziv (LZMTF) algorithm is based on the Lempel-Ziv algorithm invented in 1977 (LZ77)
- JPEG lossless is an implementation of the low complexity lossless compression (LOCO I) algorithm for image processing, which complies with the JPEG standard.

Execution Time

Time to Process 1GByte with the Pentium 4 at 2.8 GHz in Hours (8550 MIPS)



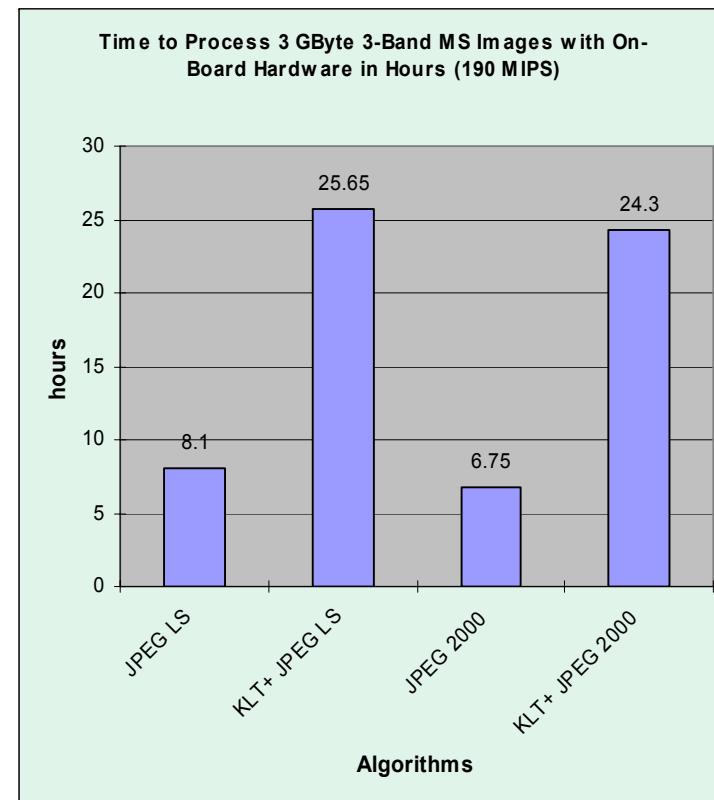
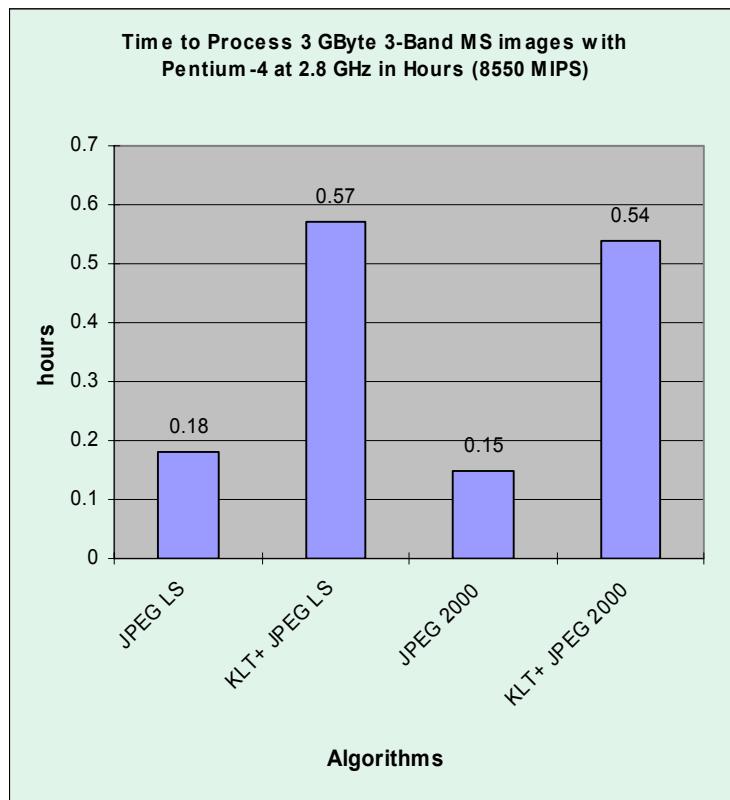
Time to Process 1GByte with the On-Board Hardware in Hours (190 MIPS)



Compression Algorithms

- The following algorithms performed best with regard to execution time and image distortion:
 - JPEG-LS for lossless image compression
 - JPEG-2000 for lossy image compression
- The Karhunen-Loeve Transform (KLT) is considered theoretically the optimum method to spectrally de-correlate multispectral (MS) imaging data.
- KLT improves the compression ratio when the spectral bands are more than 4, which is expected in future missions
- Experimental results were carried out to evaluate the execution time for JPEG-LS and JPEG-2000 in conjunction with KLT.

