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THE ARGENTINE REMOTE MONITORING & SURVEILLANCE SYSTEM[1]

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RESUMEN

A los fines de verificar el estado de las variables asociadas al monitoreo y seguimiento de las actividades relacionadas con instalaciones nucleares, en particular con salvaguardias, es que el Ente Nacional Regulador Nuclear (ENREN) ha desarrollado, en forma independiente, un sistema de monitoreo y seguimiento remoto (RMSS). Este sistema incluye una serie de sensores distribuidos en la instalación, un enlace de comunicaciones autenticado, una unidad de recepción, un sistema de captura de imágenes y un sistema de computación provisto de una interfase amigable a los fines de adquirir, almacenar y consultar datos correspondientes a eventos históricos. Una base de datos de tiempo real permite las tareas de consulta, mantenimiento y actualización. El sistema desarrollado permite su integración en una LAN (red local) o WAN (red extensa) via modem a los fines de su operación remota. En el presente trabajo se describen el sistema de referencia y su aplicación en una instalación nuclear bajo salvaguardias perteneciente a la Comisión Nacional de Energía Atómica (CNEA). Se presentan además resultados y conclusiones del sistema relacionados con esta instalación.

ABSTRACT

The Scientific and Technical Support Department of the Argentine National Board of Nuclear Regulation (ENREN) has developed a Remote Monitoring and Surveillance System (RMSS) that provides a media to verify the state of variables related to the monitoring and surveillance activities of nuclear facilities, mainly safeguard applications. RMSS includes a variety of on site installed sensors, an authenticated radiofrequency communication link, a receiver processing unit, an active vision set and a user friendly personal computer interface to collect, view and store pertinent histories of events. A real time data base allows consulting, maintenance, updating and checking activities. RMSS could be integrated into a LAN or WAN via modem for use in a remote operation scheme. In this paper a description of the RMSS is provided. Also, an overview of the RMSS operation at one facility under safeguards belonging to the National Commission of Atomic Energy (CNEA) is presented. Results and conclusions of the system associated with this facility are given.

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Abstract

The Scientific and Technical Support Department of the Argentine National Board of Nuclear Regulation (ENREN) has developed a Remote Monitoring and Surveillance System (RMSS) that provides a media to verify the state of variables related to the monitoring and surveillance activities of nuclear facilities, mainly safeguard applications. RMSS includes a variety of on site installed sensors, an authenticated radiofrequency communication link, a receiver processing unit, an active vision set and a user friendly personal computer interface to collect, view and store pertinent histories of events. A real time data base allows consulting, maintenance, updating and checking activities. RMSS could be integrated into a LAN or WAN via modem for use in a remote operation scheme. In this paper a description of the RMSS is provided. Also, an overview of the RMSS operation at one facility under safeguards belonging to the National Commission of Atomic Energy (CNEA) is presented. Results and conclusions of the system associated with this facility are given.

1. INTRODUCTION AND SYSTEM DESCRIPTION

The RMSS is the argentine remote monitoring and surveillance system. It's main features are associated with safeguard activities and the scope is, essentially, to reduce the cost, both for monitoring agencies and monitored facilities, or to increase the effectiveness of the safeguard actions. RMSS was developed taking into account these points of view. The system is composed basically by sensors, a receiver processing unit, a radiofrequency communication link, an active vision set, a power supply set and a computer processing block. See Figure 1.

The sensors detect motion, measure temperature, have a fiber optic seal instead of mechanical seal, are tamper-proof and have some free general inputs: one digital and two analog which allows them to have other application.

The number of sensors are scaleable up to 255 and can be programmed on site or by remote way. Sensors have energy autonomy of about 2 years. Safety and reliability of the communication link is provided by both authenticated and redundant messages. Authentication of transmissions prevents surreptitious substitution on line of an authentic sensor with another, probably counterfeit. Redundancy is provided by a parallel hot stand-by, using two frequencies in the range of 300 to 900 MHz. in compliance with standards of several countries. Redundancy is also provided by the repetition of the messages in order to avoid missing messages due to collisions.

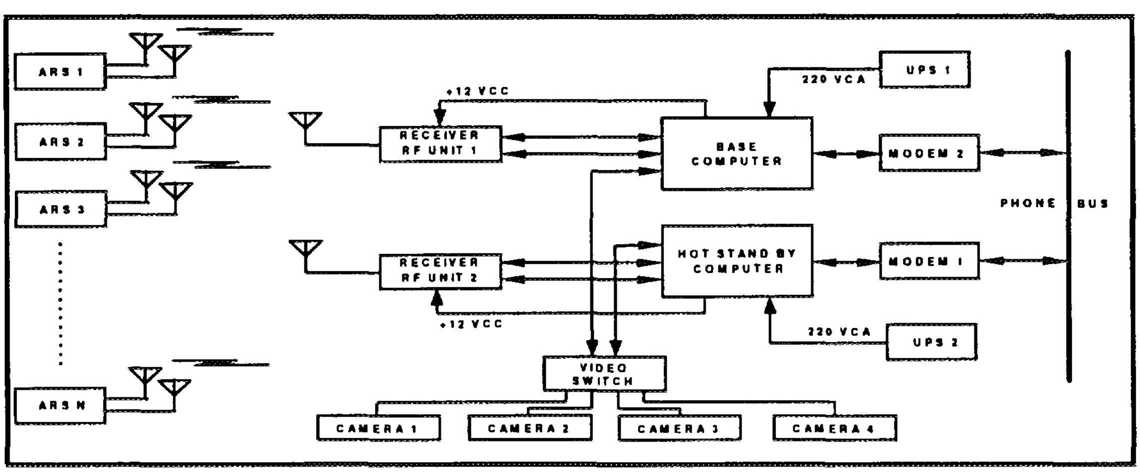


Figure 1. Argentine Remote Monitoring & Surveillance System

The link works up to 300 m. The receiver unit outputs are normalized RS 232/422/485 and reach the serial inputs of two personal computers of industrial type in hot stand-by configuration to provide high reliability and availability.

The operative system QNX provides reliability and portability for multitasking and real time operation. The active vision set includes cameras equipped with motorized zoom and focus lenses, two image frame grabbers and an electronic switcher which controls up to 4 cameras. Cameras can be triggered by sensor and a software comparison of different captured images can recognize different patterns. Also relevant events originate a message that is send via fax.

Self-checking is one of the main important built-in tests of the whole system. In such case the detection of a failure is immediately followed by a correction action and the reinitiation of the system. Two uninterrupted power supplies plus a voltage adder improve the availability of the system. Processes provided as main features can be classified as follows:

- Serial port driver
- Data base management and message interpreter
- Image acquisition
- Fax sending
- Local and remote historical real time data base access
- Sensor programming
- Receiver unit programming

The internal structure of the real time data base contains all the information related to the sensors, including file names associated with the set of images acquired.

The access to the real time data base, to consult via a personal computer, is possible using standard communication protocols. Sensor integrity, real time message arrival, fiber optic state, temperature, anomalies, tamper state, events by day and sensor characteristics can be consulted locally or remotely. Other installation variables, such as those provided by standard instrumentation interfaces could be monitored.

2. DATA ACQUISITION

Data acquisition is performed by means of different sensors which provide digital or analog variables to the acquisition device. Also variables could be classified as internals and externals depending on the application. The acquisition devices could handle up to 4 digital variables and up to 3 analog variables. Usually, devices drive only one digital internal variable (tamper-proof) and only one analog internal variable (temperature). Additional boards provide measures of the fiber optic seal state, movement detection, passive infra-red detection and passive magnetic proximity detection as external variables. Two external analog variables are free and could be used for radiation, pressure or other extra measure. The control of the state of all digital signals is performed by sampling at 1Hz.

3. REMOTE AUTONOMOUS SENSOR

The development of the remote autonomous sensor device is centered on the 68HC705P9 Motorola microcontroller (MCU) and the RFM hybrid monolithic transmitters. Main features of the MCU are the following:

- Low current supply
- 128 Bytes RAM
- 2112 Bytes EPROM
- 20 bidirectional I/O ports and 1 input only port
- 16 Bits Capture/Compare Timer
- 4 channels, 8 Bits ADC
- Single power supply requirements

- Operating temperature from - 40 to 125 CEL
- DC supply voltage from 3.3 to 5 volts
- Clock frequency up to 4.2 MHz

Main features of the RFM hybrid monolithic transmitters are:

- Low current supply
- High stability because carrier frequency is quartz surface acoustic wave
- Several unlicensed work frequencies from 300 to 1000 MHz
- On-Off keyed modulation (OOK)
- Operating temperature from - 40 to 85 CEL
- 2 dBm maximum output power

Block diagram of the RAS device is shown in Figure 2.

