INSTITUTO SUPERIOR DE CIÊNCIAS DO

TRABALHO E DA EMPRESA

Utilização da Norma JPEG2000 para codificar proteger e comercializar Produtos de Observação Terrestre

Hélder Carvalho

DISSERTAÇÃO DE MESTRADO EM ENGENHARIA INFORMÁTICA E DE TELECOMUNICAÇÕES

Apresentada ao Instituto Superior de Ciências do Trabalho e da Empresa como requisito parcial para obtenção do grau de Mestre em Engenharia Informática e de Telecomunicações.

Orientador:

Prof. Dr. Miguel Salles Dias

Outubro de 2006

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Aplicações como, detecção de mudanças no terreno, monitorização planetária, detecção e gestão de desastres, têm necessidades prementes que necessitam de vastas quantidades de dados. Estes dados estão presentemente a ser capturados por uma multiplicidade de instrumentos e sensores de observação terrestre, que originam uma enormidade de dados que necessitam de ser armazenados processados e acedidos de forma a se tornarem úteis – por exemplo, a ENVISAT acumula anualmente varias centenas de terabytes de dados.

Esta necessidade de recuperar, armazenar, processar e aceder introduz alguns desafios interessantes como o espaço de armazenamento, poder de processamento, largura de banda e segurança dos dados só para mencionar alguns.

Estes desafios são muito importantes no mundo tecnológico de hoje. Se olharmos, por exemplo, ao número actual de subscritores de ISP (Internet Service Providers) de banda larga nos países desenvolvidos podemos ficar surpreendidos com o facto do número de subscritores desses serviços ainda não ser uma maioria da população ou dos agregados familiares. Nos países subdesenvolvidos o quadro é ainda mais negro não só do ponto de vista da largura de banda mas também de todos os outros aspectos relacionados com Tecnologias da Informação e Comunicação (TICs).

Todos estes aspectos devem ser levados em consideração se se pretende que um serviço se torne o mais abrangente possível em termos de audiências. Obviamente a protecção e segurança dos conteúdos é um factor extra que ajuda a preservar possíveis valores de negócio, especialmente considerando industrias tão onerosas como a Industria Espacial.

Esta tese apresenta e descreve um sistema que permite, não só a codificação e descodificação de diversos produtos de observação terrestre para formato JPEG2000 mas também o suporte de alguns requisitos de segurança identificados previamente que permitem, á Agência Espacial Europeia e a outros serviços relacionados com observação terrestre, a aplicação de politicas eficientes de acesso seguro a produtos de observação terrestre, permitindo até o aparecimento de novas forma de comercialização de produtos de observação terrestre através da Internet.

Outubro de 2006

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TRABALHO E DA EMPRESA

Using JPEG2000 Norm to Code, Protect and Trade Earth Observation Products

Hélder Carvalho

MASTER OF SCIENCE THESIS IN COMPUTERS AND TELECOMUNICATIONS ENGINEERING

Presented to Instituto Superior de Ciências do Trabalho e da Empresa as a partial requisite to obtain the degree of Master of Science in Computers and Telecommunications Engineering.

Adviser:

Prof. Dr. Miguel Salles Dias

October 2006

Using JPEG2000 Norm to Code, Protect and Trade Earth Observation Products

Hélder Carvalho

Instituto Superior de Ciências do Trabalho e da Empresa

Adviser: Prof. Dr. Miguel Salles Dias

Applications like, change detection, global monitoring, disaster detection and management have emerging requirements that need the availability of large amounts of data. This data is currently being capture by a multiplicity of instruments and EO (Earth Observation) sensors originating large volumes of data that needs to be stored, processed and accessed in order to be useful – as an example, ENVISAT accumulates, in a yearly basis, several hundred terabytes of data.

This need to recover, store, process and access brings some interesting challenges, like storage space, processing power, bandwidth and security, just to mention a few. These challenges are still very important on today's technological world. If we take a look for example at the number of subscribers of ISP (Internet Service Providers) broadband services on the developed world today, one can notice that broadband services are still far from being common and dominant. On the underdeveloped countries the picture is even dimmer, not only from a bandwidth point of view but also in all other aspects regarding information and communication technologies (ICTs).

All this challenges need to be taken into account if a service is to reach the broadest audience possible. Obviously protection and securing of services and contents is an extra asset that helps on the preservation of possible business values, especially if we consider such a costly business as the space industry.

This thesis presents and describes a system which allows, not only the encoding and decoding of several EO products into a JPEG2000 format, but also supports some of the security requirements identified previously that allows ESA (European Space Agency) and related EO services to define and apply efficient EO data access security policies and even to exploit new ways to commerce EO products over the Internet.

October 2006

Acknowledgements

I would like to thank all my colleagues in the HICOD2000 project and on ADETTI especially to my friends Carlos Serrão, for the guidance and motivation and António Serra for the advices and for keeping the pressure, helping me push forward with this thesis.

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I would like to thank my family for all their support, my parents' in-law for their trust and affection and especially to my parents and my brother for continuing to love, care inspire and believe in me after all this time.

A final word to my wife, thank you for your continuous love, your warm laughter and for being so bounded by heart, when we still weren't by law. For all the loving, caring, comforting, helping and building, during all these years.

Lisbon, October 2006

Hélder Miguel Maia de Carvalho

To Ilda, Álvaro, Nelson

And Marisa

After one look at this planet any visitor from outer space would say
"I want to see the manager."

William S. Burroughs (1914 - 1997)

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1. INTRODUCTION

1.1 Introduction

According to the United Nations (UN)[RD-1], the term "remote sensing" means the sensing of the Earth's surface from space by making use of the properties of electromagnetic waves emitted, reflected or diffracted by the sensed objects, for the purpose of improving natural resources management, land use and the protection of the environment.

Images acquired by remote sensing satellites offer a unique perspective of the Earth, its resources, and the human impact upon it. In little more than a decade, satellite remote sensing has proven itself, as a commercial industry, to be a cost-effective source of valuable information for numerous applications including urban planning, environmental monitoring, agricultural management, oil exploration, market development, real estate sitting, disaster control and management and many others [RD-2].

The value of satellite images and the information derived from them are obvious. They provide the user with an overhead look at objects and features on the Earth’s atmosphere, surface or underground and help him in understanding relationships among those features that might not be as apparent when viewed from ground level. Of course, the ‘remote’ aspect of satellite imaging also enhances this value by enabling the user to see things halfway around the globe without ever leaving his office [RD-2].

The practical value and applicability of satellite imagery continue to grow as advanced new satellites are launched and join those already in orbit. With more satellites on the way, imagery is available in an increasing — and often confusing — selection of scene sizes, spectral resolutions, revisit frequencies, and spatial details [RD-2]. While these new space-based sensors make imagery more useful than ever, they also present users with greater challenges in choosing the right imagery.

Remote sensing applications require efficient implementation of the compression algorithms for very large images, interactive tools for data selection and personalization of the content. Content security is also a relevant aspect to be considered [RD-3] [RD-4], whose images have intrinsic value that must be protected both in terms of privacy protection, conditional access and Business to Business (B2B) and Business to Consumer (B2C) e-commerce business processes

[RD-5] [RD-6]. The study of these two problems and the creation of a system that could combine a solution for both problems, were the two key objectives of this work.

The image compression standard JPEG2000 brings not only powerful compression performance but also new functionality unavailable in previous standards (such as region of interest, scalability and random access to image data, through flexible code stream description of the image). The compression performance using JPEG2000 overcomes JPEG, with the drawback of a much higher complexity. For software and hardware platforms, the complexity of JPEG2000 is believed to be around ten times higher than JPEG [RD-5] [RD-6]. This is a crucial problem for its adoption for real-time systems such as earth observation satellites.

JPEG2000 introduces flexibility in the transmission of images with a progressive improvement in image quality. The standard supports the capability of transmitting arbitrary regions of interest inside the image, with greater fidelity than others. It is also capable of providing lower resolution and/or low quality representations of an image for quick viewing, by only decoding a selected portion of the total transmitted image. JPEG2000 is able to code a wide range of images, from black and white, to grayscale, full-colour (24 bit/pixel) images, to hyper-spectral space and planetary images that typically contain several dozen-color bands [RD-5] [RD-6]. Another important feature is the ability to provide error-resilience during transmission; that is to say, an error during progressive transmission will only affect a small portion of the final image rather than the whole image. As it stands currently, an image than has been compressed to the same final size with JPEG2000 and JPEG, will show much less visible artifacts with the first, due to the increased ability of wavelets to represent an image at low resolution than with the later, where the individual 8x8 blocks become noticeable for large compression ratios. The two formats behave similarly for high quality reproductions but JPEG2000 increasingly outperforms JPEG as more and more compression is introduced, while maintaining the same visual fidelity [RD-5] [RD-6]. The issue of secure access to satellite imagery, is sensitive, since they contain value that image producers and providers, think that requires protection. An effective way for protecting, not only digital images, but also other types of digital content, is to use a Digital Rights Management solution, which deploys protection and security, and controlled access to content and which is particularly relevant in the digital content e-commerce.

1.2 Background and Objectives

The work presented on this dissertation was performed during a project called HICOD2000 [RD-7] conducted with the European Space Agency (ESA) [RD-6] to study the applicability of the new image-encoding standard – JPEG2000 - to Earth Observation (EO) products [RD-9]. This dissertation also specifies the system that was developed with ESA to allow, not only the encoding and decoding of EO products, but also the secure trading of these products over the Internet on a specific portal.

The work performed was based on EO data captured by the ENVISAT [RD-13] [RD-11] and SPOT5 satellites. Each of the ENVISAT instruments products [RD-11] was examined during the project to determine its suitability for JPEG2000 coding [RD-9] [RD-12], and as a result several have been identified. Each of these identified products is coded in an ESA proprietary format called Payload Data Segment (PDS) [RD-14]. This data format does not feature any compression and so can usually result in quite large product files, not very suitable for an easy Internet transfer.

Figure 1: ENVISAT satellite (left) and SPOT5 satellite (right) being prepared for fairing [RD-6]

The SPOT5 vegetation products, considered for the project, are stored in the Hierarchical Data Format (HDF) format [RD-16], having the same large file problem as the ENVISAT products. The challenges and objectives of this dissertation is to present a way that not only compress this products into a more internet and archive friendly format without losing any information but also a way to protect and secure these products.

Another of the focus of this dissertation was the distribution model of the EO products. The method ESA uses to delivers their EO product to its clients is outdated in terms of security, but it's adequate for its business model. Currently the final client selects the EO product (or products) from the ESA EOPortal [RD-16], and after payment the user has two options to obtain the products, the user can download the EO product from a File Transfer Protocol (FTP) site

(authenticated by username and password), or the product is sent to the user in a CD-ROM by mail. The problem with this method is that the products are sent to the client completely unprotected and uncompressed, jeopardizing ESA as a service provider.

This dissertation explores the possibility to integrate a better security model and at the same time empower ESA, or ESA EO product retailers, to develop new business models based on this new, more secure paradigm.

1.3 Chapter organization

This document is organized as follows:

- **Chapter 1 - Introduction** - This is the present chapter where a brief description of the practical value and applicability of satellite imagery is presented as well as the main objectives of this dissertation.

- **Chapter 2 - Earth Observation Products Business Model** - This chapter will be dedicated to the explanation of the various business model possibilities for the proposed system and to the analysis of the business initiatives related to Earth Observation.

- **Chapter 3 - Enabling Technologies** - In this chapter the author will discuss the key technologies that enabled the development of the HICOD2000 system.

- **Chapter 4 - Earth Observation Products** - In this chapter the author will introduce the several ESA EO products that were studied in order to test its compatibility to a JPEG2000 conversion, specifically the products of the SPOT and ENVISAT satellites.

- **Chapter 5 - System Requirements -** This chapter will be dedicated to present a systemic approach to the author proposed system. Here it will be discussed its key components and respective functionalities as well as the requirements for each of the system components.

- **Chapter 6 - System Architecture -** the HICOD2000 system is a combination of different components, it is the architecture of each of this components as well as the overall architecture that will be discussed on this chapter.

- **Chapter 7 - System Validation and Usability evaluation -** In this chapter, the author will analyze the work performed to test and validate the proposed solution and how a usability test on the developed prototype was designed and conducted, as well as its results. User feedback will be described, as well as the main pointed problems.

- **Chapter 8 - Conclusions and final remarks** - This chapter will be dedicated to conclusions and final remarks. It will also be discussed possible future lines of research in this area.

1.4 Invited Presentations

Until this date, this work has already spawned some papers on international conferences, proving the continuing interest of the scientific community in this area. Publications of this work follow:

Dias, J.M.S., Carvalho, H. , “JPEG2000 Flexible Compression and Secure Access to EO Products using SSE and Grid Computing”, in SSE 2005 Workshop service support environment ESRIN Frascati, Italy, March 17, 2005

Carvalho, H., Serrão, C., Serra, A., Dias, J.M.S., “Accessing Earth Observation data using JPEG2000”, in COMPIMAGE: Computational Modeling of Objects Represented in Images: Fundamentals, Methods and Applications, Coimbra, Portugal, October 20-21, 2006

Carvalho, H., Serrão, C., Serra, A., Dias, J.M.S., “Flexible access to ESA Earth Observation data using JPEG2000 and DRM”, in “ESA-EUSC 2006 Conference on Image Information Mining for Security and Intelligence", EUSC Torrejon air base, Madrid, Spain on November 27 and 28, 2006

Carvalho, H., Serrão, C., Serra, A., Dias, J.M.S., “ENVISAT Products Secure Browsing in Mobile Clients Using JPEG2000 Interactivity Protocol”, ENVISAT Symposium, April 2007 (submitted)

Carvalho, H., Serrão, C., Serra, A., Dias, J.M.S., “Using JPEG2000 Norm to Code, Protect and Trade Earth Observation Products”, International Journal for Computation Vision and Biomechanics (IJCV&B), invitation made by the editorial board on November 2006, to be submitted December 2006.

2. EARTH OBSERVATION PRODUCTS BUSINESS MODEL

2.1 Introduction

This chapter will allow the identification and definition of the Business Model as well as its components. It will also be used to identify business opportunities that could be used for the exploitation of the proposed system.

According to White a Business Model concept can be resumed and defined as a "set of planned activities that may result in profit in a given market" [RD-18]. By using the same line of action and taking advantages of the unique qualities of the Internet and the World Wide Web, the proposed system becomes part of a type of Business Model denominated e-Commerce Business Model, specifically a B2B Business Model.

The following table presents the main different types of B2B models [RD-19] introducing which are the profitability models of each of them.

B2B Business Model	Description	Variation	Profitability Model
Marketplace/Exchange (B2B Hub)	An electronic market where suppliers and clients can perform electronic transactions.	Vertical	Transaction Payment Model
		Horizontal	Transaction Payment Model
E-Distributor	Connect directly businesses to each other		Sales Model
B2B Service Provider	Trades online business services to other companies	Traditional	Services Sales Model
		ASP	Renting Fees Model
Matchmaker	Connects businesses to each other		Transaction Payment Model
Infomediary	Collects information about consumers and sells them to costumers	Audience Broker	Information sale model
		Lead Generator	Referring Tax Fee Model

Table 1: B2B Electronic Commerce Models

From the analysis of this table, the author found the most adequate B2B business models to be Electronic Marketplace, E-Distributor or B2B Service Provider. Obviously the final choice between this three will have to take into consideration the final solution to the problem and its possible applicability to each of the models.

On section 2.2 a number of projects that have similar Business Model approaches or that are in related to the trading of Earth Observation products will be presented.

Next on section 2.3 Business Model Exploitation and Profitability Model alternatives will be explained.

Finally, section 2.4 is reserved for Business Model final considerations and conclusions.

2.2 Earth Observation Business Initiatives

The EO business examples identified during the preliminary stages of the project are based on two regions, Europe and United States and are interconnected with these two regions space operational institutions, ESA and the National Aeronautics and Space Administration (NASA) [RD-19].

2.2.1 European Business Initiatives

In Europe, the main driver for Earth Observation activities is the European Space Agency, through its Earth Observation Program based on the European Space Research Institute (ESRIN) [RD-20] centre. The identified systems are the Multi Application Support Service System (MASS) project [RD-21], an ongoing ESA activity that aims to become a central point for the EOPortal services, including the satellite catalogues Information on Earth Observation (INFEO) [RD-22] and Open Distributed Information Systems & Services on Earth Observation (ODISSEO) [RD-23].

2.2.1.1 MASS project

Figure 2: MASS prototype Portal entrance page[RD-21]

Background

One of the most interesting ongoing initiatives is the MASS project. MASS is a General Support Technology Program (GSTP) project funded by the ESA/ESRIN. The current consortium is composed by the following companies: SPACEBEL (Belgium – leader), Intecs HRT (Italy), Telespazio (Italy), Kongsberg Spacetec (Norway), GIM (Belgium) and VITO (Belgium).

The pre-operational activity started in April 2001 and it is foreseen to terminate at the end of 2003. This activity aimed at building the system and validating the concept of integrating services in a workflow. It is already established that an operational phase of the project will start in the beginning of 2004. An in-depth description of this system is provided on section 4.6

2.2.1.2 INFEO - INFormation on Earth Observation

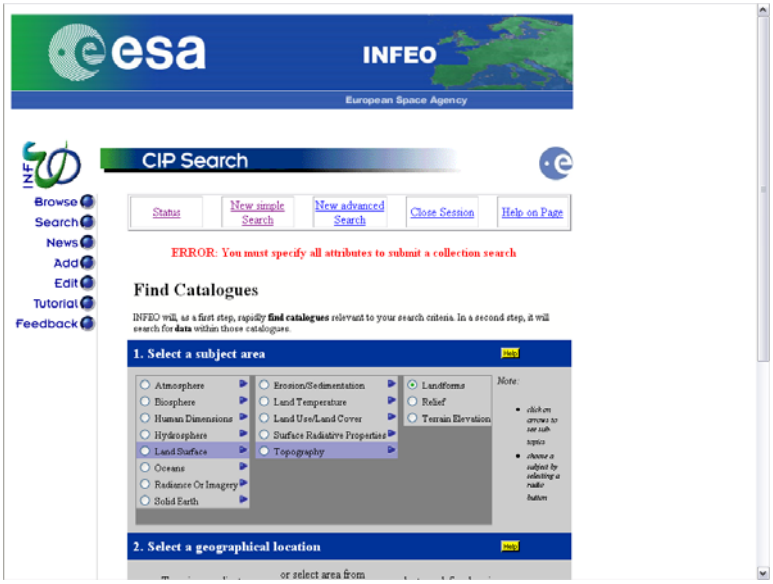


Figure 3: INFEO Search page [RD-23]

Background

INFEO has been developed in the framework of the Centre for Earth Observation (CEO) program/project for and by the Space Applications Institute (SAI) of the Joint Research Centre of the European Commission and is operated by the ESA/ESRIN in Frascati (Italy) since 2001.

Description

INFEO offers the possibility to search for satellite images and EO related data held in remote catalogues worldwide. One can search multiple catalogues simultaneously from a single user interface, without knowing where the images are held, or even the names of the catalogues, simply specifying the subject area of interested and INFEO will identify the most appropriate

catalogues for the search. INFEO also offers access to some non-space data catalogues, such as European Environment Agency's (EEA's) Catalogue of Data Sources (CDS), which contains ancillary information.

INFEO uses the Catalogue Interoperability Protocol (CIP) to carry out catalogue searches. All the other EO related information is held locally on the system. INFEO has adopted CIP which is essentially a set of communication rules, which specifies how data products can be searched and retrieved from several data catalogues at the same time.

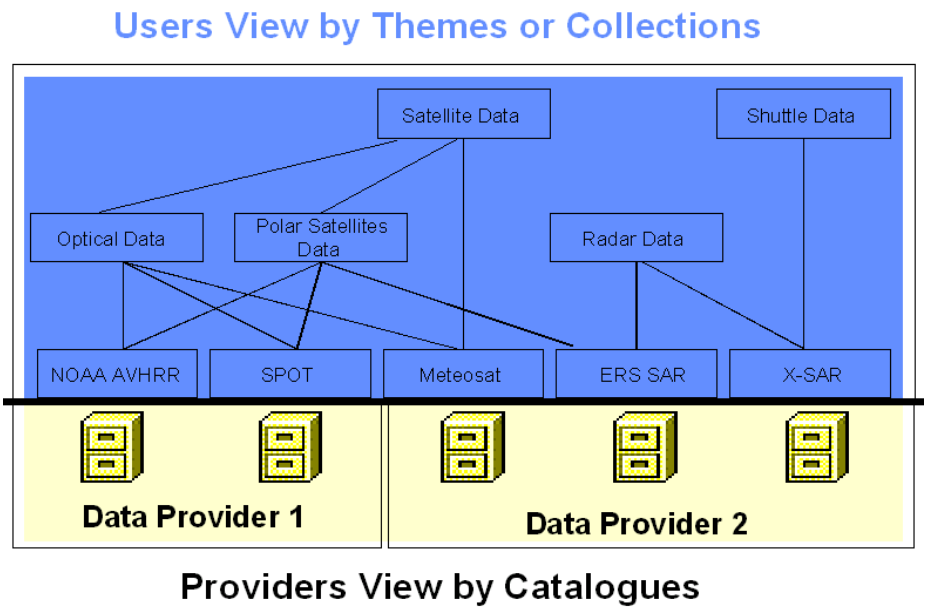


Figure 4: Logical view of INFEO

INFEO offers users the following services:

- One user interface to browse and search many remote catalogues
- Search across catalogues using the same generic, rather than catalogue specific, terms
- Simultaneous search of multiple catalogues worldwide
- Access to both space and non-space catalogues
- The possibility to view these catalogues by themes or collections

Data provider catalogues are connected to the INFEO system by means of a CIP gateway. This is simply a piece of software that translates terms from catalogue specific terminology to CIP and vice versa. It is offered free-of-charge from the CEO. The INFEO system is now a fully integrated part of the EOPortal [RD-17] catalogues system.

2.2.1.3 ODISSEO - Open Distributed Information Systems & Services on Earth Observation

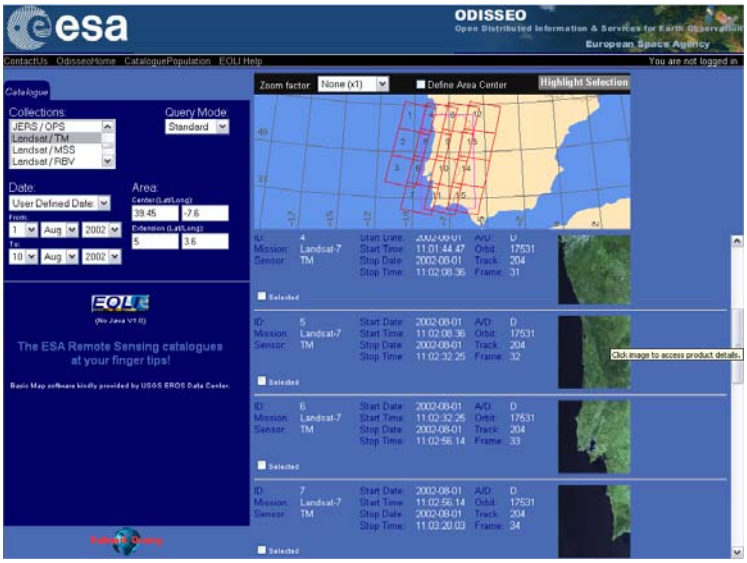


Figure 5: ODISSEO search page

Background

ODISSEO is the collection of all Information System Servers which provide ESA user services, such as the Envisat User Services Facilities, the ESA Multi-Mission User Information Services (MUIS) and the ERS Central User Services (CUS). It started operating in the beginning of the year 2000.

Description

ODISSEO allows users and S/W applications to access the ESRIN Earth Observation Multi-mission system through its single harmonized EOLI interface. Users may collect information relative to catalogue browse products. Only Authorized Users (currently Principal Investigators in the frame of AOs or Category 1 projects) are capable of ordering products using EOLI, in accordance with both the ESA Distribution Policy and the agreements between ESA and the various Commercial Distributors. These products are usually provided in non-standard formats.

2.2.2 US Initiatives

US Earth Observation efforts are mostly tied to the Landsat [RD-25] satellites. The first was launched in 1972 with two Earth-viewing imagers - a return beam vidicon and an 80 meter multispectral scanner (MSS). Landsat 2 and 3, launched in 1975 and 1978 respectively, were configured similarly. In 1984, Landsat 4 was launched with the MSS and a new instrument called the Thematic Mapper (TM). Instrument upgrades included improved ground resolution (30 meters) and 3 new channels or bands. Landsat 5, a duplicate of 4, was launched in 1984

and even today after 19 years – 14 years beyond its 5 year design life - is still returning useful data. Landsat 6, equipped with a 15 meter panchromatic band, was lost immediately after launch in 1993.

Landsat 7 is the newest satellite in the family, was launched in April 1999, and is equipped with the Enhanced Thematic Mapper Plus (ETM+), which replicates the capabilities of the Thematic Mapper instruments on Landsats 4 and 5. It also has a 5-year design lifespan, which terminates in 2004.

The US Government has decided that it no longer wants to build, launch and operate Landsat satellites. It does, however, want access to Landsat-type data. For this end, it is procuring a successor to Landsat under the Landsat Data Continuity Mission (LDCM). This calls for Landsat quality data to be provided freely to the Government, while allowing for higher-quality data to be available only commercially.

Satellite EO data is distributed on two public operated sites: the United States Geological Survey (USGS) EarthExplorer [RD-26] and NASA's EOS Data Gateways.

In imaging terms, there are also two commercial operators of imaging satellites in the visible and near infra-red bands: Space Imaging (which owns the Ikonos satellite) and DigitalGlobe (which owns the Quickbird satellite).

2.2.2.1 USGS EarthExplorer

Introduction

The US Geological Survey's Earth Explorer data discovery and access tool [RD-26] is the replacement information system for the Global Land Information System (GLIS), which was disconnected at the end of April 2003. It has been operational since March 2000.

Description

The EarthExplorer system uses metadata queries, and users can search multiple inventories from a single query, save the metadata in the Federal Geographic Data Committee (FGDC) Geo profile, and place orders securely using credit cards.

Another feature is the ability to establish standing requests that query for data based on the user's criteria and send e-mail messages whenever a match occurs. The user enters their criteria once and then receives metadata describing query matches entirely outside the system. Earth Explorer does not contain any data within the interface itself, but it portrays datasets and allows users to place orders for those data. Generally, Earth Explorer lists and describes remotely sensed and cartographic data. Examples of the remotely sensed datasets include Landsat Multispectral Scanner (MSS), Corona, and aerial photographs. Cartographic holdings include Digital Line Graphics and Digital Raster Graphics (DRG).

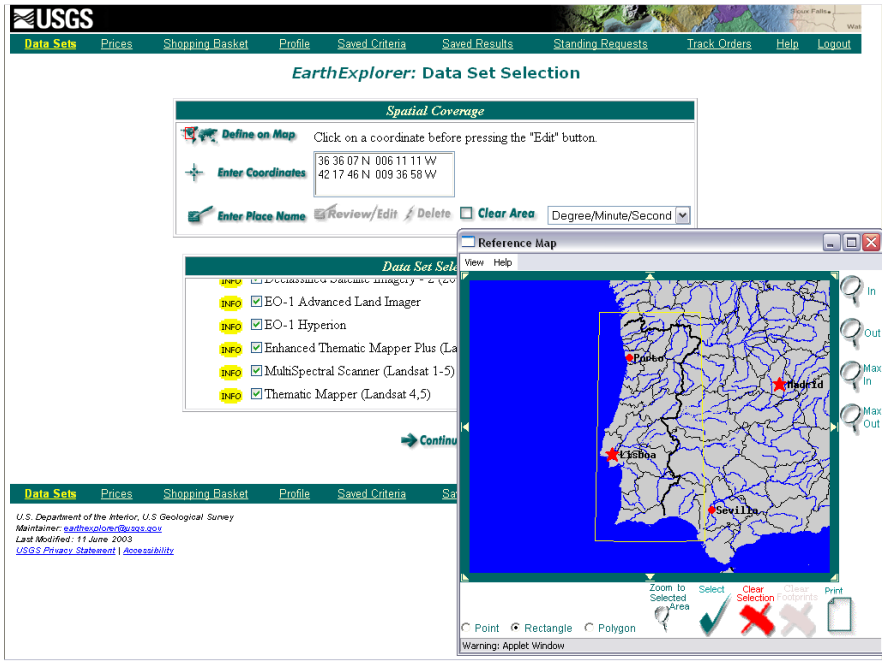


Figure 6: EarthExplorer search page [RD-26]

Other EO-related systems administered by the USGS are:

- US Global Visualization Viewer, containing Landsat7 ETM+, Landsat 4/5 TM and Terra ASTER images.

- DataPool (http://edcdaac.usgs.gov/tutorial/datapool.html), containing ASTER data from the Terra mission, and MODIS data from the Terra and Aqua missions.

2.2.2.2 EOS Data Gateway

Introduction

From all the Earth Observation missions NASA has active today (Terra, Aqua, Landsat, SeaStar), there is a vast amount of information being produced. In order to handle all this data, NASA created the EOS Data and Information System (EOSDIS). EOSDIS holds more than 1450 data sets and manages extraordinary rates and volumes of scientific data. The Terra spacecraft, for instance produces 194GB raw data per day (over 850GB with higher level processing), while Landsat 7 produces 150GB per day. Users can access all this data through the EOS Data Gateway (EDG) [RD-28]. This system started in 1994 as EOSDIS v0 IMS. EDG is spread across the world in the following locations:

- ASF - Alaska USA

- CCRS - Ontario Canada
- DLR - Germany
- CSIRO - Australia
- EDC - South Dakota USA
- GHRC - Alabama USA
- GSFC/NASA - Maryland USA
- IRE-CPSSI - Russia
- ISA-MEIDA - Israel
- JPL - California USA
- LARC - Virginia USA
- NASDA - Japan
- NSIDC - Colorado USA
- ORNL - Tennessee USA

Description

The purpose of the EDG is to facilitate Earth science research through improved access to existing data and provide the search-and-order service for the EOSDIS Core System (ECS). The ECS was developed to accommodate the archival and distribution of the tremendous amount of data being received from a new series of EOS instruments, the first of which were launched on the Terra satellite in December 1999.

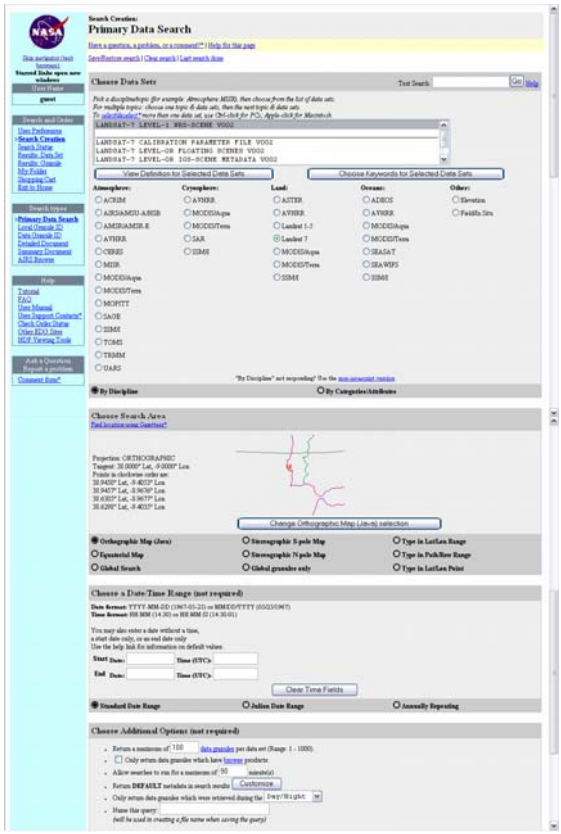


Figure 7: EDG search page [RD-28]

The EDG provides a consistent view of more than 1,300 data products held at several EOSDIS and international data centers. The system allows users, including those without specific knowledge of the data, to search science data holdings, retrieve high-level descriptions of data sets and detailed descriptions of the data inventory, view browse images, and place orders for data products. This service is accessible over the Internet via the World Wide Web.

2.2.2.3 Space Imaging (Ikonos)

Introduction

Ikonos [RD-29], launched on September 24th 1999, was the first commercial high-resolution satellite, collecting 1-metre panchromatic and 4-metre multispectral imagery. Ikonos has a repetitive, circular, sun-synchronous, near-polar orbit guaranteeing full coverage of the Earth. The sensor can be inclined to acquire imagery up to 700 km either side of the track (maximum incidence angle 26º), thus giving the satellite the capacity to revisit, albeit with different sensor angles and resolution, any area on the earth on average every 1.5 days (data resolution up to 2 meters). An average 2.9 day revisit can be achieved for 1 meter resolution data in an area that covers up to 300 kms either side of the track (angle +/- 10°).

Product and Services

There are six levels of Ikonos imagery products, determined by the level of positional accuracy:

- Geo: Map Oriented
- Reference: Ortho-Rectified without Ground Control Points (GCPs) - 25m horizontal accuracy
- Map: Ortho-Rectified without GCPs - 12m horizontal accuracy
- Pro: Ortho-Rectified, may require GCPs - 10m horizontal accuracy
- Precision: Ortho-Rectified, with GCPs and a Digital Elevation Model (DEM) - 4m horizontal accuracy
- Precision Plus: Ortho-Rectified, with GCPs and a DEM - 2m horizontal accuracy.

In addition to Ikonos satellite imagery, Space Imaging provides imagery from the Indian Remote Sensing (IRS) satellite, Landsat-7 and aerial digital photography.

2.2.2.4 Digital Globe (QuickBird)

Introduction

QuickBird [RD-29] from DigitalGlobe is the highest-resolution commercial remote sensing satellite now operating, offering imagery from 61 cm resolution.

Launched October 18, 2001, QuickBird collects multi-spectral and panchromatic imagery concurrently, and Pansharpened products in natural or infrared colors are offered. Both strip

and area mode imaging are supported. Strips up to 10 scenes in length (165 km) can be collected in a single pass.

QuickBird provides the widest swath, largest on-board storage, and highest resolution of any current commercial satellite. QuickBird is designed to efficiently and accurately image large areas with industry-leading geolocational accuracy.

The QuickBird satellite was launched on a Delta II rocket from Vandenberg AFB, California on October 2001.

Products and Services

QuickBird products are available in three processing levels; (1) Basic Imagery with the least amount of processing (geometrically raw), designed for customers desiring to process imagery into a useable form themselves, (2) Standard Imagery with radiometric and geometric correction, and delivered in a map projection, and (3) Orthorectified Imagery with radiometric, geometric, and topographic correction, and delivered in a map projection.

In addition to QuickBird imagery, DigitalGlobe distributes SPOT products and services to the US.

2.3 Exploitation and Profitability Model alternatives

There were some exploitation that were taken into consideration, first of all the case of the B2B Service Provider where a business, through its EO products, supplies services directly to other businesses, which incorporate EO products in their value chain. Another possibility is an E-Marketplace where a business will use an E-Marketplace technology to provide an infrastructure for several EO products providers (including or not the E-Marketplace business owner) and EO products acquirers to browse, search, negotiate and trade imaging products. A final scenario could be a variant of the previous example, where a single EO product provider uses a Portal for trading its own content to several business clients.

The ultimate objective of any Business Model is to be profitable. In this chapter first section several profit models were introduced which are used in most of the existing electronic commerce business today. A specific profitability model may be used separately or together with other profitability models (for instance, it is usual to find electronic commerce business models that use more than one profitability model (sales and publicity)). Therefore in this section the different hypotheses that our system business model may use to make profit are presented.

One of the most obvious profitability models is to use paid publicity at the System E-Marketplace/Portal. This publicity may be exploited by using a fixed rate system to charge by each of the banners placed in the E-Marketplace, or it may use a more flexible rate depending on the number of times this publicity banner is displayed (page views). The most common choice would be to use the publicity model together with other profitability alternatives (more

related with our system core business – the trading of EO products). This profitability model can be considered either in the Portal or E-Marketplace case.

Taking into account the system core business, perhaps one of the most reasonable profitability models to consider is the subscription model. Therefore, since the E-Marketplace will join a common framework, both EO suppliers and EO clients, each of these clients will need to pay a fixed subscription rate in order to access the E-Marketplace that will allow them to obtain EO products from several sources. This model may even be somewhat more flexible, in the sense that the subscription fee may depend on the EO products and source the customer wants to be able to access. For instance, if customer A wants to be able to access to products from supplier Y and EO products type X, it will pay a subscription fee Z, but if he wishes to access extra types it will need to pay an higher fee. This profitability model can be considered either by the different EO products suppliers or by the E-Marketplace/Portal exploiting company.

Another profitability model possibility is the transaction fee model. This model presupposes that each of the E-Marketplace suppliers establishes his own prices, considering the supplied products, and that the E-Marketplace owner charges a fixed transaction fee for each of the products actually traded through the E-Marketplace framework. This model presents the flexibility of each of the EO suppliers in the E-Marketplace to able to establish the pricing models, the supplying conditions the usage terms and other for each of the product types commercialized, independently of the E-Marketplace owner. Although this solution has clear advantages in terms of business flexibility it is harder to implement in terms of technology. This is the most adequate profitability model if EO suppliers are not the owners of the E-Marketplace.

All this profitability models were presented to our client ESA and a final decision on what model to adopt is still under discussion. The strongest possibility at the moment is the adoption of the transaction fee model since it's currently the practice norm for the majority of the services available at ESA service providers' portal where the HICOD2000 service was integrated.