Execution Time and KLT

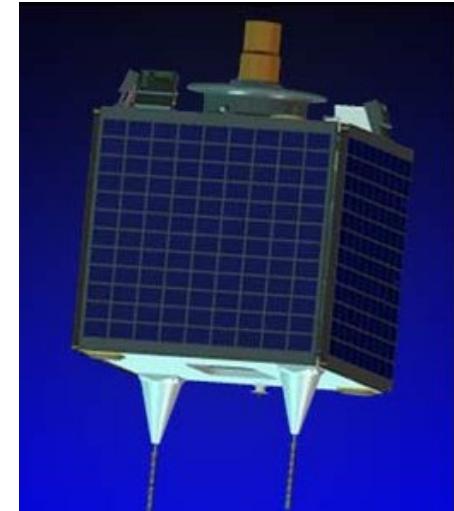


Conclusions

- Suitable algorithms for on-board registration, change detection, flood detection and compression of multispectral images were evaluated in terms of required computing power.
- The evaluation results show that high-performance computing and parallel processing are required on board small satellites if these techniques are to be utilized in orbit.

Disaster Monitoring Constellation (DMC)

- Developed by SSTL, UK
- 5 micro-satellites in a constellation
 - AISAT, UKDMC, NigeriaSAT, BilSAT
 - Beijing-1 – launched 27 October 2005
- Each satellite carrying 32 m GSD 3-band multispectral imagers providing 600x600 km max image size
- Daily revisit of any place on Earth
- International collaboration