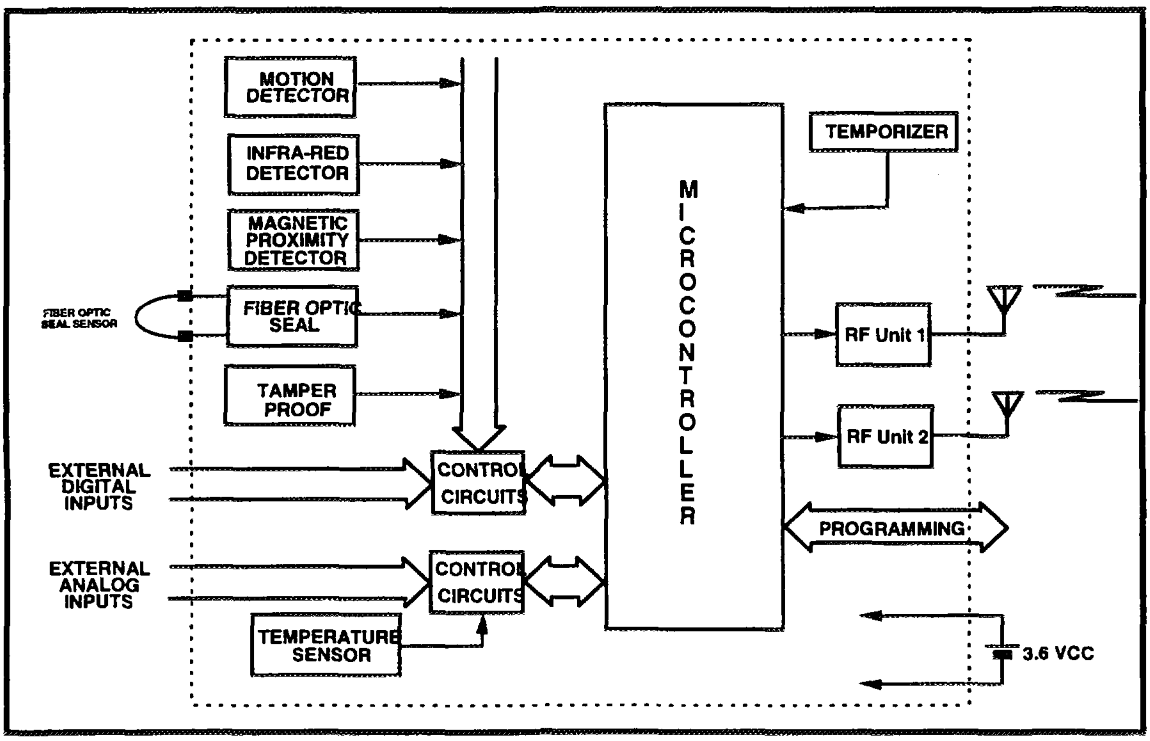


Figure 2. Remote Autonomous Sensor

Main blocks are:

- Microcontroller 68HC705P9 and associated circuits
- Timer and associated circuits
- Transmitters and associated circuits
- Tamper-proof control circuit
- Temperature measure control circuit
- Fiber optic seal control circuit
- Motion detector control circuit
- Passive Infra-red detector control circuit
- Passive magnetic proximity detector control circuit
- Power supply

A timer provides a low frequency clock of 1 Hz. to be used as sampling rate over the monitored signals. High stability and low current supply are their main characteristics. The microcontroller processes the sampled signals to detect the change of the actual state. Two types of messages are handled by the microcontroller named "State Of Health" (SOH) and "Change Of State" (COS) respectively. Messages are conformed by 8 blocks of data, 12 Bytes each one. Bytes characteristics are:

- System (1 Byte) = Number of systems associated with sensors. From 1 to 127
- Sensor (1 Byte) = Number of sensor. From 1 to 255
- Counters (2 Bytes) = Number of messages transmitted. From 1 to 65535
- Authenticated (2 Bytes) = Certify the block of data concerning to a sensor
- Checksum (1 Byte) = Block of data integrity check
- Header (1 Byte) = Start of the block of data
- Data (4 Bytes) = Data information

Messages are transmitted four times with a random gap of up to 15 sec. to avoid collision problems between blocks of data belonging to different sensors. Last generation algorithms provide data authenticity and encryption to fit the security system requirements.

SOH messages are transmitted at a variable rate of 15 sec. to 18 hs. set by program. Data information complies with the state of digital and analog variables and the storage of historical digital variables behavior for the last 24 hours.

COS messages provide information about the change of digital variables from normal to abnormal state and vice versa. COS messages are transmitted immediately after the change from normal to abnormal state and with a delay of up to 255 sec., selected by program, from abnormal to normal state. This last technique avoids the possibility of a block up in the communication channel in the course of the system installation and programming. Also, a change of analog variables could be monitored originating a COS message when variables reach some reference level (upper or lower level).

SOH and COS messages are transmitted via two radiofrequency channels in the range of 300 MHz to 900 MHz. using On-Off keyed modulation (OOK) techniques. The Manchester synchronous protocol provides high noise immunity. Versatility is improved since protocol parameters such as velocity are set during sensor programming.

Acquisition devices comply:

- Fiber optic seal control circuit: composed by optoelectronic elements and control circuits to provide the microcontroller with signal to control the integrity of a fiber optic loop.
- Tamper-proof control circuit: composed by a mechanical toggle switch normally closed and associated circuits to detect the RAS opening.
- Motion detector control circuit: combination of mercury tilt switches with typical life of 250 000 operations and a digital divider. This set provides motion detection with an operating angle of about 2 degree. Sensibility could be set during installation by means of the digital divider according to the operating scenario.
- Passive Infra-red detector control circuit (PIR): consist of a passive infra-red sensor with a variety of interchangeable lenses which include wide angle, long range and vertical curtain styles selected according to the nature of the room and the specific area requirements.
- Passive magnetic proximity detector control circuit (PMP): consist of a magnetic passive face to face proximity detector which allows to detect opened or closed doors and windows.
- Temperature measure control circuit: composed by a thermistor as detector which allows temperature measurement in the range of - 20 CEL to 80 CEL with 10% of maximum relative error.

Power supply is provided by a 3.6 volts Lithium inorganic battery AA size, which allows a RAS autonomy of 2 years. A capacitor in parallel with the battery allows continuous operation in case of battery replacement.

4. RADIOFREQUENCY RECEIVER UNIT

The radiofrequency receiver unit (RRU) is a smart type receiver. The development of RRU device is centered on the 68HSC705C8A Motorola microcontroller (MCU) and the RFM hybrid monolithic receivers. The main features of the MCU are the following:

- 176 Bytes RAM, configurable
- 7744 Bytes EPROM, configurable
- 20 bidirectional I/O lines and 7 input only lines
- Computer operating properly watchdog timer
- Serial communication interface system
- Single power supply requirements
- Operating temperature from - 40 to 85 CEL
- DC supply voltage from 3.3 to 5 volts
- Clock frequency up to 8 MHz

Main features of the RFM hybrid monolithic receivers are:

- Low current supply
- High selectivity by means of the use of surface acoustic wave devices
- High sensitivity passive design with no RF oscillation
- 5 Kb/s or 10 Kb/s baseband data rate
- Several unlicensed work frequencies from 300 to 1000 MHz
- On-Off keyed modulation (OOK)
- Operating temperature from - 40 to 85 CEL
- 10 dBm incident RF power

Block diagram of the RRU device is shown in Figure 3

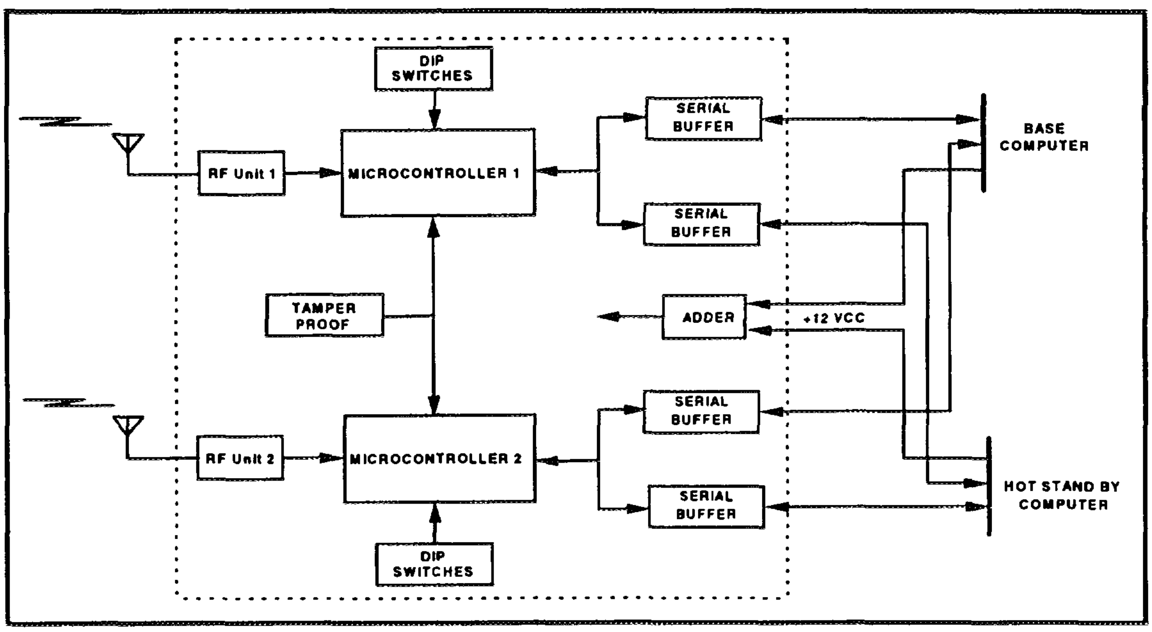


Figure 3. Radiofrequency Receiver Unit

Main blocks are:

- Microcontroller 68HSC705C8A and associated circuits
- Receivers and associated circuits
- Asynchronous serial driver circuit
- Tamper-proof control circuit
- Dip-switches and associated circuits
- Power supply

SOH and COS messages transmitted from RAS are received by the RRU via two radiofrequency channels in the range of 300 MHz and 900 MHz. using On-Off keyed modulation (OOK) techniques. A variety of statistics over signals provided by the receivers is performed by the microcontroller in order to minimize de noise to signal ratio.

