OPERATIONAL METEOROLOGICAL PRODUCTS EXTRACTION FROM METEOSAT IMAGE DATA BASED ON A DISTRIBUTED UNIX WORKSTATION SYSTEM

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ABSTRACT

The Meteorological Products Extraction Facility (MPEF) is part of the new EUMETSAT ground segment for the geostationary meteorological satellites METEOSAT. The paper addresses the general concept, the system design and some specific database and man-machine-interface (MMI) features of the system.

The new ground segment is defined as a near real-time processing system in which the MPEF is embedded as a stand-alone facility. Real-time extraction of meteorological products minimises the delay for product distribution and reduces the processing load on the workstation based processing system. Three processing chains for operational product extraction, commissioning and test support, and a separate development environment guarantee high availability of the operational system. The performance margin of at least 50% of all hardware elements leaves sufficient flexibility for future developments and improvements.

For the surrounding support functionality MPEF makes use of a number of software tools and utilities. For instance, the MPEF information base is divided into two parts, the system information base and the application information base. The system data are stored in a relational database (Oracle) and this database acts as a configuration control system for the set-up data. The application information base contains the set of input and output files.

The Man-Machine-Interfaces are based on X Windows/Motif and are standardised across the whole EUMETSAT ground segment. The visualisation and analysis of MPEF products and Meteosat image data and the manual quality control of the products is based on the PV-Wave software tool and provides similar functionality as a meteorological workstation.

1 INTRODUCTION

The Meteorological Products Extraction Facility (MPEF) has been developed by EUMETSAT as part of the new METEOSAT Mission Control Centre which will take full control of all Meteosat satellites from the start of the METEOSAT Transition Programme (MTP) on 1st December 1995. The new MTP Ground Segment includes a Mission Control Centre, located in the EUMETSAT headquarters building in Darmstadt, Germany and a Primary Ground Station, located in Fucino, Italy. The MCC is divided into four main facilities. The Core Facility (CF) is the central element of the MCC and includes the functions of mission management, satellite control, ground segment control and pre-processing of satellite data. The Meteorological Archive and Retrieval Facility (MARF) provides the capability for the users to access the historical data from Meteosat satellites. The User Station Display Facility (USDF) provides real-time visibility of the end image products to operations staff within the MCC. The MPEF processes rectified image data to derive a range of meteorological products for the end-users. The overall MTP ground segment architecture is shown in Figure 1.