2.4 System Business Model

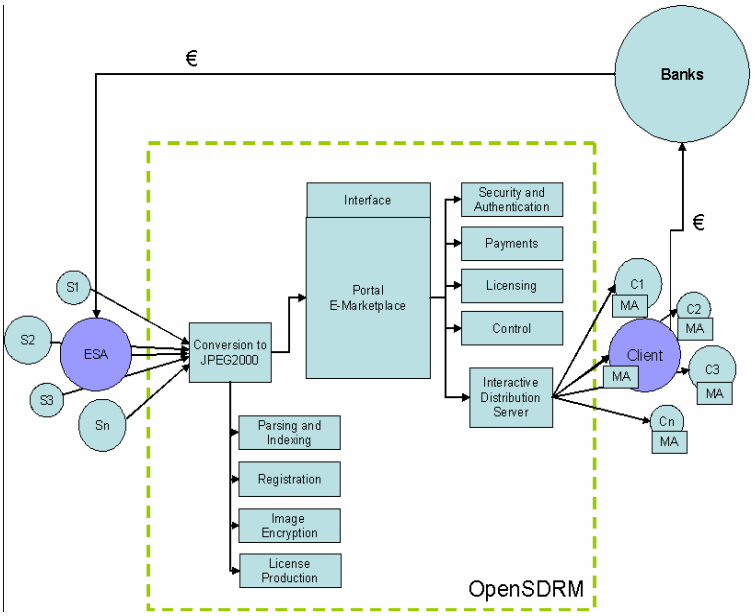
According to the market opportunity analysis and as demonstrated on the introduction of this chapter the most appropriate type of Electronic Commerce to be exploited by the HICOD2000 system is the B2B type. The Business model needs to have the following characteristics:

- The Business model chosen connects electronically a set of different image suppliers (starting by ESA) and different corporate clients;
- Both the suppliers and the clients connect through an electronic marketplace, and establish among them the business conditions to conduct business. Among these conditions, some examples are presented next:

- Pricing models;
- Types of data;
- Special supplying conditions;
- Licensing rules;
- Usage rules;
- Payment types;
- … Among others.

- Includes all the functionalities of conversion between the supplied EO products raw format to the image format choose by HICOD2000 (JPEG2000), protection/security, Digital Rights Management (DRM), electronic payments and others.

The following image (Figure 8) describes graphically the Business Model that will be adopted by HICOD2000. Next a detailed presentation about the business model is provided.



Note:

S1,Sn-EO Products Suppliers

C1,Cn-EO Products Clients

MA-Media Application

Figure 8: The HICOD2000 Business Model

The possibility for this Business Model to be integrated with the MASS project is a reality. In fact, three different integration possibilities were considered between the MASS and the HICOD2000 Business Model:

- MASS could act as a HICOD2000 Business Model EO products supplier;
- MASS could be part of the HICOD2000 Business Model as EO products Portal/eMarketPlace/B2B Service Provider;
- The HICOD2000 Business Model can be integrated in MASS, extending its functionalities.

The goal of the electronic marketplace is to establish the connection among several EO image providers and several clients (both businesses of individuals). A specific case that needs also to be considered is the portal. In the present case ESA is the company that exploits the system. To provide part of the functionalities displayed within this business model the author used the Open Source DRM (OpenSDRM) [RD-31] reference architecture. OpenSDRM was the solution found to provide the framework needed to protect and secure the EO products. By doing so it provides the following features:

1. Conversion to JPEG2000: this is the process that receives the EO product raw data from suppliers in a proprietary format and using the appropriate tools converts to JPEG2000 format. This process extensively uses the low-cost massively parallel processing (LCMPP) architecture to use High Performance Computing architectures to deal with large amounts of data and convert them to JPEG2000. Additionally this process also has to deal with the following:
    - Parsing and Indexing: the JPEG2000 file is parsed and indexed to allow a much more efficient interactive navigation experience to the users;
    - Registration: the new created JPEG2000 file is registered on an authority which assigns unique identifiers to images as well as image metadata;
    - Image encryption: encrypts/scrambles the JPEG2000 image according to a set of options and parameters, that will protect the image code-stream from unauthorized users;
    - License Production: production of a “generic” license that will hold the appropriate cryptographic parameters used for encrypting/scrambling the image code-stream.

2. Publishing and trading at the E-Marketplace: this process organizes the EO products in a structure to make it available to the E-Marketplace users in a later stage. The organization of the image data will conform to the typology of the EO products as well with geographic information. This E-Marketplace will (may) connect several EO products suppliers and several final clients (individuals or companies). The E-Marketplace will provide to clients a set of functionalities that include the following:

- Security and Authentication: the E-Marketplace clients will have to register and authenticate in the E-Marketplace through a strong authentication mechanism. For simplicity, the HICOD2000 E-Marketplace will use single-sign on mechanisms.

- Payments: the customers will process payments through payment gateways that will clear the payment methods presented. The payment gateways will have to connect to a real payment infrastructure in order to achieve a real financial flow from the customer to the service provider and content owner.

- Licensing: this process corresponds to the production of a specific license that defines the user access and control over the image data. Each license is produced to a given customer identifier and to each EO.

- Control: a set of control mechanisms that will be implemented in the client browser part that will be used to enforce content protection control on the user side. This includes the image interactive browser and viewer as well as the Intellectual Property Management and Protection (IPMP) tool and the licenses that contain the rules applied to each content. This will help to make the system more flexible, allowing for instance that a customer might for instance browse/navigate through a low detail level EO product without actually buying it, choose the appropriate piece of visual data that really interests him, download it with the level of detail chosen and paying for it, without ever compromising all the image data.

- Interactive Distribution Server: an interactive distribution service will be used to allow the user to browse through a possible new level (Level 3) of EO products described with the JPEG2000 format. This interactive distribution server will work seamlessly distributed over a data grid, providing abstraction at the user side of the content source.

As explained previously the presented Business Model architecture (Figure 8) was mapped on a technological architecture called OpenSDRM (to manage the digital rights associated with EO products, to handle electronic payments, etc) that will be described on the next sections.

For the specific case of the HICOD2000 project the OpenSDRM architecture features described on point 2 are not fully available, thus the final decision was to integrate the HICOD2000 service on ESA service provider's portal. A final decision concerning the way to publish and trade the images as not been reached yet.

2.5 Conclusion

This chapter identified the HICOD2000 system Business Model and cleared how it can be exploited, identifying some of the major EO business initiatives and explained how they operated in the market, and how they could, to some extent, compete with the proposed solution.

Having in mind the previously identified choices, this chapter also specified the major options in terms of profitability models, which could be applied to the Business Model.

The HICOD2000 Business Model success depends on the deployment of several key technologies: DRM, JPEG2000, and a web services platform. This set of technologies will introduce a set of flexible trading options in the Business Model, which are inexistent in the other major competitor's business models. The next chapter explains all this enabling technologies.

3. EARTH OBSERVATION PRODUCTS

3.1 Introduction

Earth Observation (EO) products may use different file formats depending on the corresponding instruments. In this chapter three different file formats are explained (PDS, HDF and PIX) along with the respective products. The PDS file format is generated by ESA ENVISAT satellite instruments, HDF is used in SPOT Vegetation EO products and the PIX file format is produced by the CASI sensor EO products. Therefore, both satellite and airborne EO products can be represented using one of these file formats.

The ENVISAT satellite operates a total of nine measuring instruments. Each of these instruments is tuned to a certain range in the used electromagnetic spectrum. The purpose of these instruments is to image the Earth under different viewing conditions or to measure physical quantities or concentrations of chemical substances.

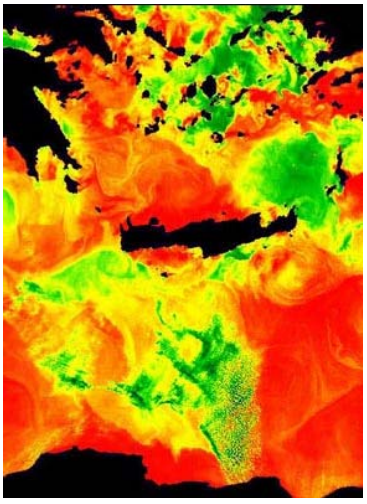


Figure 9: AATSR-derived image of Sea Surface Temperature around Crete in August 2002. The brighter the color the higher the temperature [RD-73]

Each instrument produces several categories of measurement products with increasing levels: level 0 (raw telemetry data), level 1 (engineering data, subdivided in level 1a and level 1b), and level 2 (physical measurements based on the engineering data). Additionally a browse product, containing data from level 1b or level 2 products, can be available for certain instruments for previewing with a browser application. The specifications of each of these products are included on Annex A - ENVISAT products specifications and analysis.

According to the PDS file structure and the source image data requirements for JPEG2000 compression, a methodology was developed to verify the product suitability for JPEG2000 trans-coding. This methodology was, in the development of this chapter, applied to each of the products of ENVISAT and also, using the necessary modifications, to the CASI sensor products.

The CASI sensor is a push broom imaging spectrograph covering a spectral range from 405 nm to 950 nm with 288 spectral samples. This sensor operates in 4 different modes. Each of these 4 modes of operation can be identified with a product of the CASI sensor, and represent a compromise between data recording requirements and the time to read all elements of the CASI CCD array.

3.2 PDS Product Format

ENVISAT products are coded in an ESA proprietary format called Payload Data Segment (PDS). It's an uncompressed data format. The following categories are included in each PDS coded product:

- One Main Product Header (MPH). Metadata information, common to all instruments and products;
- One Specific Product Header (SPH). Metadata information, specific of some instrument and of some product;
- Several Measurement Data Sets (MDS's). Measured data from the sensor at a specific level. Each MDS is composed of consecutive records containing measurements relative to successive time frames. For each record there is a tag with the time frame at which it was recorded;
- Several Annotation Data Sets (ADS's). Auxiliary information to the principal data in MDS's. It has the same number and structure of records of the MDS's;
- One Global Annotation Data Set (GADS). Another annotation data set with auxiliary information, referenced to all the time the instrument was in operation;

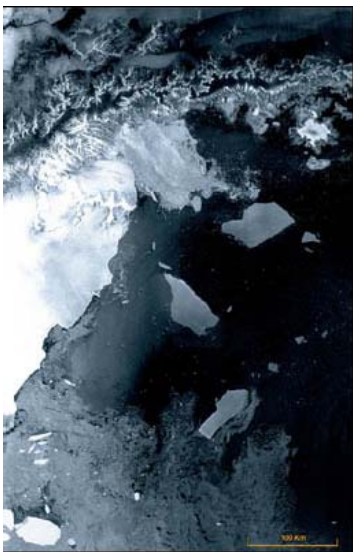


Figure 10: ASAR image showing the collapse of the Larsen B ice shelf observed on 18 March 2002 in the Antarctic [RD-74]

The parameters stored in the headers and data sets of a PDS file can have several different data types. Examples of these data type are ASCII strings, integer numbers, Boolean flags and arrays of integers or floating point numbers.

Taking into consideration the present status of the JPEG2000 standard, it is possible to order all the ENVISAT products by degree of applicability for JPEG 2000 trans-coding, from their original PDS format, using the HICOD2000 system. The author partitions the products into four categories, listed by decreasing order of applicability:

- Suitable Products: These products have an almost straightforward conversion into a JPEG 2000 format. Typically, these will be products that generate already some form of image data. A good rule of thumb to identify the best products is to check for ENVISAT instruments that provide Browser products.
- Possible Products. These products can be encoded with JPEG 2000 but do not contain image datasets. JPEG 2000 encoding becomes possible by exploiting statistical correlations among the data either along one dimension or preferably along two dimensions. Actual implementation tests have to be performed to determine if these correlations do exist and if they are of such a nature that JPEG 2000 can take advantage of them to perform efficiently.
- Doubtful Products: These are products whose status at this point, regarding JPEG 2000 trans-coding, is not clear. From a technical point of view, they can be encoded with JPEG2000 but it is not know if such compression will have any benefits. These will typically be the case of products that are quite small in size.

- Unsuitable Products: Products whose payload is dominantly formed by floating point data are currently not suitable for JPEG2000 trans-coding. The situation may change, however, in the foreseeable future because the JP3D extension should become a standard in about two to three years. JP3D enables the encoding of floating point data and also the encoding of three-dimensional data. This last ability to encode three-dimensional data creates new opportunities to encode Earth Observation products (products that have a dependency on time, for example).

Table 2, presents these products grouped together by instrument. No Level 0 products are mentioned since all of them, independently of the instrument; contain telemetry data that is not amenable for image compression algorithms like JPEG2000. By simple inspection of the table it can be seen that both ASAR and MERIS are the best instruments for JPEG 2000 trans-coding, with a large percentage of suitable products. Advanced Along-Track Scanning Radiometer (AATSR) is also a good candidate. Other instruments show mixed results with some good and some bad products and, at the end of the scale, there are products like MIPAS, which should not be considered for JPEG 2000 coding at this stage.

		Suitable	Possible	Doubtful	Unsuitable
AATSR	ATS_TOA_1P	x			
	ATS_NR__2P	x			
	ATS_AR__2P				x
	ATS_MET_2P				x
	ATS_AST_BP	x			
ASAR	ASA_IMS_1P	x			
	ASA_IMP_1P	x			
	ASA_IMG_1P	x			
	ASA_APS_1P	x			
	ASA_APG_1P	x			
	ASA_APP_1P	x			
	ASA_WVI_1P	x			
	ASA_WVS_1P			x	
	ASA_IMM_1P	x			
	ASA_APM_1P	x			
	ASA_WSM_1P	x			
	ASA_GM1_1P	x			
	ASA_IM__BP	x			
	ASA_AP__BP	x			
	ASA_WS__BP	x			
	ASA_GM__BP	x			
	ASA_WVM_2P				x
DORIS	DOR_DOP_1P			x	
GOMOS	GOM_TRA__1P				x
	GOM_LIM__1P		x		
	GOM_EXT__2P				x
	GOM_NL___2P			x	
	GOM_RR__2P			x	
MERIS	MER_RR__1P	x			
	MER_FR__1P	x			
	MER_RR__2P	x			
	MER_FR__2P	x			
	MER_LRC_2P	x			
	MER_RRC_2P	x			
	MER_RRV_2P	x			
	MER_RR__BP	x			
MIPAS	MIP_NL__1P				x
	MIP_NL__2P				x
	MIP_NLE_2P				x
RA2/MWR	RA2_GDR_2P		x		
	RA2_MWS_2P		x		
	RA2_FGD_2P		x		
	RA2_IGD_2P		x		
	RA2_WWV_2P		x		
SCIAMACHY	SCI_NL__1P		x		
	SCI_NLC_1P				x
	SCI_NL__2P				x
	SCI_OL__2P				x
	SCI_RV__2P				x

Table 2: EO Products JPEG2000 Conversion Suitability

3.3 HDF Product Format

This product data format is used by instruments of other satellites such as SPOT (e.g. SPOT Vegetation).

HDF (Hierarchical Data Format) is a multi-object file format with the purpose of sharing scientific data in a distributed environment. HDF was created at the National Center for Supercomputing Applications (NCSA) with a design intended to meet several requirements for storing scientific data, including [RD-68]:

- Support for types of data and metadata normally used by scientists
- Efficient storage of and access to large data sets
- Platform independence
- Extensibility for future improvements and compatibility with other standard formats

The HDF file format standardizes the formats and descriptions of several commonly used data sets, such as raster images and multidimensional arrays. It can be adapted to accommodate a great variety of data.

HDF provides a set of primary constructs to store data, known as HDF data structures. These constructs are named raster image, palette, scientific data set, annotation, vdata, and vgroup. The final construct vgroup is used to group HDF data structures. SPOT Vegetation (the products aimed by the referenced EO project) uses scientific data sets. In the following section is a succinct description of the scientific data set model.

HDF files are self-describing; meaning that for each HDF data structure in a file, there is complete information regarding the data and its location in the file. The file-size limit is 2 gigabytes.

The basic structure of a HDF file consists of a file header, at least one data descriptor block, and zero or more data elements. The file header identifies the file as an HDF file. A data descriptor block contains a certain number of data descriptors. By joining a data descriptor and a data element a data object is formed, which is the basic conglomerate for encapsulating data in the HDF file.

3.4 PIX Product Format

The PIX product format is a data structure for storing digital images and related data.

PIX was designed with several objectives in mind [RD-72]:

- Simplicity: a simple design is easier to maintain, design and expand

- Expandability: reserved fields were allocated to allow the accommodation of new requirements not for seen when designing the format. It is also allowed the construction by the user of new data structures (segments) for specific applications
- Portability: the product format must be made compatible with computers having different architectures to make possible networking, distributed processing and file exchange.
- Speed of Access: since image processing demands the throughput of high volumes of data, PIX is designed to minimize disk activity. The PIX file structure is based on 512 byte blocks. This dimension equals the block size on most disk drives, therefore minimizing access overhead at the disk and operating system level.

3.5 Methodology to Verify ENVISAT Product Suitability for JPEG2000 Trans-coding

For each product of a certain instrument the following methodology was applied in order.

1. Identify the parameters in the PDS file that contribute mostly to the total PDS file size.
2. Order the parameters from step 1 in decreasing contribution to the total PDS file size.
3. Go through the sequence obtained in step 2, starting with the parameter with the largest contribution.
4. If the parameter selected in step 3 has a floating point data type, then the PDS file is not applicable to JPEG2000 compression, using JPEG2000 standard part 1 alone. The analysis of the product can be quit, otherwise, continue to step 5.
5. If several consecutive parameters in the sequence of step 2 are two dimensional and have the same resolution, they can be coded in JPEG2000 as a single multi-component stream. Two dimensional parameters appear in the MDS and ADS components often by concatenation of several records, within the dataset, with consecutive time tags. In this case, each record is a one-dimensional array of data, which generates a two-dimensional array as the satellite sweeps forward, gathering new records with increasing time tags.
    a. If there is a significant correlation between some or all of the same resolution parameters, apply a multi-component transformation to further compress the data. This is a JPEG2000 standard part 2 feature that requires a decoder capable of dealing with multi-component features.
6. If several parameters or sets of parameters in the sequence of step 2 are two dimensional but with different resolutions they will be coded as independent JPEG2000 streams. These streams will then be collected in a single JP2 or JPX file.

7. Use the same procedures of steps 5, 5a, and 6 for one dimensional array parameters, most likely to be stored in the GADS component.

Figure 11: Mosaic of MERIS images showing the country of Portugal and the rest of the Iberian Peninsula [RD-75].

8. Finish going through the sequence from step 2, once the contributions from the parameters to the total PDS file size become negligible. From this point on, all the parameters not coded this far will be considered as meta-data. They will be coded in XML, retaining the hierarchy of the original PDS file.

The end result of this trans-coding process of a PDS file will be a JP2 or JPX file (JPEG2000 standard file formats for Part 1 and Part 2 respectively). Each JP2 or JPX file contains one or more JPEG2000 code-streams. Each of these code-streams in turn has one or more image components. The file includes a XML box describing the complete hierarchy of PDS data.

3.6 Conclusion

This chapter introduced the several ESA EO products that were studied in order to test its compatibility to a JPEG2000 conversion, specifically the products of the SPOT and ENVISAT satellites. In order to perform this JPEG2000 conversion the project realization was dependent of the deployment of several key technologies: DRM, JPEG2000, and a web services platform. This set of technologies will introduce a set of flexible trading options in the Business Model, which are inexistent in the other major competitor's business models. The next chapter explains all this enabling technologies.

4. ENABLING TECHNOLOGIES

4.1 Introduction

In this chapter the author analyses a set of technologies that were used to establish the core of the HICOD2000 system. This enabling technologies range from the capacity to protect proprietary rights, DRM, to the establishment of new services using state-of-the-art compression techniques based on wavelet technology, JPEG2000. It is this wide variety of technologies that is closely reviewed on this chapter. Section 4.2 analyses the DRM technology used to protect and manage the usage rights of the EO products. Section 4.3 presents an overview of the JPEG2000 standard that was one of the key parts of the project. Section 4.4 presents Kakadu Software and Libraries that was the chosen implementation of Part 1 of the JPEG2000 standard used on the HICOD2000 project. Section 4.5 describes the Service Support Environment (SSE) Portal and the Mass ToolBox two key requirements and at the same time enabling technologies provided by ESA.

4.2 Digital Rights Management

DRM is the chain of hardware and software services and technologies managing the authorized use of digital content, as well as dealing with the consequences of that use, through the entire life cycle of the content.

The combination of Internet global penetration, enabling transmission of content on an enormous scale, and cheap, easily available digital technology, makes possible the creation of a unlimited number of copies of a piece of content without loss of quality and the diffusion of a single copy to an unlimited number of users.

Consequently, unprotected digital content is extremely vulnerable to theft, unauthorized access, and propagation.

DRM technology protects the commerce, intellectual property ownership, and privacy rights of digital content creators and owners as the digital content travels from producer to distributor to consumer and, even further, from consumer to other consumers (by consumer, its meant any recipient of the content). It enforces a protection mechanism based on a set of usage rules agreed between the content owner and the consumer. DRM can be used to control and track

authorized access and use for a number of reasons including marketing, sales, royalty, and penetration, among others.

Each organization type has its specific motives for protecting and managing digital content. While content owners and service providers might want to control access to their content in order to assure revenue from its sale, an enterprise might want to share content instead of selling it. Usually an enterprise that wishes to share content controls its access trough a policy of username/password authentication. However, this does not provide any mechanism to control the policy of content usage, once the users have access to it. In this context, DRM offers three advantages: 1) persistent protection of content through encryption, 2) expression and association of usage rules with content, and 3) enforcement of the usage rules. There are two essential definitions of DRM: a narrow one and a broader one.

The narrower definition of DRM has its focus on persistent protection of digital content. It refers to a technology that provides the encryption of files and restricts the access to these files to users or devices that have their identity authenticated and its rights to that specific type of access verified. Protection in such DRM systems is said to be persistent, because it remains active wherever the content goes; on the contrary, a file that is on a server at the back of the server's access control mechanism loses its protection after being moved from the server.

Persistent protection is formed by these fundamental technology components:

- Packagers, assembling content and metadata into secure files that can be named packages, containers, envelopes, etc.
- Controllers that reside on client devices (PCs, music players, e-book readers, etc). They authenticate the identities of the devices and/or users, requesting access to content, check the nature of that access, decrypt the content, and provide the access. Controllers may also initiate financial transactions.
- License servers (only available in new persistent protection solutions). These create and distribute encrypted licenses that describe rights to content, the identities of the users or devices owners of rights, and the conditions (e.g., payment) under which they are given. DRM solutions not including separate license servers install rights description in the content file at the time of package.

The broader definition of DRM handles everything that can be done to define, manage, and track rights to digital content. It includes in addition to persistent protection these elements:

- Business rights: the rights associated by contract to an item of content (e.g. musician's rights to a song recording). These rights often have some correspondence with content's use, like royalties.

- Access tracking: ability to track access to and operations on content. This information is usually very valuable to content providers, independently of existing or not charge on access to content.
- Rights licensing: makes available by contract specific rights to content, defined by content providers.

Rights licensing normally is not possible to track by technological means. DRM technology was of extreme importance for HICOD2000 project since it allowed the conception of a Business Model related to the way on how content is to be used by end users. Therefore is one of the main components of this EO Business Model as shown.

4.3 OpenSDRM

4.3.1 Introduction

OpenSDRM deploys a traditional DRM solution for content rights protection and can be applied for publishing and trading of digital multimedia content. The OpenSDRM architecture is adaptive, since it can be configured for use with several business models and different types of content. Additionally, the security architecture proposed started from the Open Platform Initiative for Multimedia Access (OPIMA) international specifications [RD-32], MPEG-4 IPMP Extensions[RD-33][RD-34]and the emerging MPEG-21 IPMP architecture [RD-33][RD-35] as well as with some of the proposals for JPEG2000 standard Part 8 – JPSEC – JPEG2000 security [RD-36]. Open SDRM was developed primarily in the scope of the MOSES [RD-37] project. MOSES was an EC project joining some companies over Europe that implemented the new MPEG IPMP Extensions framework and at the same time developed business models and applications for secure content exchange between embedded devices [RD-33]. This DRM solution is composed of several optional elements covering the content distribution value chain, from content production to content usage. It covers several major aspects of the content distribution and trading: content production, preparation and registration, content, interactive content distribution, content negotiation and acquisition, strong actors and user's authentication and conditional visualization/playback [RD-36]. Even though the MOSES project refers explicitly to MPEG-4 file format as the content format, this infrastructure was designed with the concern to be adaptable and applicable to all types of content and business models (both for download, streaming or even broadcasting).

4.3.2 External Components & Interfaces

This part will present in detail the components and actors that interact externally with the OpenSDRM architecture [RD-38]: User, IPMP Tools Provider, Content Provider, Payment Infrastructure and Certification Authority.

- User represents a person who wishes to operate a way of enjoying some piece of content (this content may or may not be protected, however the way to access and display such content may require the use of protected devices, software and licenses). The user will make requests to OpenSDRM in order to: identify him, download licenses and play multimedia (using a web browser, Electronic Program Guide (EPG), Media Player). In a final analysis the User interaction with OpenSDRM will always result in one of two things: either the user can play/render the content and enjoy it or he can't; being then informed of the reason for this prevention.
- IPMP Tools Provider is any organization that produces tools for encryption, scrambling, watermarking and others that can be applied to content protection. These tools will be made available to OpenSDRM for use in content rights protection. These tools will need to comply with some guidelines. These guidelines and a subscription translates into a business relation that must exist between a given Content Provider and the IPMP Tools Provider, since mostly, a given producer and/or distributor of content may want to choose which type of protection the content will have and which tools can be applied to the content and from which supplier.
- Content Provider is any multimedia content supplier that feeds OpenSDRM with content and/or metadata. The content can be complex multimedia content that is ready for distribution, or simple content, for example JPEG images, that can be edited and combined with other content.
- Payment Infrastructure facilitates Open SDRM e-commerce features by providing services for handling electronic payments. The interface between Open SDRM and the Payment infrastructure would be generic and independent of the payment method, allowing therefore a multiplicity of payment systems.
- Certification Authority is responsible for receiving requests for and issuing credentials to, entities. These credentials will be used by entities to authenticate themselves to each other, allowing the establishment of secure and authenticated communication channels between them. All the components in the Open SDRM architecture communicate using the channel security provided by the Secure Socket Lair or by Transport Lair Security (SSL/TLS) protocol. This Certification Authority may be internal to Open SDRM, and therefore entirely managed by some entity, or it may be an external commercial Certification.

4.3.3 Internal Components & Interfaces

In this part, the internal components of the Open SDRM platform and the corresponding interfaces are presented. These components include: Media Application, Media Delivery Server,

Commerce Server, Authentication Server, License Server, IPMP Tools Server, Registration Server, Content Preparation Server and the Payment Gateway.

- Content Preparation server this server component is responsible for the content preparation. It receives raw content from a specified source or sources and encodes it on a specified format, adds metadata and protects it. Currently, and under the MOSES project, content will be encoded in MPEG-4 format, according to some pre-established templates. These templates will allow the creation of MPEG-4 files containing music files in MP3 or AAC format together with some JPEG images about the album and artist.
- Commerce server is a server component responsible for trading the content with the users. Normally, content is chosen via web browser, some very generic metadata might be consulted, information about the price is also available, and especially the content usage conditions might be established.
- Media Delivery server is a server component responsible for exchanging pieces of content with the client. This Media Delivery server will implement a specific protocol (download (FTP, HTTP, or other), streaming (Real Time Streaming Protocol (RTSP), other), broadcast) to exchange protected content with the client application.
- Registration server is a server component whose role is to assign unique identifiers to content and to register metadata information for that specific content. This architecture will be as close as possible to standards and therefore for this unique ID, it follows the MPEG-21 directives about Digital Item Identification (DII), using a reduced version of the MPEG-21 DII Digital Object Identifiers (DOI) [RD-39].
- Authentication server is responsible for authenticating all the entities, internal and external to the DRM system. It validates the access rights of all the entities and components in the system working as a Single Sign On (SSO) point, registering and managing components and users on the system. It uses cryptographic XML credentials to authenticate both components and users in order to authenticate the transactions exchanged between them (XML Encryption and XML Signatures).
- License server is a server component responsible for house-keeping the rules associating a user, the content and his/her corresponding access rights. This component will accept connections from authenticated client Media Players for downloading of licenses, which will be applied to the protected content through an appropriate IPMP tool. The licenses are XML formatted using Open Digital Rights Language (ODRL/OMA) [RD-40], and, in the future, they will migrate to the Rights Expression Language (REL) [RD-41], currently being developed by MPEG-21.
- IPMP tools server is the server component responsible for registering new IPMP tools and for receiving authenticated client Media Player requests for the downloading of a

specific IPMP tool. It is also responsible for making IPMP tools available to the Content Preparation Server to allow the protection of content.

- Media Application This component represents the software that will be used to render the content. This is a generic component with the particularity of being able to display/playback the appropriate content for which the necessary audio/video codec is available (if this codec is not available it may be downloaded from a remote secure server). This player may work with one or several IPMP tools in order to control how a particular user accesses the content. This component works on the client side of the general architecture; however it plays an important role in the DRM functions.

4.4 JPEG2000

4.4.1 Introduction

JPEG2000 is the new international standard for still image compression. JPEG is an acronym that stands for “Joint Photographic Experts Group”. The “Joint” term means that this a standard published both by the International Standardization Organization (ISO) and the International Electro-technical Committee (IEC). JPEG2000 was also adopted by International Telecommunication Union (ITU-T) as a recommendation”. The continual expansion of multimedia applications has urged the need for image compression techniques with greater performance and new features. JPEG2000 addresses this need in the specific area of still image encoding [RD-42]. This new image compression standard defines a flexible and scalable access to compressed images. By scalability it’s meant the way a compressed bit-stream can be partially discarded to obtain an efficient representation of the original image, or a lower resolution version of it at a different compression ratio. A highly scalable bit-stream may be decompressed in several different manners with different results, depending on the information that was discarded.

JPEG2000 was conceived with a set of clear objectives [RD-43]:

- Define a superior standardized coding system
- Provide appropriate features for emerging applications
- Improve performance in relation to previous standards
- Expand market capabilities
- Allow for upgradeability and addition of new functionalities

JPEG2000 target is the development of a still image coding standard for different types of still images (bi-level, grey-level, color, multicomponent, hypercomponent) with different characteristics (natural, scientific, remote sensing, etc), allowing different imaging models

(client/server, real-time transmission, image library archival, etc) preferably within a unified and integrated environment [RD-44].

JPEG2000's new features make it suitable for a number of markets and applications such as medical imagery and earth observation. These features include lossless and lossy compression, superior low bit rate performance, region-of-interest coding, content based description, among others. The new features of the JPEG2000 standard make it superior to previous ones. It also has single decompression architecture, the possibility to transmit code-streams in noisy environments, and good performance with computer generated imagery [RD-44]. Additionally it can deal with large images (JPEG compression algorithm does not allow images larger than 64k by 64k without tiling).

The downside is that JPEG is limited by the lack of a unified system to deal with lossless and lossy compression and unavailability of interaction between the JPEG's four modes of operation (sequential, progressive, hierarchical, and lossless). JPEG2000 has a feature set that overcomes these limitations. This feature set includes code-stream quality and resolution scalability, and the additional possibility of spatial and component random access.

4.4.2 JPEG2000 Main Features

The requisites of distinct applications and markets such as medical imagery, color facsimile, earth observation, internet, scanning, digital libraries, digital photography, and remote sensing, are fulfilled by corresponding JPEG2000 features. The most important of these features are as follows [RD-12]:

- Lossless and lossy compression: achieves lossless compression in progressive decoding. Ability to create embedded bit-stream to allow progressive lossy to lossless build-up. Lossless compression is required in applications like medical imagery, and earth observation where all details of the image are important.
- Superior low bit-rate performance: higher performance in the range of low bit-rates than JPEG, maintaining good performance in higher bit-rates [RD-12].
- Progressive transmission by pixel accuracy and resolution: an application can request the image to be reconstructed with increasing pixel accuracy or spatial resolution. This feature is useful in applications in the World-Wide-Web, when receiving images over low bandwidth communication links, and image archiving. In code-streams progressive transmission by "pixel accuracy" there is an improvement of quality of decoded imagery as more data is received. Whereas in code-streams progressive transmission by "resolution" an improvement of resolution, or size, of decoded imagery occurs as more data is received.

Figure 12: JPEG (left) and JPEG2000 (right) at low bit-rate for "Goldhill" image(0.125 bpp) [RD-42]

- Random code-stream access and processing: user defined ROI can be randomly accessed and decompressed with less distortion than the rest of the image. Also random code-stream processing with operations such as rotation, translation, filtering, among others, is allowed.
- Robustness to bit-errors: the code-stream is designed to be tolerant to bit-errors. This feature is particularly important when there is transmission over wireless links.
- Open architecture: the system can be optimized for different image types and applications. Part 1 and Part 2 of the standard are royalty-free and any developer can implement a JPEG2000 encoder/decoder.
- Content-based description: XML boxes can be included in the JPEG2000 file format, to insert information about the image, author, etc.
- Protective image security: protection of a digital image is achievable using watermarking, labeling, stamping, and encryption.

In the field of earth observation, as can be seen from the listed features, JPEG2000 offers a number of advantages over proprietary data formats like PDS, since it is a recognized worldwide format, achieving good compression ratios, and having interesting features oriented towards scalable coding of data, with progressive quality improvement. Since JPEG2000 has the option of performing lossless coding, it is capable of transcoding proprietary data formats to JPEG2000 data without loss of information. Its main limitation has to do with the lack of ability to deal with floating point data, in what concerns part 1 of the JPEG2000 standard.

4.4.3 JPEG2000 Feature Set

In order to surpass known limitations of JPEG four modes of operation (sequential, progressive, hierarchical, and lossless), JPEG2000 provides a very comprehensive feature set.

Referring to these limitations, in JPEG sequential mode the decompressor is unable of lower quality decompressions. In JPEG lossless mode, lossy decompression is unavailable, and high compression ratios are usually unattainable. JPEG-LS has a superior performance than JPEG lossless, and also provides a lossy (near lossless) compression. Nevertheless, the decompressor only has access to the image resolution and quality envisioned at compression time.

In progressive JPEG it is allowed decompression of a code-stream at any desired lower quality than some maximum quality specified at compress time. Hierarchical JPEG is similar. The same functionality exists, but for the resolution (or size) of the decoded image.

The JPEG four modes of operation normally do not interact (although progressive and hierarchical modes can be mixed, few implementations have exploited this possibility). Additionally, the technologies for lossy and lossless compression in JPEG are very different.

In the following section, it is briefly described the JPEG2000 feature set that overcomes the referred limitations of previous image compression systems (mainly JPEG).

If it is desired to compare in generic terms JPEG with JPEG2000, it can be observed that JPEG2000 offers a number of advantages: new functionalities (ROI, error resilience, progression orders); lossy to lossless progression in one system; better compression at low bit-rates; better performance at compound images and graphics (palletized).

4.4.3.1 Compress Once: Decompress Many Ways

The benefits of JPEG four modes of operation are integrated in JPEG2000. The compressor states maximum image quality, up to and including lossless and maximum resolution (or size). At decompress time, any image quality or size can be decompressed from the resulting code-stream, up to and including the maximum values decided at encode time [RD-5].

A part from quality and resolution scalability, JPEG2000 code-streams supports spatial random access. Also, there is the capability of random access of components.

It should be noted that when a certain image product is extracted from the code-stream it is only necessary to decode the relevant bytes, not the entire code-stream.

4.4.3.2 Compressed Domain Image Processing/Editing

In JPEG2000 it is possible to extract image products from the code-stream by extracting only the necessary bytes, without the need to decompress the code-stream [RD-5]. More specifically, if it is desired to obtain reduced resolution and/or reduced quality compressed imagery, they can be produced with no decompress/recompress cycle. That means these operations are accomplished in the compressed domain.

It is also possible to do compressed domain image cropping. This operation consists in accessing the compressed data associated with a given spatial region and rewriting it in a compliant code-stream.

Some geometric manipulations are also supported in the partially compressed domain, such as image rotations of 90, 180, and 270 degrees; and image “mirroring” or “flipping”.

4.4.3.3 Progression

JPEG2000 supports progression in four dimensions: Quality, Resolution, Spatial Location, and Component. With progressive transmission as more data is received, the rendering of the displayed image improves in some way [RD-5].

Figure 13: Example of progressive by resolution of color image “woman” [RD-12]

The Quality progression dimension is used to improve quality as more data is received. This dimension in JPEG2000 code-stream ordering is equivalent to JPEG progressive mode code-stream. The Resolution progressive dimension applies the first bytes received to represent a small “thumbnail” of the image. As more bytes are received, the resolution (or size) increases on each side by factors of 2, until the full size image is obtained. A JPEG2000 resolution progression code-stream corresponds roughly to JPEG hierarchical mode code-stream.

The spatial location dimension of progression receives imagery in approximately raster fashion, from top-to-bottom. This type of progression is useful for encoding, and in memory limited applications. A JPEG2000 codestream ordered for progression by spatial location is roughly equivalent to a JPEG sequential mode code-stream. The final dimension of progression is the component. This kind of progression controls the order in which the data relative to different

components is decoded. With progression by component, the grey scale version of an image might first be decoded, followed by color information, overlaid annotations, etc.