The retrieved information is sent to the serial input driver to be handled later by the System Process Unit (SPU). A serial asynchronous protocol RS232/422/485 is used to provide communication between RRU and SPU in a redundant and independent modality.

Tamper-proof control circuit composed by a mechanical toggle switch normally closed and associated circuits provide detection of SPU opening.

In order to personalize different receiver functions according to installation topology, dip-switches are used. It is also possible to modify these functions from the SPU directly.

Power supply is provided directly from SPU by means of a voltage adder which receives in a redundant modality voltages from two computer power supplies belonging to the SPU.

5. SYSTEM PROCESS UNIT

SPU is composed of two Pentium computers of industrial type in hot stand-by configuration in order to increase reliability, availability and safety of the whole system. Both computers receive via multiport cards the information from the RRU. Two image frame grabbers, one per computer, receive via an electronic switcher, the information of up to 4 cameras. Cameras and switcher are Burle. Computers are powered by two independent uninterrupted power supplies and the communication link is performed via two independent modems. The SPU has a self-checking capability therefore when anomalies occur the system is rebooted.

Software development platform is QNX 4.22, C as third-generation programming language and WATCOM C 9.52 as compiler.

Hardware architecture is CPU ADVANETCH PCA-6157 Pentium, 100 MHz, 8 Mb RAM, HD 1 Gb, FD 1.44 Mb 31/2, frame grabber WINVISION, 187x194 pixels resolution expanded up to 310x194 pixels and a serial multiport card (4 ports). The main features of the SPU are:

- **Serial Driver:** The data could arrive from any RAS (up to 127 systems with 255 RAS each one as maximun). SOH and COS messages are repeated four times per transmission frequency. The driver reads the data at the serial port, checks block of data integrity, screens repeated messages, makes the statistics about the number of messages received from each sensor and sends the respective event to the messages interpreter. This driver is sleeping during RRU programming.

- **Message interpreter and data base manager:** Checks the message system correspondence, the actual existence of sensor number, the right authenticated and stores the events and data in the data base. An anomaly is detected, identified and registered when some of the above conditions are not fulfilled. The time between SOH belonging to a RAS is well Known, if a SOH doesn't arrive in an expected time interval, a missing message will be assumed. A fax is sent to a predeterminated fax telephone number if some COS message arrives. No new faxes are sent if new COS messages arrive during an interval of 20 min. from the first one, so the user has enough time to keep in touch with the system to check the cause of the COS message.

  The message interpreter and the data base manager create a data base composed of daily data files, image files associated to COS and erroneous data files.

Daily data files have a format [aammdd] where the fields are [aa] for the year, [mm] the month and [dd] the day in which the files are created. The intemal structure of the real time data base contains the following information:

- Sensor number
- Message number
- Event type
- Event date
- Event calendar time
- Source of data
- State of digital variables
- State of analog variables
- File name associated with the set of acquired images

To avoid data inconsistency, updating of the data base is reported to the system by the RAS programming process. By means of the real time option in the query menu program the information can be displayed on the monitor screen.

- **Image capture:** This process captures an image from a specified camera when it is required by the user or when it is associated with a defined COS messages. Image resolution is 310 x 194 pixels, gray scale. After capture, the image is compressed and stored in a file. Images format is jpeg which allows a good compression rate. File name is alphanumeric and admits a capacity of up to 12 960 000 different images.
- **Fax sending:** A fax is sent when a COS message is presented or a system malfunction occurs. Fax sending process checks modem state prior releasing a fax. When the modem is busy the process checks the modem state every until it finds enabled. Process controls also the acknowledge of fax receipt return and, in case of error release, sends a new fax.
- **Local and remote query of the historical data base:** By means of simple software supporting phone protocol (Zmodem) it is possible to link a remote PC receiving data from the different RAS via the RUU. The main menu is shown in Figure 4.

Menu principal

SISTEMA DE MONITOREO REMOTO
Consultas y Transferencia de Datos

1. Tiempo Real
2. Eventos por día
3. Transferncia por período
4. Datos de los sensores
5. Anomalías

S. Salir

Seleccione la opción deseada:

Figure 4. RMSS Main Menu

Main menu provides the following queries:

- Tiempo Real: Real-time. Display all messages (COS and SOH) as they are receiving from the RUU. See Figure 5. Fields are the following:

Sensor	= Sensor number
Evento	= message type (in case of COS with the corresponding D_i)
Mensaje	= message number (COS and SOH)
Alarma	= out of limits alarm from analog variables
D_i	= Digital variables description (sensor type) and state (normal or abnormal)
A_i	= Analog variables description (variable name) and actual value
Hist.	= Description of digital variables behaviour for the last 24 hours
Fecha	= message date (COS and SOH)
Hora	= message actual time (COS and SOH)
Imagen	= video image captured by a camera associated with a COS message from a sensor

TIEMPO REAL

Sensor: 1	Evento: Cambio-estado 3	
Mensaje: 20477	Alarma:	
D1: 1 normal	A1: temperatura 22.30	
D2: 2 violado	A2:	
D3: 3 normal	A3:	
D4: 4 normal	Hist:	
Fecha: 03/09/1996	Hora: 13:24:48	Imagen: I_0002U.jpg

Espere un momento o presione una tecla para salir.........

Figure 5. RMSS Real Time Query

EVENTOS DEL 03/09/96

Sensor: 1	Evento: Estado de salud-SOH	
Mensaje: 20476	Alarma:	
D1: 1 normal	A1: temperatura 22.30	
D2: 2 violado	A2:	
D3: 3 violado	A3:	
D4: 4 normal	Hist: nVVn	
Fecha: 03/09/1996	Hora: 13:24:43	Imagen:
Sensor: 1	Evento: Cambio-estado 3	
Mensaje: 20477	Alarma:	
D1: 1 normal	A1: temperatura 22.30	
D2: 2 violado	A2:	
D3: 3 normal	A3:	
D4: 4 normal	Hist:	
Fecha: 03/09/1996	Hora: 13:24:48	Imagen: I_0002U.jpg

<ESC>: sale <A>: avanza

Figure 6. RMSS Events per day Query

- Events per day: Display all messages originated by sensors for a determined date as shown in Figure 6.

- File transfer by time period: With this option all message files for some selected period of time are transferred from the local PC to a remote PC. Since those files are provided in ASCII format, they can be consulted by means of a conventional text editor. Also data files could be picked up and handled by a data base manager in order to make some statistics over them or directly by means of an EXCEL for WINDOWS worksheet.

DATOS DE LOS SENSORES

Sensor: 1	Estado: ACTIVO		Cámara:1
Nombre: 1	Tipo: 1	Id: a0	
Tiempo SOH: 20.00	Expanción: 6		
Fecha Alta: 29/08/96	Fecha Baja:		

Digitales

D1: 1	D2: 2
D3: 3	D4: 4

Analógicos	**Unidad**	**Nivel Superior**	**Nivel Inferior**
A1: temperatura		50.00	9.88
A2:			
A3:			

<ESC>: sale <A>: avanza

Figure 7. RMSS Sensor Data Query

- Sensor data: Display all the information about sensors. See Figure 7. Fields are the following:

Sensor	= Sensor number
Estado	= State (active or inactive)
Camara	= Camera number associated with sensor
Nombre	= Sensor name
Tipo	= Sensor type
Id	= Programmig control mode
Tiempo SOH	= SOH time interval
Expansión	= Trasmission speed mode
Fecha Alta	= Sensor entry date to system
Fecha Baja	= Sensor exit date to system
D_i	= Description of digital variables (sensor type)
A_i	= Description of analog variables (variable name)
Unidad	= Analog measure unit
Nivel Superior	= Maximum limit value for analog variables
Nivel Inferior	= Minimum limit value for analog variables

ANOMALIAS DEL 01/01/96 AL 31/03/96			
sensor	**fecha**	**hh:mm:ss**	**mensaje de error**
1	04/03/96	14:56:33	Sensor no válido
2	04/03/96	14:57:28	Sensor no válido
3	04/03/96	14:58:24	Sensor no válido
4	04/03/96	14:59:20	Sensor no válido
5	04/03/96	15:00:15	Sensor no válido
6	04/03/96	15:01:10	Sensor no válido
7	04/03/96	15:03:01	Nro. sist. distinto
8	04/03/96	15:03:57	Nro. sist. distinto
9	04/03/96	15:04:57	Nro. sist. distinto
10	04/03/96	15:05:49	Nro. sist. distinto
11	04/03/96	15:07:39	Mal autenticado
12	04/03/96	15:08:40	Mal autenticado
13	04/03/96	15:09:35	Mal autenticado
14	04/03/96	14:56:33	Sensor no válido
15	04/03/96	14:57:28	Sensor no válido
16	04/03/96	14:58:24	Sensor no válido
<ESC>: sale	<A>: avanza		

Figure 8. RMSS Anomalies Data Query

• Anomalies: Display all not coherent messages received with the error message associated as shown in Figure 8 Fields are:

sensor	= Sensor number
fecha	= Message date (COS and SOH)
hh:mm:ss	= Message time (COS and SOH)
mensaje de error	= Error message type

6. RAS AND RUU PROGRAMMING

Programming RAS and RUU are easy tasks and must be done from the mainframe base computer via programming and/or communication ports. RAS programming is off line. It is necessary to connect RAS with the base computer programming port via cables and connectors. RAS stores the following internal parameters related to its operation:

- Time between SOH messages
- Delay time from the end of programming at the beginning of operation
- Radiofrequency characteristics
- System number
- Sensor number
- Authentication and encryption keys

Due to the diversity of places in which the RUU could be installed and the different electromagnetic characteristics of these places, the internal RUU parameters can be modified in order to provide integrity and security to the arriving data. RUU programming could be done on line and/or off line. In the first case it is not necessary to disconnect the RUU from the base computer communication port. RUU stores the following internal parameters related to its operation:

- Radiofrequency characteristics
- System number

- RUU number
- Time between SOH messages
- Authentication and encryption keys

7. APPLICATION AND RESULTS

A reduced version of RMSS has been installed at one facility under safeguard belonging to the National Commission of Atomic Energy (CNEA) in order to measure RMSS performance characteristics.