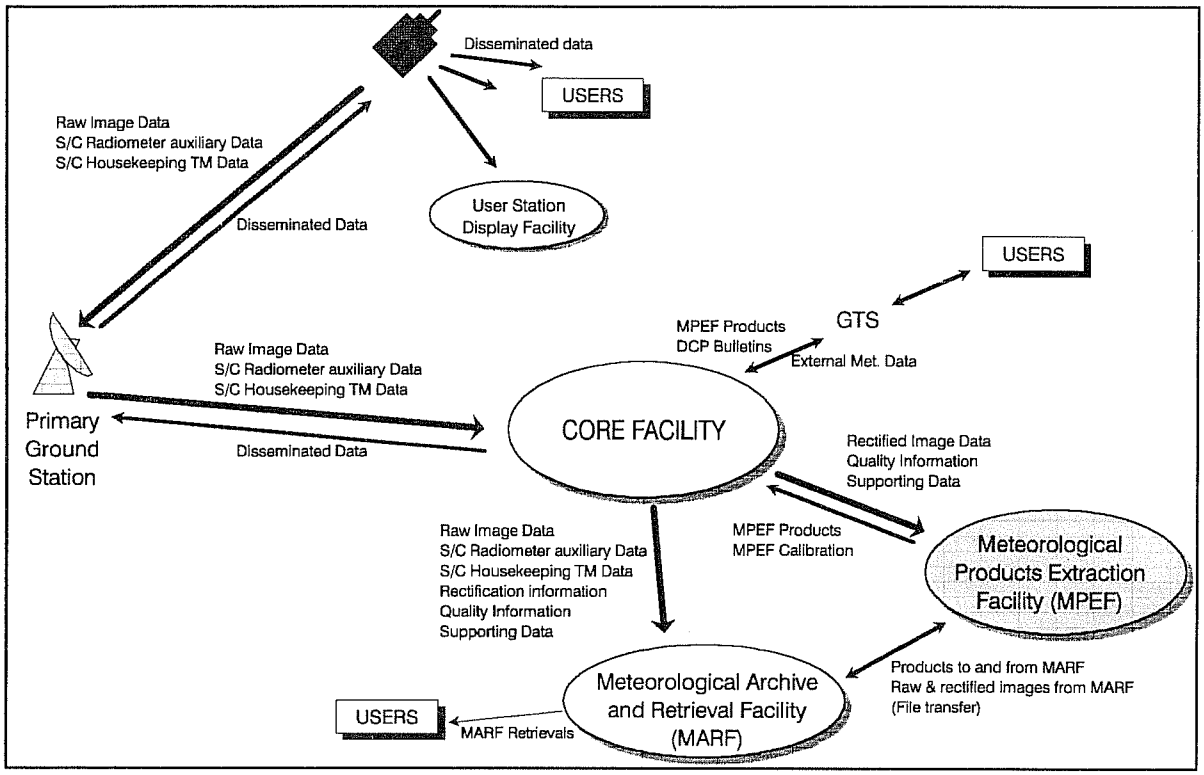

Figure 1 MPEF as part of the MTP Ground Segment

2 MPEF ARCHITECTURE

The MPEF is implemented on a distributed UNIX workstation system and includes two physically separated processing environments, the operational and the development environment. A sketch of the MPEF hardware configuration is depicted in Figure 2.

The MPEF workstations and system controllers in the operational environment are inter-connected through a local area network (LAN) based on an FDDI ring with routers providing connections to the hardware elements via Ethernet spurs. The interface to the Core Facility is via two redundant routing devices connected to both the MPEF LAN and the Core Facility LAN. The high rate image data stream is received in the MPEF and distributed to the processing chains by an image data handler workstation. In the case of failure the image data stream can be re-directed to a backup workstation.

The operational environment includes three processing chains each comprising two workstations. These chains are used for operational product extraction, support for satellite commissioning and test support. Each processing chain consists of two Hewlett Packard 9000/735 workstations. When acting as hot

stand-by the commissioning chain or the test chain receives the same data and performs the same processing as the operational chain, but does not normally distribute the derived products. In the event of a failure of the operational chain no manual intervention is necessary to bring the stand-by to operational status. Up to two parallel image data streams may be processed by the chain workstations so that MPEF can support the commissioning of a new satellite without interrupting its operational processing activities.