The four dimensions of progression are very versatile and can be “mixed-and-matched” within a single codestream. This means that the progression type can be modified throughout the code-stream. In brief, the imagery can be improved in several dimensions as more data is received, and only the data required by the viewer needs to be transmitted. This implies a great improvement in the latency observed by the user.

4.4.3.4 Low Bit-Depth Imagery

Binary valued components can be compressed with JPEG2000. In this encoding no wavelet transform is done, and the binary image is treated as a single bit-plane at a single resolution. With these settings scalability in quality and resolution is not available [RD-5].

Graphic imagery containing a small number of colors can also be compressed using JPEG2000.

4.4.3.5 Region of Interest Coding

In JPEG2000, as it was already referred, it is possible to vary quality by spatial region. This variations can be performed at encode time, or in parsing or decode operations. This ability is a consequence of the independence of code-blocks [RD-5].

JPEG2000 also permits the encoder to select regions of arbitrary shape and size for a privileged treatment in the optic of compression quality. For this situation, the ROI must be defined at encode time and is not easily modified via parsing or decoding (Figure 14).

Figure 14: Example of ROI with circular mask [RD-43]

4.4.4 JPEG2000 Lossless Performance

4.4.4.1 Lossless versus Lossy Compression

Lossless compression is the process by which there is minimization of the number of bits required to represent the original image samples without loss of information. Nevertheless, for most image compression applications, it is usually accepted some loss of information for the following reasons:

• Significant loss can be tolerated by the Human Visual System

• Digital input is in most cases an imperfect representation of the real world scene

• Lossless compression normally does not accomplish high compression ratios

In the case of lossy compression, by allowing small errors, the image representation can be done using a lower number of bits than in the lossless compression. The greater the distortion allowed, the smaller the compression representation can be. The primary objective of lossy compression is to minimize the number of bits required to represent an image for a certain allowed level of distortion. The most common measures of distortion are Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR).

4.4.4.2 JPEG2000 Lossless Performance Compared With Other Standards

When comparing the JPEG2000 lossless compression performance (the one foreseen for Earth Observation products) with other compression standards such as lossless mode of JPEG and JPEG-LS some conclusions can be drawn [RD-12]:

- In natural images JPEG2000 performs equivalent to JPEG-LS, but with the added benefit of scalability.
- If the generality of JPEG2000 could be sacrificed, JPEG-LS might still be used since it is much less complex.

4.4.5 JPEG2000 Standard

JPEG2000 standard consists of 12 parts [RD-10]. Their content is as follows:

- Part1, core coding system: defines the core of the standard, with the syntax of the JPEG2000 code-stream and the indispensable steps for image encoding and decoding. Part 1 also defines a basic file format named JP2. This file format allows metadata information to be included in the JPEG2000 code-stream.
- Part 2, extensions: several extensions to Part 1 are defined such as more flexible forms of wavelet decomposition and quantization; a different process of encoding regions of particular interest (ROIs); a new file format JPX, based on JP2, that supports multiple

compositing layers, animation, extended color spaces, among other features; and a complete metadata set for photographic imagery.

- Part 3, motion JPEG2000: defines a file format (MJ2) for motion sequences of JPEG2000 images. It also includes support for associated audio. In MJ2 there is no inter-frame coding. Each frame is coded independently using JPEG2000. It is foreseen that medical and satellite imagery is one of the applications for this file format.
- Part 4, conformance: deals with testing conformance to JPEG2000 Part 1. It specifies test procedures for both encoding and decoding processes.
- Part 5, reference software: includes a text document and two open-source packages that implement JPEG2000 Part 1, one written in C and another in Java. Support for JP2 file format has been included.
- Part 6, JPEG2000 compound image file format: defines the JPM file format for document imaging. JPM extends the JP2 file format, and it uses the same architecture and the same boxes defined in Part 1 (JP2) and Part 2 (JPX). JPM can store multi-page documents with many objects per page, and supports the use of other coding or compression technologies besides JPEG2000.
- Part 7 has been abandoned.
- Part 8, JPSEC (security aspects): specifies a set of standardized tools and solutions that ensures security of transaction, protection of contents, and protection of technologies, allowing applications to generate, consume, and exchange JPEG2000 secured bit-streams. JPSEC addresses, among other applications: encryption (flexible mechanism to allow for encryption of image content and metadata), source authentication (verification of authenticity of the source), data integrity (data integrity verification), conditional access (conditional access to portions of an image or its associated metadata), ownership protection (protection of the content owner rights). In order to protect the content techniques such as digital signatures, watermarking, encryption, and key generation and management, are used.
- Part 9, JPIP (interactive protocols and API): defines tools for supporting delivery of image and metadata in the context of networked environments. Part 9 exploits JPEG2000 flexibility in relation to random access, code-stream reordering and incremental decoding in that context. Part 9 uses a client-server protocol named JPIP that can be built on top of HTTP. JPIP can handle several different image data types from the server. It also allows selective access to image metadata that might be included in JPEG2000 files. Part 9 is focused on JP2 file format, but also supports some file format extensions from Part 2 (JPX). It is also available a mechanism to provide selection amongst multiple code-streams in JPX, MJ2 and JPM files. It is additionally defined new file format boxes for indexing JPEG2000 files and code-streams.

- Part 10, JP3D (volumetric imaging): concerns the extension of planar JPEG2000 images to volumetric images. It also deals with the encoding/decoding of floating point data. In volumetric coding there is the use of non-uniform grids to concentrate the data were is most meaningful. A concept that can have applications in two dimensions as well.
- Part 11, JPWL (wireless applications): standardizes tools and methods to achieve the efficient transmission of JPEG2000 imagery over error-prone wireless networks. JPWL additions mechanisms for error protection and correction to the elements in the core coding system as defined in Part1. JPWL system supports three distinct functionalities: protection of the codestream against transmission errors; description of the degree of sensitivity of different parts of the code-stream to transmission errors; description of locations of residual errors in the codestream.
- Part 12, ISO Base Media File Format: creates a base file format for future applications of JPEG and MPEG. This format is to be used with timed sequences of media data.

4.4.5.1 JPEG2000 Standard Stage of Development

JPEG2000 Part 1 is complete and has been published as an International Standard (ISO/IEC 15444 Part 1). Parts 2-6 and 12 are complete or nearly complete. The remaining four parts (8-11) are under development. The stage of completion of each of the parts is presented next [RD-45]:

- Part 2 publication is imminent; it has already reached the Final Committee Draft stage.
- MJ2 format of Part 3 is defined in ISO/IEC 15444-3:2002 as a standalone document. There are two amendments to this standard ISO/IEC 15444-3:2002/Amd 2:2003, specified in terms of ISO Base format, ISO/IEC 15444-12, and ISO/IEC 15444-3:2002/FPDAM 3.
- Part 4 is published as ISO/IEC 15444-4:2002 as a text document associated with a set of files for conformance testing.
- Part 5 is published in ISO/IEC 15444-5:2003 - as a short text document, and two source code packages - and in an amendment ISO/IEC 15444-5:2003/Amd 1: 2003 to fully support the JP2 file format.
- Part 6 is published as ISO/IEC 15444-6:2003
- Part 9 has reached second Final Committee Draft stage in December 2003
- Parts 8, 10 and 11 are expected to reach Committee Draft stage soon.
- Part 12 is published as ISO/IEC 15444-12:2004, and subjected to IEC approval

4.4.6 JPEG2000 Compression/Decompression System

Compression is only possible due to the redundancy of some of the bits of the uncompressed representation of the image sample values. This redundancy can have one of the following causes:

- Statistical redundancy
- Irrelevance
- Visual irrelevance (limit of Human Visual System)
- Application specific irrelevance (military, medical, among others)

The block diagram of JPEG2000 compression / decompression system is presented in Figure 15 [RD-12].

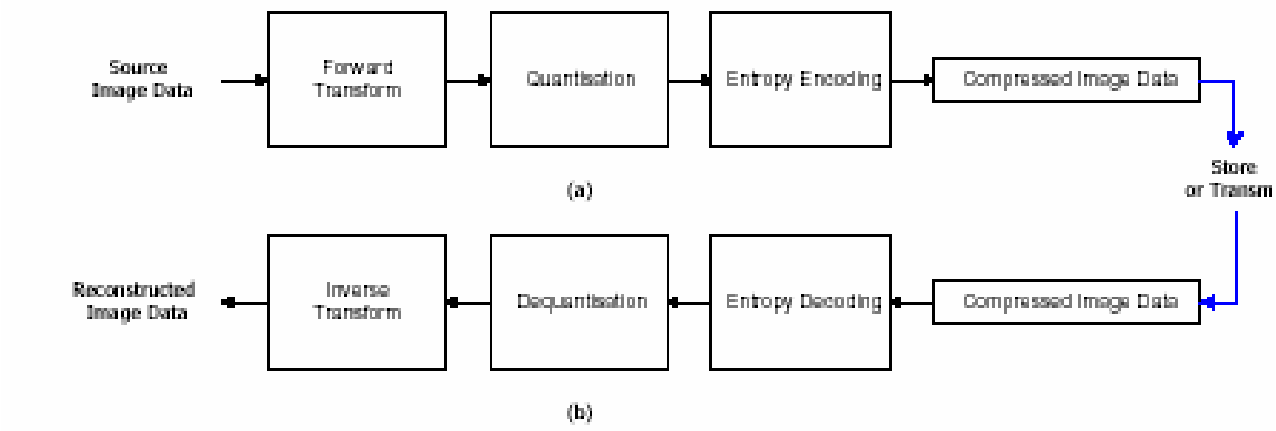


Figure 15: Block diagram of JPEG2000 (a) encoder and (b) decoder [RD-12]

The compression system starts by applying the discrete transform to the source image data. The obtained transform coefficients are then quantized and entropy coded, and the output code-stream is formed. The decompression system is the reverse of the compression system. The code-stream is first entropy decoded, dequantized, and inverse discrete transformed, thus obtaining the reconstructed image data. The objective of the transforms is to convert the original image samples into a form which enables simple quantization and coding operations. Transforms discover statistical dependencies amongst the original image samples, so that the transform samples and consequently the quantization indices present only very low local dependencies. The transform operation also separates relevant and irrelevant information. The quantization is the process that allows for high compression ratios and is responsible for introducing distortion (lossless compression does not use quantization).The coding procedure exploits statistical redundancy amongst the quantization indices; this redundancy is spatially localized. The standard has on its basis image tiles. This term is relative to the partition of the

original image into rectangular non-overlapping blocks (tiles), which are compressed independently, as if they were completely distinct images.

Describing more in detail the encoding procedure, these steps should be considered [RD-12]:

- The source image is decomposed into components
- The image and its components are decomposed into rectangular tiles. Thus, obtaining the tile component, that is the basic unit of the original or reconstructed image.
- The wavelet transform is applied on each tile. The tile is consequently decomposed in different resolution levels.
- These decomposition levels are made up of sub-bands of coefficients, describing the frequency characteristics of local areas of the tile-component
- The sub-bands of coefficients are quantized and collected into rectangular arrays of "codeblocks"
- The bit-planes of the coefficients in a "code-block" are entropy coded
- The encoding procedure can define certain ROI's that can be coded in a higher quality than the background
- Markers are added in the bit-stream to permit error resilience
- The code-stream has a main header that describes the original image and the various decomposition and coding styles, used to locate, extract, decode and reconstruct the image with the desired resolution, fidelity, region of interest and other characteristics
- Jpeg2000 and earth observation products

4.5 Kakadu software and libraries

Kakadu [RD-46] is an implementation of Part 1 of the JPEG2000 standard. It should be fully conformant with what will likely be called "Profile-1", "Class-2-H", although Part 4 of the standard, which describes compliance, is still evolving. It conforms at "Profile-2" (unrestricted profile), except in a number of minor (quite outlandish) respects, where oversights in the original standard had to be corrected through minor restrictions in Profile-0 and Profile-1.

The core system is intended to be fully platform independent and to be well suited to both embedded systems and higher level operating systems. The target platform must at least support 32-bit integers. Various processing enhancements are currently available only on Pentium machines, but may easily be ported to other popular architectures [RD-47].

Custom messaging services support the delivery of error and warning messages and the handling of fatal error conditions with methods supplied by the application. Due to the complexity of the JPEG2000 standard, a key focus in the implementation is on memory

efficiency and execution speed. Another key focus is the provision of a highly flexible architecture, which is able to meet the demands of a large diversity of applications from simple compression or decompression filters to sophisticated interactive applications, client-server systems and network transcoders [RD-47].

4.6 SSE Portal and Mass Toolbox

The current situation in terms of EO services is far from optimal: each service provider needs to develop its own portal, including all the non-service related infrastructure and then it needs to make known to the potential clients the availability of the service, while on the other hand, the users do not easily find the available services, and when they do, these usually supply only a fraction of the user needs, forcing him to use several providers.

The Service Support Environment (SSE) [RD-16] project was developed to address these problems, while at the same time developing the EO economy through the development of a “marketplace”.

The main objectives of the SSE are to:

- provide an infrastructure enabling the business to business interactions among service providers (B2B) and with users (B2C),
- allow basic and end-to-end services to remain on the service provider infrastructure,
- allow for easy plug-in and plug-out of services to/from the SSE environment,
- allow chaining of services into more complex ones,
- support “subscription” type services (e.g. fires active monitoring and alerting),
- support the evolution and maintenance of services,
- allow easy identification of, and access to requested services, with progress follow-up until completion,
- integrate services from multiple domains, to exploit multi-domain synergies.

Two main components are the result of this activity:

- The SSE portal, where users access the available services, order the products they are interested in, pay for them in a secure manner and with a large selection of payment methods, and track the progress of their order. (a simpler version of the SSE portal – called Access Point – based on open-source software will also be made available) [RD-16];
- The MASS toolbox, which service providers can use to chain their services into the MASS catalogue, eventually combining with other services to produce added-value services [RD-21].

From the user point of view, access to the SSE portal is like the access to any other Web site, where he can register, browse the list of available products, create an order, pay for it and track its status. The most notable difference should be the wide range of available services.

The real difference however is from the service provider's point of view. A crucial factor in the design of the SSE system is the possibility of interoperability and chaining of services. This means that a service provider does not need to build its services from scratch, starting by processing the raw satellite (and ancillary) data – it can request the parts it needs from other service providers and just perform the steps required to create his products. This is done in several ways, first through the use of standard technologies such as XML, Single Object Access Protocol (SOAP) or Web Services Description Languages (WSDL) which facilitates the development, and through the provision of a toolbox that simplifies the integration of the services within the SSE portal [RD-48].

The Toolbox is a configurable application that will help the Service Provider to easily convert his service in SOAP based service without code development. The new Web Services will be integrated on the SSE portal. The Toolbox will also help the service provider on developing new simple SOAP based services from scratch providing an internal Open Source Database to manage the Order [RD-48].

To this end, the identification of a set of common EO business related standards and the support of a neutral and open service-enabling environment becomes mandatory. The SSE developed for the Ground Segment Department at ESA-ESRIN aims to identify a path to solve the above problems, by implementing an open service-oriented and distributed environment among business users (service users and service providers), enabling the integration of EO, meteorological and Geographic Information System (GIS) data [RD-16]. The SSE service-enabling environment facilitates service provision and orchestration, allowing each organization to exploit the service know-how and provision ability of the others, also for the creation of new services from a horizontal set of basic services supplied by multiple service providers.

The SSE infrastructure was initially developed in the MASS GSTP project in the period 2001-2003. Due to the interest the GSTP project has generated, ESRIN has decided to enhance the initial system and upgrade it to an operational system which is now known as the ESA "Service Support Environment".

The TOOLBOX has been developed under the SSE project, allowing the creation of message based web Services. It is based on a XML scripting language allowing the specification of the operation that has to be performed when a SOAP message is received. It is based on free and Open Source software. Although developed under the SSE project the TOOLBOX is a generic TOOL allowing the publishing of any kind of Web Service based on the message routing mechanism, however it provides some features specific for the SSE framework that facilitate the development of a SSE compliant Web Service [RD-48].

4.7 Conclusion

This chapter was used to introduce a set of key technologies essential to achieve the proposed project goals. Each of the technologies was analyzed in depth, the use of DRM technology to protect and trade EO products, an extensive introduction to the JPEG2000 standard was made and its benefits for compression large quantities of data, as well as is flexibility properties both for compressing and decompressing large pieces of information, as is the case of EO products, was presented. In order to take advantage of the full potential of the JPEG2000 standard, the project team came to the conclusion that the Kakadu framework was the best choice.

From the business and deployment perspective the SSE Portal in conjunction with the Mass Toolbox allowed the integration of the HICOD2000 system in a practical way on ESA own service portal environment, taking the first step for the full implementation of the original business model idea.

The combination of these enabling technologies allowed the creation of a system that respects all major system requirements that are going to be discussed on the next chapter.

5. SYSTEM REQUIREMENTS

5.1 Introduction

In order to achieve a good System Requirement Definition, some specific steps need to be taken into account. The most important ones are the following:

- Gaining an agreement on the problem definition.
- Understanding the root causes— in fact what is causing or what the originator of the problem is.
- Identifying the stakeholders and the users.
- Defining the solution system boundary.
- Identifying the constraints to be imposed on the solution. These constraints may also be considered as requirements.

This chapter will focus on the identification of the system requirements that were found by the project team using the above steps and will categorize them according to the appropriate system/sub-system to which they relate to.

The requirements will be identified in the following way: H2K-XXX-YY-ZZZZ, and will be presented the same way they were for the project client, ESA.

H2K is a reserved field meaning HICOD2000. XXX identifies which sub-system the requirement refers to, and may contain the values identified in the next document sections. YY identifies the requirement itself and may be:

- FR for Functional Requirement;
- IR for Interface Requirement;
- OR for Operational Requirement;
- RR for Resource Requirement;
- PR for Portability Requirement;
- SR for Security Requirement.

ZZZZ is a four digit sequential number.

Each of the sub-systems will be analyzed in terms of software requirements on the following chapter sub-sections. These requirements will be divided, whenever possible, according to the following categories:

(a) Functional requirements

(b) Interface requirements

(c) Operational requirements

(d) Resource requirements

(e) Security requirements

(f) Portability requirements

The HICOD2000system may be divided in two systems: the HICOD2000TOOLBOX service and the HICOD2000viewer/application. These two systems can be divided in several sub-systems.

The following diagram (Figure 16) displays the HICOD2000 architecture and the relation existing between the client and the server part.

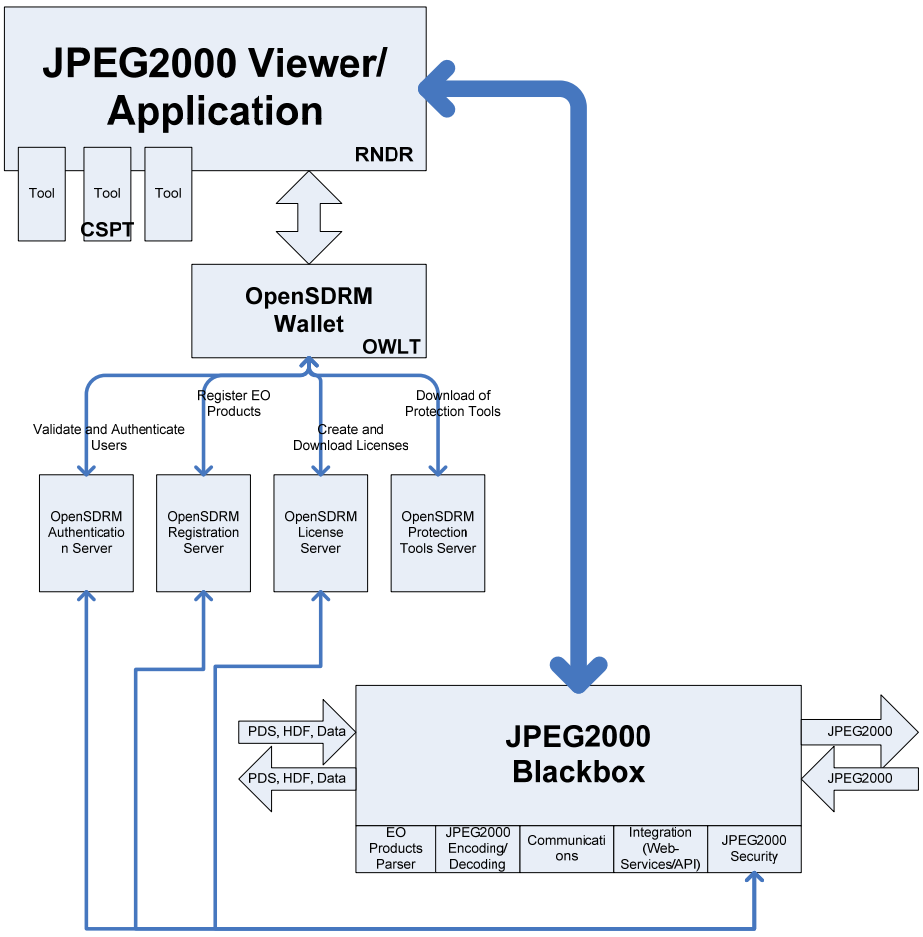


Figure 16: HICOD2000 overall architecture relationship connections

In terms of Software Requirements Document, the overall system will be divided in two sub-systems: (a) the JPEG2000 viewer/application more related to the client part of the system and (b) the JPEG2000 Black-Box, defining the server part of the system. Both these two systems may be even further decomposed on other sub-components.

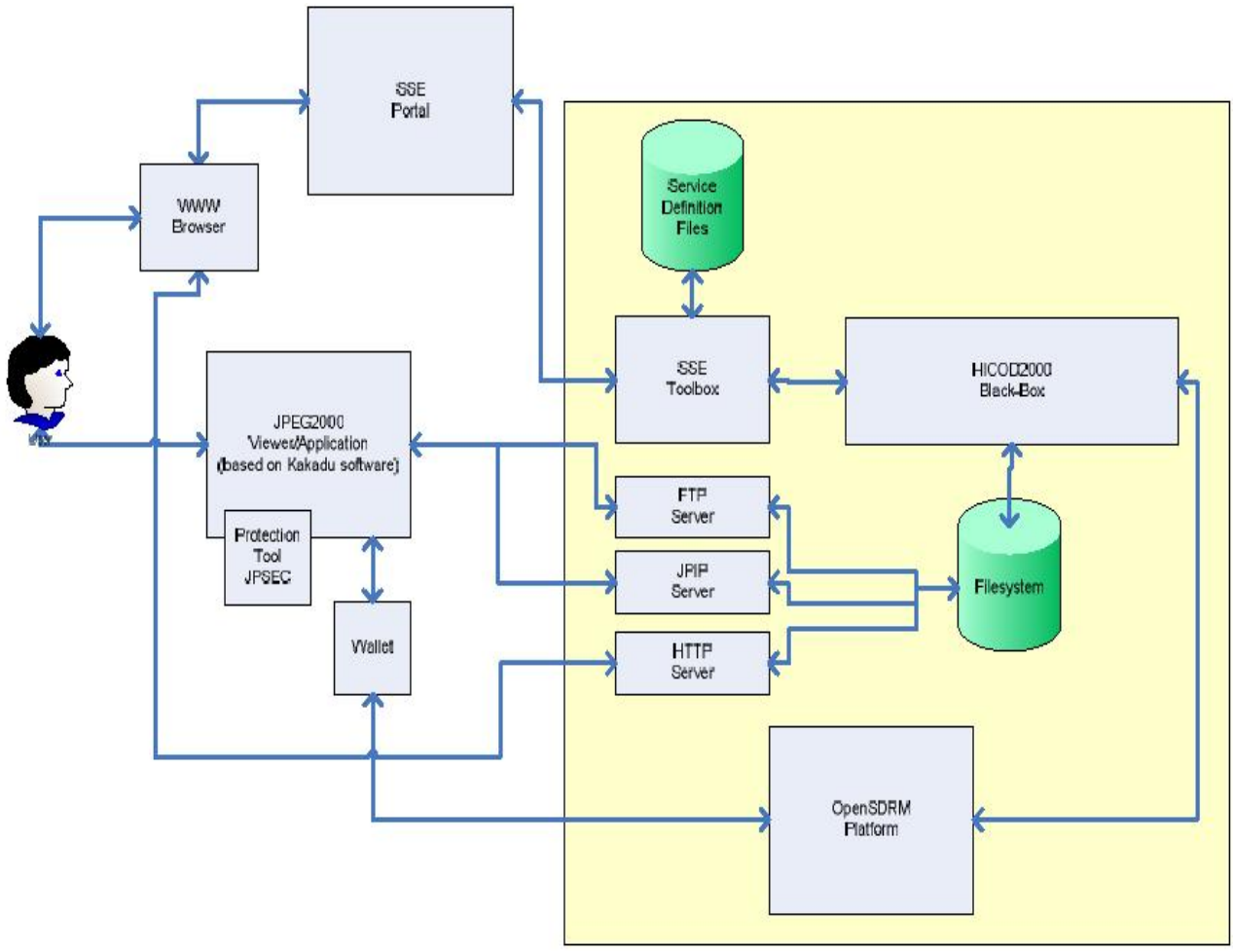


Figure 17: HICOD2000 integrated architecture

5.2 RNDR – JPEG2000 Render modules

This subsystem will control most of the actions related to the image choose and display. This system will also interact with both the HICOD2000 server part and the security infrastructure as well as with the SSE Portal and integrated SSE services.

5.2.1 Functional requirements

The list of functional requirements of this system is:

Requirement ID	Description
H2K-J2KVA.RNDR-FR-0001	All users should be allowed to browse image thumbnails for the case of visible EO products. If a selection is made upon an EO product, login shall be requested to the user
H2K-J2KVA.RNDR-FR-0002	All users should be allowed to access an EO product basic metadata by browsing the image directory basic metadata. If access to detailed metadata is required, login shall be requested to the user
H2K-J2KVA.RNDR-FR-0003	All users should be allowed to search EO products. For advanced search mechanisms login shall be requested to the user
H2K-J2KVA.RNDR-FR-0004	All users shall be allowed to access a registration form. The site registration may not be accepted if mandatory fields are not filled. The registration process shall run on a secure channel

Table 3: RNDR Functional Requirements

For HICOD2000 registered users the must allow all operations allowed to any user plus:

Requirement ID	Description
H2K-J2KVA.RNDR-FR-0005	all registered users shall be allowed to login in the site
H2K-J2KVA.RNDR-FR-0006	all registered users shall be allowed to access EO products on-line in a non-interactive manner
H2K-J2KVA.RNDR-FR-0007	all registered users shall be allowed to access visible EO products on-line in an interactive manner
H2K-J2KVA.RNDR-FR-0008	all registered users shall be allowed to access and edit his personal data at any time
H2K-J2KVA.RNDR-FR-0009	All registered users shall be allowed to access advanced search options on image searching
H2K-J2KVA.RNDR-FR-0010	The viewer shall operate in standalone mode
H2K-J2KVA.RNDR-FR-0030	It shall be possible to the user to select a set of parameters for the EO JPEG2000 product. Among these parameters, are included: • Number of layers; • Number of components; • Progression order; • Region of interest.
H2K-J2KVA.RNDR-FR-0035	This module shall be able to read JPEG2000 code streams (and the appropriate protection signaling, if this is the case)

Table 4: RNDR Registered Users Requirements

5.2.2 Interface requirements

The list of interface requirements of this system includes:

Requirement ID	Description
H2K-J2KVA.RNDR-IR-0040	The viewer shall allow the following operations: • Zoom-in and Zoom-out operations; • Pan operations; • Definition of ROI (Regions of Interest); • Selection of different components; • Selection of different layers.
H2K-J2KVA.RNDR-IR-0050	Shall provide a list of EO products for the User to choose
H2K-J2KVA.RNDR-IR-0060	Shall provide the display of metadata (if available)
H2K-J2KVA.RNDR-IR-0070	Shall provide the necessary interface to allow the user to encoding parameters for the EO products

Table 5: RNDR: Interface Requirements

5.2.3 Operational requirements

The list of operational requirements of this system is:

Requirement ID	Description
H2K-J2KVA.RNDR-OR-0080	The system should work with a minimum screen resolution of 800x600

Table 6: RNDR Operational Requirements

5.2.4 Resource requirements

The list of resource requirements of this system are:

Requirement ID	Description
H2K-J2KVA.RNDR-RR-0090	The system shall run on all Windows 2K and XP platforms
H2K-J2KVA.RNDR-RR-0150	The host system should have at least 128 MB of RAM

Table 7: RNDR Resource Requirements

5.2.5 Portability requirements

The list of portability requirements of this system are:

Requirement ID	Description
H2K-J2KVA.RNDR-PR-0090	The viewer should run on Windows systems
H2K-J2KVA.RNDR-PR-0091	The viewer shall run on Linux systems using the Wine emulator

Table 8: RNDR Portability Requirements

5.2.6 Security requirements

The list of security requirements of this system are:

Requirement ID	Description
H2K-J2KVA.RNDR-SR-0100	In order to access to protected EO products the users shall authenticate themselves to the system
H2K-J2KVA.RNDR-SR-0110	The system shall integrate OpenSDRM security functionalities
H2K-J2KVA.RNDR-SR-0120	The system should allow the download remote protection tools
H2K-J2KVA.RNDR-SR-0130	The system shall allow the download of remote licenses

Table 9: RNDR Security Requirements

5.3 OWLT – OpenSDRM Wallet

This sub-system is responsible for providing the necessary security functionalities and mechanisms to control the access to protected EO products. This sub-system depends on other system called OpenSDRM which already exists, and therefore is out of the scope of this document. As the name indicates, this component is a client-wallet, a software component, installable on each client machine, providing the functionalities of secure storage of sensitive information and connection to the OpenSDRM servers to exchange private information.

5.3.1 Functional requirements

The list of functional requirements of this system is:

Requirement ID	Description
H2K-J2KVA.OWLT-FR-0160	This system shall allow the user to subscribe for an authentication account
H2K-J2KVA.OWLT-FR-0170	This system shall allow the storage of sensitive information. This information includes: • Personal data about the user, including payment information; • Licenses to access to protected content; • Cryptographic credentials to authenticate the user to services.
H2K-J2KVA.OWLT-FR-0180	The system shall allow the retrieval of storage information to appropriate and authenticated users or applications
H2K-J2KVA.OWLT-FR-0190	The system shall communicate to the application to provide the necessary information to operate in security: licenses, protection tools and keys
H2K-J2KVA.OWLT-FR-0200	This system shall communicate with OpenSDRM servers to obtain the necessary security and content access control functionalities

Table 10: OWLT Functional Requirements

5.3.2 Interface requirements

The list of interface requirements of this system is:

Requirement ID	Description
H2K-J2KVA.OWLT-IR-0210	The system should provide a registration form. This registration form should include information about: • User full name; • User full address and contacts; • Choose user name to access to the system; • Choose password and password verification; If necessary, also a payment mechanism can be provided.
H2K-J2KVA.OWLT-IR-0220	The system should provide an authentication/login form. This form should ask to the User the following elements: • Username; • Password.
H2K-J2KVA.OWLT-IR-0230	The system should provide a list of licenses. This list should be composed by: • Identification of the content; • License Expiry date.
H2K-J2KVA.OWLT-IR-0240	The system should provide the details of each license. The details should include information about: • Identification of the content; • License provider identification; • License specific conditions; • License expiry date;
H2K-J2KVA.OWLT-IR-0241	Additionally the system should also provide the possibility to delete licenses

Table 11: OWLT Interface Requirements

5.3.3 Operational requirements

The list of operational requirements of this system is:

Requirement ID	Description
H2K-J2KVA.OWLT-OR-0250	The system should work with a minimum screen resolution of 800x600

Table 12: OWLT Operational Requirements

5.3.4 Resource requirements

The list of resource requirements of this system are:

Requirement ID	Description
H2K-J2KVA.OWLT-RR-0260	The system should be portable, running on Windows and Linux platforms
H2K-J2KVA.OWLT-RR-0270	The system needs at least 128 MB RAM
H2K-J2KVA.OWLT-RR-0280	The system shall require the Java SDK 1.4

Table 13: OWLT Resource Requirements

5.3.5 Portability requirements

The list of portability requirements of this system are:

Requirement ID	Description
H2K-J2KVA.OWLT-PR-0290	The system should run on Windows and Linux systems

Table 14: OWLT Portability Requirements

5.3.6 Security requirements

The list of security requirements of this system are:

Requirement ID	Description
H2K-J2KVA.OWLT-SR-0300	The system should provide strong authentication mechanisms (based on X.505 certificates, Public-Key cryptography and Secret-key cryptography)
H2K-J2KVA.OWLT-SR-0310	The system should communicate securely with the OpenSDRM servers
H2K-J2KVA.OWLT-SR-0320	The system should provide a secure storage repository, resistant to brute-force attacks
H2K-J2KVA.OWLT-SR-0330	The system should provide secure download of content licenses
H2K-J2KVA.OWLT-SR-0340	The system should provide a license tamper-resistance mechanism

Table 15: OWLT Security Requirements

5.4 CSPT – JPEG2000 code stream protection tool

This module refers to the software module that will handle the access to the EO product JPEG2000 code stream, in case it is protected. In fact, this tool represents the protection algorithms that were applied to the code-stream on production, and that together with the appropriate clearance mechanism (keys) open the content to be displayed for the final User. This module interacts both with the render part of the system and also with the wallet.

5.4.1 Functional requirements

The list of functional requirements of this system is:

Requirement ID	Description
H2K-J2KVA.CSPT-FR-0350	This module should receive as input a cryptographic-key
H2K-J2KVA.CSPT-FR-0355	This module should be able to un-scramble a code stream

Table 16: CSPT Functional Requirements

5.4.2 Resource requirements

The list of resource requirements of this system are:

Requirement ID	Description
H2K-J2KVA.CSPT-RR-0360	This module should run on Windows and Linux
H2K-J2KVA.CSPT-RR-0370	This module should run integrated on the application/viewer

Table 17: CSPT Resource Requirements

5.4.3 Security requirements

The list of security requirements of this system are:

Requirement ID	Description
H2K-J2KVA.CSPT-SR-0390	This module should be signed and authenticated (in order to identify that it has not been modified and that the source is authentic)

Table 18: CSPT Security Requirements

5.5 JPEG2000 Blackbox

This part of the document describes the server component part of the HICOD2000 system. This part starts by providing an overview of the sub-system architecture, describing its overall functionality and identifies each of the sub-components of the sub-system.

The following image depicts the building-blocks of the JPEG2000 Black Box.

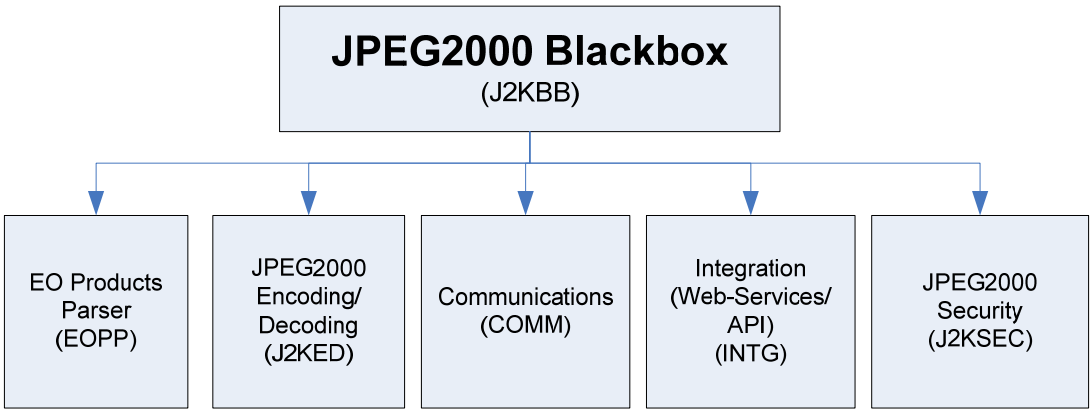


Figure 18: The JPEG2000 Black Box components

The JPEG 2000 Black Box is the integrator component which implements the business logic of the system. Basically, it performs either the coding or decoding tasks of the EO products and provides a set of additional functionalities such as interactive downloads or security. The overall HICOD2000 Black-Box architecture (Figure 19) is composed of a set of components integrated

to provide a set of functionalities. The basic functionality of the software is: bidirectional conversion between PDS/HDF and lossless JPEG2000 file formats.

Conceptually, the architecture can be seen as a box, having as input a PDS/HDF product and producing as output a lossless JPEG2000 image file (during this process, no information from the original product is lost). This box has also the possibility to perform the inverse operation, i.e., receive as input a JPEG2000 file and producing as output the original PDS/HDF file.