In this case RMSS is composed of only one camera, four RAS, one RUU and one SPU as shown in Figure 9. The place was conditioned to make more easy the installation.

RAS #1 and #2 detect motion and fiber optic seal opening. Both of them were installed over fissionable material containers inside the warehouse.

RAS #3 detects main warehouse door opening and fiber optic seal opening. A passive magnetic proximity detector was installed over the main door and fiber optic seal was installed over the warehouse air-conditioning equipment.

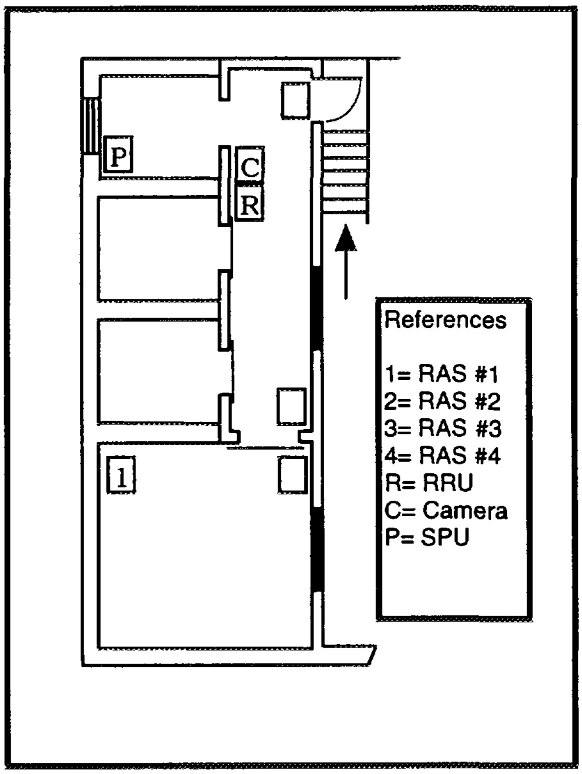


Figure 9. RMSS top view installation site

RAS # 4 detects seal opening and volumetric motion in the area. Fiber optic seal was installed all around the three internal doors of the warehouse and a passive infra-red detector was installed looking at the warehouse entrance.

A camera was installed looking at the warehouse entrance main door and is triggered by RAS #3 or RAS #4.

Files analyzed cover the period 3/10/96 - 14/11/96. Figure 10 shows COS messages versus date over that period for all RAS. Most of the COS messages occurring early at the beginning are associated with the installation phase. Detailed COS messages for 24 hours belonging to a date is shown in Figure 11.

For a selected day, that is 5/10/96 for this example, COS messages belong to RAS #3 and RAS #4, main door warehouse opening and volumetric motion respectively. Between 13.05

hs. and 13.25 hs. approximately, there was an intrusion in the warehouse, therefore a camera was triggered when the main door was opened and closed and also when people moved inside the warehouse, at a rate of one image per RAS demand.

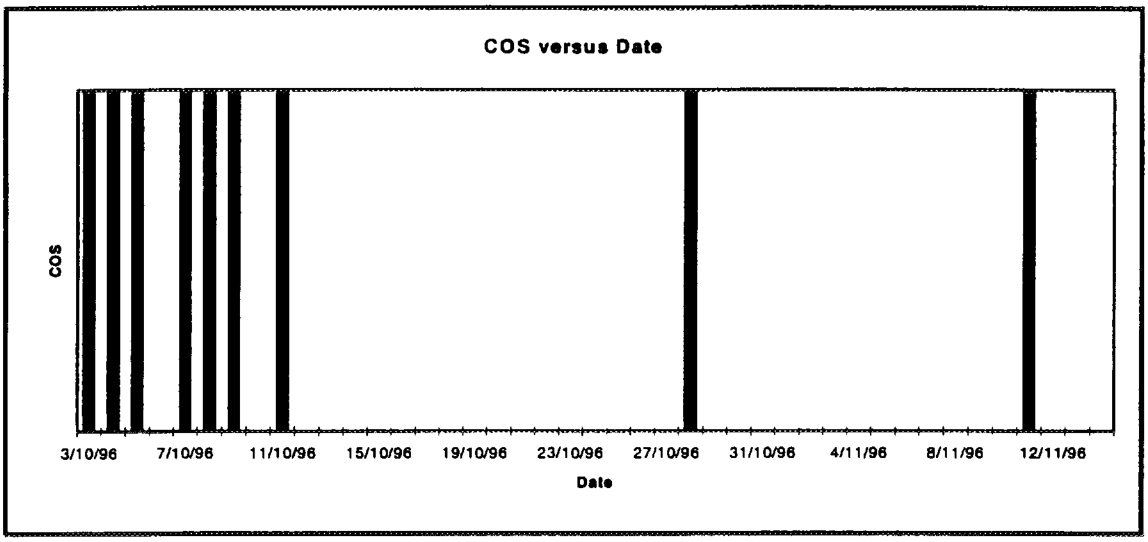


Figure 10. COS messages versus Date for period 3/10/96-14/11/96

Typical images captured by camera are shown in Figure 12 and 13 related to triggered actions of RAS #3 and RAS #4 for date 5/10/96.

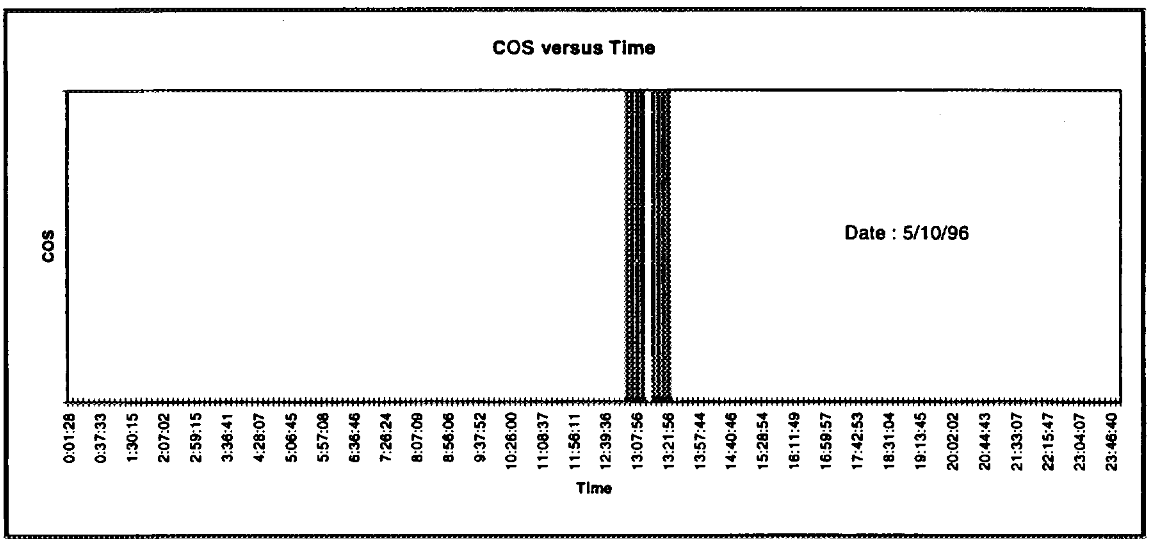


Figure 11. COS messages versus time for date 5/10/96

Figure 12. Captured image by main door sensor trigger

Figure 13. Captured image by infra-red sensor trigger

All RAS measure temperature inside warehouse. Different position of sensors provide different ranges of temperature, nevertheless all RAS present the same variations in time. Figure 14 to 17 show the variation of temperature versus time for all RAS within the analyzed period.

RAS #4 presents some problems at the very end of the period under analysis mainly owing to poor board connection terminals.

Figures 18, 22, 26 and 30 show missing block messages versus time for RAS #1, #2, #3 and #4 respectively. Vertical scales are different since the quantity of missing complete block messages, this is four messages per block of data, change with the RAS.

Figures 19, 23, 27 and 31 show missing messages per block of data versus time for RAS #1, #2, #3 and #4 respectively. Since messages are transmitted four times per block in order to avoid collisions, this is a configuration one out of four, it would be possible to miss up to three messages without problems.