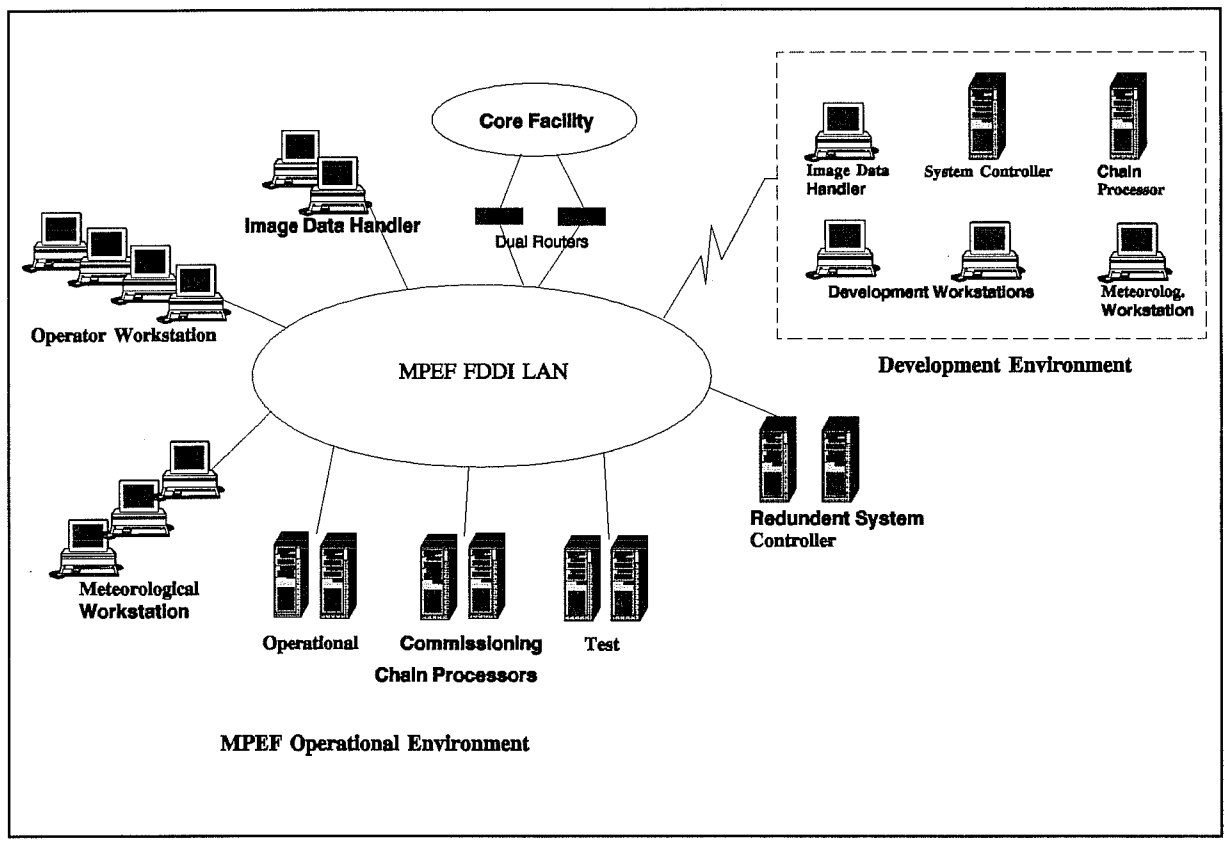

Figure 2 MPEF Hardware Configuration

The system controller consists of two (redundant) Hewlett Packard E35 servers connected to a dual ported, mirrored disk system. The main function of these servers is to provide support for the monitoring of system performance, the scheduling of processes and the maintenance of a relational database containing a wide variety of system information such as logged parameters, display definitions, user details, etc.

In addition there are two other types of workstations in operational environment, namely Operator Workstations (four Hewlett Packard 9000/715s) and Meteorological Workstations (MWS, three

Hewlett Packard 9000/735s with enhanced graphics). These provide access to all operational functions although the manual quality control of MPEF products and the visualisation of products and images can only be performed from the MWS workstations which have enhanced graphics capabilities. The prime function of the operator workstations is to facilitate hardware and software monitoring along with other operator functions. The MWS workstations are based on off-the-shelf software and feature a state-of-the-art graphics display and development facility. Three printers are connected to the network to provide hardcopy facilities and a video subsystem provides the capability to record and print graphical information from the MWS workstations.

MPEF has been designed with a performance margin of 50% for all hardware elements and also with the possibility of re-allocating processes to different workstations. This will provide sufficient flexibility for future developments, improvements and the inclusion of new operational products.

The development environment is based on an Ethernet LAN and includes at least one of each workstation or system controller type as in the operational environment. This configuration ensures that development and testing of new product or system software can be performed in a realistic pre-operational environment.

3 GENERAL CONCEPT OF THE MPEF DESIGN

The MTP MPEF is the successor to the Meteosat Information Extraction Centre (MIEC) for MOP. It features modular software design and incorporates a number of improvements in image data processing and product generation algorithm implementations. In addition the product algorithms are configured at run-time by a set of user-defined parameters whose values are under operator control. In this way the product generation processes may be tuned to produce optimum results. An example of these parameters is the thresholds used in the automatic quality control of the products.