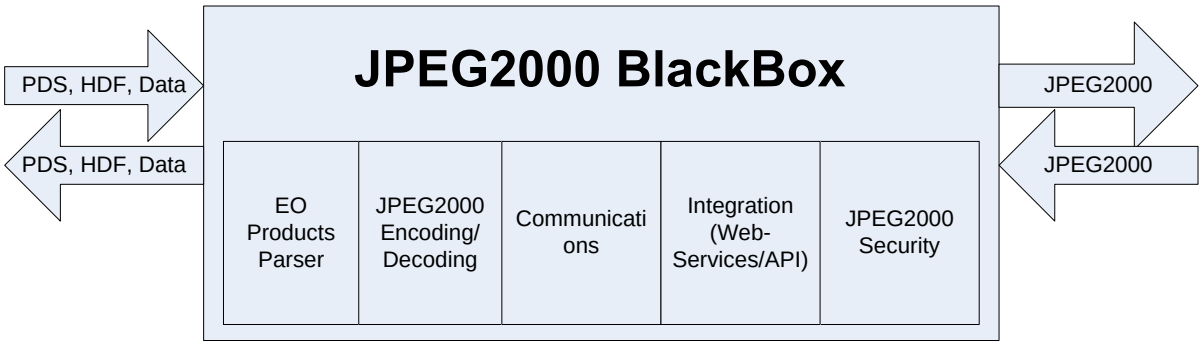


Figure 19: BlackBox system input output architecture line

From the architecture in Figure 19, several components can be identified:

- EO Products Parser: parses the EO products and prepares the data for the JPEG2000 encoder/decoder.
- JPEG2000 Encoding/Decoding: encodes raw data and metadata to JPEG2000 file format or decodes JPEG2000 file format to raw data and Metadata according to a set of parameters.
- Communications: provides the box with the necessary means of communication with the outside world. This is only used in client-server mode for providing JPEG2000 code-stream data to a specific client.
- Integration: provides the integration mechanisms between the HICOD2000 toolbox and the MASS portal and also other tools that want to use HICOD2000 functionalities.
- JPEG2000 Security: this component provides the necessary security mechanisms to protect the JPEG2000 code-stream and metadata. It will also provide the integration mechanisms with DRM platform.

5.5.1 Functional requirements

The list of functional requirements of this system is:

Requirement ID	Description
H2K-J2KBB-FR-0010	Shall be able to handle with mega-images (at least 1024x1024)
H2K-J2KBB-FR-0030	Shall produce lossless JPEG2000 files
H2K-J2KBB-FR-0050	Shall support the Web Services paradigm, defining clear interfaces in WSDL and providing the SOAP messaging protocol for communication
H2K-J2KBB-FR-0060	Shall be able to receive JPEG2000 files
H2K-J2KBB-FR-0080	Kakadu shall be used to supply the JPEG2000 encoding and decoding services, i.e., converting from RAW format to JPEG2000 code stream and vice-versa
H2K-J2KBB-FR-0090	Linux shall be used as the preferred platform for the system
H2K-J2KBB-FR-0100	The JPEG2000 Black Box service shall be able to provide the following functions: • REQ: Request to make available a list of available EO products to order; • ORDER: Order an EO product with the following options: • SOURCE FORMAT (PDS or HDF) • TYPE OF INSTRUMENT (ASAR, MERIS, SPOT, other) REQUIRED SERVICE (Lossless J2K compression, Lossy J2K compression, with Security service – JPSEC compliant).
H2K-J2KBB-FR-0110	The service shall be able to return the STATUS, PRODUCT LOCATION and possibly a LICENSE to access the JPEG2000 content

Table 19: J2KBB Functional Requirement

5.5.2 Interface requirements

The list of interface requirements of this system is:

Requirement ID	Description
H2K-J2KBB-IR-0120	This system shall be connected to the MASS toolbox and made available the operations defined
H2K-J2KBB-IR-0121	Shall receive as input both PDS and HDF files
H2K-J2KBB-IR-0122	Shall be able to conform and integrated to MASS-ICD specifications
H2K-J2KBB-IR-0123	Shall be able to produce PDS and HDF files
H2K-J2KBB-IR-0125	This system shall provide an API to integrate its functionalities with other existing applications

Table 20: J2KBB Interface Requirement

5.5.3 Operational requirements

The list of operational requirements of this system is:

Requirement ID	Description
H2K-J2KBB-OR-0130	This system shall be available for Linux and Windows platforms
H2K-J2KBB-OR-0131	Should be possible to be run 24/7 without the need to restart the machine
H2K-J2KBB-OR-0132	Shall provide a memory cleanup and cache mechanism
H2K-J2KBB-OR-0133	Shall be possible to install new software updates without the need to use the administrator account. Make separate the management of the operating system and the operation of the application
H2K-J2KBB-OR-0134	Shall exist a logging mechanism on the resources used, number of requests, etc
H2K-J2KBB-OR-0135	Should be used some mechanism to manage/monitoring disk space (cleanup); Devise a procedure to perform garbage collection
H2K-J2KBB-OR-0136	The components should work in parallel (parallel requirements), avoiding file and resource locking

Table 21: J2KBB Operational Requirement

5.5.4 Portability requirements

The list of portability requirements of this system are:

Requirement ID	Description
H2K-J2KBB-PR-0137	This system shall work on both Windows and Linux systems
H2K-J2KBB-PR-0138	The system shall be composed of self-contained components that can be separated and integrated with other applications

Table 22: J2KBB Portability Requirement

5.5.5 Security requirements

The list of security requirements of this system are:

Requirement ID	Description
H2K-J2KBB-SR-0139	The system shall be integrated with OpenSDRM security platform

Table 23: J2KBB Security Requirement

5.6 J2KBB.EOPP - EO Products Parser

This system provides the parsing functionalities to the black box. This allows the black box to read the PDS and HDS metadata information from the EO products, extract the raw data and afterwards provide the necessary input for the coder to encode the products in JPEG2000 format. This module will also be responsible for extracting the information from within the JPEG2000 product and recover the original product format.

5.6.1 Functional requirements

The list of functional requirements of this system is:

Requirement ID	Description
H2K-J2KBB.EOPP-FR-0140	Shall be able to parse mainly the following products: MERIS (LR, FR) and ASAR (LR, FR) in PDS format and SPOT in HDF format
H2K-J2KBB.EOPP-FR-0145	The parser shall be able to provide an easy configuration mechanism that will allow the support for any kind of EO product
H2K-J2KBB.EOPP-FR-0150	The parser shall be able to extract the raw data from the referred products.
H2K-J2KBB.EOPP-FR-0151	The parser shall be able to extract relevant EO products information to be provided for the JPEG2000 Encoding service.
H2K-J2KBB.EOPP-FR-0152	The parser shall be able to produce the necessary XML files, containing the extracted metadata, organized in a appropriate logical structure (according to the type of product), and using available XML schemas (probably from the Derby software, or using the Generalized Markup Language (GML));
H2K-J2KBB.EOPP-FR-0153	The parser shall be able to read the raw files, plus the XML file (specific for the EO product) and re-construct the original file (PDS or HDF)
H2K-J2KBB.EOPP-FR-0160	Shall interface with the encoding and decoding service

Table 24: J2KBB.EOPP Functional Requirement

5.6.2 Resource requirements

The list of resource requirements of this system are:

Requirement ID	Description
H2K-J2KBB.EOPP-RR-0161	This component shall require Windows or Linux operating systems
H2K-J2KBB.EOPP-RR-0163	This component shall require at least 128 MB RAM to run

Table 25: J2KBB.EOPP Resource Requirement

5.6.3 Portability requirements

The list of portability requirements of this system are:

Requirement ID	Description
H2K-J2KBB.EOPP-PR-0168	This component shall run on Windows and Linux platforms

Table 26: J2KBB.EOPP Portability Requirement

5.7 J2KBB.J2KED - JPEG2000 Encoding/Decoding Service

This is the core system in the black box. This system is responsible for compressing and decompressing an EO product in JPEG2000 and vice-versa. It is also responsible for the introduction and extraction of relevant metadata from it.

5.7.1 Functional requirements

The list of functional requirements of this system is:

Requirement ID	Description
H2K-J2KBB.J2KED-FR-0180	Shall be able to provide a selection of encoding parameters for the product: • The number of layers (optionally, also the bit-rate of each layer); • The progression order; The Region of Interest (in terms of defining a better encoding part of the product);
H2K-J2KBB.J2KED-FR-0190	Shall be able to read the XML encoding parameters retrieved from the EO product specific data from the Parser service
H2K-J2KBB.J2KED-FR-0210	Shall be able to read the XML formatted EO product specific metadata and package this information in the code stream in a appropriate XML box
H2K-J2KBB.J2KED-FR-0230	Shall be able to support simple decompression
H2K-J2KBB.J2KED-FR-0240	Shall be able to support progressive and interactive decompression
H2K-J2KBB.J2KED-FR-0250	Should be able to support the controlled decompression
H2K-J2KBB.J2KED-FR-0270	Shall be able to extract the XML box metadata

Table 27: J2KBB.J2KED Functional Requirement

5.7.2 Interface requirements

The list of interface requirements of this system is:

Requirement ID	Description
H2K-J2KBB.J2KED-IR-0170	Shall be able to receive raw data (image data sets) and produce Part 1 compliant JPEG2000 code stream in both lossless or lossy format
H2K-J2KBB.J2KED-IR-0200	Shall be able to handle JP2 file formats
H2K-J2KBB.J2KED-IR-0205	Should be able to handle JPX file formats
H2K-J2KBB.J2KED-IR-0220	Shall be able to store the resulting files in the file system
H2K-J2KBB.J2KED-IR-0260	Shall interact with the following services: • JPEG2000 Security Services; • Downloading and interactive services; Parser service.

Table 28: J2KBB.J2KED Interface Requirement

5.7.3 Resource requirements

The list of resource requirements of this system is:

Requirement ID	Description
H2K-J2KBB.J2KED-RR-0271	This component shall require Windows or Linux operating systems
H2K-J2KBB.J2KED-RR-0273	This component shall require at least 128 MB RAM to run

Table 29: J2KBB.J2KED Resource Requirement

5.7.4 Portability requirements

The list of portability requirements of this system is:

Requirement ID	Description
H2K-J2KBB.J2KED-PR-0275	The system shall run on Windows and Linux systems

Table 30: J2KBB.J2KED Portability Requirement

5.8 J2KBB.J2KSEC - JPEG 2000 Security Services

This system provides the necessary security services to the box, based on DRM technologies and on the emerging JPSEC standard part.

5.8.1 Functional requirements

The list of functional requirements of this system is:

Requirement ID	Description
H2K-J2KBB.J2KSEC-FR-0280	Shall be possible to protect a JPEG2000 code-stream using the JPSEC requirements [RD-3]
H2K-J2KBB.J2KSEC-FR-0290	Shall be possible to cipher or scramble a JPEG2000 code-stream according to the following parameters: • Resolution Level; • Progression Order; Component;
H2K-J2KBB.J2KSEC-FR-0300	Shall be possible to define specific access conditions to the product for specific users
H2K-J2KBB.J2KSEC-FR-0310	Shall be possible to control the access of a specific user to a product
H2K-J2KBB.J2KSEC-FR-0320	Shall be possible to prevent unauthorized users to access to access products
H2K-J2KBB.J2KSEC-FR-0330	Shall be possible to prevent non-authorized users to access to protected parts of the product
H2K-J2KBB.J2KSEC-FR-0340	Should be used a rights expressions language to control the access to the product (for instance ODRL [RD-49]or MPEG-21 REL [RD-50])
H2K-J2KBB.J2KSEC-FR-0350	Should be possible to register different protection tools and corresponding parameters on a JPSEC compliant registration authority
H2K-J2KBB.J2KSEC-FR-0360	Should be possible for the JPEG protection method to be applied also to the image metadata
H2K-J2KBB.J2KSEC-FR-0370	Shall be used a set of external components to enforce the IPR management of the product. Among these external tools should be included: • OpenSDRM Authentication Server: to authenticate the users and to control the access system; • OpenSDRM License Server: to create, store and offer the download of licenses; • OpenSDRM Registration Server: to register content; • OpenSDRM Protection Tools Server: to register and to download protection tools; OpenSDRM wallet: to control the access to the licenses on the client side;

Table 31: J2KBB.J2KSEC Functional Requirement

5.8.2 Resource requirements

The list of resource requirements of this system is:

Requirement ID	Description
H2K-J2KBB.J2SEC-RR-0371	This component shall require Windows or Linux operating systems
H2K-J2KBB.J2SEC-RR-0373	This component shall require at least 128 MB RAM to run

Table 32: J2KBB.J2KSEC Resource Requirement

5.8.3 Portability requirements

The list of portability requirements of this system is:

Requirement ID	Description
H2K-J2KBB.J2KED-PR-0375	The system shall run on Windows and Linux systems

Table 33: J2KBB.J2KSEC Portability Requirement

5.9 J2KBB.COMM – Communications

This system will provide the implementation or integration of two servers to provide the EO products to clients. It will be FTP for non-interactive requests and JPIP for interactive requests.

5.9.1 Functional requirements

The list of functional requirements of this system is:

Requirement ID	Description
H2K-J2KBB.COMM-FR-0380	Authorized users shall be possible to download entire JPEG2000 EO product remotely
H2K-J2KBB.COMM-FR-0390	Shall be possible to recover the original product format from the downloaded JPEG2000 EO products
H2K-J2KBB.COMM-FR-0400	Authorized users shall be able to download JPEG2000 EO products interactively
H2K-J2KBB.COMM-FR-0410	The interactive protocol to be used shall be JPIP over HTTP
H2K-J2KBB.COMM-FR-0420	Authorized users shall be able to request and download parts of an image

Table 34: J2KBB.COMM Functional Requirement

5.9.2 Interface requirements

The list of interface requirements of this system is:

Requirement ID	Description
H2K-J2KBB.COMM-IR-0421	Shall be possible to access a configuration service for this system.
H2K-J2KBB.COMM-IR-0422	XML files shall support configuration service.

Table 35: J2KBB.COMM Interface Requirement

5.9.3 Resource requirements

The list of resource requirements of this system is:

Requirement ID	Description
H2K-J2KBB.COMM-RR-0423	This component shall require Windows or Linux operating systems
H2K-J2KBB.COMM-RR-0424	This component shall require at least 128 MB RAM to run

Table 36: J2KBB.COMM Resource Requirement

5.9.4 Portability requirements

The list of portability requirements of this system is:

Requirement ID	Description
H2K-J2KBB.COMM-PR-0425	The system shall run on Windows and Linux systems

Table 37: J2KBB.COMM Portability Requirement

5.9.5 Security requirements

The list of security requirements of this system is:

Requirement ID	Description
H2K-J2KBB.COMM-SR-0426	Whenever possible, server elements shall use port 80 for security reasons.

Table 38: J2KBB.COMM Security Requirement

5.10 J2KBB.INTG – Integration

This system will provide the necessary integration layer with MASS toolbox via Web Services.

5.10.1 Functional requirements

The list of functional requirements of this system is:

Requirement ID	Description
H2K-J2KBB.INTG-FR-0421	This system shall expose a WSDL interface, publishing the services offered for integration with other systems (MASS Toolbox, for instance)
H2K-J2KBB.INTG-FR-0421	This system shall expose a well document API, for other applications to use the services provided by the HICOD2000 Black box

Table 39: J2KBB.INTG Functional Requirement

5.10.2 Resource requirements

The list of resource requirements of this system is:

Requirement ID	Description
H2K-J2KBB.INTG-RR-0430	This component shall require Windows or Linux operating systems
H2K-J2KBB.INTG-RR-0435	This component shall require at least 128 MB RAM to run

Table 40: J2KBB.INTG Resource Requirement

5.10.3 Portability requirements

The list of portability requirements of this system is:

Requirement ID	Description
H2K-J2KBB. INTG -PR-0450	This component shall run on Windows and Linux platforms

Table 41: J2KBB.INTG Portability Requirement

5.11 Conclusion

This chapter identified the HICOD2000 system requirements and introduced the system architecture. The requirements described above represent the specific details of what the client should expect from the final system and were obviously designed by the project team taking this into account. Likewise the system constraints, that included subjects so important as economical, political, resources and schedules, were also studied and defined and played a significant role on the definition of the requirements.

In order to respect the requirements defined on the sections above a global architecture had to be defined to cope with this. This architecture as already been briefly revealed on previous chapters but it will be explained in detail on the next chapter of this document.

6. SYSTEM ARQUITECTURE

6.1 Introduction

HICOD2000 has a fairly complex architecture, and integrates with a series of already existing components and tools (such as MASS and OpenSDRM), and also a set of new tools were developed from scratch to achieve the HICOD2000 objectives it this architecture that will be discussed on this chapter.

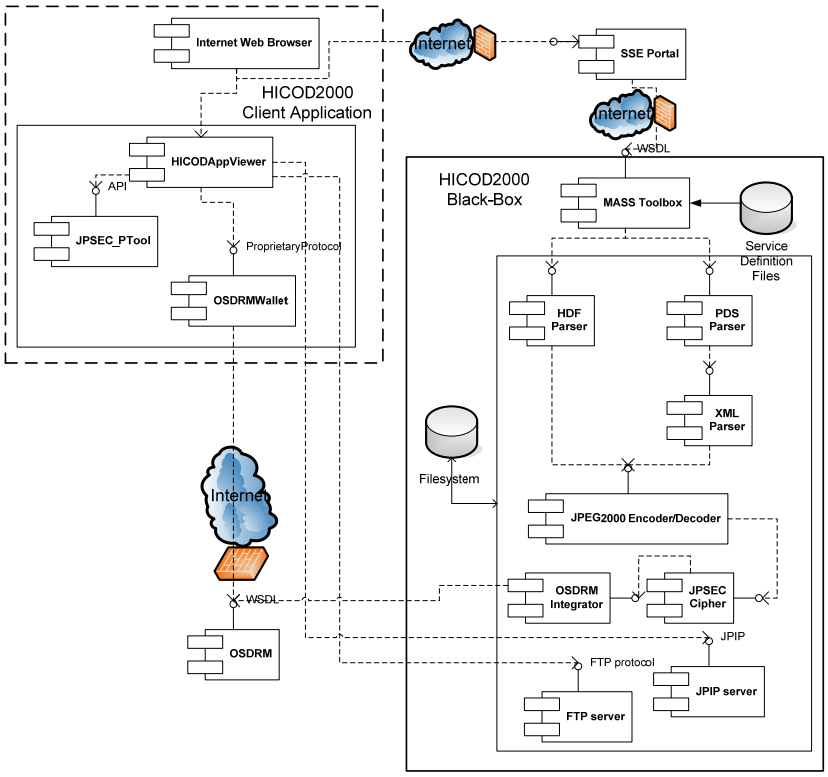


Figure 20: HICOD2000 software architecture

HICOD2000 project produced software that allowed the coexistence of the upcoming JPEG2000 image file format with EO PDS file format (mainly for MERIS and ASAR products) and also the HDF file format (SPOT Vegetation).

The HICOD2000 system is composed of several components that are integrated in 2 major components, the HICOD2000 Client Application in which the HicodAppViewer is the key component and the HICOD2000 Back-Box that is the real core of the HICOD2000, and which can be integrated either in stand-alone client mode as well in client-server mode.

This architecture will have several components, both on the client side (HICOD2000 Viewer and Wallet) and on the server side (HICOD2000 BlackBox). The client side is responsible for requesting, obtaining and displaying JPEG2000 EO products, and also responsible for controlling the access to such products. The server side is responsible to serve several clients and prepares, produces and sends EO products in JPEG2000 format.

6.2 SSE Mass Portal/Toolbox Integration Services

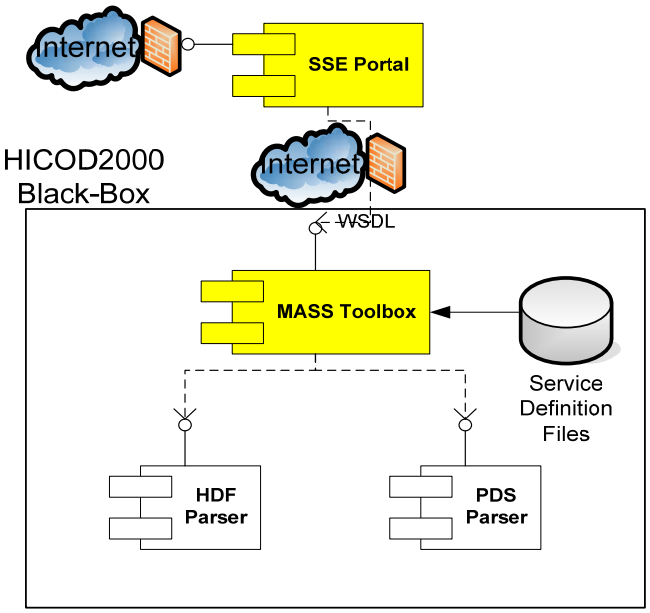


Figure 21: SSEPortal Mass Toolbox Integration Architecture

Type

This component has the following characteristics:

- Logical: Package;
- Physical: WebService;

This component was developed in XML protocol based languages.

Purpose

This component implements the following software requirements which are described in chapter 5.

Requirement ID	Title
H2K-J2KVA.RNDR-FR-0001	Image Thumbnail Browsing
H2K-J2KVA.RNDR-FR-0002	Basic Metadata Access
H2K-J2KVA.RNDR-FR-0003	Search EO Products
H2K-J2KVA.RNDR-FR-0004	Registration Form
H2K-J2KVA.RNDR-FR-0005	Login
H2K-J2KVA.RNDR-FR-0006	EO products online access non-interactively
H2K-J2KVA.RNDR-FR-0007	EO products online access interactively
H2K-J2KVA.RNDR-FR-0008	Access, edit personal data
H2K-J2KVA.RNDR-FR-0009	Advanced search options
H2K-J2KBB.INTG-FR-0421	WSDL interface, publishing the services
H2K-J2KBB.INTG-FR-0421	Document API, for other applications to use the services provided

Table 42: SSE Mass Portal/Toolbox Integration Services Requirements Overview

The main purpose of this component is to allow the communication and usage of HICOD2000 service on the SSE portal.

Function

In order to make our service available on the SSE portal, as a data conversion service, the service needed to be converted into web service.

On the SSE portal side this is done by configuring the service using three files, a WSDL file, a XSL style Sheet and a Schema file. These files are used to design the user interface, catch and validate the service parameters, and link to the web service provider Toolbox server, were the service should be installed.

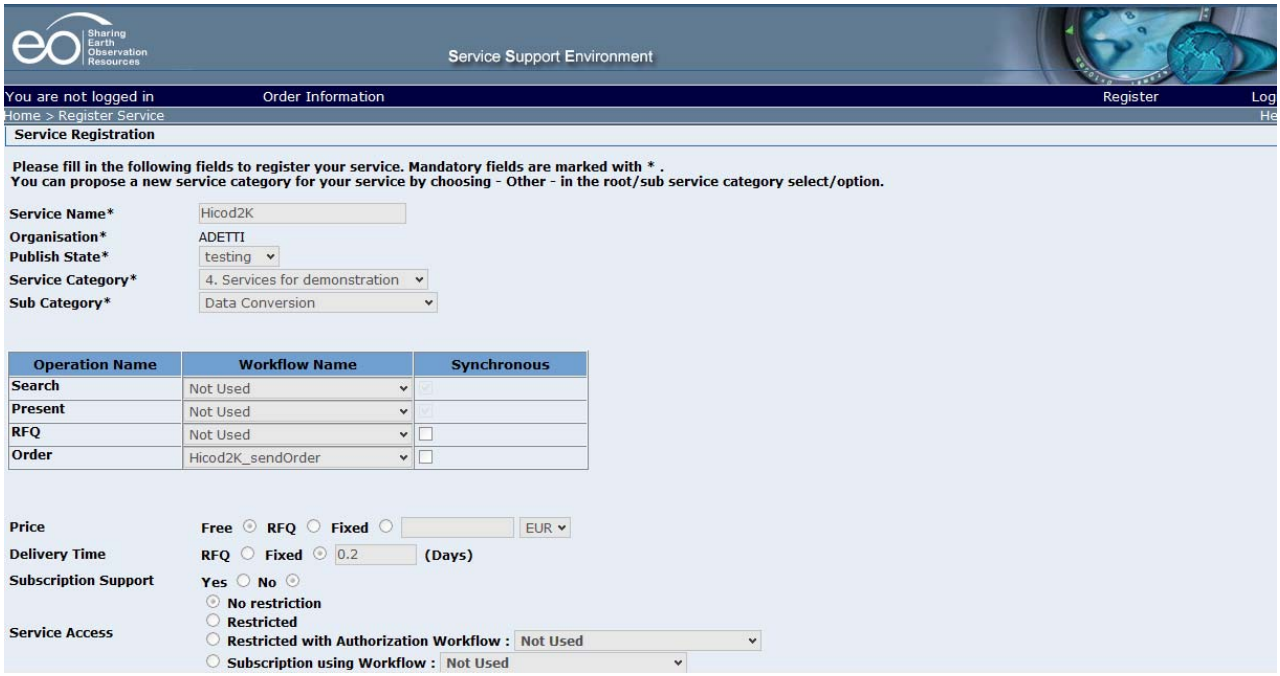


Figure 22: SSE Portal HICOD2000 service configuration page

On the service server side, the Toolbox functionalities, allow the specification of the operation that has to be performed when a SOAP message is received, through the use of a series of schema files that define the service and trigger the action of the Black-Box components.

Figure 23: Mass Toolbox HICOD2000 service configuration page

Processing

When a message is sent, from the SSE portal to the web service provider Toolbox server, the web service, previously installed and configured thought the use of XML Schema Definition (XSD) files, triggers the Black-Box application. The result of this application is catched by the Toolbox and then sent to the SSE Portal in a compatible SOAP message. This message states the success or unsuccess of the service and the resulting link to the product

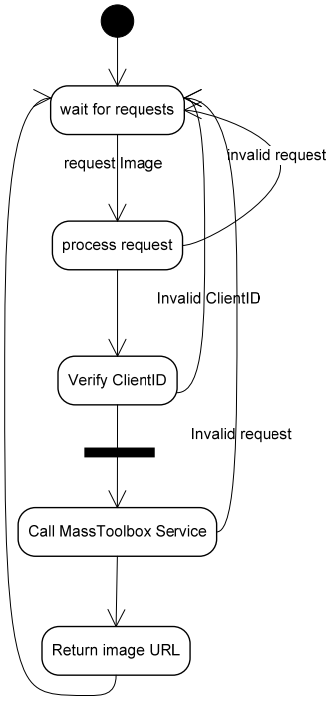


Figure 24: SSE Portal Mass ToolBox integration flow diagram

6.3 HICODAppViewer

This application was developed on top of the original “kdu_show”, with some additional functionality, such as the interaction with the Wallet and security.

Type

This component has the following characteristics:

- Logical: Application;
- Physical: Executable;

This component was developed in C++. This implementation is restricted by the original language of the Kakadu viewer, which serves as basis for the HICOD2000 viewer. The main purpose of this component is to allow the visualization and interaction with EO JPEG2000 products.

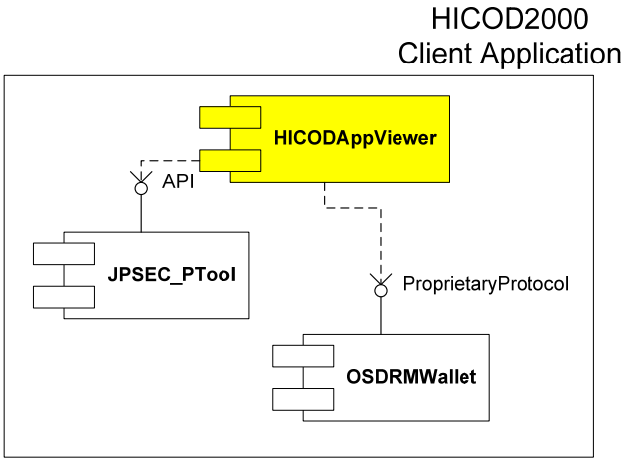


Figure 25: HICOD2000AppViewer Architecture

Purpose

This component implements the following software requirements which are described in chapter 5.

Requirement ID	Title
H2K-J2KVA.RNDR-FR-0010	Standalone
H2K-J2KVA.RNDR-FR-0030	Select parameters
H2K-J2KVA.RNDR-FR-0035	Read JPEG2000 codestreams
H2K-J2KVA.RNDR-IR-0040	Viewer options
H2K-J2KVA.RNDR-IR-0060	Display Metadata
H2K-J2KVA.RNDR-IR-0070	Encoding parameters
H2K-J2KVA.RNDR-OR-0080	Minimum resolution
H2K-J2KVA.RNDR-RR-0090	Win2K/XP ability
H2K-J2KVA.RNDR-RR-0150	128MB RAM lower limit
H2K-J2KVA.RNDR-PR-0090	Viewer Windows ability
H2K-J2KVA.RNDR-PR-0091	Viewer Linux ability

Table 43: HICODAppViewer Requirements Overview

The main purpose of this component is to allow the visualization of EO JPEG2000 protected products.

Function

The function of this component, as referred before is to visualize and interact with EO JPEG2000 products. This component can be launched in standalone mode, or invoked via web-browser, as a helper application.

This component can open JPEG2000 files directly stored on a physical storage device, or directly connect to a JPIP server, allowing the user to progressively view and browse the EO product.

Dependencies

This component depends on several other components:

- Wallet: this component depends on the wallet to obtain the necessary credentials to access the image parts which are protected;
- JPSEC Protection tool: this component depends on this JPSEC protection tool to be able to decipher the image correctly and display it on the screen.

Interfaces

The Interface of the HICOD2000AppViewer is explained on

Annex D - Hicod2000APP Viewer User Manual, of this document.

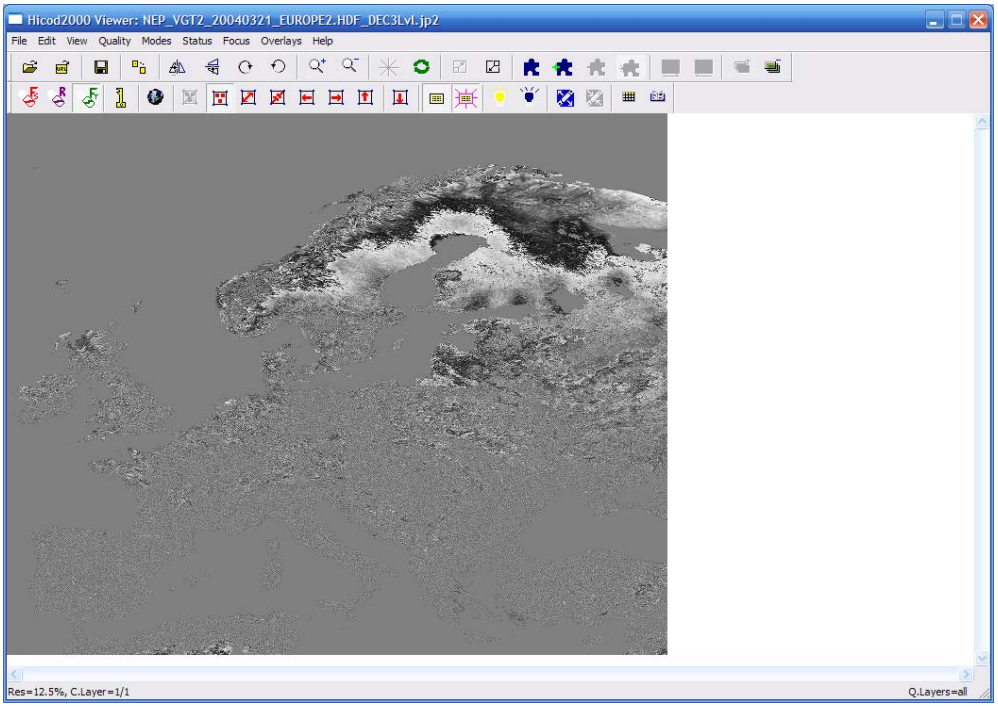


Figure 26: HICOD2000APPViewer GUI

Resources

In order to run this component needs Microsoft Windows 2000 or Microsoft Windows XP or a Linux distribution with Wine cross platform software installed on the hosting machine.

Processing

This component represents a GUI that will allow the user to view, interact and browse EO products in JPEG2000 format.

This component can be started/launched either manually by the user, or automatically, as a helper application, by the web-browser, when an image request is made on a web site. Therefore, after the software component is launched, it waits for user requests. The most relevant user requests will be to access images, and to navigate through these images. Therefore, when the user uses this component to open an image (either stored locally, or introducing a remote URL location) it checks if the image is or not protected. If the image is unprotected then it is automatically rendered on the on the viewer, and the user can navigate freely to any of the image available resolutions.

If the viewer detects that the image is protected, then viewer has to contact the wallet to obtain the appropriate keys to decipher the image the user is trying to access. If those keys are returned with success to the viewer, they are passed to the JPSEC tool to decipher the image and render it correctly on the viewer.

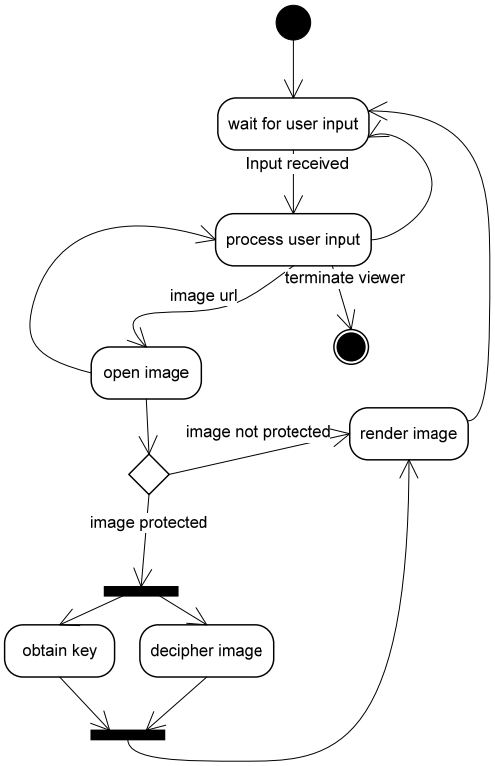


Figure 27: HICOD2000AppViewer flow diagram

6.4 IPMP software/ Protection tool

This software component, works integrated with the viewer, and its main functionality is to provide the deciphering functionalities to the viewer.

This software component depends on the viewer requests to perform its functionality.

Type

This component has the following characteristics:

- Logical: Package;
- Physical: Library;

This component was developed in C++.

Purpose

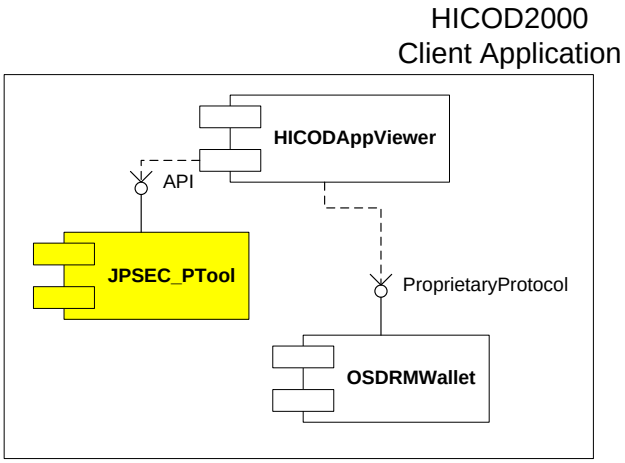


Figure 28: JPSEC_PTool architecture

This component implements the following software requirements which are described in chapter 5.

Requirement ID	Title
H2K-J2KVA.CSPT-FR-0350	Cryptographic key
H2K-J2KVA.CSPT-FR-0355	Unscramble
H2K-J2KVA.CSPT-RR-0360	Portability
H2K-J2KVA.CSPT-RR-0370	Viewer integration
H2K-J2KVA.CSPT-SR-0390	Signature and authentication

Table 44: JPSEC_PTool Requirements Overview

The main purpose of this component is to allow the deciphering of EO JPEG2000 protected products.

Function

The function of this component is to provide the security functionalities on the client side. It should receive the necessary parameters to decipher a code-stream and return it deciphered.

Dependencies

This component depends on the Viewer component.

Resources

In order to run this component needs Microsoft Windows 2000 or Microsoft Windows XP installed on the hosting machine.

Processing

The processing made by this component is quite simple. It receives a set of ciphered data, a key and a resolution level, and using the appropriate deciphering algorithm returns the image data deciphered.

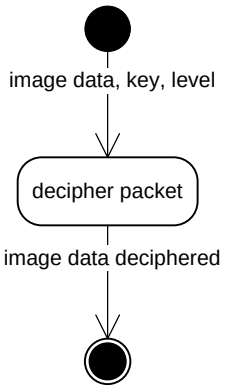


Figure 29: JPSEC_PTool flow diagram

6.5 Wallet

This software component is used to control the access to content licensing information as well as to cryptographic keys needed to decipher image data. This component determines how a given content can be used by a given user.

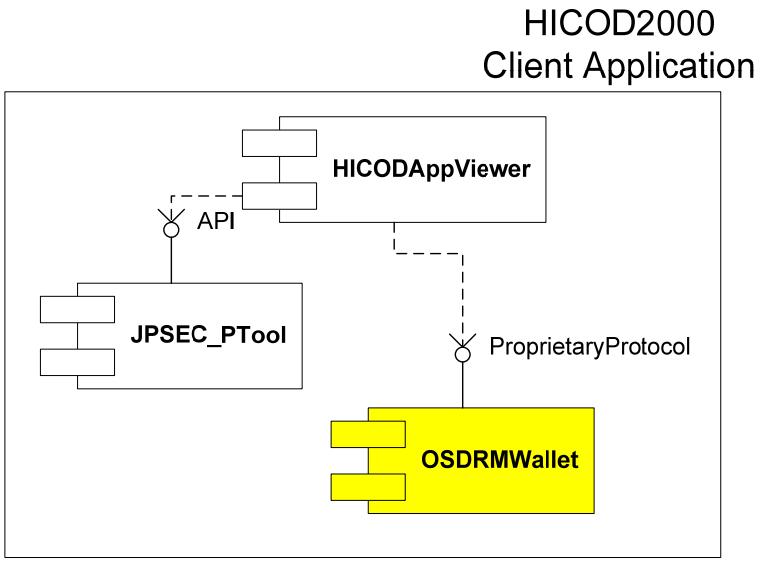


Figure 30: OpenSDRM Wallet Architecture

Type

This component has the following characteristics:

- Logical: Application;
- Physical: Executable;

This component was developed in C#.