COS messages versus time for RAS #1, #2, #3 and #4 are shown in Figures 20, 24, 28 and 32. These figures present a correlation with Figure 10, since it shows all COS messages.

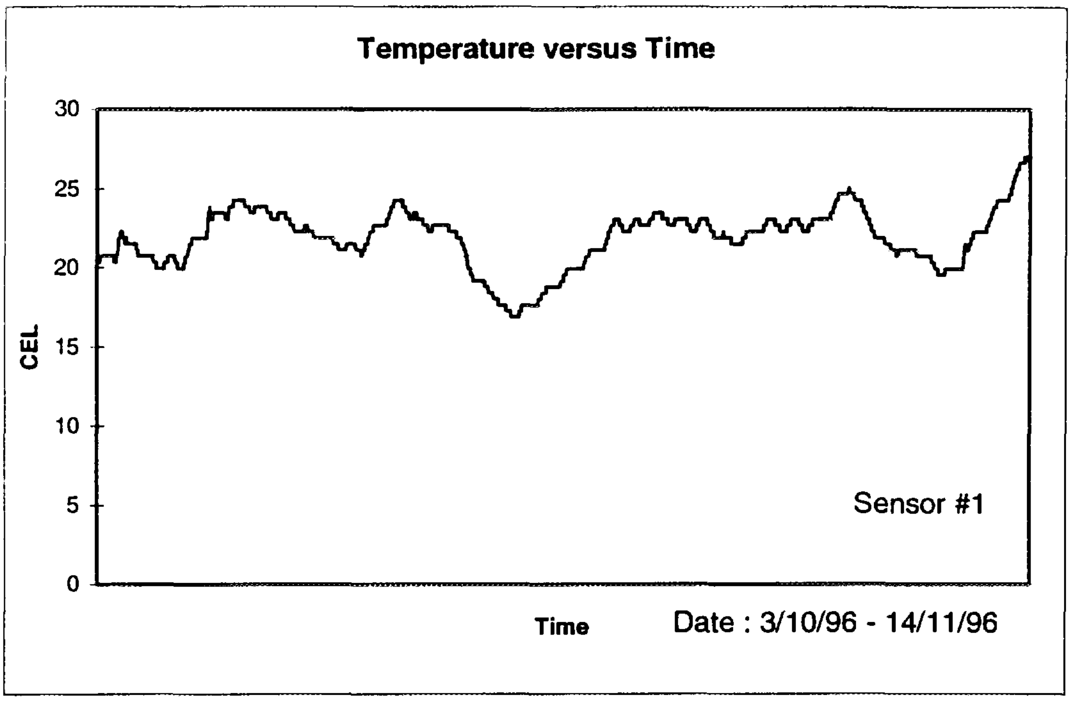


Figure 14. Temperature versus time RAS #1

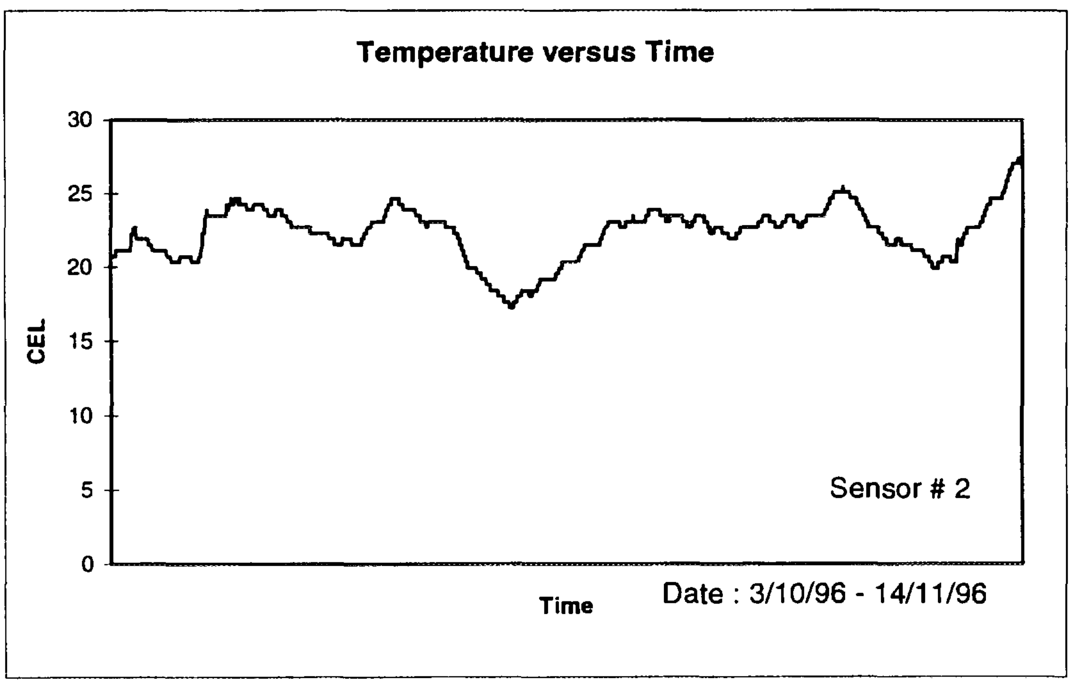


Figure 15. Temperature versus time RAS #2

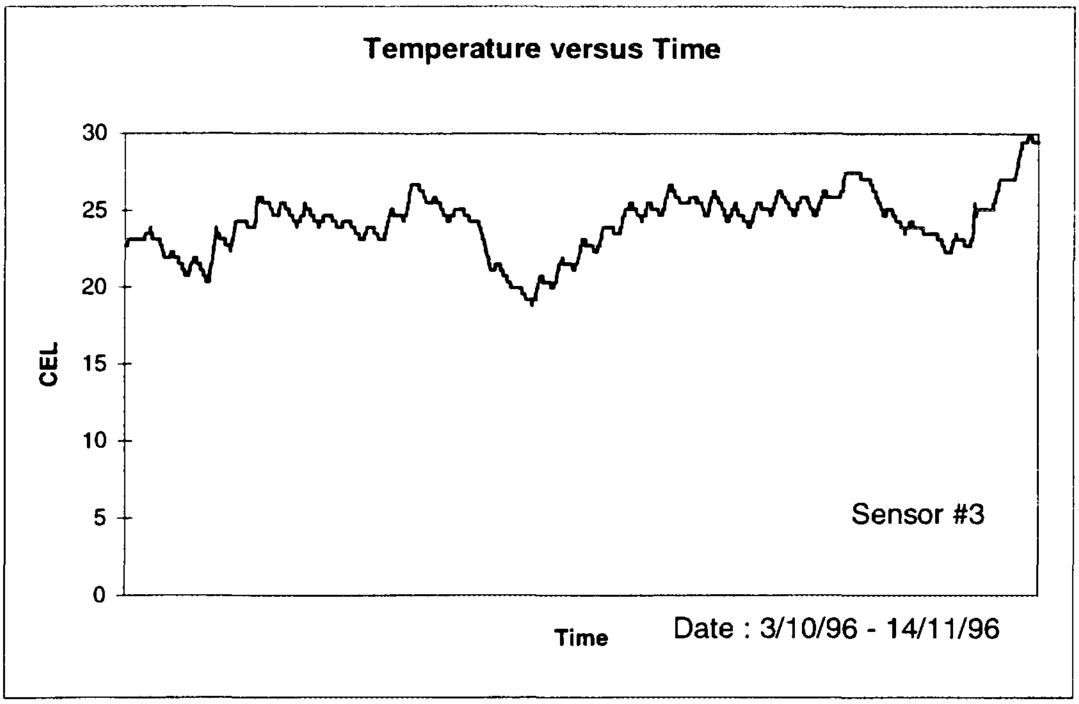