The whole MTP ground segment is defined as a near real-time processing system in which the MPEF is embedded. The MPEF will receive pre-processed (rectified) satellite image data from the Core Facility on a line-by-line basis, it will process these data to derive meteorological products and it will return the products to the Core Facility for distribution. The near real-time derivation and distribution of the MPEF products will minimise the delay for product distribution and will reduce the overall processing load on the system. The system will, for instance, enable products extracted from a half-hourly image slot to be computed for the southern hemisphere when Meteosat is still scanning the

northern part of the earth disk.

For Monitoring & Control (M&C) and for Analysis & Reporting (A&R) a parameterised approach has been adopted in which system parameters are continuously logged and automatically checked against their expected state. This enables the dynamic monitoring of hardware elements as well as application processes. Parameters may also be combined to derive other parameters to enable, for example, the monitoring of parameter means and percentage completion of activities. Another set of application parameters are logged and used for algorithm related analysis and form the basis for the generation of reports on system performance and product quality. About 1500 of the two types of parameters can be monitored at the same time on the facility level and on each processing chain in the operational environment.

Maximum use has been made of off-the-shelf software packages which have been integrated into the overall system. PV-Wave is used for the visualisation and analysis of image data and products; ApplixWare supports the analysis and report preparation of product and system related parameters; the DataViews software package allows the display of online monitored parameters, e.g.the monitoring of the CPU and disk usage.

In addition to these software packages more than 250,000 lines of code have been written using C language for the system software and using FORTRAN for about 70,000 lines of code for the meteorological product processing software.

4 MPEF PRODUCT PROCESSING

The MPEF algorithms are extensions of the MIEC algorithms incorporating improvements in several areas. For instance, different cross correlation methods for the Cloud Motion Wind (CMW) product derivation (including a Fast Fourier Transform (FFT) based method) have been implemented. The baseline product extraction and distribution frequency for a number of products has been increased to allow, for instance, the distribution of the CMW product, derived from all three spectral channels (IR, WV and VIS), every 1½ hours.

The SST product is derived for every slot in order to monitor the IR calibration but is distributed to end-users twice a day. The CTH product is produced four times a day and the CLA and UTH products every 3 hours. The extraction of the CDS product is at hourly intervals which makes the product useful

for detailed analysis of daily variations of the extracted cloud features. Table 1 summarises the MPEF products to be extracted and the baseline schedule for their extraction frequency. It is important to note, however, that the extraction times can be configured and the performance margin of the system will allow increased extraction frequency if required.

MPEF Product	Extraction Times (UTC)
Cloud Motion Wind (CMW)	0000, 0130, 0300 . . . . 2100, 2230
Sea Surface Temperature (SST)	0000, 1200
Cloud Analysis (CLA)	0000, 0300, 0600 . . . . 1800, 2100
Upper Tropospheric Humidity (UTH)	0000, 0300, 0600 . . . . 1800, 2100
Cloud Top Height (CTH)	0300, 0900, 1500, 2100
Climate Data Set (CDS)	0000, 0100, 0200 . . . . 2200, 2300
Precipitation Index (PI)	Extracted at 0000, 0300, 0600 . . . . 1800, 2100 and accumulated for 5 days
ISCCP Data Set (IDS)	0000, 0300 . . . . 1800, 2100 (for B1 and B2 data sets) AC data set according to coordinated schedule

Table 1: List of MPEF products and their daily extraction times

A combination of automatic and manual quality control processes will ensure the quality of the disseminated products and, with the introduction of BUFR code for the products disseminated over the GTS (instead of the currently used SATOB code), selected quality information may then be distributed along with the product parameters.

The CMW, SST, CLA and UTH products are distributed to users via the GTS in WMO coded form, the CTH in pictorial form as part of the Meteosat Wefax dissemination schedule and the CDS, PI and IDS products are sent to the Meteosat Archive and Retrieval Facility (MARF) from where they are disseminated to users.