Purpose

This component implements the following software requirements which are described in chapter 5.

Requirement ID	Title
H2K-J2KVA.OWLT-FR-0160	Account subscription
H2K-J2KVA.OWLT-FR-0170	Sensitive information storage
H2K-J2KVA.OWLT-FR-0180	Information retrieval
H2K-J2KVA.OWLT-FR-0190	Application communication
H2K-J2KVA.OWLT-FR-0200	Communication with OpenSDRM
H2K-J2KVA.OWLT-IR-0210	Registration Form
H2K-J2KVA.OWLT-IR-0220	Authentication form
H2K-J2KVA.OWLT-IR-0230	License list
H2K-J2KVA.OWLT-IR-0240	License details
H2K-J2KVA.OWLT-IR-0241	License deletion
H2K-J2KVA.OWLT-OR-0250	Screen resolution
H2K-J2KVA.OWLT-RR-0260	Running platforms
H2K-J2KVA.OWLT-RR-0270	Memory
H2K-J2KVA.OWLT-RR-0280	SDK
H2K-J2KVA.OWLT-SR-0300	Authentication mechanisms
H2K-J2KVA.OWLT-SR-0310	Communication security with OpenSDRM
H2K-J2KVA.OWLT-SR-0320	Secure storage
H2K-J2KVA.OWLT-SR-0330	License download
H2K-J2KVA.OWLT-SR-0340	License tamper resistance

Table 45: OpenSDRM Wallet Requirements Overview

The main purpose of this component is to control the access to EO JPEG2000 protected products.

Function

The function of the Wallet is to control the access to the protected JPEG2000 code-streams (images resolution levels). The Wallet is also the client-side element responsible for interacting with the OpenSDRM platform in order to perform the DRM functionalities:

- User validation and authentication;
- License download;
- License enforcement.

Dependencies

This component depends on the Viewer component.

Interfaces

This component provides a very simple interface to external applications that wish to use them. The simplicity of the interface allows it to be called from other JPEG2000 viewers.

Figure 31: OpenSDRM Wallet User Interface

The interface is provided via TCP/IP communication on the localhost (127.0.0.1) and on port 9999. It allows external applications (Viewer) to issue one command order and receive two possible answers:

- Request: “GETKEY RES_LVL X IMG Y” (requests the license for a Resolution Level X, and for the image which the identifier is Y)
- Answer: two possibilities:
    - “ERROR”: returns an error in the case some is not correct (license could not be obtained or license has expired)
    - “KEY X”: this returns the X key for the resolution level

Resources

In order to run this component needs Microsoft Windows 2000 or Microsoft Windows XP installed on the hosting machine.

Processing

The processing of the Wallet works in the following way:

- The Wallet waits for requests from the localhost machine;
- When a request is received the Wallet verifies the request format, and processes the request;

- The Wallet tries to find locally the license to which the request refers to. If the license is found locally, and is valid in terms of time, the Wallet checks for the correct key inside it;

- If the license cannot be found locally, the wallet connects to the OpenSDRM license server, and tries to download a license remotely. The remote license is then stored securely on the user-side.

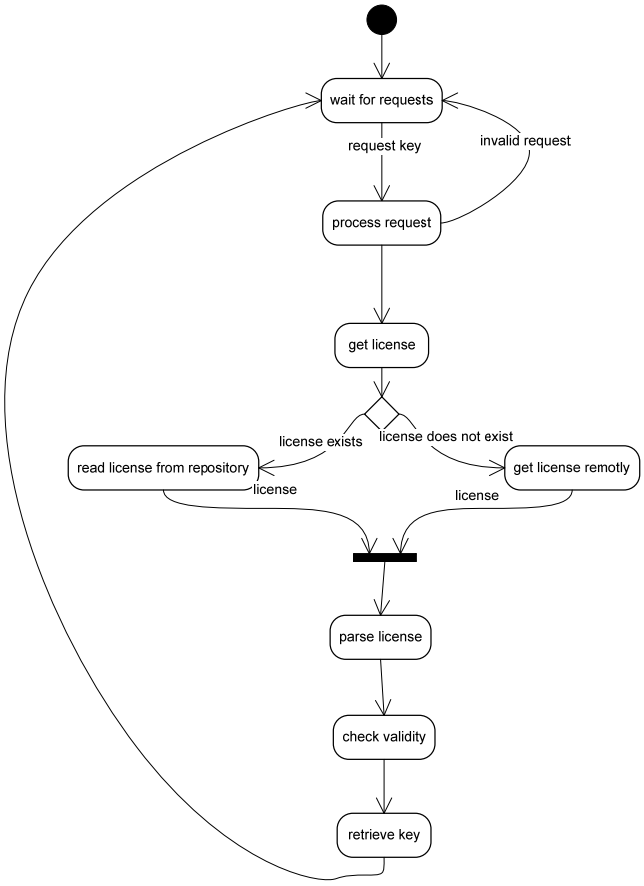


Figure 32: OpenSDRM flow diagram

If the license validity is overcome then it is automatically deleted from the Wallet repository.

Data

This component relies on several external data sources:

- User data repository: which contain the Wallet user details, such as the username, and cryptographic credentials, ciphered with an Advanced Encryption Standard (AES) secret key;
- The license files: a list of files, one for each content identifier that contains the licenses and corresponding keys. These files are also ciphered with a secret key.

6.6 PDS Parser

The PDSparser is the component on the HICOD2000 black-box that is responsible for interpreting the PDS files and extracts the relevant data from it, to be used on subsequent steps/tools.

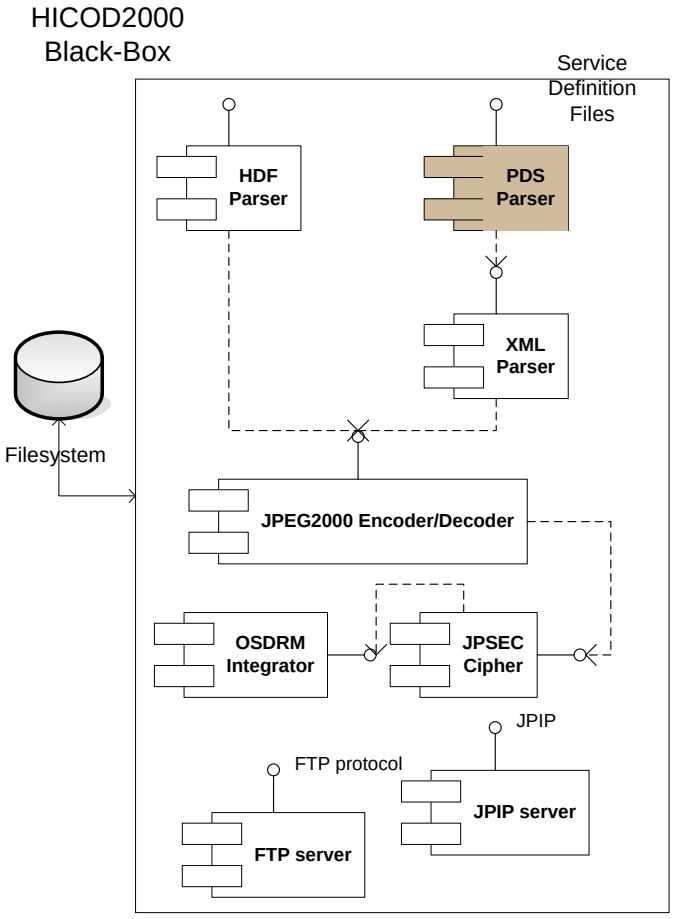


Figure 33: PDS Parser System Architecture

The relevant data that is extracted from the PDS file by the parser is:

- A set of RAW image components that will be compressed with the JPEG2000 encoder;
- A set of ASCII metadata that will be formatted in XML by the XMLparser and added afterwards to the final JPEG2000 product.

Type

This component has the following characteristics:

- Logical: Application;
- Physical: Executable;

This component was developed in C.

Purpose

This component implements the following software requirements which are described in chapter 5.

Requirement ID	Title
H2K-J2KBB.EOPP-FR-0140	Products to parse
H2K-J2KBB.EOPP-FR-0145	Configuration
H2K-J2KBB.EOPP-FR-0150	Raw data extraction
H2K-J2KBB.EOPP-FR-0151	EO products information extraction
H2K-J2KBB.EOPP-FR-0152	XML files production
H2K-J2KBB.EOPP-FR-0153	Raw files reading
H2K-J2KBB.EOPP-FR-0160	Interface with encoding/decoding service
H2K-J2KBB.EOPP-RR-0161	Portability
H2K-J2KBB.EOPP-RR-0163	Memory
H2K-J2KBB.EOPP-PR-0168	Systems

Table 46: PDS Parser Requirements Overview

The main purpose of this component is to parse/extract data from PDS files.

Function

The purpose of this subsystem is to build a jp2 file from a PDS file and back from jp2 file to PDS file. The PDS to jp2 transform is made by retrieving the JPEG2000 compressible data from the PDS file into separate raw files, non compressible data into a separate file, and two files to be handed to the JPEG2000 Encoder/Decoder (only kakadu) with the command line needed to encode/decode. The jp2 file to PDS file transform is accomplished passing the decode command file to the JPEG2000 decoder and assembly the resulting data into a PDS file.

Subordinates

Although the PDS parser can perform in a perfect standalone mode, receiving as input a PDS product and extracting raw data and ASCII metadata, in the context of the HICOD2000 black-box, it is expected that it provides data into other tools: XMLparser and the JPEG2000 encoder. In that sense, both the XMLparser and the JPEG2000 encoder are subordinates of the PDSparser.

Resources

This component can run both on Windows 2000/XP and on Linux.

Processing

The PDS parser expands a PDS file into raw data and metadata for JP2000 compression, conversely it can also merge the raw data and metadata files into one PDS.

For the parsing operation the parser reads the input file name from the command line and checks it regarding if it is a PDS file and if the product can be processed. The generated output has two file types (raw and xml) and N files (one for metadata and one for each band). Two auxiliary files are also produced to be used with the JPEG2000 codec (Kakadu only) for the compression and expand operations.

The unparsing operation takes a xml file (the metadata generated by the parsing operation) and rebuilds the original PDS file using the information on the xml file. The xml and raw files must be all in the same path so the parser can produce the PDS file.

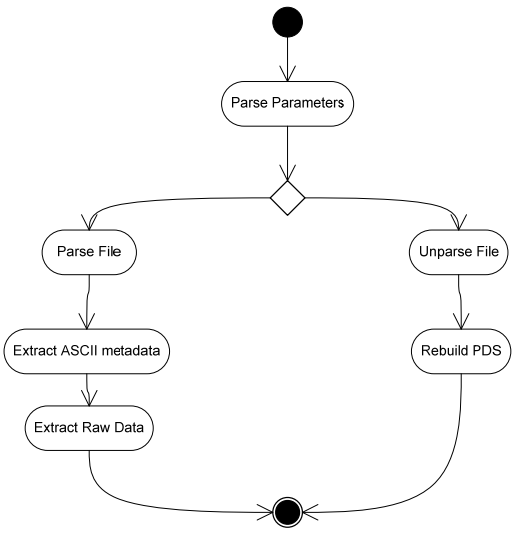


Figure 34: PDS Parser Flow Diagram

Data

This component uses a file that describes the PDS file structure.

6.7 HDF Parser

The HDFparser is the component on the HICOD2000 black-box that is responsible for interpreting the HDF files and extracts the relevant data from it, to be used on subsequent steps/tools.

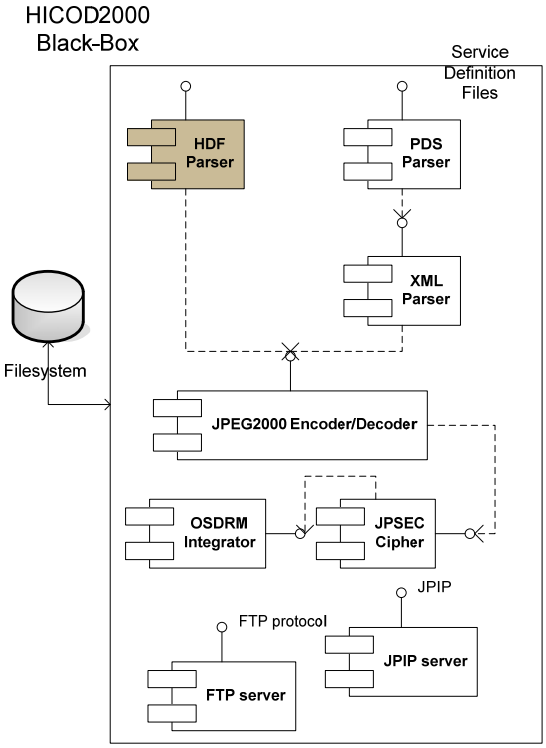


Figure 35: HDF Parser System Architecture

The relevant data that is extracted from the HDF file by the parser is:

- A set of RAW image components that will be compressed with the JPEG2000 encoder;

Type

This component has the following characteristics:

- Logical: Application;
- Physical: Executable;

This component will be developed in C.

Purpose

This component implements the following software requirements which are described in chapter 5.

Requirement ID	Title
H2K-J2KBB.EOPP-FR-0140	Products to parse
H2K-J2KBB.EOPP-FR-0145	Configuration
H2K-J2KBB.EOPP-FR-0150	Raw data extraction
H2K-J2KBB.EOPP-FR-0151	EO products information extraction
H2K-J2KBB.EOPP-FR-0152	XML files production
H2K-J2KBB.EOPP-FR-0153	Raw files reading
H2K-J2KBB.EOPP-FR-0160	Interface with encoding/decoding service
H2K-J2KBB.EOPP-RR-0161	Portability
H2K-J2KBB.EOPP-RR-0163	Memory
H2K-J2KBB.EOPP-PR-0168	Systems

Table 47: HDF Parser Requirements Overview

The main purpose of this component is to parse/extract data from HDF files.

Function

This service is used to process the HDF files (specifically the SPOT vegetation products).

This service receives as input an HDF file and produces a lossless JPEG2000 file. It also can receive a JPEG2000 file and recover the original HDF file. This subsystem is responsible for the extraction of the core data from SPOT Vegetation HDF files, and also of the relevant API level metadata.

The usage of this system can be expressed in the following:

Usage: **hdfparser hdfdata_file hdfxmldata_file**

hdfdata_file: Input parameter with the path for the HDF file to be parsed.

hdfxmldata_file: The original accompanying XML file obtained together with the product. An example XML file can be found on the Annex

The output of this subsystem consist of two files, one containing the core data, and the other one a XML file with the API level metadata.. The HDF parser joins both the original XML file together with XML extracted directly from the HDF file.

Subordinates

Although the HDF parser can perform in a perfect standalone mode, receiving as input a HDF product and extracting raw data, in the context of the HICOD2000 black-box, it is expected that

it provides data into other tools: JPEG2000 encoder. In that sense, the JPEG2000 encoder is a subordinate of the HDFparser.

Dependencies

This component depends on the NCSA HDF4 libraries.

Resources

This component can run both on Windows 2000/XP and on Linux.

Processing

The HDF parser performs in the following way:

- It reads the HDF file and the parsing/unparsing parameters;
- Extracts the RAW data from the HDF file;
- Writes the RAW data files to be converted afterwards to JPEG2000.

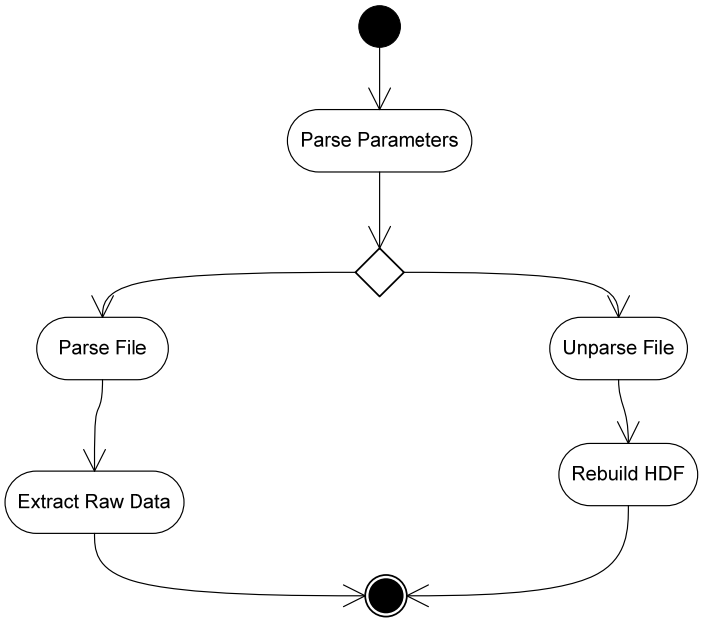


Figure 36: HDF Parser Flow Diagram

XML Parser

The XMLparser is the HICOD2000 black-box component responsible for converting the ASCII data that is retrieved by the PDSparser from PDS-formatted EO products into W3C-compliant XML.

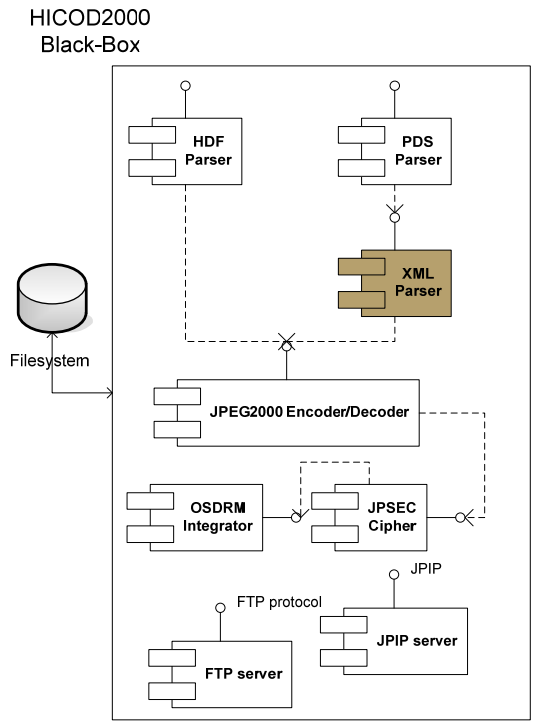


Figure 37: XMLParser System Architecture

The resulting output of the XMLparser is a XML data file that is after passed to the JPEG2000 encoder and stored on a JPEG2000 code-stream specific box.

Type

This component has the following characteristics:

- Logical: Application;
- Physical: Executable;

This component will be developed in C++.

Purpose

This component implements the following software requirements which are described in chapter 5.

Requirement ID	Title
H2K-J2KBB.EOPP-FR-0152	XML files production
H2K-J2KBB.EOPP-FR-0151	EO products information extraction

Table 48: XML Parser Requirements Overview

Function

The function of this component is to accept the ASCII text input of the PDSparser extracted data and to convert it to XML.

Dependencies

This component depends on the ASCII data input provided by the PDSparser.

Resources

This component can run both on Windows 2000/XP and on Linux.

Processing

This component processes in the following way:

- It receives the ASCII data file;
- For each of the lines of the input ASCII data file it:
    - Searches for the name of the tag and the corresponding value;
    - On the output XML file, it creates a new XML entity tag and deploys the value;
- It adds an root entity tag, in the beginning and the end of the file;
- It adds at the beginning of the XML file, the XML file marker identification;
- If there are non-printable characters on the ASCII file, then those are converted to base-64 format.

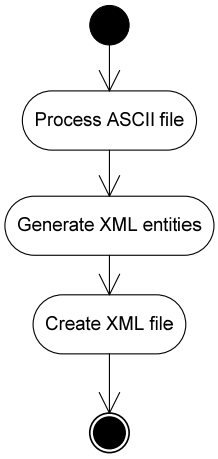


Figure 38: XMLParser Flow Diagram

6.8 JPEG2000 Encoder/Decoder

This component is Commercial off-the-shelf (COTS). It is based on the Kakadu software

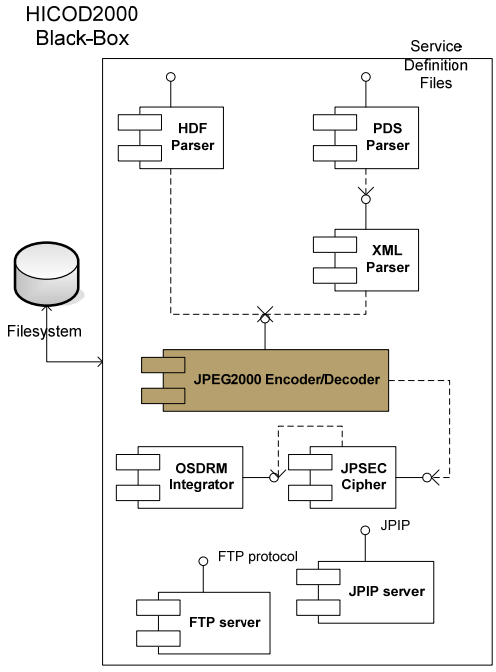


Figure 39: JPEG2000 Encoder/Decoder System Architecture

described on section 4.5.

Kakadu (see section 4.5) is one of the best JPEG2000 compression and decompression tools currently available. The HICOD2000 black-box uses this software to compress and decompress the EO PDS/HDF products.

Type

This component has the following characteristics:

- Logical: Application;
- Physical: Executable;

This component is COTS (it has been developed in C++).

Purpose

This component implements the following software requirements which are described in chapter 5.

Requirement ID	Title
H2K-J2KBB.J2KED-FR-0180	Encoding parameters
H2K-J2KBB.J2KED-FR-0190	XML encoding parameters
H2K-J2KBB.J2KED-FR-0210	Read XML data
H2K-J2KBB.J2KED-FR-0230	Simple decompression
H2K-J2KBB.J2KED-FR-0240	Progressive and interactive decompression
H2K-J2KBB.J2KED-FR-0250	Controlled decompression
H2K-J2KBB.J2KED-FR-0270	XML extraction
H2K-J2KBB.J2KED-IR-0170	Raw data
H2K-J2KBB.J2KED-IR-0200	JP2 file format
H2K-J2KBB.J2KED-IR-0205	JPX file format
H2K-J2KBB.J2KED-IR-0220	Store results in the filesystem
H2K-J2KBB.J2KED-IR-0260	Interaction with other services
H2K-J2KBB.J2KED-RR-0271	Resources
H2K-J2KBB.J2KED-RR-0273	Memory
H2K-J2KBB.J2KED-PR-0275	Portability

Table 49: JPEG2000 Encoder Decoder Requirements Overview

Function

The main purpose of this component, within the HICOD2000 black-box architecture is to encode RAW image data files into JPEG2000 code-stream and vice-versa. Since this is COTS, the actual number of functions of Kakadu is quite variable and applicable to several different situations. For more information on this component, please refer to section 4.5 of this document.

Resources

This component can run both on Windows 2000/XP and on Linux.

6.9 JPSEC Cipher

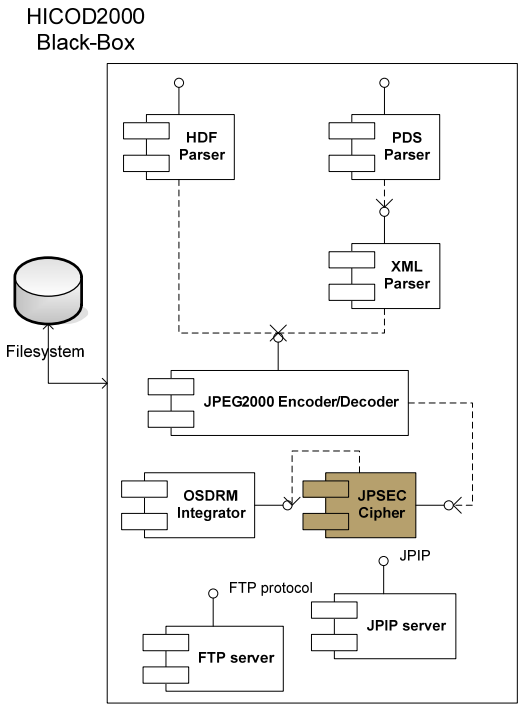


Figure 40: JPSEC Cipher System Architecture

This software component is the responsible in the HICOD2000 black-box architecture for ciphering the JPEG2000 images according to a set of parameters.

Type

This component has the following characteristics:

- Logical: Application;
- Physical: Executable;

This component was developed in C++.

Purpose

This component implements the following software requirements which are described in chapter 5.

Requirement ID	Title
H2K-J2KBB.J2KSEC-FR-0280	JPSEC protected file
H2K-J2KBB.J2KSEC-FR-0290	Scramble
H2K-J2KBB.J2KSEC-FR-0300	Access conditions
H2K-J2KBB.J2KSEC-FR-0310	Access control
H2K-J2KBB.J2KSEC-FR-0320	Unauthorized access prevention
H2K-J2KBB.J2KSEC-FR-0330	Deny access to parts of content
H2K-J2KBB.J2KSEC-FR-0340	Rights expression language
H2K-J2KBB.J2KSEC-FR-0350	Different protection tools
H2K-J2KBB.J2KSEC-FR-0360	Metadata protection
H2K-J2KBB.J2KSEC-FR-0370	IPR management
H2K-J2KBB.J2SEC-RR-0371	Resources
H2K-J2KBB.J2SEC-RR-0373	Memory
H2K-J2KBB.J2KED-PR-0375	Portability

Table 50: JPSE Cipher Requirements Overview

Function

This software component performs in the following way:

- The component receives a file containing the resolution levels, and the keys for each resolution levels;
- The software then uses a secret-key algorithm to cipher the appropriate image resolution levels and/or image metadata.

Resources

This component can run both on Windows 2000/XP and on Linux.

Processing

The JPSEC tool takes a jp2 file format JPEG2000 file and adds security to it. The tool receives a file with the encryption keys, one for each resolution, a Unique Resource Name (URN) to identify uniquely the image and the decryption keys. The encryption process starts by building the encryption objects and resolution per resolution the proper encryption object is called to do the data encipher. In the end a jp2 file as been produced with its content protected.

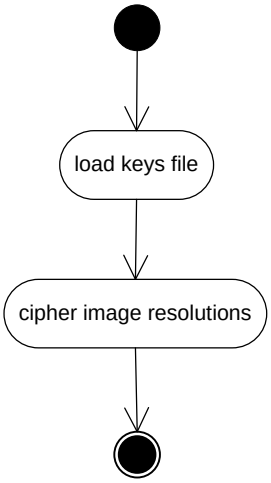


Figure 41: JPSEC Cipher Flow Diagram

Data

This component uses an external file that contains all the keys and the resolution levels that will be ciphered.

6.10 OSDRM integrator

The OSDRM integrator is the component that deals with OpenSDRM DRM platform integration, for providing DRM services to the HICOD2000 black-box.

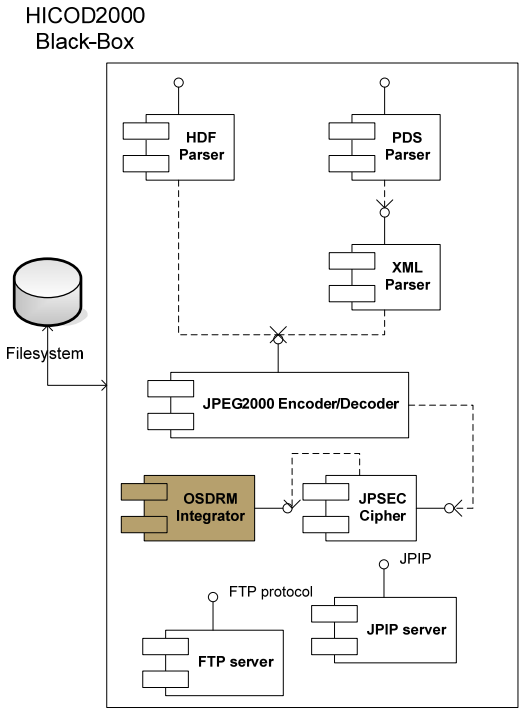


Figure 42: OpenSDRM Integrator System Architecture

Type

This component has the following characteristics:

- Logical: Application;
- Physical: Executable;

This component has been developed in PHP.

Purpose

This component implements the following software requirements which are described in chapter 5.

Requirement ID	Title
H2K-J2KBB.INTG-FR-0421	WSDL interface
H2K-J2KBB.INTG-FR-0421	API
H2K-J2KBB.INTG-RR-0430	Resources
H2K-J2KBB.INTG-RR-0435	Memory
H2K-J2KBB. INTG -PR-0450	Portability

Table 51: OSDRM Integrator Requirements Overview

Function

The main purpose of this software component is to be used as an integration mechanism between the HICOD2000 black-box and the OpenSDRM DRM platform. This integration will provide the following DRM capabilities to HICOD2000:

- The possibility to register a specific image file on a OpenSDRM registration server, and assign it a unique identifier;
- The possibility to store the encryption keys that had been used for ciphering the content, for posterior usage;
- The possibility to produce licenses according to a set o parameters that can be established between the image supplier and the client.

Dependencies

This component depends on the PHP environment installation (at least version 4.3.6).

Resources

This component can run both on Windows 2000/XP and on Linux.

Processing

This software component, implemented in PHP provides the integration between OpenSDRM and HICOD2000 black-box. Three different operations are provided:

- Content Registration: in this operation the OSDRM integrator receives the filename that is going to be registered and the some additional (optional) XML file containing information about the content. It then generates an MD5 hash and invokes a remote OpenSDRM functionality (using SOAP) to register the content. The content gets registered on the OpenSDRM platform and a unique identifier is returned back to the software component;

- Content Encryption Keys storage: in this operation the OSDRM integrator component receives the content unique identifier, plus a file that associates the different resolution levels with the corresponding encryption keys. Using this information the OSDRM integration invokes remotely a function (via SOAP) to register the content encryption keys. This will allow the possibility to create in the future licenses for that specific content;

- Content license production: in this operation the OSDRM integrator receives the user identification, the content identification and the licensing parameters (a file containing the image resolution levels and the validity of the license). With this data the OSDRM remotely invokes OpenSDRM function (via SOAP), requesting that a specific license needs to be produced for that specific user, specific content identifier and with that specific parameters. This license will be downloaded afterwards.

6.11 FTP Server

This software component is a normal FTP server. It is COTS (for Windows Filezilla server will be used, while for UNIX the standard Linux-distribution FTP, will be used).

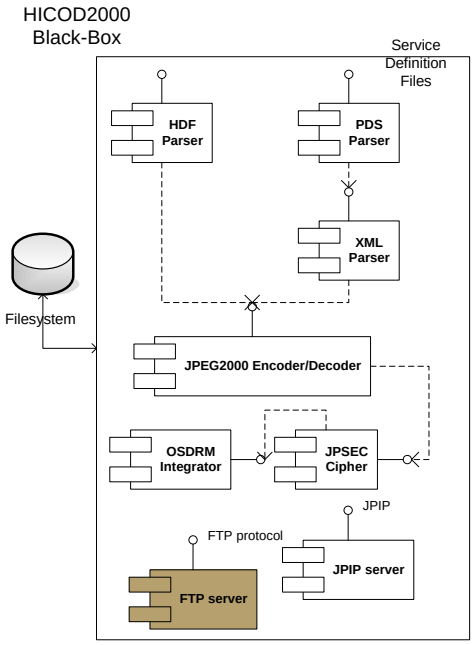


Figure 43: FTP Server System Architecture

Type

This component has the following characteristics:

- Logical: Application;
- Physical: Executable;

Purpose

This component implements the following software requirements which are described in Table 51.

Requirement ID	Title
H2K-J2KBB.COMM-FR-0380	Remote access to products
H2K-J2KBB.COMM-FR-0390	Recover original products
H2K-J2KBB.COMM-IR-0421	Configuration system
H2K-J2KBB.COMM-IR-0421	XML configuration files
H2K-J2KBB.COMM-RR-0423	Resource
H2K-J2KBB.COMM-RR-0424	Memory
H2K-J2KBB.COMM-PR-0425	Portability
H2K-J2KBB.COMM-SR-0426	Security

Table 52: FTP Server Requirements Overview

Function

The main function of this component is to provide the image download functionalities to the HICOD2000 service.

6.12 JPIP Server

This software component is a JPIP server. It is COTS (the Kakadu JPIP server was used).

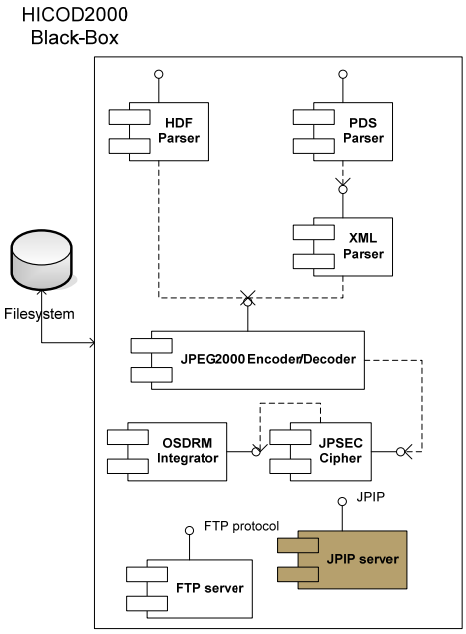


Figure 44: JPIP Server System Architecture

Type

This component has the following characteristics:

- Logical: Application;
- Physical: Executable;

Purpose

This component implements the following software requirements which are described in section

Requirement ID	Title
H2K-J2KBB.COMM-FR-0380	Remote access to products
H2K-J2KBB.COMM-FR-0390	Recover original products
H2K-J2KBB.COMM-FR-0400	Interactive access
H2K-J2KBB.COMM-FR-0410	JPIP over HTTP
H2K-J2KBB.COMM-FR-0420	Download parts of image
H2K-J2KBB.COMM-IR-0421	Configuration system
H2K-J2KBB.COMM-IR-0421	XML configuration files
H2K-J2KBB.COMM-RR-0423	Resource
H2K-J2KBB.COMM-RR-0424	Memory
H2K-J2KBB.COMM-PR-0425	Portability
H2K-J2KBB.COMM-SR-0426	Security

Table 53: JPIP Server Requirements Overview

Function

The main function of this component is to provide the interactive image download functionalities to the HICOD2000 service.

Dependencies

Depends on the Kakadu libraries.

Resources

This component can run on Windows 2000/XP.

6.13 Conclusion

On this chapter a general architecture was presented to solve the proposed system. This architecture is the response to all system requirements presented earlier on this document. Those requirements represented a wide variety of problems and constraints that had to be taken into account when building the system architecture. Each of the HICOD2000 architecture components were explained in various levels from its position in the general architecture to the resources needed and the functionalities of each component. All this components were integrated into the two main anchor components of the HICOD2000 architecture, the HICOD2000 Client Application and the HICOD2000 Black-Box, corresponding to a Client/Server paradigm. However the system was build so that both sides could be integrated on only one machine being flexible to work on both models without radical changes.

In order to certify the architecture and the final HICOD2000 system, the team planned a series of system validation procedures and usability tests, this process results are presented on chapter 6.

7. SYSTEM VALIDATION AND USABILITY TESTING

7.1 Introduction

In this chapter, the author describes the steps involved in providing rigorous industrial validation and acceptation of a system like the HICOD2000, as well as showing and describing the test results needed to achieve the system validation. This chapter also has a section dedicated to the creation and analysis of a usability test for the HICOD2000 System. The HICOD2000 is a complex system with a very simple guiding concept, so the objective of the usability test was to get some information feedback from possible users of the final system.

The author wanted to establish the degree of satisfaction and the evaluation each user would give, changing from the traditional ESA trading model to the more elaborate model provided by the HICOD2000 system. The author starts by explaining the main objectives of the tests, followed by an analysis of the methodology and correspondent evaluation metrics for both the validation and usability tests. Finally, the obtained results are presented on the conclusions section.

7.2 System Validation

The ability to deal with a high level of complexity in a flexible way makes software an essential and increasing part of space segment and ground segment products. In space systems, software engineering is found at all levels ranging from system level functions down to the firmware of a space system part [RD-51].

The software requirements engineering process consumes a large and often underestimated amount of effort in the development of software for space systems. As a result of the complexity of the functional and performance requirements, it also follows that special measures and emphasis apply for software verification and validation, especially for space segment software [RD-51].

According to ESA standard for product assurance [RD-52], objectives of software product assurance are to provide adequate confidence to the customer and to the suppliers that developed or reused software satisfies the requirements throughout the system lifetime. In

particular the software is developed to perform properly and safely in the operational environment meeting the quality objectives agreed for the project.

In order to enlarge the consortium, to ensure proper validation and quality of product to be developed, Critical Software [RD-53] was invited to join the project. This was a natural choice given its adequacy to the tender objectives and its well known experience in large National and International Software Engineering projects, including projects with ESA. Critical's renowned expertise in mission-critical system dependability evaluation, and validation technologies like the Xception [RD-54] technology provided the means to validate critical system elements such as recovery and fault-tolerance and providing insight into the levels of system dependability achieved.

Being a Research and Development kind of project, the HICOD2000 introduced some difficulties in terms of management and quality management. Its scope has been successively changed during execution with agreement of all parts involved. As result the quality processes defined upon the design of the project quality assurance plan, were not followed on some occasions.