Figure 16. Temperature versus time RAS #3

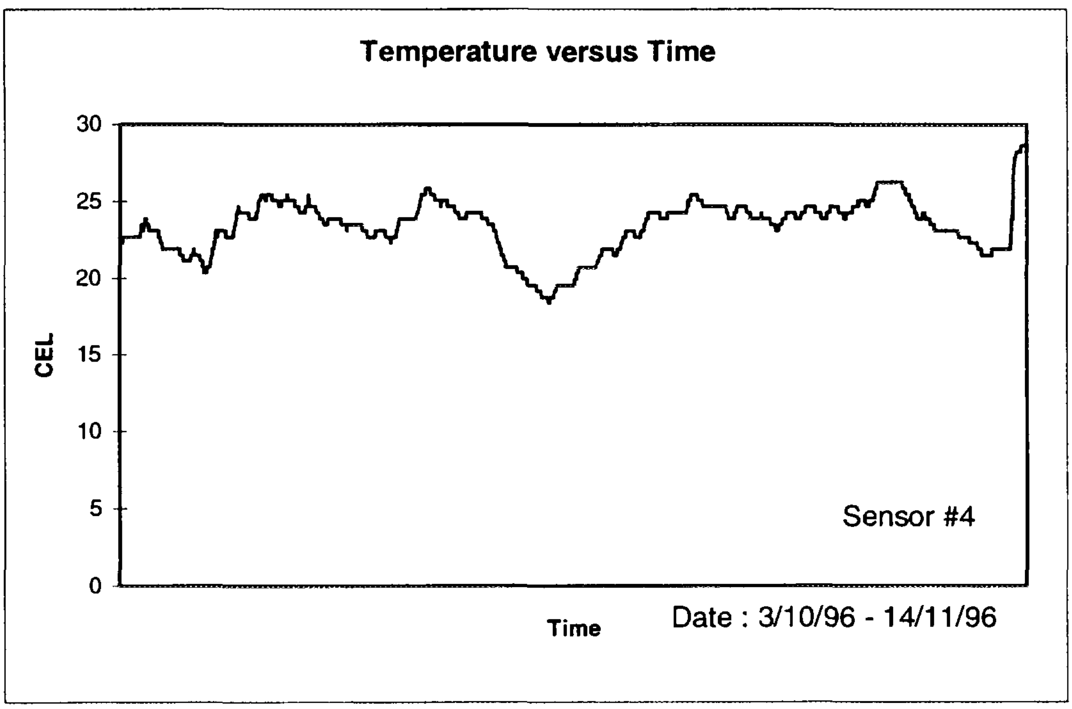


Figure 17. Temperature versus time RAS #4

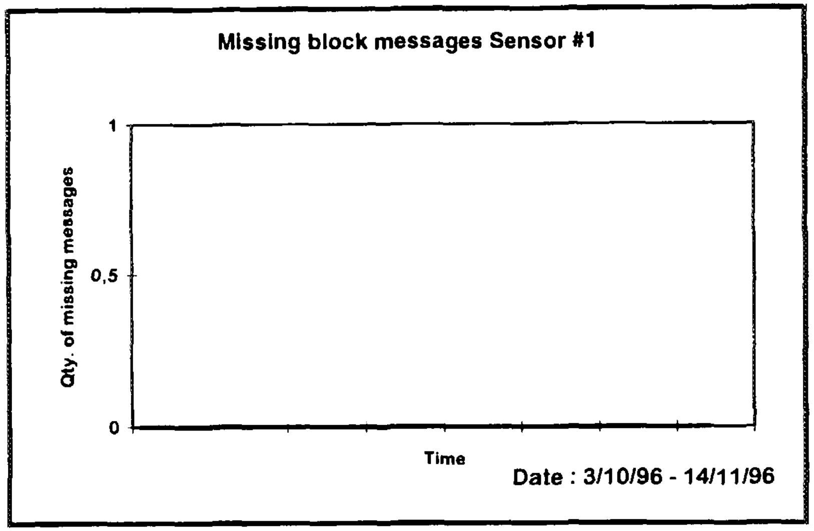


Figure 18

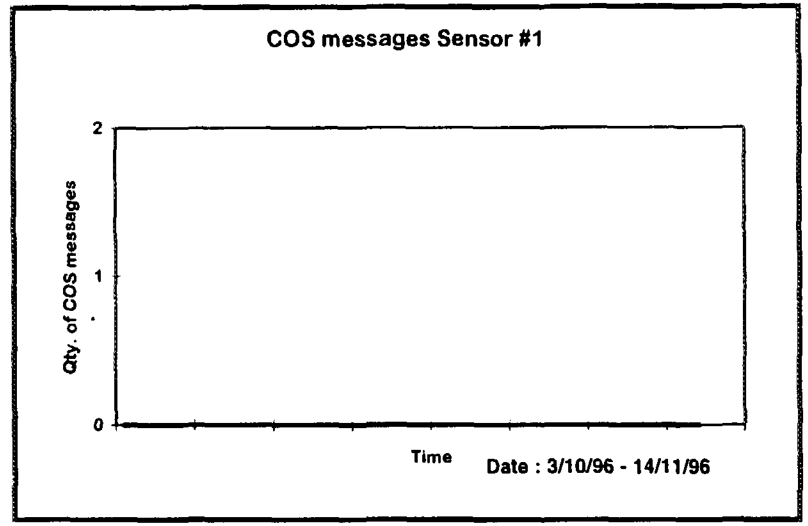


Figure 19

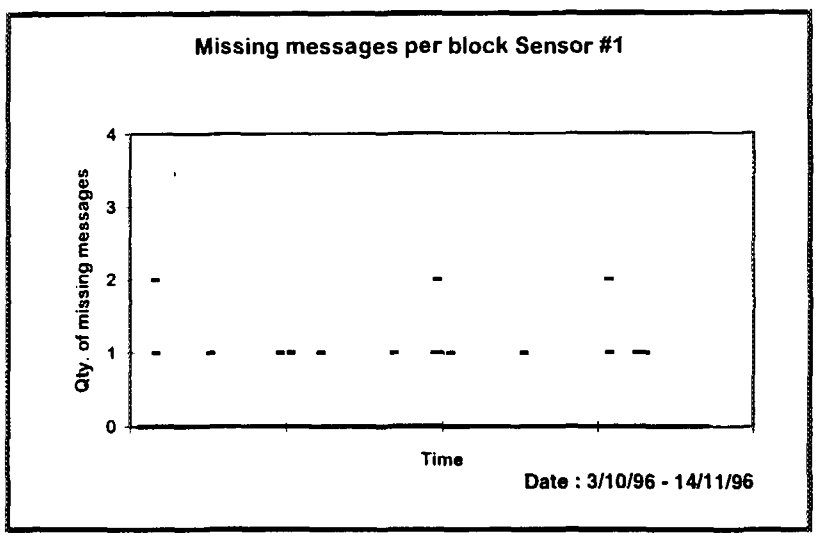


Figure 20

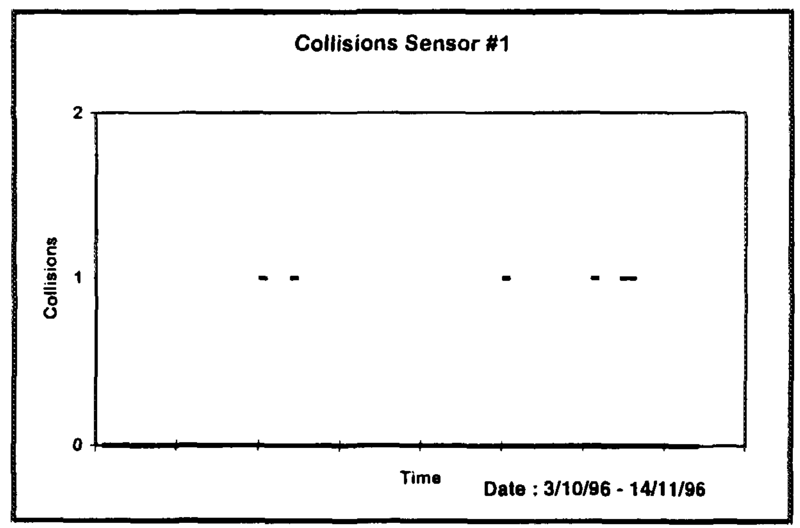


Figure 21

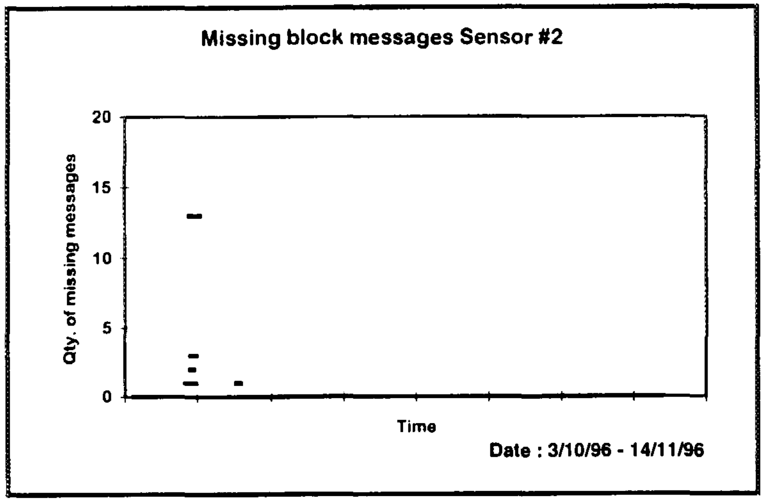


Figure 22