5 MPEF DATABASE DESIGN

Considering the different nature of MPEF system and application data the database has been divided into two parts, the MPEF Application Information Base (MAIB) and the MPEF System Information Base (MSIB). The MAIB consists of a large number of dynamic and static input and output files required by the product extraction processing. Each processing chain has its own MAIB and up to 3 MAIBs can be held on a physical chain. The MSIB is based on the relational database software package ORACLE. The MSIB is a hierarchy of logical items and is divided into data partitions. Table 2 lists the MSIB partitions and describes the data type. The MPEF Local Archive (MLA) allows the storage of MAIB and MSIB data on to DAT tapes.

MSIB Partition	Data Types
System Control	Monitor& Control Data
System Support	User, Workstation & Event Definitions
Scheduling	Activity based Scheduling Data
Analysis Data	Retrieval Definition
System Data	MPEF Entity Definition
Archiving	Meta Data

Table 2: MPEF MSIB Partitions

6 MPEF MAN-MACHINE-INTERFACE

A standardised man-machine interface, based on OSF/Motif, has been developed with all operator interaction taking place through a system of user rôles and associated menus. All operational user rôles are accessed from the workstations by invoking a system menu. The following rôles have been defined in order to fulfil the operational requirements: Monitoring & Control (M&C), Scheduling, Analysis & Reporting (A&R), Database Preparation & Administration, Manual Quality Control, Visualisation & Analysis and System & Software Maintenance. An example of a typical MPEF screen with the MPEF system menu and an invoked M&C display is depicted in Figure 3.

The Scheduling rôle enables an operator to exert control over the various processes in terms of their initialisation, mode of operation and expected completion. Such is the nature of the product derivation processes and the predictability of the various input data that such a system lends itself well to control by repeating schedules of this type. This approach allows a high level of flexibility in the derivation, quality control and dissemination of the products.

The underlying functionality of the M&C and A&R rôles has already been explained in Section 3. The Database Preparation & Administration rôle provides access to the MSIB and MAIB. The System and Software Maintenance rôle gives access to UNIX and appropriate tools.