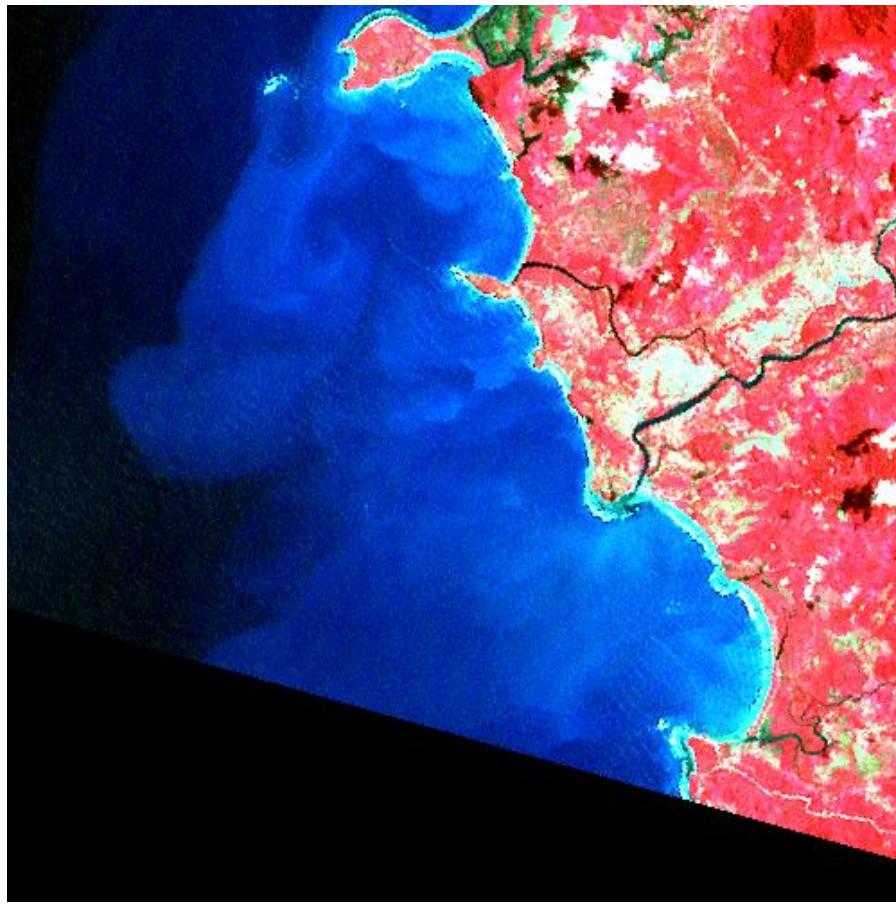
Test Images

- Tsunami disaster on 26 December 2004

<i>Place Name</i>	<i>Date Acquired</i>	
	<i>Before Flood</i>	<i>After Flood</i>
North Sumatra, Indonesia	15 Aug 2001	4 Jan 2005
West Thailand	15 Jan 2002	27 Dec 2004

- Some areas were inundated for a couple of hours, others for a few days, and some lost to the sea
- The algorithms should detect flooding on the date of acquired image