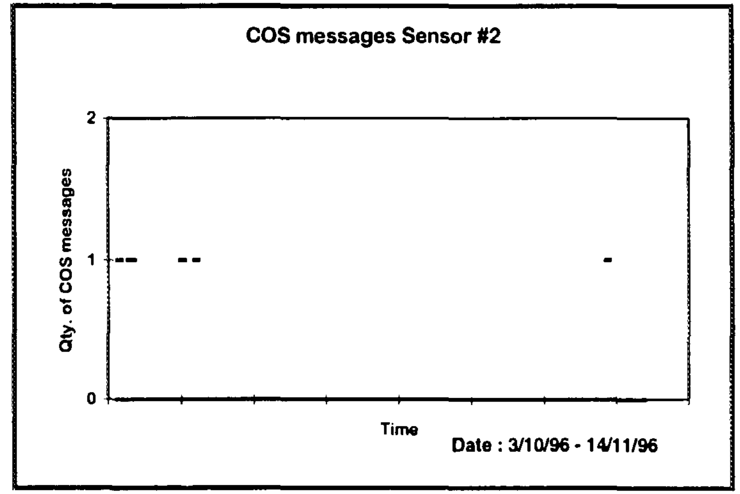


Figure 23

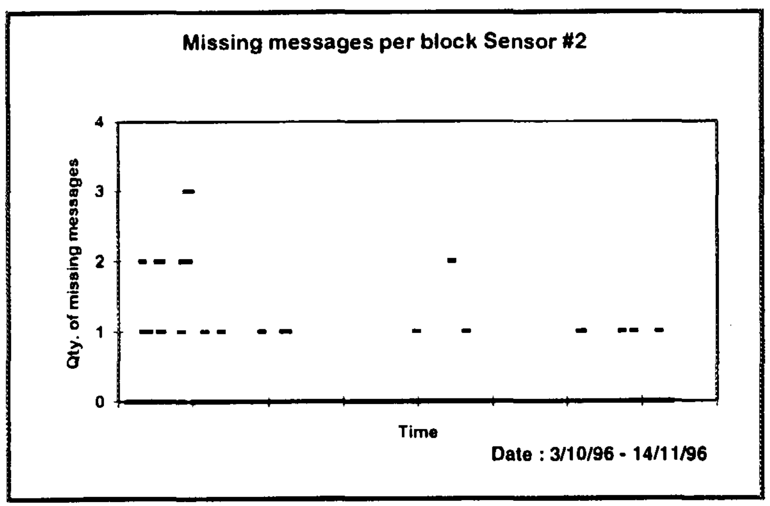


Figure 24

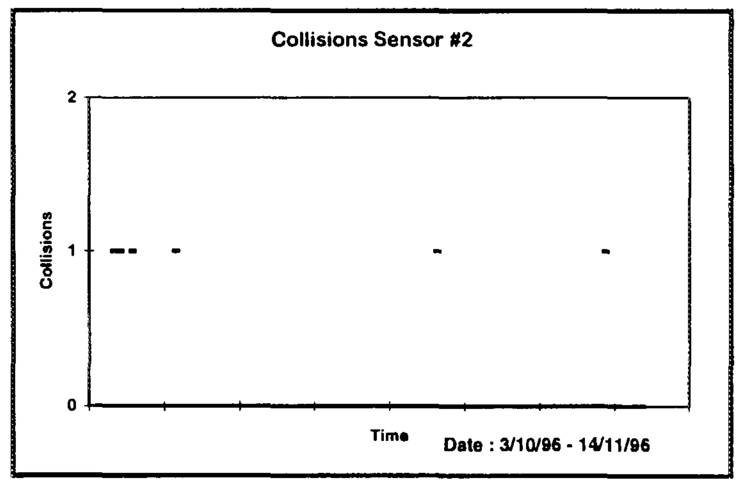


Figure 25

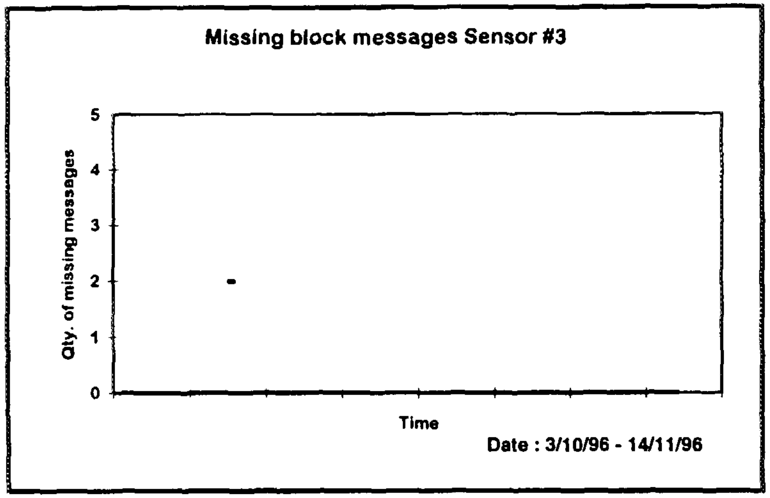


Figure 26

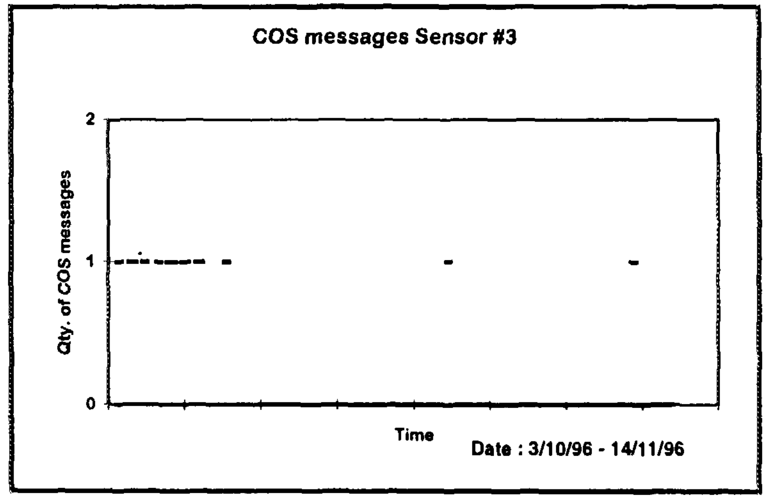


Figure 27

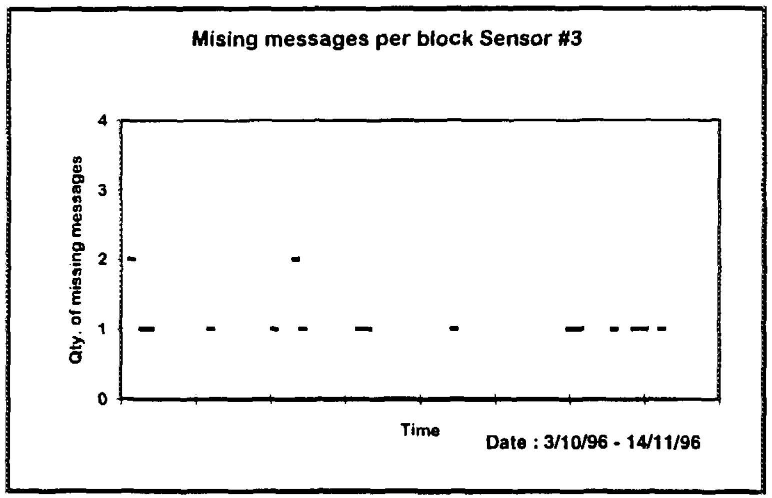


Figure 28

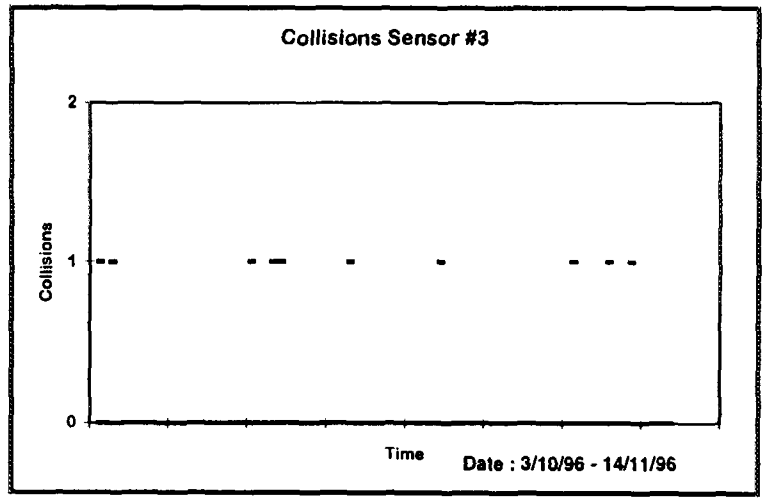
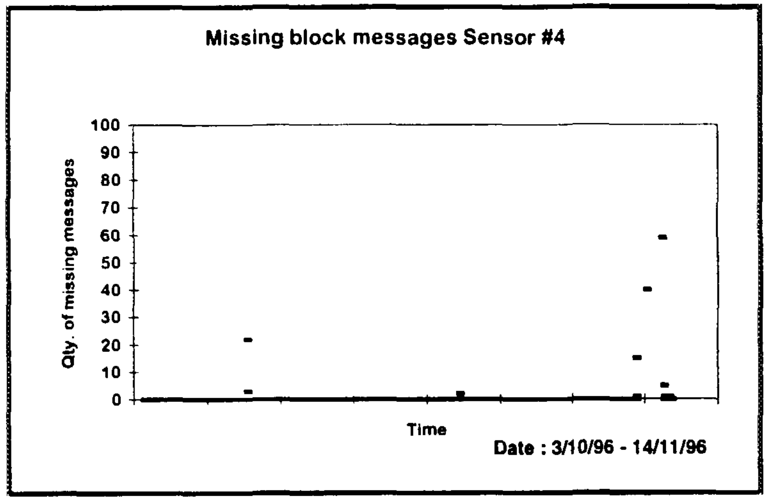