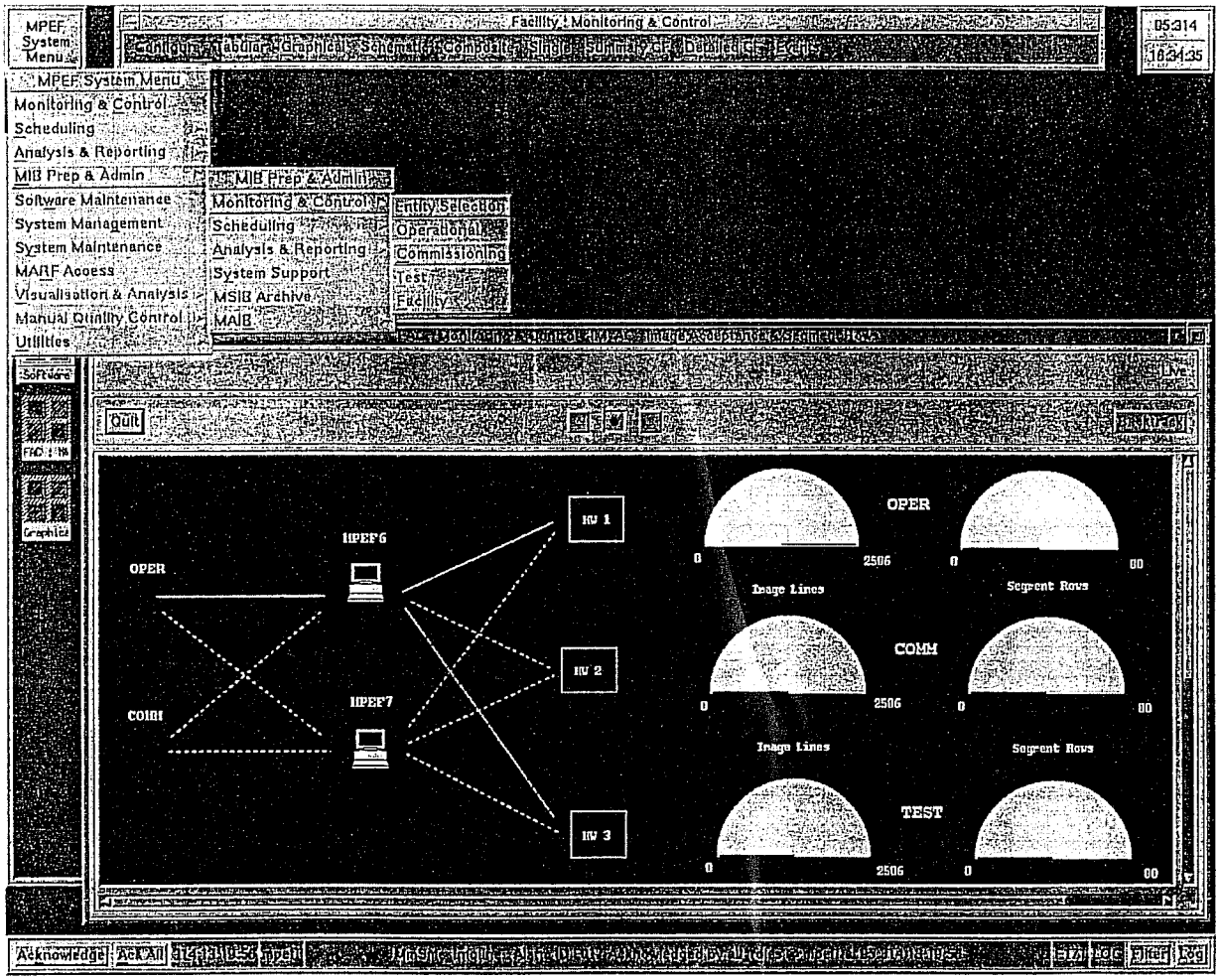

Figure 3: Example of a typical MPEF screen

7 METEOROLOGICAL WORKSTATION (MWS)

The Meteorological Workstation supports the visualisation and analysis of image data and MPEF products and the manual quality control of the latter. The MWS runs on an HP Apollo 735 with a 24 Bit Graphics board. The PV-Wave visualisation tool and additional application software make use of the graphics capabilities by creating up to 5 simultaneous 8 Bit private colour maps.

The MWS allows the display of the following type of data:

- Meteosat image data in all three spectral channels

- all eight MPEF products
- derived statistical MPEF products
- meteorological surface observations as fields
- meteorological upper air observations as fields and as tephigrams
- meteorological forecast data fields and climatological data.

In order to support image analysis and product quality control the MWS features area-of-interest selection, animation, panning, zooming, colour manipulation, different projections, one and two dimensional image histograms, image pixel interrogation, product segment information display and detailed header information display for image data and products.

Simultaneous animation and panning, required for the manual quality control of some MPEF products, have been implemented by a software solution. The MWS colour editor allows colour manipulation using a colour wheel and applying RGB and HSV colour models. Furthermore it is possible to view MPEF product overlays over image data in transparency mode.

The MWS is able to retrieve historical image data (in raw and in pre-processed form) and MPEF products from the central Meteosat Archive and Retrieval Facility (MARF) for visualisation and analysis.

8 CONCLUSION

The MTP MPEF as the successor of the MOP MIEC features increased modularity and a number of new or improved processing and algorithms implementations.

The near real-time processing in the whole MTP ground segment will minimise the delay for product distribution. The MPEF architecture with three processing chains and the use of off-the-shelf hardware guarantees high availability of the operational system. The possibility to reallocate application processes and a performance margin of about 50% of the key hardware elements will leave sufficient flexibility for future developments, improvements and the possible addition of new operational products.

The modular design of the algorithms software will reduce maintenance effort and allow future improvements in this area. The separate development environment will provide the necessary facilities for research and development activities.