The following subsections summarize the results of the evaluations performed to the software development process.

7.2.1 Product quality objectives and metrication

7.2.1.1 Methodology

The objective of the section is to analyze and summarize the final outcomes of the HICOD2000 project by collecting source code metrics.

Understand of C++ tool [RD-55] was used to collect the metrics for each individual component of Black Box (core, HDF Parser, PDS Parser, JPSEC) and HICOD Viewer. This analysis did not consider the following components:

1. DRM server (OpenSDRM-server) – the component was used as COTS, being performed minor changes to cope with the system architecture;
2. Kakadu libraries - it wasn't developed for the project so it was considered a COTS. However, some extensions to the libraries were made to accommodate the project requirements.

Three metrics were selected for the analysis: Average Cyclomatic Complexity, Lines of Code and Ratio Comment to Code. The results obtained are organized per component file.

Collected metrics were checked against target values obtained from Standard Performance Evaluation Corporation **(**SPEC) [RD-56]. Two set of metrics were considered:

- SPEC maintainability (analyzability) metrics for class D software: Cyclomatic complexity and Lines of Code per module.
- SPEC documentation quality (Development & maintenance documentation quality) metrics for class D software: code comment frequency.

The target values of SPEC depend from the software criticality. It is assumed the software produced is criticality D (low criticality) although any criticality analysis was performed. Based on this assumption, the metrics target values applicable for each module (file) are summarized in the following table:

Target Metrics	Class D values
Cyclomatic Complexity	20
Lines Of Code	400
Ratio Comment/Code	0,3

Table 54: SPEC Target Values

7.2.1.2 BlackBox

PDSParser (C code)

File Name	Average Cyclomatic Complexity	Lines of Code	Ratio Comment/Code
b64.c	7	123	0,8
getopt.c	14	58	1
Main.c	12	435	0,44
pdsparser.c	4	711	0,8
b64.h	0	2	26,5
getopt.h	0	6	0,33
pdsparser.h	0	117	4,6

Table 55: PDS Parser metrics results

HDFparser (C++ code)

File Name	Average Cyclomatic Complexity	Lines of Code	Ratio Comment/Code
hdfraw.c	6	297	0,42
parserSD.c	8	996	0,29

Table 56: HDF Parser metrics results

JPSEC (C++ code)

File Name	Average Cyclomatic Complexity	Lines of Code	Ratio Comment/Code
main.cpp	8	621	0,22
J2KCryptoStream.cpp	5	110	0,04
JPSECProtection.cpp	3	64	0,06
J2KCryptoStream.h	1	21	0,00
JPSECProtection.h	1	25	0,12

Table 57: JPSEC metrics results (1)

JPSEC for Windows (C++ code)

File Name	Average Cyclomatic Complexity	Lines of Code	Ratio Comment/Code
JPSECProtection.cpp	3	62	0,06
main.cpp	8	567	0,19
JPSECProtection.h	1	23	0,17

Table 58: JPSEC metrics results (2)

HDF4Parser (C code)

File Name	Average Cyclomatic Complexity	Lines of Code	Ratio Comment/Code
compressor.c	5	122	0,67
Getopt.c	14	61	0,95
hdf4parser.c	15	493	0,32
main.c	5	143	0,48
compressor.h	0	28	2,93
Getopt.h	0	6	0,33
hdf4parser.h	0	2	18,5

Table 59: HDF4 Parser metrics results

H2KBB (C code)

File Name	Average Cyclomatic Complexity	Lines of Code	Ratio Comment/Code
getopt.c	14	58	1,05
h2kbb.c	5	381	0,64
getopt.h	0	6	0,33

Table 60: H2KBB metrics results

7.2.1.3 HICOD Viewer (C++ code)

File Name	Average Cyclomatic Complexity	Lines of Code	Ratio Comment/Code
ChildView.cpp	5	390	0,34
MainFrm.cpp	2	99	1,58
SecurityControl.cpp	4	451	0,07
Utils.cpp	2	162	0,02
WalletConnection.cpp	3	37	0
WalletConnection_.cpp	2	30	0,37

Table 61: HICOD Viewer metrics results

7.2.2 Conclusion

The HICOD2000 system was exercised by verifying each of the software requirements as provided on chapter 5. Only the exceptions below were not tested.

Fail criteria: whenever the specified test output wasn't verified.

Failures can be classified as Minor and as Major.

- Minor failures don't have impact on the normal application functioning, for example, the incorrect messages. The application may still be used.
- Major failures have impact on the application functioning, that is, it cannot be used if these types of errors aren't corrected.

Success criteria: whenever the test case specified output was verified.

The software testing phase was considered successful if all executed tests were successfully executed.

Concerning the product quality objectives and metrication all modules have cyclomatic complexity lower than target value 20, meaning that the complexity of the methods (or functions) is inside a good range.

As for lines of code components PDSParser, JPSEC and ParserHDF contain a file, which has a Lines of Code (LOC) value above target values. PDSParser file pdsparser.c contains more 514 LOC than the target value. JPSEC file main.cpp contains more 221 LOC than the target value. ParserHDF file parserSD.c contains more 596 LOC than the target value

In terms of code comments frequency most of the components have a good ratio comments/LOC. The exception is JPSEC, which presents values below the target value.

The following table summarizes the results of each component:

Component	Average Cyclomatic Complexity	Total Lines of Code	Average Ratio Comment/Code
PDSParser	5	1452	5
HDFParser	7	1293	0,355
JPSEC	3,6	841	0,1
JPSEC for Windows	4	652	0,14
HDF4PARSER	5,6	855	3,5
H2KBB	6,3	445	0,6
HICOD Viewer	3	1169	0,4

Table 62: Cyclomatic Complexity resume

Concerning the software validation testing and all tests were executed and after a few iterations between Critical software team and ADETTI's team the results achievements were reduced to 2 minor "problems" which are both external to the project.

Tests		Number	Percentage
Total		29	100,00%
Descoped		7	24,14%
Not Performed		0	0,00%
Completed		22	100,00%
Passed		20	90,91%
Failed	Major		0,00%
	Minor	2	9,09%

Table 63: Tests statistics

The BlackBox behaved successfully with no errors

HICOD2000AppViewer was successfully installed and ran. It showed very dark images on some particular ASAR data file which wasn't found on the original file. This problem is due to a high dynamic grayscale range that the viewer can't handle – this would require the implementation of a specific converter on the viewer. Toolbox was successfully installed, too.

Connection with OpenSDRM server showed to be insecure, because secure https connection is not forced with the user. This is however not a vulnerability of the software, but rather a miss configuration issue. It is specifically referred on the manual that the server machine needs to be configured for https connections.

Communication and operations through ESA SSE Portal was successfully achieved and tested according to system requirements. On the overall Critical Software validated the HICOD2000 system with distinction, with only minor errors, related to changes made to the project that put some of the items of the validation plan out of scope.

7.3 Usability Evaluation

To try to determine the usability of the system, a test was developed to assess the usefulness of the HICOD2000 system and compare it with the ESA traditional distribution model. The author main goal was to compare both models and try to determine if the final user would see the proposed system as an important advantage over the current model, as well as establish an evaluation of the different components of the system.

7.3.1 User Test Pool and Methodology

The test was performed on 11 test users, with ages between 21 and 33 years. From this lot, 5 have degrees in computer science, 2 are computer science students and the remaining 4 have university degrees in other areas. The test was divided into four stages:

- On a first stage, each user was individually questioned about their familiarity regarding satellite images, satellite images products and JPEG2000 image format. This questionnaire aimed at accessing the previous experience that the users might have with these items. The questionnaire used can be seen on Annex C.

- The second stage was a general explanation about the SSE portal and the Odisseo catalogue system was presented to the users for 15mns. The use of the catalogue, to navigate and choose an area of interest and querying for satellite images of the specified area, was presented and the process to obtain the images was explained.

- On a third stage, the user was asked to fill in a small questionnaire about the ESA EO products and their distribution model.

- After this the author presented the HICOD2000 system, performing all the actions required to have a global view of the system, from the time of requesting the product on the SSE portal to the time of viewing the retrieved product on the HICOD2000 viewer client application. The users were then asked to perform the same actions and leave their feedbacks on a third questionnaire focusing on:

    - User feelings regarding the HICOD2000 performance

    - Establish a comparison between the HICOD2000 distribution model and those of ESA

    - User feelings regarding download response time

    - Other eventual problems.

7.3.2 Tasks

On the fourth stage of the usability test the users were presented with a number of very simple tasks that needed to be performed without any time constraints:

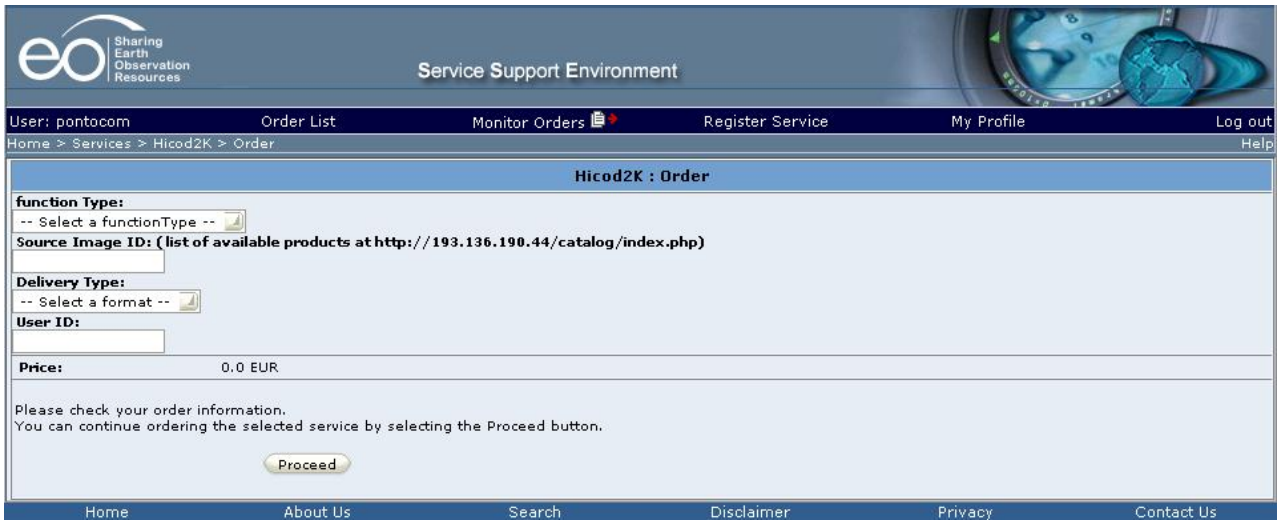


Figure 45: HICOD2K SSE Portal Service Order Page

- First they had to order a product from the HICOD2K service page on the SSE portal.
- The next phase was to check the order list and download the image when the order was completed and available for download.

Figure 46: HICOD2K SSE Portal Service Order Result Page

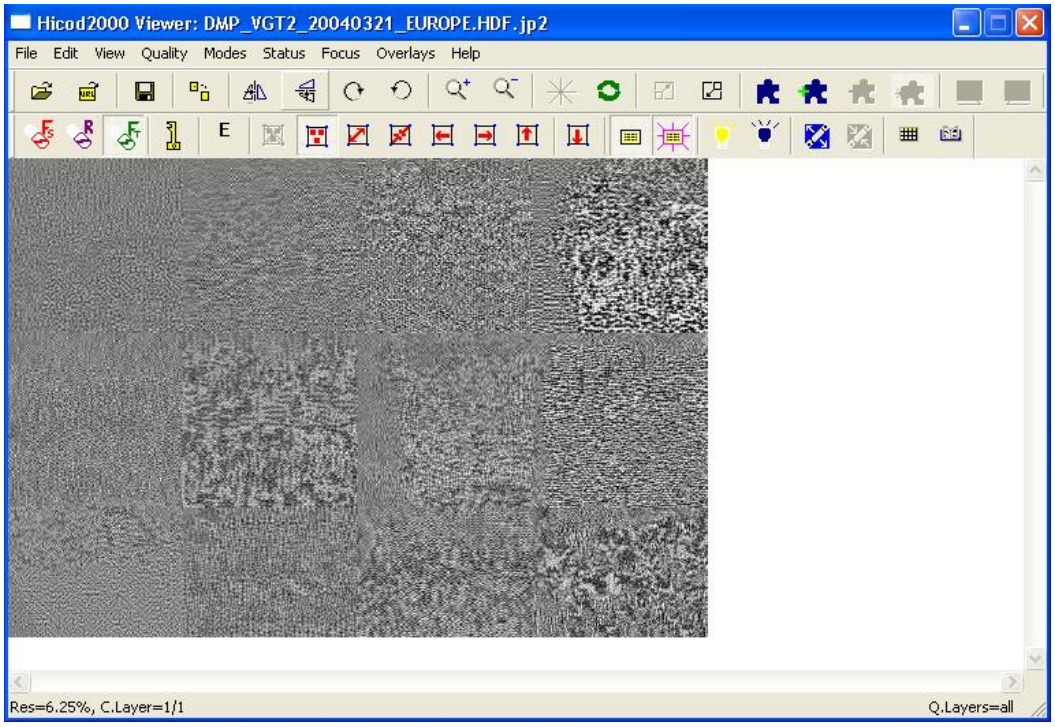


Figure 47: HICOD2000APPViewer Opened With Ciphered Image

- The third phase was to open the downloaded image on the HICOD2000 viewer

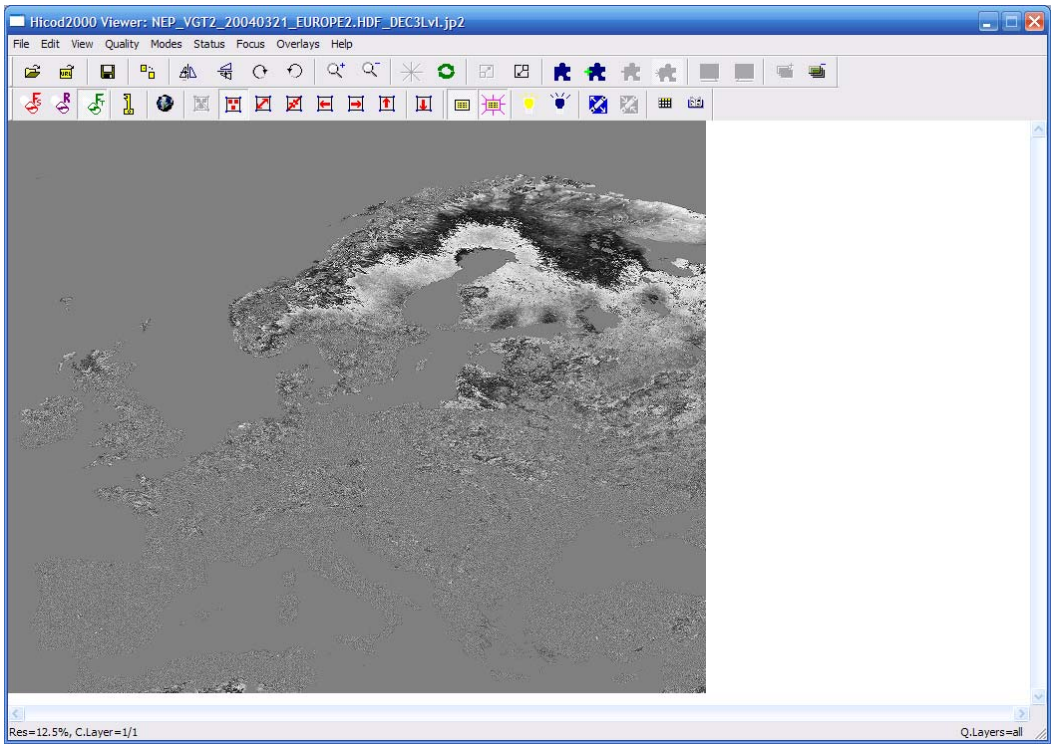


Figure 48: HICOD2000APPViewer Opened With 3 Levels Deciphered Image

- The fourth and final phase was to ask for the deciphering of the image at any of the 6 available resolutions.
- In order to give a better informed feedback of the system the users were given the liberty of continuing exploring the HICOD2000 viewer options as they wished.

7.3.3 Subject questionnaire

As previously stated the test was divided in 4 phases each of the phases with its own set objectives and conclusions.

First Questionnaire

On the first questionnaire the author tried to access the level of knowledge of each of the users on the topics closely related to the project, huge images, satellite images, satellite related systems and JPEG2000 file format. From the answers to the first question the author can say that huge image (images with more than 80 MB), like the ones used by the HICOD2000 project, are nowadays a relatively common work subject with 6 of the 11 users stating that they did had worked with such images. From this group, 3 had worked with huge images for purposes similar to some of the objectives of the HICOD2000 system, conditional access to satellite images,

image compression and conversion of *.tif images. The other 3 users work purposes were related to photo manipulation.

The second question asked if the users had ever worked with satellite images, 4 of the eleven users answered positively, when asked for the purpose of that work the answers ranged from academic purposes to completion of map information.

On the third question the users were asked if they had ever worked with systems like Google Earth [RD-57] or similar. This set of questions was used not only to access the involvement of the users in satellite related systems but also as to establish a first comparison with the answers given by the users to the last questionnaire related to the HICOD2000 system.

What the author concluded was that Google Earth definitely contributed to the widespread use of satellite systems. All users answered that they had worked with this or similar systems. They then proceeded to evaluate the systems in terms of usefulness, complexity and system response. In terms of usefulness the general feeling is that the systems are useful or very useful with only one user declaring, the system, completely useless. In terms of complexity the users stated they thought the systems were simple, finally, the system response was considered to be adequate.

The last 2 question of the first questionnaire were used to evaluate the knowledge of the users on the JPEG2000 image format. Only 3 users had ever used the format, confirming the idea that the widespread use of JPEG2000 still as a long way to go, with uses being somewhat restricted to the academic level and to very specific areas, as is the case of the HICOD2000 system. The 3 users were familiarized with the format and declared that it was better or much better than other image formats.

Second Questionnaire

After the author presented the SSE portal and the Odisseo catalogue, as well as their business models, the users were invited to state their opinions about those services and their business models on a second questionnaire. The users were asked if they knew any EO products, the results to this question were within what was expected only 3 users knew about this products.

The second question was their opinion about ESA product distribution model; answers to this question pointed that the users were not very convinced with ESA distribution mode and feel there is a need to make improvements.

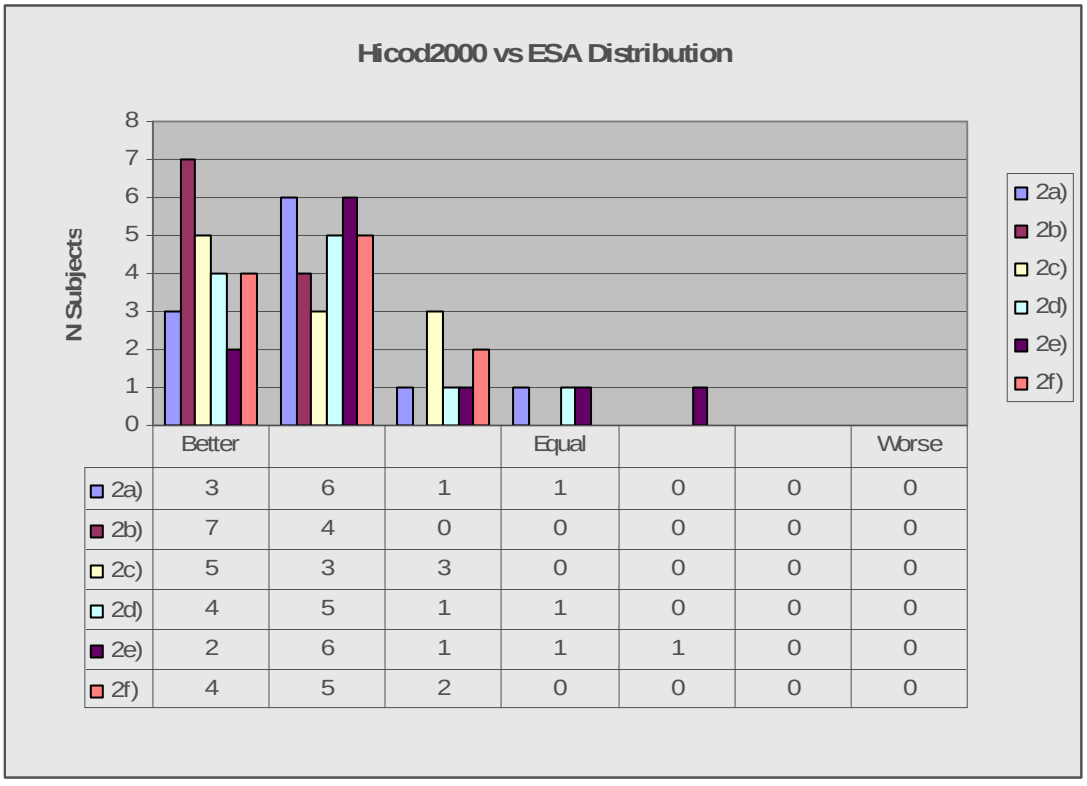
The third question was if they thought the distribution model was secure, opinions about this were divided between those who thought the model was secure, with 4 positive opinions, and those who thought it was insecure, with 5 negative opinions, with 2 of the users saying the model was not secure, nor insecure. This division as probably something to do with the users' perception of security and ownership, the author should have stated in a clearer way the notion of security necessary to comprehend this question. Finally, as a follow up of the third question, it

was asked if they thought the postal delivery method was the right choice for this case. All except 1 answered it wasn't the right choice, confirming that they thought ESA should change their delivery method into something more satisfying from the customer point of view.

7.3.4 The Test and feedback

The final part of the usability test was a questionnaire made to the users after each usability session. This questionnaire was divided in four parts, the first part was related to the opinion the users had on the HICOD2000 system, the second part was used to compare the HICOD2000 distribution model and ESA traditional distribution model, the third part established two very important aspects of the HICOD2000 system, response time and easiness of use and finally a fourth part trying to find out what were the problems that users found most uncomfortable about the system.

From the analysis of the answers to the first group the author can say that the users considered the system easy to use, stable, was rather faster retrieving data, had a reasonable response and the users understood quite well what was happening during the all process. The overall opinion of the users was that the system was quite good.

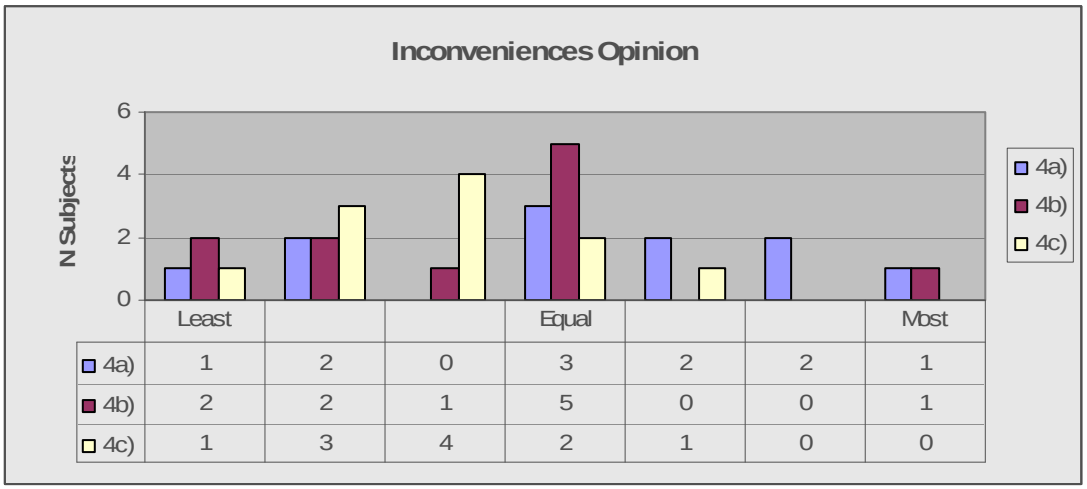


	Better			Equal			Worse
2a)	3	6	1	1	0	0	0
2b)	7	4	0	0	0	0	0
2c)	5	3	3	0	0	0	0
2d)	4	5	1	1	0	0	0
2e)	2	6	1	1	1	0	0
2f)	4	5	2	0	0	0	0

Table 64: Tests Results on Questions 2

On the second set of questions, the comparison between the HICOD2000 distribution system and the usual ESA distribution system, the users rated the HICOD2000 system always as their preferred system with high notes on items like speed in retrieving data and system security. The overall opinion was that the HICOD2000 system was a better model to distribute EO products.

To analyze critical aspects of the system, from the point of view of the users, the author created a third group of questions. In this group the users had to rate the system response time and easiness of use. The large majority of the users rated both items in a positive way. These two aspects are so important because they can determine the success of an application. If an application or service misses on these two items the clients may lose interest and kill a good idea or concept. Google Earth is such a good application, because besides the great concept behind it, the response time is very short and the interface is extremely user friendly.



	Least			Equal			Most
4a)	1	2	0	3	2	2	1
4b)	2	2	1	5	0	0	1
4c)	1	3	4	2	1	0	0

Table 65: Tests Results on Questions 4

The fourth poll of questions was about situations that could bother the users, namely delay in data retrieval, system instability and system complexity. From the users answers the author can say none of this situation was considered a real bothering problem to the users, only the delay in data retrieval had an average classification but that can be attributed mainly to the network speed constraints.

Taking into account the user's experience, the different fields of knowledge and homogeneity of the answers to the usability test questions, the author believes the HICOD2000 system was considered to be a very robust and innovative prototype, that considerably more user friendly than the system currently in used by ESA, and which according to almost all the beta testers should in the future become an ESA standard service to code protect and trade EO products.

7.4 Conclusion

In this chapter the validation and the usability testing was presented by the author. The objective of the first section was to give a view on how the system was validated by ADETTI partner in the project, Critical Software. The author explained the steps needed to validate a project like the HICOD2000 with an organization has rigorously conscious as ESA, as well as the conclusions of that validation report.

In Section 7.3 the author presented every step involved in the realization of the usability test. The author also presented the feedbacks achieved by those tests as well as the conclusions that were obtained from the study of the results of these tests.

After being thoroughly tested by a very rigorous and prestigious company, as is the case of Critical Software, considered to be one of the best in the World when it comes to software testing and validation, and after being put into use by a pool of beta testers, the author has a very strong conviction, that these new software and services, developed for the HICOD2000 project, can really take ESA and other companies trading EO products into a much higher level, concerning two key subjects, security and a totally digital system. These two key subjects are extremely important for both parts involved in a trade, security of value for the seller part and a totally digital system that in most cases results in a better end client experience as is the case of the HICOD2000 system, and it were these two key pieces that were rigorously tested and approved both by Critical Software and by the beta testers.

In the following chapter the author presents the final considerations about the project results and possible future works and ends the thesis with the conclusion remarks.

8. CONCLUSION

8.1 Considerations and Future work

Satellite imaging is one of the areas that can take advantage of the new image coding standard JPEG2000. Not only in terms of image compression, a quite relevant aspect, but also from the perspective of the new standard parts being currently specified and developed, such as security, interactive protocols, wireless transmission of images and multicomponent and multi-spectral representation capabilities.

The efficient compression scheme of JPEG2000 can handle images with higher quality and dimensions and provide satellites with increased storage capability. The standard can also provide more flexibility due to the compression options it offers. This could help satellite providers to reduce time-to-market in solutions for satellite imaging E-commerce, which can be turned into an important competitive advantage.

In general the described by the author in this dissertation is part of a set of exploratory actions to find new technologic opportunities to integrate in ESA processes. In this specific case, HICOD2000 proved to ESA that JPEG2000 was an interesting technology that could be used to encode and distribute some EO products. The outcomes of the project have proved that some HICOD2000 technologies may be applied in EO systems. One of the major opportunities, for the future exploitation of the solution presented, is the application of JPEG2000 for lossless compression of a range of ENVISAT products, as well as further research following the JP3D JPEG2000 extension activities, namely in coping with floating point data sets, in order to be able to comply with all the possible EO products conversion.

Another major issue is the proper organization and modularization of the software components in order to improve the ability of reuse in future work. Many projects may be purview where the use of the conversion between the JPEG, HDF and PDS formats is needed.

The author thinks this work helped ESA and their partners realize some of the opportunities presented by JPEG2000 Parts 8 and 9 on what concerns to security and access control to EO products data and on interactivity access to such data. It also established a new paradigm based on two very important aspects compressibility of large amounts of data and at the same time protection and security of that data. These characteristics are important not only for ESA and all other entities related to EO products but can prove to be very important for other entities

dealing with huge images or documents like photography achieves, museums, libraries, state achieves, etc, where the presented paradigm can be easily applied.

8.2 Conclusion

In this chapter the author concluded the presentation of his master thesis dissertation establishing some considerations on the outcome of the HICOD2000 project and how it may be used by other ESA project and services to establish a viable model to trade Earth Observation Products. On chapter 1 the author introduced the key ideas behind this thesis and presented the thesis structural organization. On chapter 2, the author identified the HICOD2000 system Business Model and cleared how it can be exploited, identifying some of the major EO business initiatives and explained how they operated in the market, and how they could, to some extent, compete with the proposed solution. Having in mind the previously identified choices, this chapter also specified the major options in terms of profitability models, which could be applied to the Business Model. On chapter 3, the author, introduced the several ESA EO products that were studied in order to test its compatibility to a JPEG2000 conversion, specifically the products of the SPOT and ENVISAT satellites. In order to perform this JPEG2000 conversion the project realization was dependent of the deployment of several key technologies: DRM, JPEG2000, and a web services platform. On chapter 4, the author, introduced a set of key technologies essential to achieve the proposed project goals. Each of the technologies was analyzed in depth, the use of DRM technology to protect and trade EO products, and an extensive introduction to the JPEG2000 standard as well as an explanation for the use of the Kakadu framework. From the business and deployment perspective this chapter explained why the SSE Portal in conjunction with the Mass Toolbox allowed the integration of the HICOD2000 system in a practical way on ESA own service portal environment. On chapter 5, the author, identified the HICOD2000 system requirements and introduced the system architecture, describing the specific details of what the client should expect from the final system as well as the system constraints which included subjects so important as economical, political, resources and schedules. On chapter 6, each of the HICOD2000 architecture components were explained in various levels from its position in the general architecture to the resources needed and the functionalities of each component. Chapter 7 was used to present the results of the Beta testers usability testers as well as the conclusions and methodologies involved in the testing and validation of the HICOD2000 project, from this chapter the author concluded that the HICOD2000 project was highly praised in both security and usability features as well as being technologically innovative. The author concluded with this chapter making some final remarks and considerations about the project and establishing future business opportunities involving the HICOD2000 service.

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ABBREVIATIONS AND ACRONYMS GLOSSARY

AAC	Advanced Audio Coding
AATSR	Advanced Along Track Scanning Radiometer
ADETTI	Associação para o Desenvolvimento das Telecomunicações e Técnicas de Informática
ADS's	Annotation Data Sets
AES	Advanced Encryption Standard
ASAR	Advanced Synthetic Aperture Radar
ASCII	American Standard Code for Information Interchange
B2B	Business to Business
B2C	Business to Consumer
CD-ROM	Compact Disc Read-Only Memory
CDS	Catalogue of Data Sources
CEO	Centre for Earth Observation
CIP	Catalogue Interoperability Protocol
COTS	Commercial off the shelf
CUS	Central User Services
DEM	Digital Elevation Model
DII	Digital Item Identification
DOI	Digital Object Identifiers
DRM	Digital Rights Management
E-Commerce	Electronic Commerce
ECS	EOSDIS Core System
EDG	EOS Data Gateway
EEA's	European Environment Agency's

EPG	Electronic Program Guide
EO	Earth Observation
EOS	Earth Observation System
EOSDIS	EOS Data and Information System
ESA	European Space Agency
ESRIN	European Space Research Institute
ETM+	Enhanced Thematic Mapper Plus
FTP	File Transfer Protocol
GADS	Global Annotation Data Set
GCPs	Ground Control Points
GIS	Geographic Information System
GML	Generalized Markup Language
GSTP	General Support Technology Program
HDF	Hierarchical Data Format
Hicod2k	HICOD2000
HICOD2000	High Performance Coding, Protection and Trading Of Satellite Images, Using PEG2000
HTTP	Hypertext Transfer Protocol
ICTs	Information and Communication Technologies
IEC	International Electro technical Committee
INFEO	Information on Earth Observation
IPMP	Intellectual Property Management and Protection
ISCTE	Instituto Superior das Ciências do Trabalho e da Empresa
ISP	Internet Service Provider
ITU	International Telecommunication Union
ISO	International Standardization Organization
JPEG2000	Joint Photographic Experts Group 2000
JPEG	Joint Photographic Experts Group
JPIP	JPEG2000 Interactive Protocols

JPSEC	JPEG2000 security
LCMPP	Low-cost massively parallel processing
LDCM	Landsat Data Continuity Mission
LOC	Lines of Code
MASS	Multi Application Support Service System
MDS's	Measurement Data Sets
MJ2	Motion JPEG2000
MOSES	MPEG Open Security for Embedded Systems
MP3	MPEG-1 Audio Layer 3
MPEG	Moving Pictures Experts Group
MPH	Main Product Header
MSE	Mean Square Error
MUIS	Multi-Mission User Information Services
NASA	National Aeronautics and Space Administration
ODISSEO	Open Distributed Information Systems & Services on Earth Observation
ODRL	Open Digital Rights Language
OMA	Open Mobile Alliance
OpenSDRM	Open Source DRM
OPIMA	Open Platform Initiative for Multimedia Access
OS	Operating System
PC	Personal computer
PDS	Payload Data Segment
PSNR	Peak Signal to Noise Ratio
RAM	Random Access Memory
ROM	Read Only Memory
REL	Rights Expression Language
ROI	Region of interest
RTSP	Real Time Streaming Protocol
SAI	Space Applications Institute

SOAP	Single Object Access Protocol
SPEC	Standard Performance Evaluation Corporation
SPH	Specific Product Header
SSE	Service Support Environment
SSL	Secure Sockets Lair
SSO	Single Sign On
TLS	Transport Layer Security
UN	United Nations
URN	Unique Resource Name
USGS	United States Geological Survey
W3C	World Wide Web Consortium
WIN2K	Windows 2000
WSDL	Web Services Description Languages
WWW	World Wide Web
XML	Extensible Markup Language
XSD	XML Schema Definition
XSL	Extensible Style Sheet Language

ANNEX A - ENVISAT PRODUCTS SPECIFICATIONS AND ANALISYS

AATSR

The Advanced Along Track Scanning Radiometer (AATSR) is a passive imaging instrument with 1km resolution, able to detect reflected and emitted electromagnetic radiation in 7 spectral regions, ranging from the visible to the thermal infrared.

ATTSR can be used at ground level and at sea level. In the first case it maps vegetation and land use. In the second it measures sea surface temperature to a 0.3 ^{o}C accuracy (Figure 12).

Data Products

Level 1b:

- **ATS_TOA_1P**: Gridded Brightness Temperature/Reflectance (GBTR)
- **ATS_AST_BP**: Browse Product

Level 2:

- **ATS_NR__2P**: Gridded Surface Temperature (GST)
- **ATS_AR__2P**: Averaged Surface Temperature (AST)
- **ATS_MET_2P**: Meteo Product

Level 1b Products

Gridded Brightness Temperature/Reflectance (GBTR) Product

The GBTR is systematically generated from a level 0 product and can be user demanded in fixed scenes (512 x 512 km), as child products (data segments with lengths and contents defined by the user), or as full orbit products.

In this product, the Measured Data Sets share the same structure, the same record length and the same number of records. They are all coded with Byte/Integer data types. Each spectral band image has the same resolution and the same bit-depth, therefore the complete set of MDS can be JPEG2000 coded as a single multi-component stream.

The Annotation Data Sets have small to medium record size, and a different number of records than the Measurement Data Sets. Some ADS include floating point data. Consequently they should be represented in XML boxes in a JPEG2000 file format.

The MPH and SPH, represented in ASCII, should also be coded in a XML box.

Browse Product

This product assists the user with product selection by providing a quick-look over the contents of the data from which it is derived. It is a sub-sampled image at 4km x 4km resolution, based

on the L1b GBTR nadir view Brightness Temperature and Reflectance data and associated cloud flags. The product, a color composite image, is partitioned into a day form that uses the visible channel data available on the illuminated part of the orbit and a night form derived from the 11 micron channel Brightness Temperatures.

The Measurement Data Set, for this product, is coded with Byte/Integer values. A complete set of records represents 24 bit coded RGB reflectance with 8 bit/component. Therefore, it is applicable for JPEG2000 coding as a single 3 component code-stream.

The Annotation Data Sets have small to medium record size, and a different number of records than the Measurement Data Sets. They have a significantly lower contribution to the PDS file size than the MDS. One ADS includes floating point data. Consequently, the ADS should be represented in XML boxes in one JPEG2000 file format.

The MPH and SPH, represented in ASCII, can be coded in XML.

Level 2 Products

These products are all derived from the Level 1 ATS_TOA_1P product.

Gridded Surface Temperature (GST) Product

The GTS product is a full resolution geophysical product, obtained from the GBTR. The GST contains a combination of geophysical parameters derived from AATSR nadir view and from combined nadir forward view channel data.

The geophysical parameters provided by this product are Sea Surface Temperature (SST) and Normalized Difference Vegetation Index (NDVI). They are calculated at a pixel level, being distributed in correspondence to Earth surface type and cloud cover status as results from the L1b GBTR classification.