Test Image 1 – Landsat



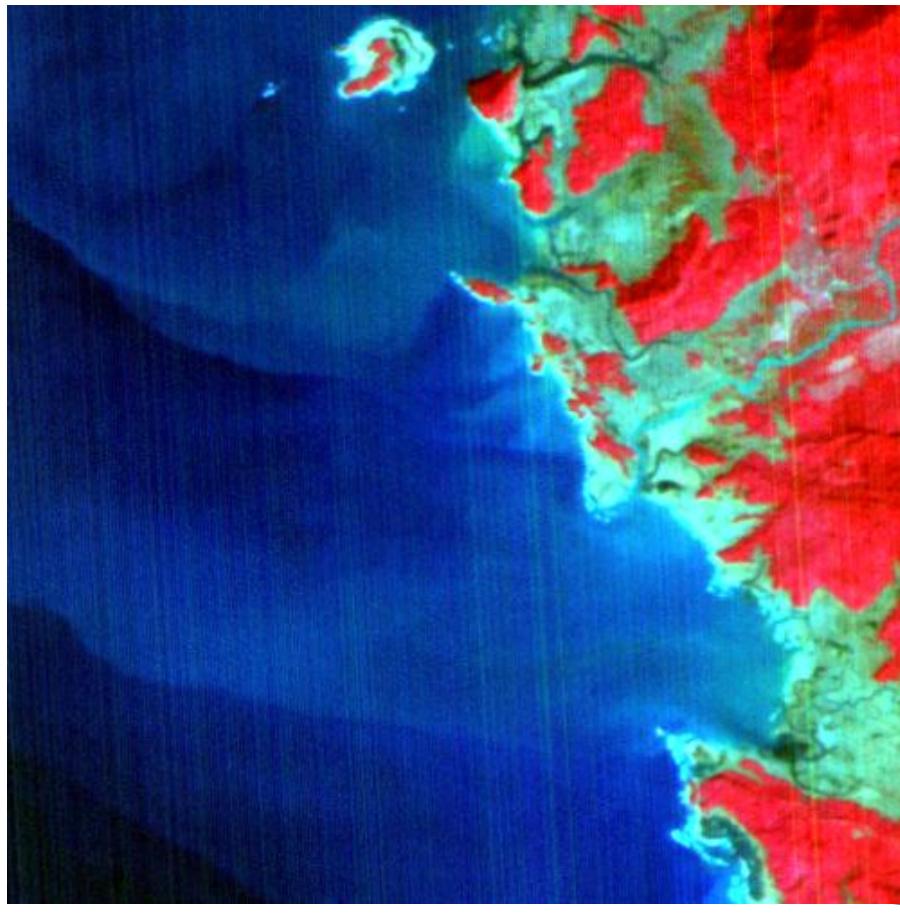
North Sumatra, 15 August 2001

September 2006

ESA Round Table

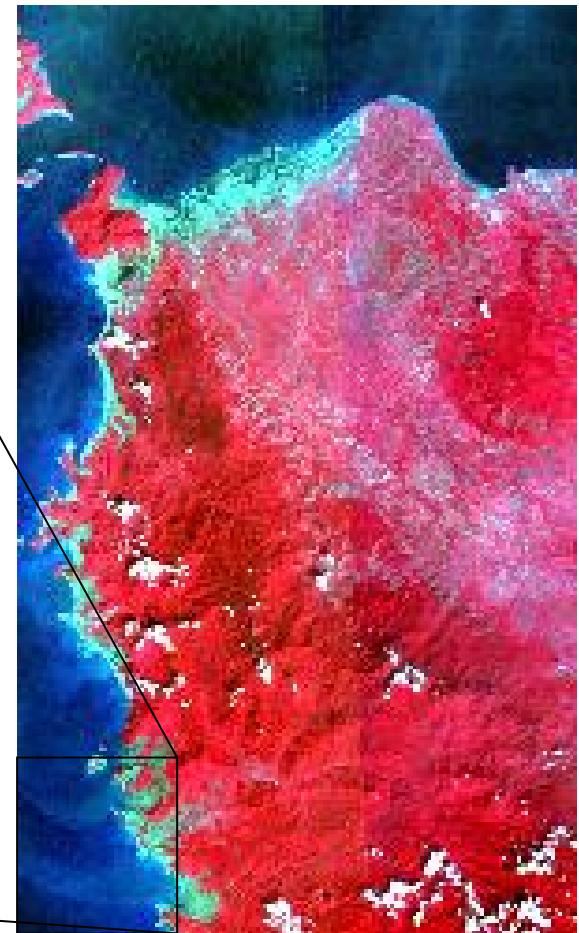
22

Test Image 1 – UKDMC



North Sumatra, 4 January 2005

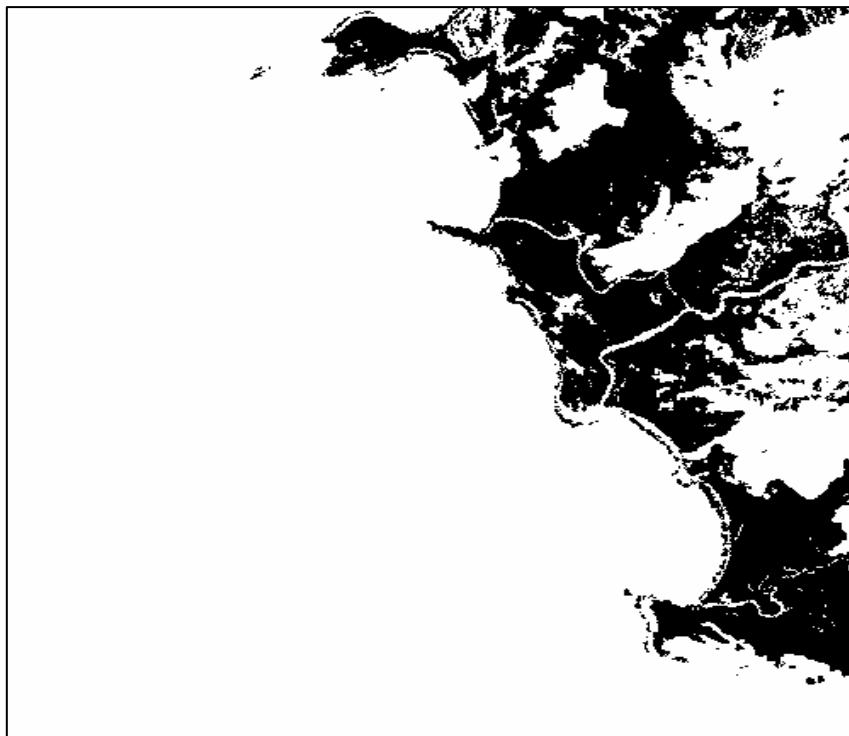
September 2006



Courtesy of SSTL

ESA Round Table

Results from NIR Differencing



- Black colour indicates flooded areas
- The NIR differencing methods gives the lowest commission error

Test Image Set for Image Compression

- The test image set is composed of 17 unprocessed SSTL DMC multispectral satellite images with total size of 3.5 GByte.
- These image files were divided into tiles, which were then decomposed into 3 components, corresponding to the individual optical wavebands
 - green,
 - red,
 - near infrared.
- The components of each tile were stored in three grey-scale files with binary Portable Grey Map (PGM) format.