All parameters are contained in one Measurement Data Set with two fields, the Nadir Field and the Combined Field.

The Measurement Data Set has three fields that are coded with Byte/Integer values. Thus, they can be interpreted as 3 independent components of the same image. This product may be directly trans-coded to JPEG2000 as a single 3 component code-stream.

The Annotation Data Sets don't contribute the most for PDS file size and have a different structure than the Measurement Data Sets. One ADS uses floating point data. Consequently, this category should be represented in XML boxes in a JPEG2000 file format.

The MPH and SPH, represented in ASCII, can by coded in XML.

Averaged Surface Temperature (AST) Product

This product is the spatially averages the geophysical parameters derived from the GBTR.

The averaged geophysical parameters provided in the AST product are organized in relation to the surface types and include the following:

• Averaged dual view and nadir only SST from cloud free sea pixels.

• Averaged NDVI from cloud-free land pixels.

• Mean Brightness Temperature of coldest 25% cloudy pixels in a cell, and Cloud Cover Percentage within the cell.

The AST product is generated on a full orbit basis and is aimed for global monitoring activities.

The MDS contains latitude and longitude data, coded with IEEE floating point data. Therefore, without the JP3D extension being available this product should not be coded with JPEG2000.

Meteo Product

The AATSR Meteo product includes spatially averaged SST and Brightness Temperature in 10 arc minute cells over clear sea, extracted from the AST product. It is intended to be used by meteorological agencies in near real time.

The comments made for the AST product can be maintained for this product as well, and consequently at it should not be coded in JPEG2000, at the current stage of development of the standard.

ASAR

The Advanced Synthetic Aperture Radar is a complex high resolution imaging radar, which can be operated in 5 distinct Measurement Modes: Image Mode (IM); Alternating Polarization Mode (AP); Wide Swath Mode (WS) (Figure 13); Global Monitoring Mode (GM); Wave Mode (WV). Within each mode, several different image swaths may be used.

Data Products

The main data products generated by ASAR are (excluding Level 0 products):

Level 1b:

- **ASA_IMS_1P** Image Single Look Complex Image
- **ASA_IMP_1P** Image Mode Precision Image
- **ASA_IMG_1P** Image Mode Ellipsoid Geo-coded Image
- **ASA_IMM_1P** Image Mode Medium Resolution Image
- **ASA_IM__BP** Image Mode Browse product

- **ASA_APS_1P** Alternating Polarization Mode Complex Image
- **ASA_APP_1P** Alternating Polarization Mode Precision Image
- **ASA_APG_1P** Alternating Polarization Mode Ellipsoid Geo-coded Image
- **ASA_APM_1P** Alternating Polarization Medium Resolution Image
- **ASA_AP__BP** Alternating Polarization Browse
- **ASA_WSM_1P** Wide Swath Standard Image
- **ASA_WS__BP** Wide Swath Browse
- **ASA_GM1_1P** Global Monitoring Mode Image
- **ASA_GM__BP** Global Monitoring Mode Browse
- **ASA_WVI_1P** Wave Mode SLC Imagette and Imagette Cross Spectra
- **ASA_WVS_1P** Wave Mode Imagette Cross Spectra

Level 2:

- **ASA_WVW_2P** Wave Mode Ocean Wave Spectra

Level 1b Products

ASAR Image Products

ASAR Level 1b Image Products can be stand-alone products or strip-line products.

STANDALONE IMAGE PRODUCTS

These products are created from Level 0 data, being generated by request only. They are ordered as if they were a scene with a size 100 km along track by the swath width of acquisition.

ASA_IMS_1P Image Single Look Complex Image

This is a Single Look, Complex (SLC), phase preserved, slant range image generated from the Level 0 Image Mode product using the Range/Doppler algorithm. This product is intended to be used in SAR quality assessment, calibration, and interferometric applications.

The Measurement Data Set fields are coded with Byte/Integer values. This product can be applicable for JPEG2000 coding as single multi-component stream. Multi-component transformation can be used to additionally compress the data.

ASA_IMP_1P Image Mode Precision Image

This product is a multi-look, ground range, digital image generated from Level 0 Image Mode Product using the Range/Doppler algorithm. The product is intended for users wanting to perform applications oriented analysis, as well as for multi-temporal imaging and to derive backscatter coefficients.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as a single component code-stream (grey level image).

ASA_IMG_1P Image Mode Ellipsoid Geocoded Image

The Image Mode Geocoded image is produced from the Level 0 Image Mode product using also the Range/Doppler algorithm with appropriate instrument corrections, and is systematically located and re-sampled on to a map projection. This product is intended for mapping applications and other uses that need map projection images.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as a single component code-stream (grey level image).

ASA_APS_1P Alternating Polarization Mode Complex Image

This is a complex, slant range image generated from Level 0 ASAR data collected when instrument is in Alternating Polarization mode, using the Range Doppler algorithm. The product use is aimed at quality assessment, calibration, and interferometric applications, and can be used to derive higher level products.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as single multi-component stream. Multi-Component Transformation can be used to further compress the data.

ASA_APG_1P Alternating Polarization Mode Ellipsoid Geocoded Image

This product is a multi-look geocoded SAR image generated from Level 0 data collected when instrument operates in Alternating Polarization mode.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as single two-component stream. Multi-Component Transformation can be used to further compress the data.

ASA_APP_1P Alternating Polarization Mode Precision Image

This is a multi-look, ground range, image generated from Level 0 ASAR product collected when the instrument is in alternating polarization mode.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as single two-component stream. Multi-Component Transformation can be used to further compress the data.

WAVE MODE PRODUCTS

These products are generated from data gathered while the ASAR instrument is in Wave Mode. During the instrument operation it acquires small measurements called wave cells, with a size of 5 km along track by 10 km in across track. Each wave cell is processed into a small SLC image called imagette. These imagettes can be further processed using cross-spectra methodology.

ASA_WVI_1P Wave Mode SLC Imagette and Imagette Cross Spectra

This is the basic Wave Mode product. The product is generated from Level 0 data, including up to 20 single look complex, slant range imagetttes, and up to 20 imagette power spectra. This product is for meteo users.

One of the Measurement Data Set fields is coded with Byte/Integer values. This MDS is directly applicable for JPEG2000 coding generating a single multi-component stream. Multi-Component Transformation can be used to further compress the data. Since there is one Measurement Data Set that includes float point coding, it needs to be represented in a XML box.

ASA_WVS_1P Wave Mode Imagette Cross Spectra

This product contains up to 20 cross spectra extracted from the **ASA_WVI_1P Wave Mode SLC Imagette and Imagette Cross Spectra** product. All Measurement Data Sets include several fields coded with floating points. Also, the overall maximum size of this product is relatively low (0.2 Mbyte). Consequently, this product is not suitable to be coded with JPEG2000.

STRIPLINE PROCESSED IMAGE PRODUCTS

This image product contains image data for an entire segment. There is the concatenation of several sub-images called “slices” to form the entire strip-line image. After concatenation of slices, the structure of the strip-line image is identical to that of the stand-alone image products except the data sets contain data concatenated from several slices in time ordered sequence.

Image Mode Medium Resolution Image

ASA_IMM_1P Image Mode Medium Resolution Image

This image product is generated from the Image Mode Level 0 Product. The product is processed to approximately 150 m resolution and can be used for ice applications due to its good radiometric resolution.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as a single component code-stream (grey level image).

ASA_APM_1P Alternating Polarization Medium Resolution Image

This product is generated from ASAR Level 0 data collected when the instrument is in alternating polarization mode. Again, the product is processed to approximately 150 m resolution and has the radiometric resolution required for ice applications. The product can be requested with two polarization channels.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as a single component code-stream (grey level image) for the case of just one MDS. Alternatively, it could be coded as a single two component stream, for the case of two MDS Multi-Component Transformation can be used to further compress the data.

ASA_WSM_1P Wide Swath Standard Image

ASAR product generated from Level 0 data relative to instrument operation in swath mode. The product is processed to approximately 150 m resolution.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as a single component code-stream (grey level image).

ASA_GM1_1P Global Monitoring Mode Image

This is the standard product for the instrument operation in Global Monitoring Mode. It is generated from Level 0 data, and is processed to approximately 1 km resolution. The product covers a full orbit.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as a single component code-stream (grey level image).

BROWSE PRODUCTS

Browse products are a special form of strip-line products. They are also created as individual slices to be concatenated together. Since these products are only intended to aid users in ordering data, many ADS relative to detailed processing can be ignored.

ASA_IM__BP Image Mode Browse

This is a low resolution product that is produced systematically with product from which it is derived the **Image Mode Medium Resolution Product (ASA_IMM_1P).**

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as a single component code-stream (grey level image).

ASA_AP__BP Alternating Polarization Browse Image

This product is derived from **ASA_APM_1P** medium resolution product, when the instrument is in alternating polarization mode.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as a single component code-stream (grey level image).

ASA_WS__BP Wide Swath Browse Image

This browse product is derived from **WS Medium Resolution Product,** when the instrument is in wide swath mode.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as a single component code-stream (grey level image).

ASA_GM__BP Global Monitoring Mode Browse Image

This product is generated from the **ASA_GM1_1P** product when the instrument is in Global Monitoring mode.

The Measurement Data Set fields are coded with Byte/Integer values. This product is directly applicable for JPEG2000 coding as a single component code-stream (grey level image).

Level 2 Products

There is one single Level 2 ASAR product:

ASA_WVW_2P Wave Mode (Ocean Wave Spectra)

This is the Wave Mode product with the highest level. It is derived from **ASA_WVI_1P Wave Mode SLC Imagette and Imagette Cross Spectra** product. This is a product for Meto users.

Several fields of each record of the Measurement Data Set, are coded with floating points. Additionally, the maximum size of this product does not exceed 0.2 MByte. Therefore, it can be concluded that this product is not suitable to be represented and compressed using JPEG2000.

GOMOS

The GOMOS instrument has the objective of measuring the amount of ozone in the upper layers of the atmosphere. It can also, in a lesser extent, measure the concentrations of other trace gases like NO_2 and NO_3, and the atmosphere's temperature and density. The instrument makes these measurements by tracking the path of a certain star as it sets behind the atmosphere's limb. The estimation of the concentration of ozone and other gases is made by detecting the changes in the star's brightness and the dispersion of different wavelengths in the atmosphere.

This instrument has its main scientific interest in the study of the ozone layer and in the development of improved models for ozone depletion due to the effect of chlorofluorocarbons (CFCs).

The analysis made on the products generated by this instrument has found them to be of less importance in the coding to JPEG2000; therefore it is only present in a summarized manner.

Data Products

The main data products generated by GOMOS are:

• **Level 1b**:

- Geo-located and calibrated atmosphere transmission spectra (**GOM_TRA__1P**).
- Geo-located and calibrated atmosphere limb emission spectra (**GOM_LIM__1P**).

• **Level 2**:

- Residual Extinction (**GOM_EXT__2P)**
- Temperature and Atmospheric Constituent Profiles (**GOM_NL___2P**)
- Extracted Profiles for Meteorological Users (**GOM_RR___2P**)

Summarized Analysis

The GOMOS instrument is not the most suitable for JPEG2000 coding. Only the GOM_LIM_1P product can be coded to this standard with a multi-component code-stream and another code-stream, although this product does not contain ozone concentration data.

The Level 2 products are very small in size and have some parameters represented in floating point, therefore its not envisaged significant advantages in the coding with JPEG2000.

The only possibility would be to code these products in JP2 or JPX files with no code-streams, where every data is considered has metadata and encoded in a XML Box. This way a unified representation of these products in JPEG2000 would be accomplished, although, with no major advantageous in the coding process.

MERIS

The MERIS instrument has the primary mission of measuring the ocean color in fifteen different spectral bands in the visible and the near infrared spectrum. Ocean color is useful to study processes like activity of phytoplankton, dissolved organic material and suspended sediments from river estuaries. The MERIS instrument is a passive imaging spectrometer that looks down at the nadir.

The secondary mission of this instrument is to provide information about vegetation coverage, total biomass and the concentration of water vapor and aerosols in the atmosphere, when the satellite passes over ground or heavy cloud layers.

Data Products

The main data products produced by MERIS are:

• **Level 1b**:

- Top of atmosphere (TOA) radiance spectra on 15 wavelength bands

• **Level 2**:

- Cloud and Water Vapor content.
- Vegetation indices.
- Geophysical product.

• **Browse Level**:

- TOA radiance information in RGB displayable format.

Level1b Products

MERIS has only two Level 1 products:

- **MER_RR__1P**: MERIS Level 1 Reduced Resolution
- **MER_FR__1P**: MERIS Level 1 Full Resolution

The two products are similar, although with different resolutions. Both contain a sequence of 15 MDS's with TOA radiance pixels values for each of the 15 spectral bands. There is an additional MDS containing spectral shift information for each pixel and integer flags with classification of each pixel.

The TOA radiance MDS's can generate a two-dimensional array of TOA radiance values by concatenating all the toa_rad parameters (two byte unsigned integers) from all records.

The other MDS has two parameter arrays:

- flag with pixel classification, one byte unsigned integer
- spectral_shfit_index with spectral shift at pixel, one (or two bytes) unsigned integer.

Two-dimensional parameters for pixel classification and spectral shift can be formed in the same fashion as the TOA MDS's.

This integer data could be encoded together in JPEG2000 as a 17 multi-component code-stream. Furthermore, a Multi-Component Transformation can be applied to the 15 TOA radiance bands to additionally compress the data.

Level 2 Products

The MERIS Level 2 products are:

- **MER_RR__2P**: MERIS Reduced Resolution Geophysical
- **MER_FR__2P**: MERIS Full Resolution Geophysical
- **MER_LRC_2P**: MERIS Extracted Cloud Thickness and Water Vapor for Meteorological Users.
- **MER_RRC_2P**: MERIS Extracted Cloud Thickness and Water Vapor
- **MER_RRV_2P**: MERIS Extracted Vegetation Indices

The MER_RR__2P and MER_FR__2P products are similar, apart from resolution, and contain 20 Measurement Data Sets that provide a combination of different geophysical quantities:

- 13 Normalized Surface Reflectance MDS's, with earth's surface reflectance reduced to 13 spectral bands from the original 15. Each MDS stores a parameter array of two byte unsigned integers.
- Water Vapor Content MDS, with a parameter array of one byte unsigned integers.
- Algal TOAVI or Cloud Top Pressure MDS, with a parameter array of one byte unsigned integers.
- Yellow Substance with Total Suspended Matter or Rectified Reflectance MDS, with two parameter arrays of one byte unsigned integers, interleaved by pixel.
- Algal BOAVI MDS, with a parameter array of one byte unsigned integers.
- Surface Pressure or Cloud Albedo MDS, with a parameter array of one byte unsigned integers.
- Aerosols or Cloud Type and Optical Thickness MDS, with two parameter arrays of one byte unsigned integers, interleaved by pixel.
- Flags MDS, with a parameter array of three one byte unsigned integer structures.

The MER_LRC_2P, MER_RRC_2P and MER_RRV_2P products contain subsets of the previous MERIS products, therefore with no new data types. All these Level 2 products contain integer information which can be coded with JPEG2000 using multi-component code-streams with additional Multi-Component Transformation to be applied for parameter arrays of similar data at different spectral bands and separate code-stream for the remaining arrays.

Browse Products

There is a single, low resolution, browse product, named MER_RR_BP. There is the reduction of the 15 different spectral bands to the 3 common red, green, and blue color channels of digital images. This product has only one MDS with a parameter array of interleaved one byte unsigned integers corresponding to the 3 color components for each pixel.

This MERIS product can be straightforwardly coded in JPEG2000 using a 3 component code-stream. It can be applied a color transform to decorrelate data from RGB color space, and achieve further compression.

RA2/MWR

The RA2 / MWR instrument is a set of two coupled sensors: a radar altimeter (RA2) and a microwave radiometer (MRW). The RA2 is an active radar, similar to ASAR that emits microwave pulses in the nadir direction. By measuring the elapsed time between initial pulses

and the reflected echo the distance between the satellite and the Earth's surface can be computed.

The MWR instrument main purpose is to calibrate the results of RA2 altimetry data. It is a passive microwave radar, receiving microwave emissions from the atmosphere. This instrument measures the amount of water vapor along the vertical direction, and cancels sources of error in the altimetry data from RA2.

The scientific applications of RA2/MWR include the measurement of:

- Global and regional sea level
- Ice sheet elevation, sea ice thickness
- Land Topography
- Lakes, wetlands and river levels
- Ionosphere, water vapor

The analysis relative to JPEG2000 coding of the products generated by this instrument is shown in a summarized manner.

Data Products

Level 1b products are not normally available to end users, since the engineering data of these products are included in corresponding Level 2 products. Therefore, only Level 2 products are presented in this section. They are as follows:

- **Geophysical Data Records (GDR)**: The basic altimetry data product.
- **Superset Geophysical Data Records (SGDR)**: The same as a GDR product, plus the waveforms of the radar echo returns.
- **Fast Delivery GDR's (FDGDR)**: It's a product useful for weather forecasting and real-time ocean circulation applications.
- **Fast Delivery Marine Abridge Record (FDMAR):** Is a subset of the FDGDR product, containing only data related to the oceans.
- **Interim GDR (IGDR):** Contains estimates with a precision between that of a FDGDR product and the final GDR or SGDR products.

Summarized Analysis

The products generated by the RA2/MWR instrument can be encoded with JPEG2000. Although it's only generated one-dimensional data for each successive altimetry measurement, it's possible to generate two dimensional data by joining corresponding parameters of all the

records. One of these dimensions is frequency and the other is distance along-track. The two dimensional dataset, obtained is not an actual image but contains a significant correlation in both image directions. Therefore it can be coded to JPEG2000.

SCIAMACHY

The SCIAMACHY instrument is a medium-resolution spectrometer operating in the ultraviolet, visible and near infrared wavelengths.

The main scientific purpose of SCIAMACHY is to measure the atmospheric distribution of several trace gases, including O_3, NO_2 and also BrO, H_2CO, OClO, SO_2 and ClO. It can measure vertical distributions of O_3 and NO_2, in ultraviolet and visible ranges, and CO_2, H_2O, CH_4, CO and N_2O, in the infrared range. SCHIMACHY can additionally determine temperature and pressure profiles, based on CO_2 distributions.

The analysis relative to JPEG2000 coding of the products generated by this instrument is presented in a summarized manner.

Data Products

The main data products produced by SCIAMACHY are:

• **Level 1b**:

- Geo-located and calibrated TOA radiance spectra (**SCI_NL__1P** and **SCI_NLC_1P)**

• **Level 2**:

- Vertical column amounts of trace gases (**SCI_NL__2P**)
- Level 2 off-line product (**SCI_OL__2P**)
- Selected vertical column amounts of trace gases for meteorological users (**SCI_RV__2P**)

Summarized Analysis

SCIAMACHY products are not in general suitable for JPEG2000 coding, as a consequence of including floating point data. The only exception is the SCI_NL__1P product. Additionally, Level 2 products have small sizes, and therefore it does not appear to be significantly advantageous to trans-code them to JPEG2000.

CASI

The Compact Airborne Spectrographic Imager (CASI-2) is a push broom imaging spectrograph with a 2 dimensional CCD array. It covers a spectral range from 405 nm (blue) to 950 nm (infrared) with 288 spectral samples at 1.8 nm intervals. The spatial samples are 512 spatial pixels. This sensor has 4 operating modes: Spatial Mode, Spectral Mode, Enhanced Spectral Mode, and Full Frame.

Measurement Characteristics

One dimension of the 578x288 element array is used to obtain an image frame with 512 spatial pixels resolution of the surface. As the aircraft moves forward, the image frame is used to form the flight line of data (Figure 19). The CASI instantaneous field of view is 54.4^{o} across track and 0.1151^{o} along track. Light levels entering the spectrometer through the lens can be adjusted via automated iris control, corresponding to apertures varying from f11 to f2.8. There is also a setting that forces the iris to close that is used prior and after a flight line.

For calibration post processing purposes, a section of the array, masked off from imaging scene pixels, is used to record electronic noise, frame shift smear and scattered light contributions.

The analogue signals generated by the complete CCD array are converted to 12 bit values, providing 4096 digital levels for each array element.

Data Products

Although in the documentation available there is not a direct reference to specific products of CASI, in this analysis it is assumed that the products identify with the modes of operation of the sensor.

There are two main operating modes: spatial and spectral modes. These modes represent a compromise in what concerns data recording requirements and the time to perform the reading of all elements of the array. The operating modes are as follows:

- Spatial Mode
- Spectral Mode
- Enhanced Spectral Mode
- Full Mode

Spatial Mode

This mode uses the full 512 pixels across swath, and a maximum of 18 spectral bands. The selection of the bands is programmable and can be made from a single detector element (with a

resolution of 1.8 nm) or by summing two or more adjacent detector elements, valid in all the CASI spectral range. The number, location, and bandwidths of the spectral bands should be adjusted to the required user application. They can be broad if it's desired to measure regions in the spectrum like near-infrared, or narrow if certain phenomena are to be studied such as chlorophyll fluorescence, or atmospheric absorptions.

For calibrated products where there is significant correlation between both array dimensions, and assuming that the structure of these products don't contain floating point data, there should be a straightforward coding to JPEG2000 using a single multi-component code-stream. Additionally a Multi-Component Transformation can be applied to further compress the data.

Spectral Mode

In this mode the full spectral profile including the 288 channels can be recorded, with the limitation of a reduced number of look directions, or pixel positions, spread across swath (maximum 39). The pixel spacing between look directions can be 4, 8, 12 or 16 pixels. The pixel spacing should be either low for high spatial resolution or high to achieve a good spatial coverage. Spectral mode includes a monochromatic image at full spatial resolution. This image is used to locate the pixels positions of the spectral data within the scene.

Referring to calibrated products, and, again, assuming that the structure of these products don't contain floating point data, there could be direct JPEG2000 coding using a single one-component code-stream for the monochromatic image, and a multi-component code-stream for the full spectral profile data. Additionally a Multi-Component Transformation can be applied to further compress the data of this last code-stream.

Enhanced Spectral Mode

The Enhanced Spectral Mode includes the full spectrum (288 channels) for 101 adjacent spatial pixels. This mode can be extended by increasing spatial coverage, with decreasing spectral resolution.

Spectral and Enhanced Spectral Mode have a disadvantage over Spatial Model, due to having longer integration times. This fact can cause lack of square ness of pixels when data is collected at low altitudes.

In Enhanced Spectral Mode there is also a scene recovery channel (SRC) formed by a monochromatic image (when the full 288 channels are recorded) at full spatial resolution. In extended modes the bandwidth of the image is formed by the summation of adjacent channels.

Once again, referring to calibrated products, and, assuming that these products don't contain floating point data, there could be direct JPEG2000 coding using a single one-component code-

stream for the scene recovery channel, and a multi-component code-stream for the full spectral profile data. Additionally a Multi-Component Transformation can be applied to further compress the data of this last code-stream.

ANNEX B - USABILITY QUESTIONNAIRE

General Questions

Questionnaire

May 2006

1. Have you ever worked with huge images?

Yes	No

If yes what was the purpose of the huge images you worked with?

_____

2. Have you ever worked with satellite images?

Yes	No

If yes what was the purpose satellite images you worked with?

_____

3. Have you ever worked with systems like Google earth or similar products?

Yes	No

If yes what do you think of those systems in terms of:

a) Usefulness	Useful	equal	Useless
b) Complexity	Simple	equal	Complex
c) System response	Fast	equal	Slow

4. Have you ever used/seen/downloaded images on JPEG2000 format?

Yes	No

5. Are you familiar with the JPEG2000 file format?

Yes	No

If yes what do you think of it comparing it to other image formats?

Better equal Worse

ESA Distribution System

Questionnaire

May 2006

1. Did you know of the existence of Earth Observation (EO) products?

Yes	No

If yes which EO products did you knew about?

_____

2. What do you think of ESA EO product distribution model?

Good ☐☐☐ equal ☐☐☐ Bad

3. Do you think it's a secure distribution model?

Very Secure ☐☐☐ equal ☐☐☐ Not Secure

4. Do you think the postal delivery method is the right delivery method for this case?

Yes	No

HICOD2000 Distribution System

Questionnaire

May 2006

1. How do you rate the HICOD2000 system:

a) Easiness of use	easy	equal	hard
b) Stability	easy	equal	hard
c) Speed in retrieving data	easy	equal	hard
d) System response	good	equal	bad
e) Understanding of what's happening	good	equal	bad
f) Overall opinion	good	equal	bad

2. How do you compare the HICOD2000 vs. other ESA traditional distribution:

a) Easiness of use	better	equal	worse
b) System security	better	equal	worse
c) Speed in retrieving data	better	equal	worse
d) System response	better	equal	worse
e) Understanding of what's happening	better	equal	worse
f) Overall opinion	better	equal	worse

3. How do you rate the data download functionality in terms of:

a) Response time	good	equal	bad
b) Easiness of use	good	equal	bad

4. What bothered you most:

a) Delay in data retrieval
b) System instability
c) System complexity

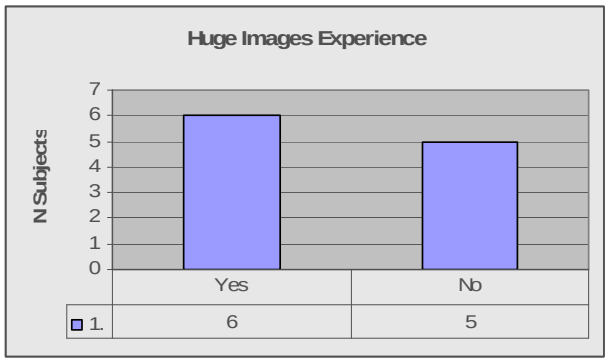
	least	equal	most
	least	equal	most
	least	equal	most

d) Other_____

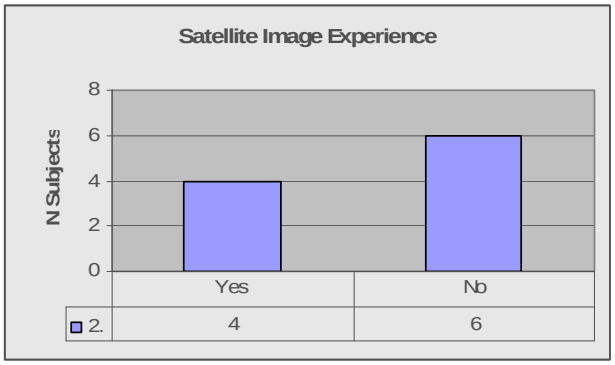
ANNEX C - USABILITY QUESTIONNAIRE COMPLETE GRAPHIC RESULTS

General Questionnaire

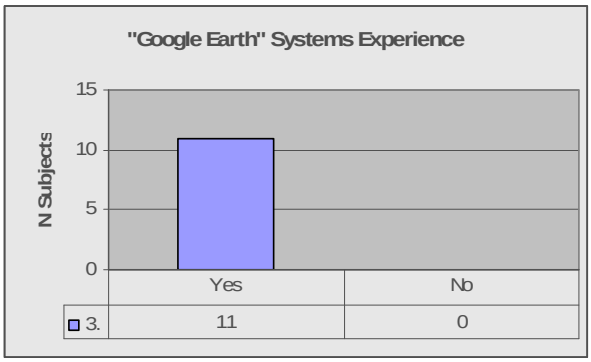
1. Have you ever worked with huge images?



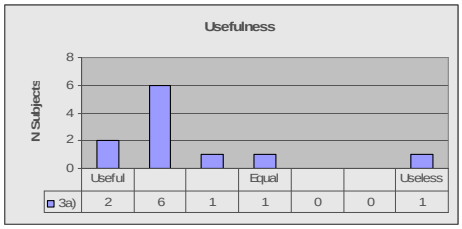
2. Have you ever worked with satellite images?

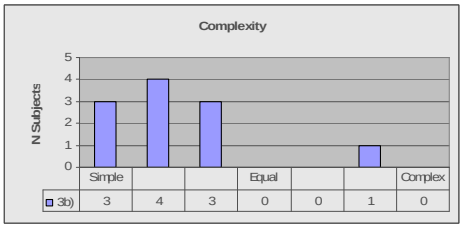


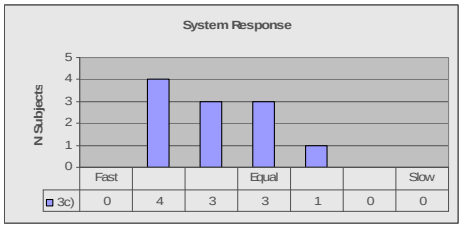
3. Have you ever worked with systems like Google Earth or similar products?



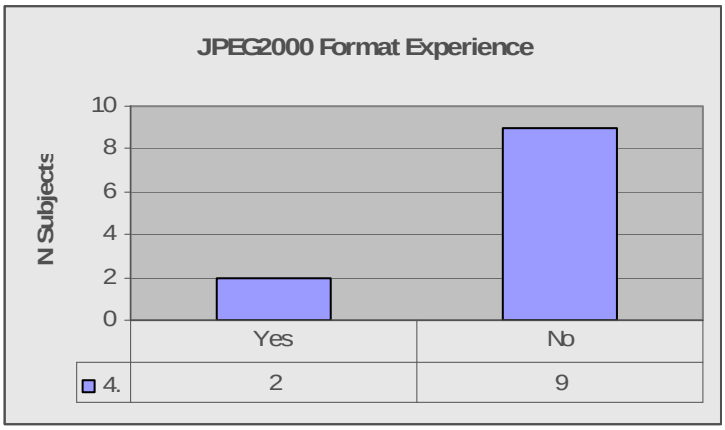
If yes what do you think of those systems in terms of:





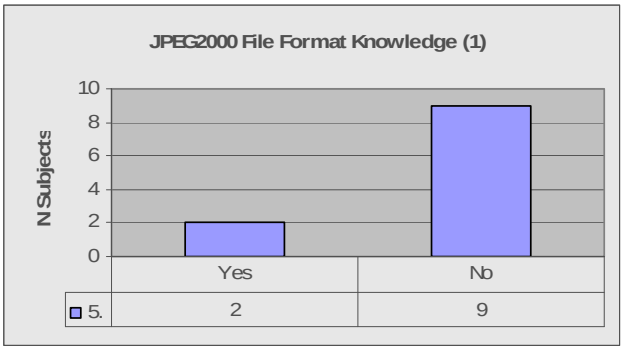


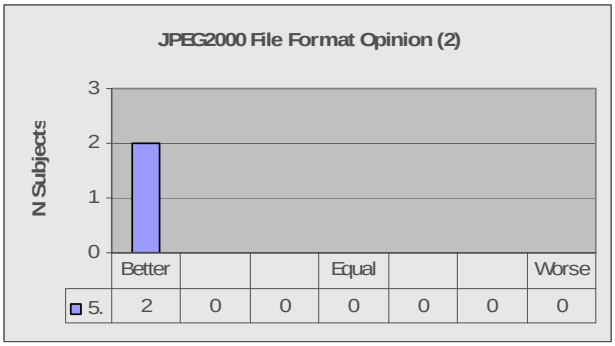
4. Have you ever used/seen/downloaded images on JPEG2000 format?



5. Are you familiar with the JPEG2000 file format?

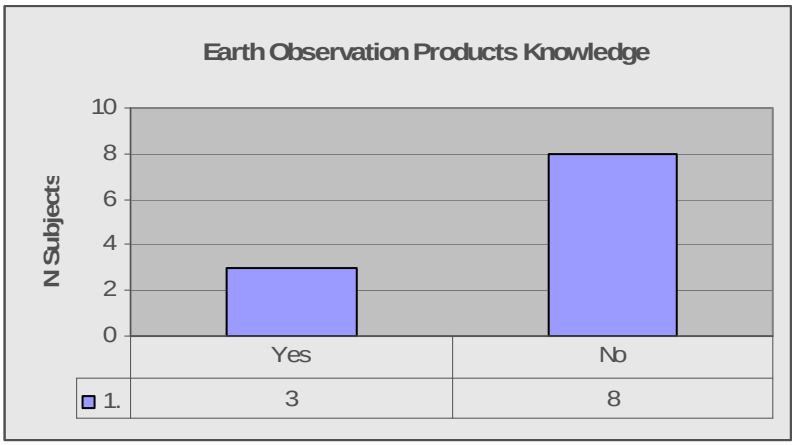
If yes what do you think of it comparing it to other image formats?



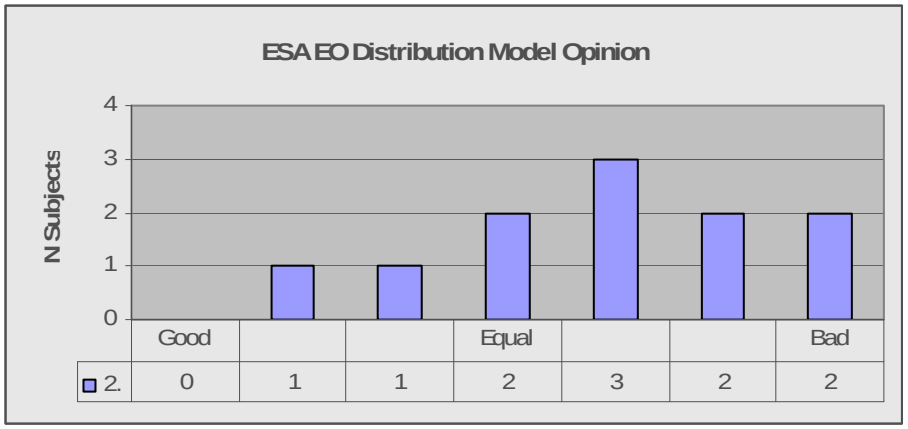


ESA Distribution System

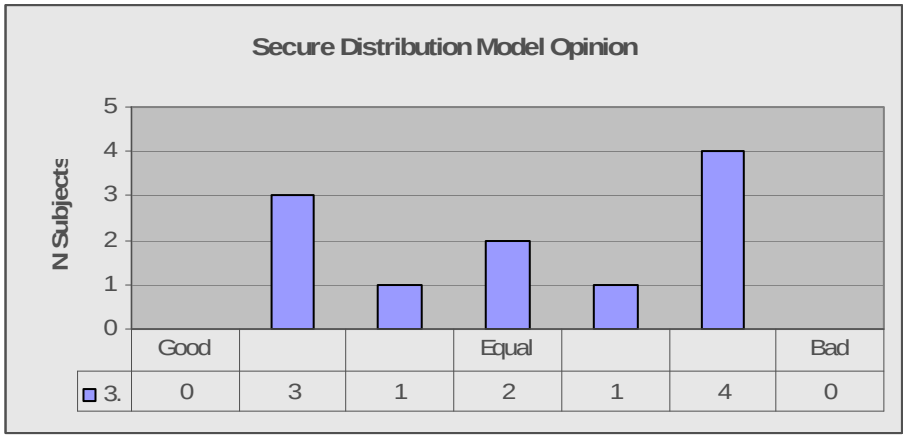
1. Did you know of the existence of Earth Observation (EO) products?



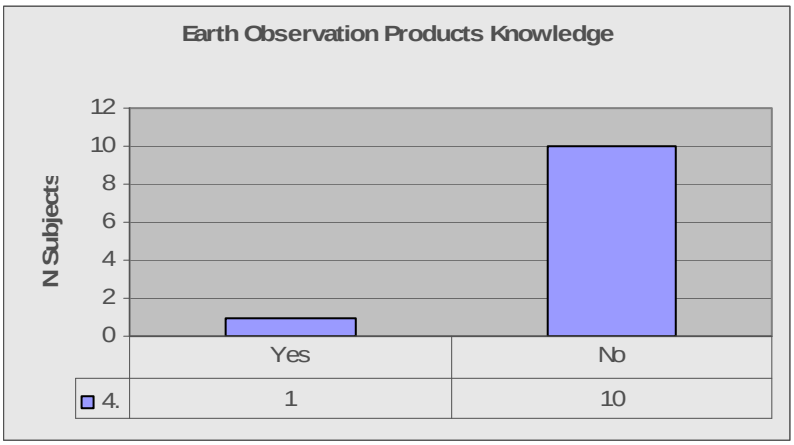
2. What do you think of ESA EO product distribution model?



3. Do you think it's a secure distribution model?

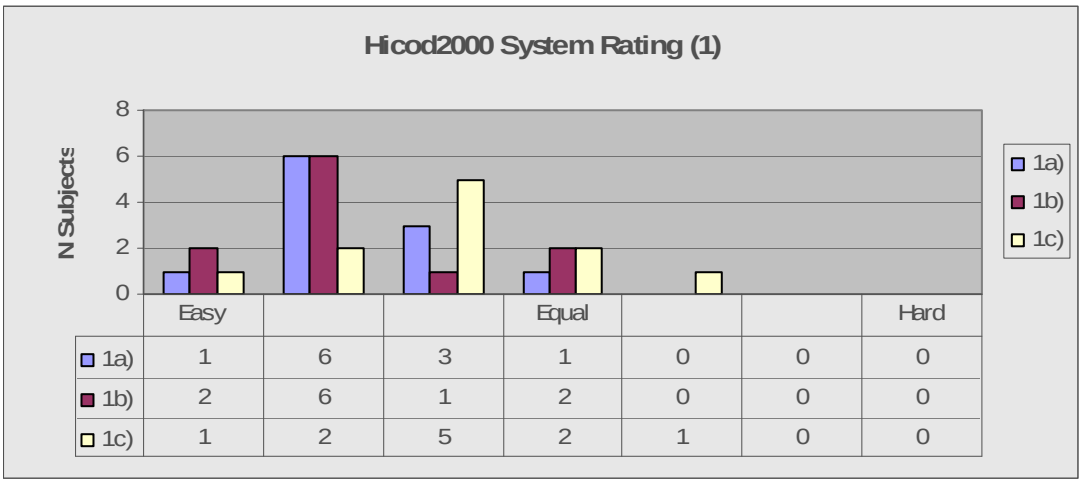


4. Do you think the postal delivery method is the right delivery method for this case?

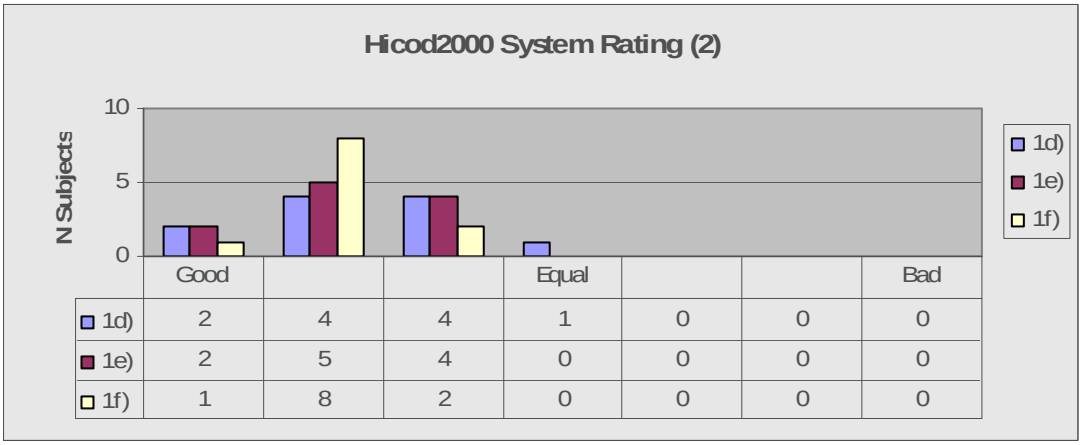


HICOD2000 Distribution System

1. How do you rate the HICOD2000 system:

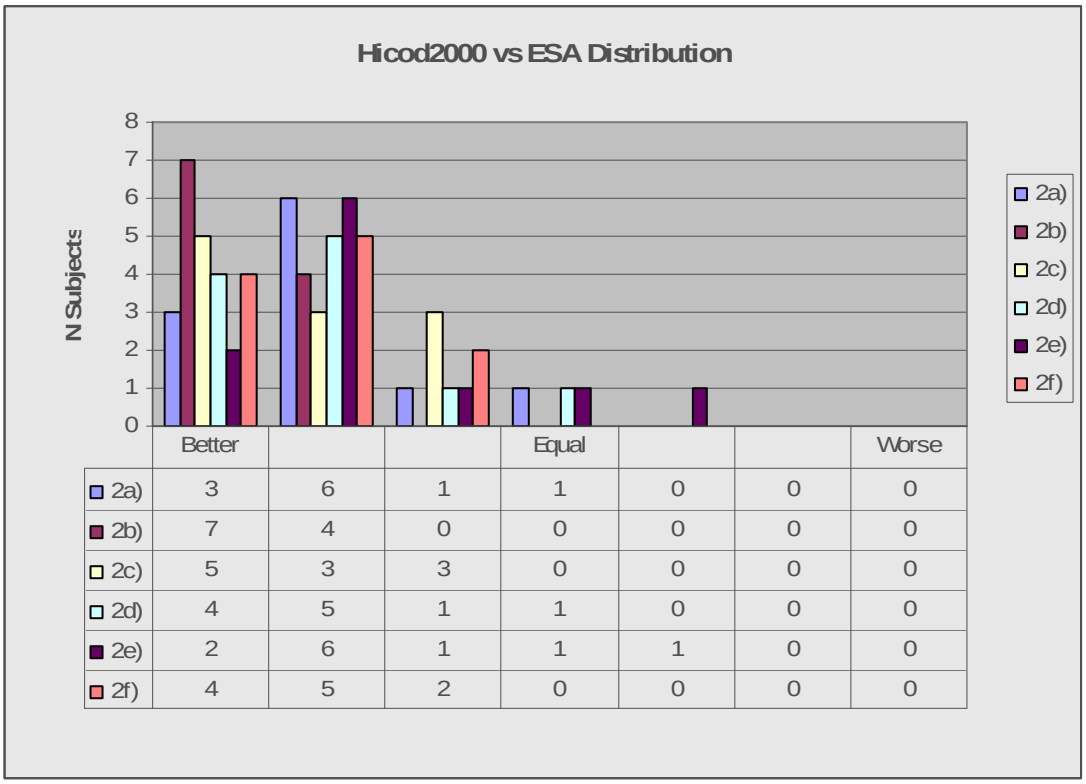


	Easy			Equal			Hard
1a)	1	6	3	1	0	0	0
1b)	2	6	1	2	0	0	0
1c)	1	2	5	2	1	0	0



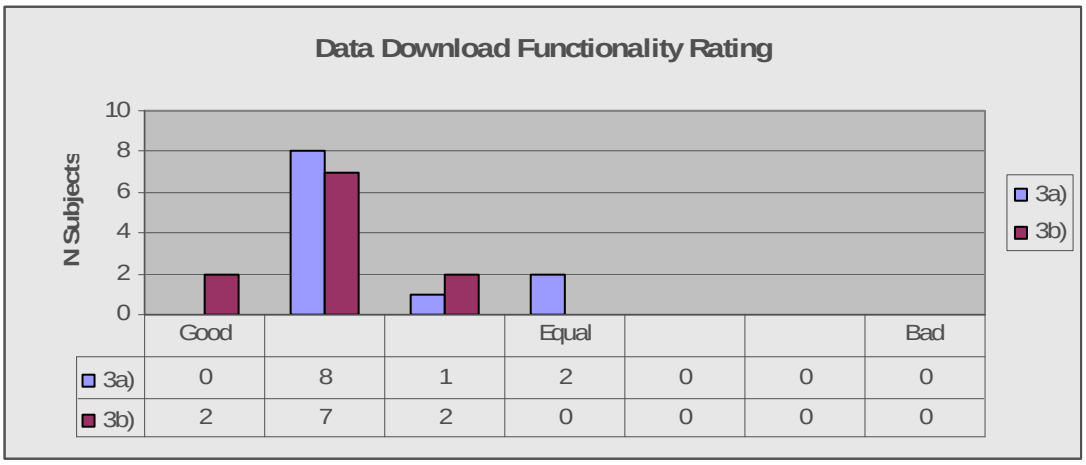
	Good			Equal			Bad
1d)	2	4	4	1	0	0	0
1e)	2	5	4	0	0	0	0
1f)	1	8	2	0	0	0	0

2. How do you compare the HICOD2000 vs. other ESA traditional distribution:



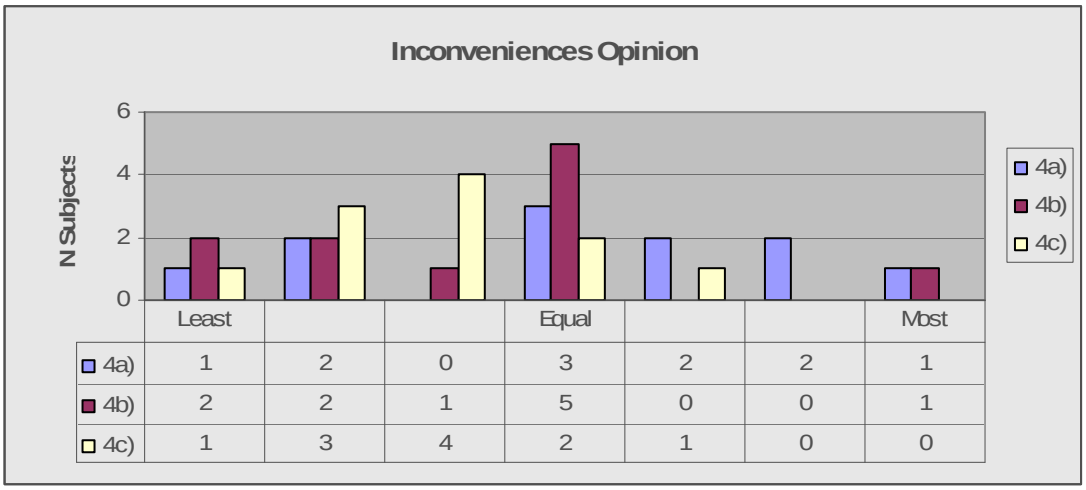
	Better			Equal			Worse
2a)	3	6	1	1	0	0	0
2b)	7	4	0	0	0	0	0
2c)	5	3	3	0	0	0	0
2d)	4	5	1	1	0	0	0
2e)	2	6	1	1	1	0	0
2f)	4	5	2	0	0	0	0

3. How do you rate the data download functionality in terms of:



	Good			Equal			Bad
3a)	0	8	1	2	0	0	0
3b)	2	7	2	0	0	0	0

4. What bothered you most:



	Least			Equal			Most
4a)	1	2	0	3	2	2	1
4b)	2	2	1	5	0	0	1
4c)	1	3	4	2	1	0	0

ANNEX D - HICOD2000APP VIEWER USER MANUAL

Introduction

This manual will introduce the reader on how to use the Hicod2000 Viewer a tool to visualize jpeg2000 images.

Basic Operations

Opening and Closing Files

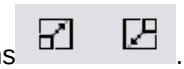
The File menu may be used to open and close files. Alternatively, you may use the open file icon  or the "o" accelerator key useful for opening files quickly. Opening a new file automatically closes any existing open file. The Hicod2000 Viewer can open JP2 files (protected and unprotected), JPX files, unwrapped JPEG2000 codestreams.

Panning, Zoom and Re-orienting

Panning may be accomplished via the scroll-bars, using the arrow. The PageUP and PageDown keys may also be used for panning. The image may also be dragged around with the mouse while the left mouse button is depressed and the shift key held down.

Zooming may be accomplished via the View menu, toolbar buttons  , or with the "z" (zoom in) and "ctrl-z" (zoom out) accelerators. By default, zooming is centered about the middle of the current viewport.

Rotation and flipping may be accomplished via the View menu, the toolbar buttons  for rotation and  for flipping, or with the "[", "]", "_" and "|" accelerators.

The application automatically resizes its window to match the image size, unless the image is too large to be viewed in the current window, in which case a restricted viewport is displayed. You may adjust the window size via the usual resize handles. Alternatively, and often more conveniently, you may enlarge or shrink the view window quickly using the "w" and "s" accelerator keys or the toolbar buttons  .

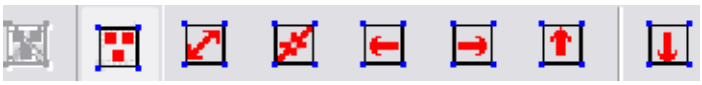
Special note on zooming for v4.4 and later: JPX files can contain compositions of codestream imagery, where each composed piece has arbitrary scale factors. The "Hicod2000 Viewer" tool handles such imagery correctly, regardless of the implied scaling factors, but there can be no one global scaling factor which results in optimal rendering of the entire composition.

Focus Boxes

Focus boxes have at least 3 uses in "Hicod2000 Viewer": 1) they define a centre for zooming; 2) they define the region of interest during remote image browsing with JPIP (see Section 3); 3) they define spatial regions to be associated with metadata added using the methods described in Section 5. To define a focus box, left click the mouse within the view window, drag the focus box, and then left click again to complete the box.

After the first mouse click, you may hit the right mouse button, or the escape key. This will leave any previously existing focus box intact.

To remove a focus box, you may do any of the following: 1) double-click in the view window; 2) use the Focus menu; or 3) hit the “f” accelerator key. By default, the focus box will be displayed using both a highlighting technique and a dashed outline. The highlighting technique makes the rest of the image slightly darker, and the focus box slightly lighter. You can turn on the highlighting by using the Focus menu, or hitting the “h” accelerator key. You can widen or shrink an existing focus box using the Focus menu, or the “shift-w” and “shift-s” accelerators.

You can pan the focus box using the arrow keys, while holding down the shift key. Basically, the accelerators which affect the focus box are identical to those used to manipulate the view window, except that the shift key is held down. An alternative to this process is using the following toolbar icons  that perform all the functionalities described above.

Quality Layers

JPEG2000 codestreams may contain multiple embedded image qualities, which form the foundation of quality progressive remote image browsing. By default, local files are opened at maximum quality, but it can be useful to see the visual quality associated with each compressed quality layer. To reduce the number of quality layers you may use the Quality menu, the “<” accelerator. You may increase the quality again using the Quality menu using the “>” accelerator.

These manipulations automatically change the status bar to one which displays the number of quality layers which are in use.

When playing video content, you may well find that displaying all of the available quality layers is too slow. Reducing the quality typically increases rendering speed dramatically, especially when the original content was lossless compressed. Of course, this is only possible if multiple quality layers are available in the source content.

Navigating Between Image Elements

The “Hicod2000 Viewer” tool has 3 fundamental modes of image display, as follows:

Single Component Mode: In this mode, only a single image component is displayed as a grayscale image. Image components typically correspond to color channels (e.g., red, green, blue, or luminance, and chrominance channels), but they may correspond to alpha blending channels, palette indices, or anything else.

To enter single component mode, use the View menu, the toolbar button or hit either of the “1” or “+” accelerator keys. While in this mode, you may navigate forward and backward within each image component

of a given codestream, using the View menu or the “+” and “-” accelerators. While in single component mode, you may navigate amongst the codestreams in the file (JPX files may have any number of codestreams) using the RETURN and BACKSPACE keys. Alternatively, you may use the View menu.

Single Compositing Layer Mode: In this mode, only one compositing layer is displayed, usually as a color image, or alpha blended against a solid white background.

To enter single compositing layer mode, use the View menu, hit the “L” accelerator key or the toolbar button  . While in this mode, you may navigate forward and backward amongst JPX compositing layers or amongst frames of a current MJ2 video track, by using the RETURN and BACKSPACE keys the View menu or the toolbar buttons  . You may also enter single compositing layer mode by holding both the “shift” and “control” keys down and left clicking the mouse, while it is over any particular compositing layer. This method allows you to quickly navigate to a particular compositing layer within a complete composition.

Composited Image Mode: In this mode, the application displays what it believes to be the intended image. For JP2 files and unwrapped raw codestreams, this is identical to the result displayed in single compositing layer mode. If a JPX file contains a composition box, however, the composition instructions are used to build the composited image which was intended by the content creator. The underlying ‘kdu-region-compositor’ object, which does all the rendering work, fully supports composed video. When a new file is opened, “Hicod2000 Viewer” starts out in the composited image mode, but if you have changed the mode to single component or single compositing layer mode, you may get back to composited image mode by using the View menu or hitting the “c” accelerator or the toolbar button  . While in composited image mode, you may navigate forward and backward between composited frames (animations contain multiple frames, each of which is a composited image) by using the RETURN and BACKSPACE keys, via the View menu or using again the toolbar buttons  .

Status Information

Some summary information is displayed at the bottom of the application window on its status bar. The status bar is divided into fields. The information displayed in these fields also depends upon the status mode, which may be toggled using the Status menu, via the “t” accelerator key or pressing the toolbar button  . In particular, you can currently toggle between the following three (or four) status modes:

Left field displays current zoom factor (percent) and image element; right field displays the number of quality layers. The image element depends on the image display mode. In single component mode, the component index and codestream index are displayed here; in single compositing layer mode, the compositing layer index is displayed here; in composited image mode, the animation frame index is displayed here. If the view window (or a focus box) covers imagery which derives from only one codestream, additional scaling factors for that codestream may be shown in parentheses after the main (global) scaling factor. The reason for

different scaling factors is that codestream imagery may be arbitrarily scaled onto composited frames in a JPX presentation.

Left field is as above; right field displays the full size of the image at the current resolution, measured in pixels.

Left field displays the amount of working memory used by the codestream management machinery (for all codestreams currently loaded into memory). This value is generally very small if the codestreams are enabled for random access (precincts, PLT marker segments and a layer-minor progression order).

(available only when connected to a JPIP server): left field displays active/ idle transmission status (idle when all requested imagery for the current view/focus window has been received); centre field displays a progress indicator, measuring the proportion of quality layers relevant to the selected region which are currently in the local cache; right field displays total transmitted bytes and the average data rate at which transmitted bytes have arrived, averaged only over non-idle periods.

Remote Image Browsing with JPIP

By and large, images may be accessed remotely from a JPIP server (such as that implemented by the “kdu-server” utility) exactly as if they were local files.

Rather than experiencing significant delays while the image downloads, you will instead observe incrementally improving quality as image data is incrementally transferred by the server. JPIP servers focus the transmitted data around the region defined by the focus window so the quality in that region increases more rapidly. If no focus window is defined, it is taken to be the current view window. Once succinct data has been received to reconstruct the image within the focus window without loss, at the current display resolution, the server enters the idle mode and will not transmit any further data until the image region, resolution (zoom factor), codestream, image components, compositing layer or animation frame are changed.

It is important to realize that the viewing tool is only loosely (asynchronously) coupled to the client component and, ultimately, to the server utility. You are always free to pan, zoom and otherwise navigate the display to any part of the image, regardless of whether any data has been received from the server to render that region. After some time, the server will adjust its transmission pattern to serve the new image region/resolution which is currently of interest.

Of course, if the server has disconnected, no amount of navigation will bring in new data, so you will generally be left with non-uniform image quality which reflects the amount of time spent browsing in different image regions.

It is also important to realize that the JPIP server is allowed to shrink the region of the image for which it will serve data, if the region is too large to be served in a quality progressive fashion without consuming excessive server memory resources. If this happens, the changed region will be reflected on the view window through a new focus box. You may move this modified focus box around, to change the region to which the server’s transmission is customized, but you may not enlarge the focus box without having the server force it back down again to its size limit.

Regular Image Browsing

To open a remote image, use the File->OpenURL menu item or the toolbar button  .The File->OpenURL dialog box provides several fields for you to fill out. For regular image browsing, enter the name of the file you want to access in the “Object requested from server” field and enter the name or IP address of the server machine in the “Server name or address” field. You may append an optional colon-separated port number to the server name or address, if your server is not listening on the default port 80.

One of three closely related JPIP transfer protocols may be selected via the “Channels and Sessions” drop-down list. For the most efficient communication, the “http-tcp” option is recommended; however, this requires the establishment of both an HTTP and a regular TCP channel, which might not be permitted by some institutional firewalls. In this case, select “http” as the next best option. The “none” option is primarily for experimental purposes. It is much less efficient, especially for the server.

If your organization requires all external traffic to flow through an HTTP proxy, select the “http” option and put the name or address of your HTTP proxy server in the “Proxy name” field — you may need to consult your system administrator to find out the name of your HTTP proxy. Proxies reduce the communication efficiency and responsiveness, so use them only if necessary.

You may elect to have your entire image browsing results saved in a local cache directory, by entering the name of this directory into the “Cache dir” field. The advantage of this is that when you open the same image again on the same server, or a compatible server (one which assigns the same unique target identifier to the image resource), the previous browsing results will be reused and that data will not be sent over again by the server.

You may explicitly disconnect from a JPIP server, without actually closing the image, by using the File->Disconnect menu item.

Viewing Codestream and File Properties

Use the File->Properties menu item or the “p” accelerator to view the properties of the current codestream. Where more than one codestream is involved in the current image display, the application chooses one of them to display its attributes. Codestream properties include comment marker segments, coding parameter marker segments and tiling attributes. You may double-click on any attribute to read a detailed description of that attribute’s interpretation, as provided by the Kakadu core system.

Additional attributes are provided by the file format in which codestreams are embedded. To examine the file format itself, use the View menu the “m” accelerator or the toolbar button  to activate the “metashow” tool. You may click on various nodes within the metashow tool’s tree view to obtain additional details or to navigate to have the main window navigate to corresponding image elements.

For example, clicking on the second compositing layer header box will cause the main window to enter single compositing layer mode and display the second compositing layer. Clicking on a contiguous codestream box

or codestream header box will cause the main application to enter single component mode, while clicking on the composition box, if any, will cause the application to enter the composited image mode.

Clicking on some leaf nodes in the metadata tree will cause their contents to be expanded as text, while for other boxes a generic hex dump is provided.

Metadata Overlays and Editing

As of Kakadu v4.1, you may use “Hicod2000 Viewer” to edit and display spatially sensitive metadata in a JPX file. You may also add metadata to a JP2 file and resave it as JPX.

To add metadata use the Edit menu or the “a” accelerator. This opens up the metadata editing dialog, which allows you to enter an arbitrary text label. If no focus box has been selected, the metadata will be associated by default with the top-most current image entity (compositing layer or codestream), depending on the current image display mode (see Section 1.5). If a focus box was selected when you hit the “a” accelerator, the metadata will be associated by default with the top-most codestream which overlaps with the focus region; it will also be associated explicitly with that region. These associations are achieved by embedding appropriate number list and ROI description boxes in the JPX file (when you save the edited result).

You may alter any of the above associations within the metadata editing dialog. It will explicitly exclude options which are illegal. For example, metadata associated with a focus region must also be associated with at least one codestream, not just with compositing layers. You will see that you can add multiple associations, but it is up to you to ensure that this is meaningful. Once you have some spatially associated metadata, you will notice that “Hicod2000 Viewer” highlights its presence via partially transparent overlays. You may use the Overlay menu to control the appearance of such overlays. Most usefully, the “ctrl-o” accelerator or the toolbar buttons  may be used to toggle the overlay mode between flashing, static, and no overlays. You may also control the darkness/lightness of overlays via the Overlay menu, by using the “ctrl-d” and “ctrl-b” accelerator keys or by using the toolbar buttons  . Finally, you may control the minimum size of elements which will appear on overlays.

In the flashing or static overlay mode, try holding the control key down and moving the mouse cursor over regions which are associated with metadata. You will notice that the cursor changes to one which contains an “M” and the application displays temporary labels where appropriate. Keeping the control key down, you may also left click to open up the metadata editor again. This allows you to modify or delete existing metadata.

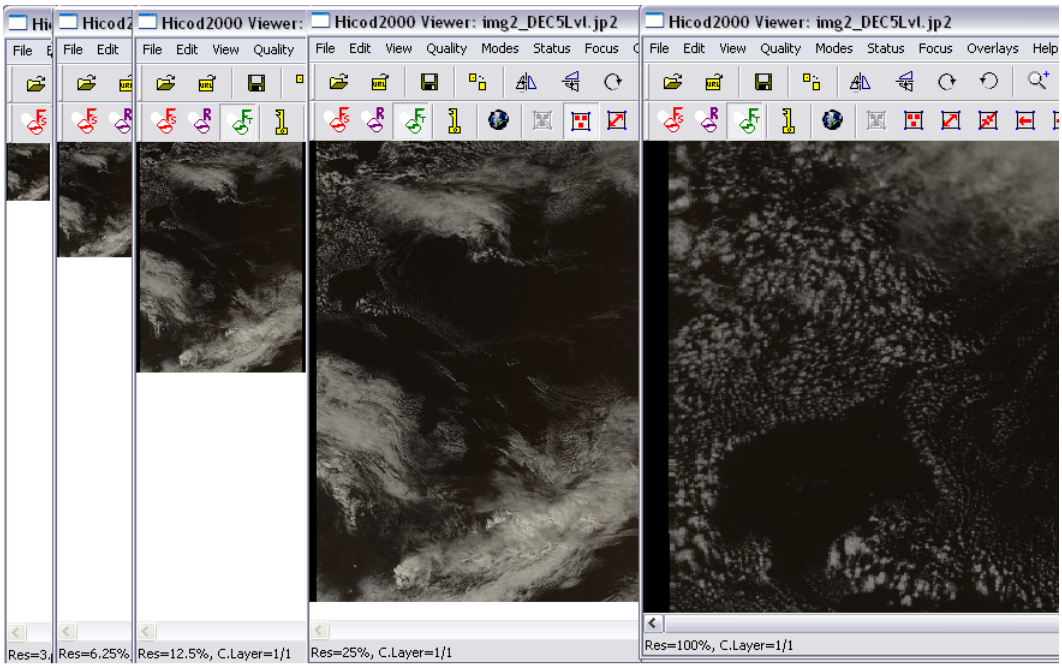
If there is any metadata associated with a codestream or compositing layer as a whole (e.g., the name of an image within a photo album), this metadata may be viewed and edited in a similar manner to region-specific metadata, described above. In particular, holding the control key down while the mouse is positioned over a compositing layer or codestream which contains metadata labels will cause the “M” cursor to appear, and any relevant label to be displayed temporarily. By left-clicking with the control key held down, you enter the metadata editing dialog. While there can be many metadata items associated with a codestream or compositing layer as a whole, only the “top-most” one associated with any given mouse location can be

displayed and edited. The “topmost’ one is determined based on the order of compositing layers. If no relevant compositing layer has metadata, individual code-streams which contribute to visible layers are examined.

Working with Jpeg2000 Secured EO Images

Normally all Hicod2000 EO products downloaded by a client, come in a secure mode (except for JPIP mode), so the client is unable to see any clear features of the jpeg2000 image, unless it asks for the permissions to access the different levels of security. There are 6 different levels of security within each image correspondent to different levels of resolution of an image.

If you want to see the highest resolution of a downloaded jpeg2000 image you need to ask for all 6 license keys. On the other hand, if you just have permission to access the lowest resolution, you can only ask for the 0 key which will grant you access to the lowest resolution version of the asked Jpeg2000 image. So all levels of security above the level requested will be secured, and therefore impossible to be correctly viewed.



(Different levels of resolution of 1 image)

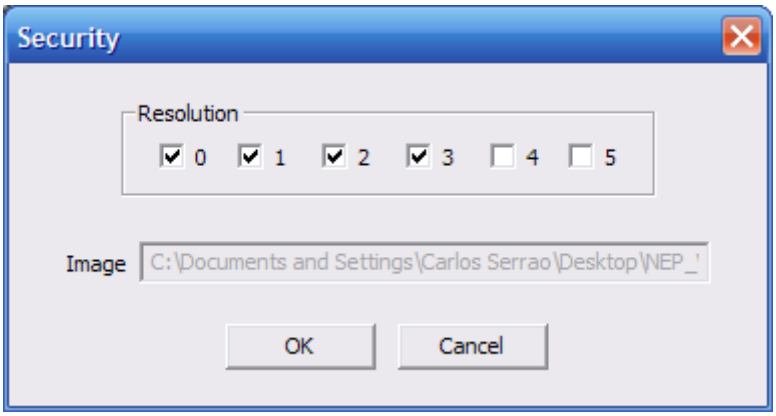
Obtaining the keys to decipher the image

When the user tries to access the image, the viewer requests to the Java Wallet proxy the keys. This proxy contacts the server-based wallet to download the appropriate keys/licenses for the image. Two different situations may occur. Either the user requests access to just some resolution levels, or to all resolution levels.

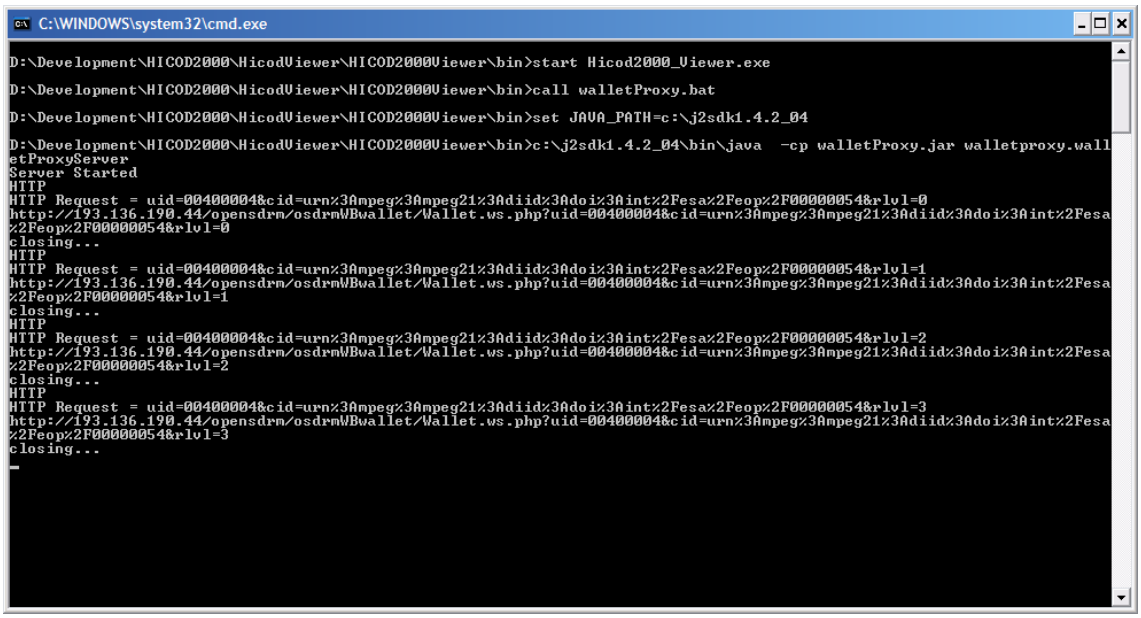
Some keys

To request the keys, the user selects the following operation  .

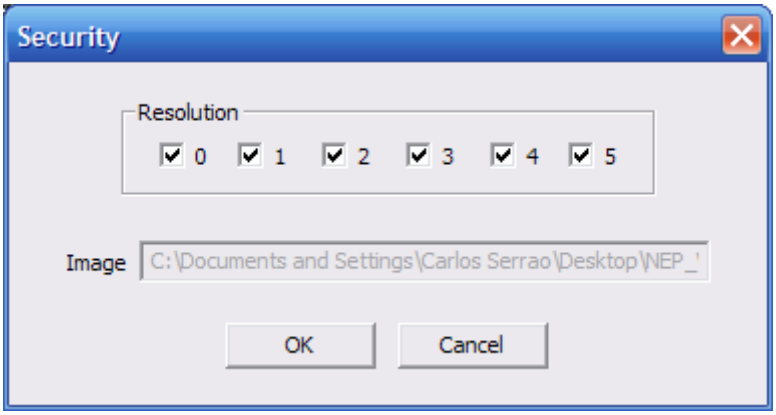
The following window is presented to the user allowing him to select the resolution levels he wishes to access.



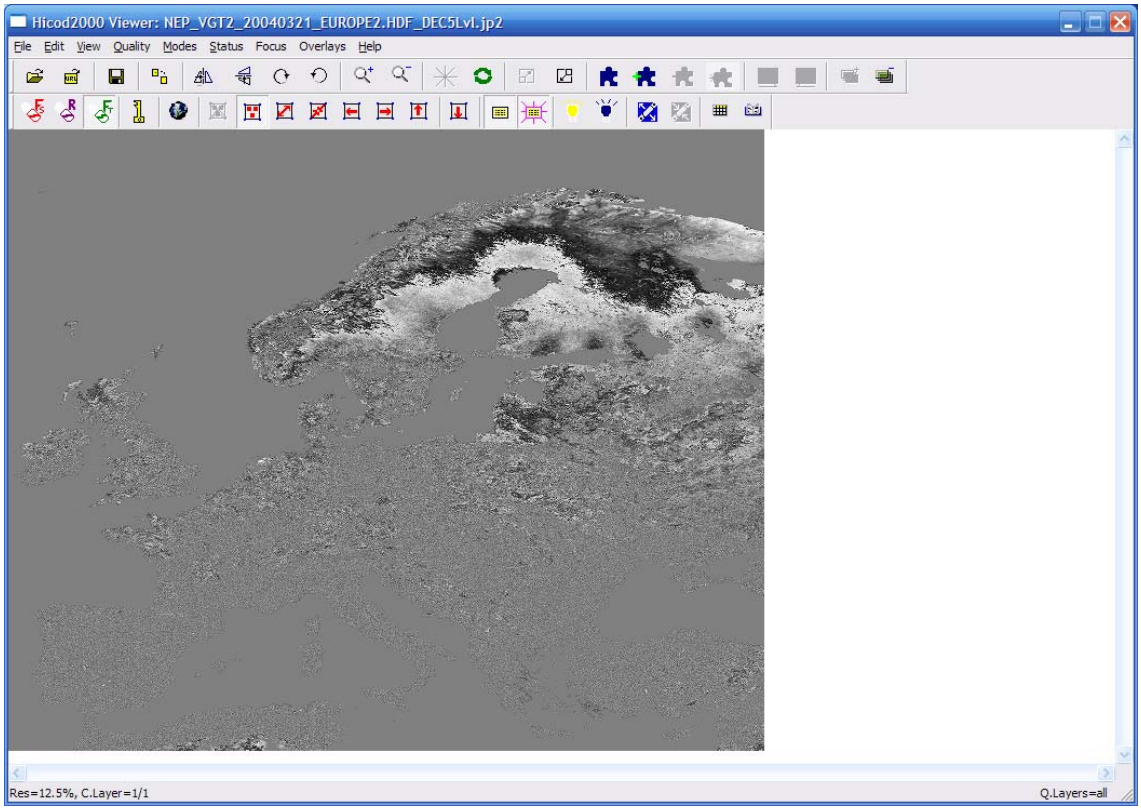
When the user selects the resolution levels, the client-side Java Wallet proxy contacts the web-based wallet and downloads the keys.

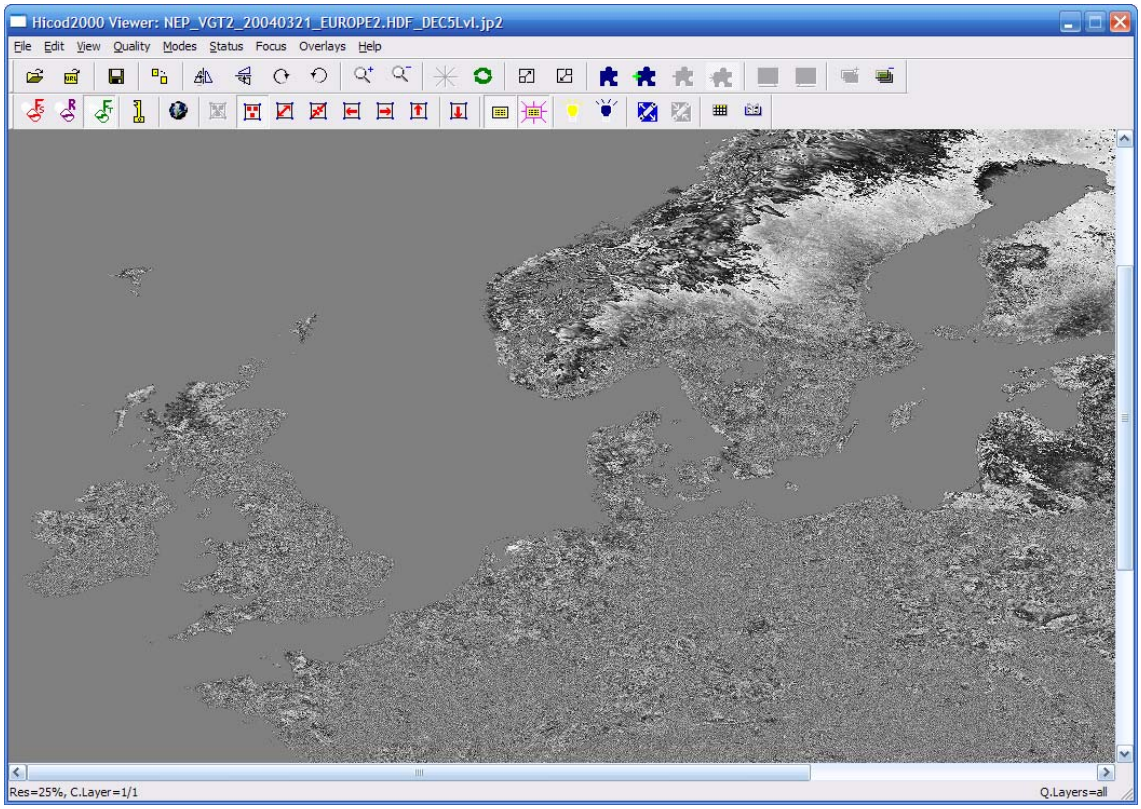


The correct keys are applied to the product and it gets deciphered.



The process is similar to the previous, with the difference that the user can access to all different image resolution levels without any restriction.





Saving Jpeg2000 Files and EO Products

You may save images back out of “Hicod2000 Viewer” using the File->Save menu item. This is of interest particularly if you have edited the image’s metadata or if the image has been obtained from a remote JPIP server - in that case, the saved file will contain whatever information had been received from the server up to the point when it is saved.

You may edit and resave a file over the top of the file you already have open. In this case, however, the file is actually saved under a different name, formed by appending the “~” character to the name of the currently open file rather than overwriting it. When you close the open file, any such saved copy is automatically renamed so as to replace the one you had open. This happens even if you close the application (by any of the usual means or by hitting the “q” accelerator).

The process of saving Jpeg2000 Images of Earth Observation products, back into the original format, can at this time, be only performed on windows platforms. To do so you need to open the original downloaded EO jpeg2000 image and afterwards press the toolbar button  . If the image is protected you need to fully unprotect it by using the security button  and asking for all 6 keys, after the image is unprotected you need to reopen the protected version and only then press the EO button  . The result of this process will be the original EO product before compression and security processes.