Figure 29



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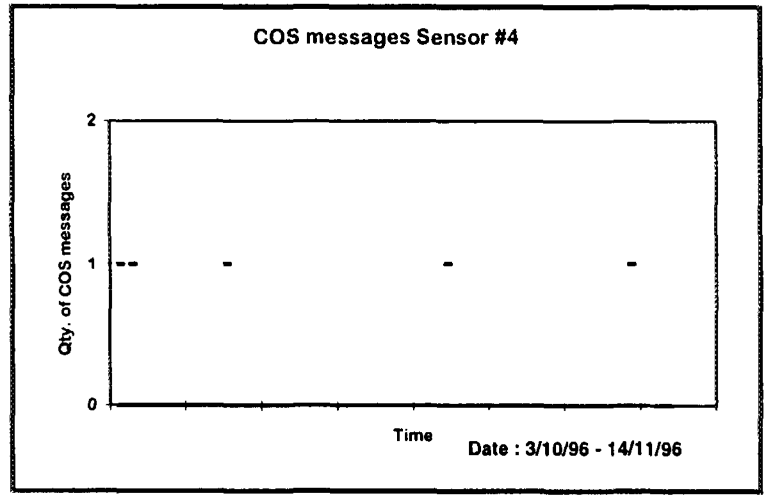

Figure 31

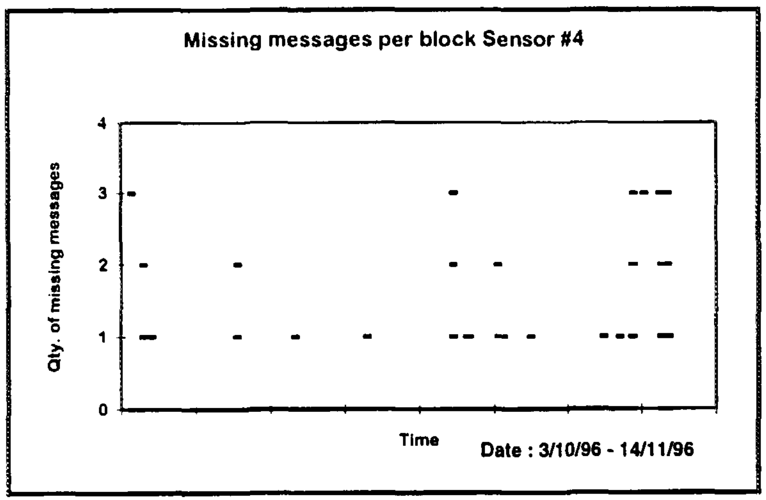

Figure 32

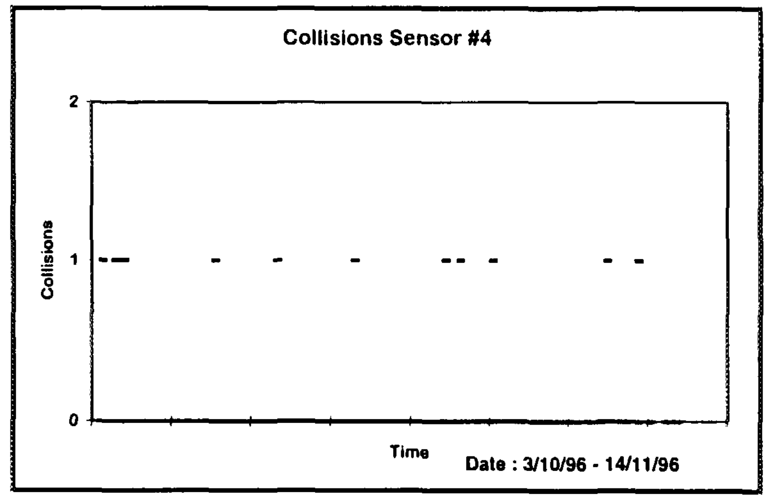

Figure 33

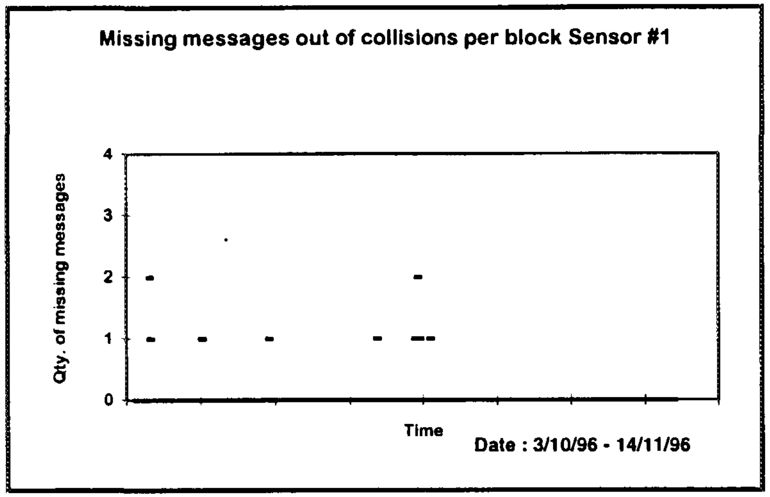

Figure 34

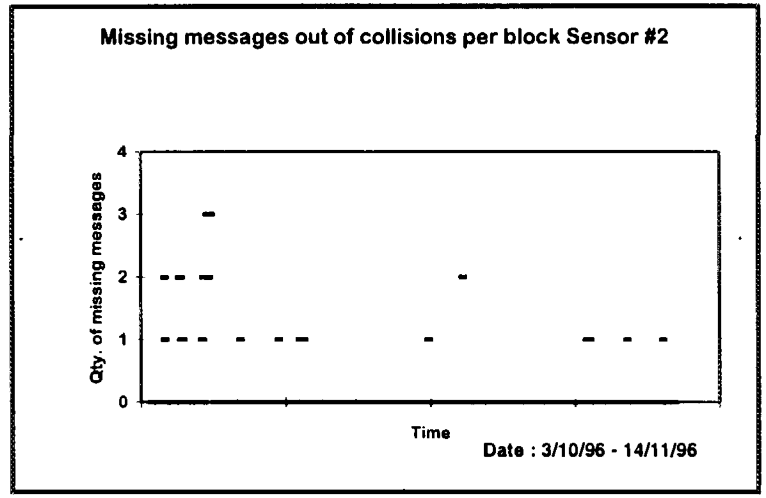

Figure 35

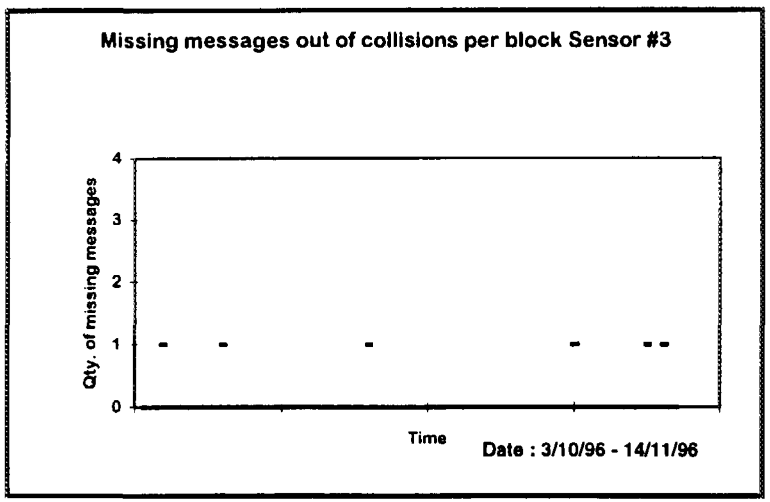

Figure 36

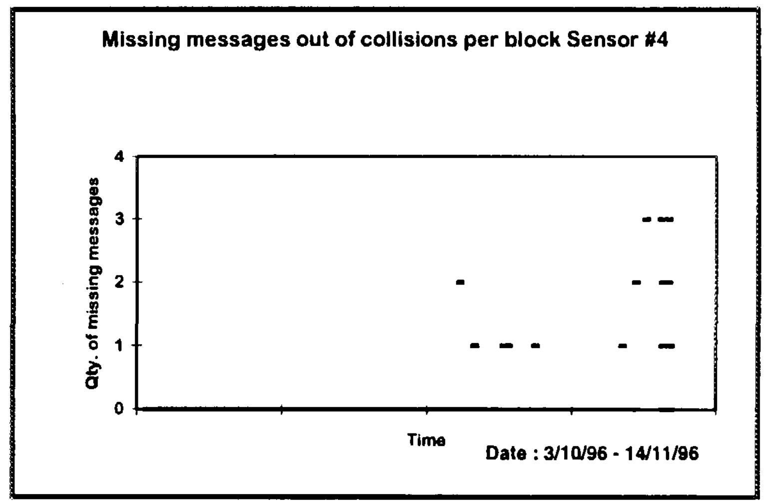

Figure 37

Figures 34, 35, 36 and 37 show missing messages per block out of collision for RAS #1, #2, #3 and #4 respectively. In fact they represent missing messages for reasons not related with collisions between blocks of data of different sensors. RAS #1 and #3 show a good behavior with one or two out of four missing messages out of collisions per block. RAS #2 shows many of those missing messages at the very beginning mainly due to installation activities. RAS #4 presents some problems at the very end of the period under analysis for reasons described before.

Missing messages rates as the relation between all missing messages over total transmitted messages are:

RAS #1: 0,24 %
RAS #2: 2,43 %
RAS #3: 0,35 %
RAS #4: 7,74 %

8. CONCLUSIONS

Although the reduced version is far from the standard version of the system, from the point of view of availability and reliability, the results are satisfactory. RAS prototypes works well and fit the requirements. RAS worked 4128 hours without failures, RAS #4 presented problems at the very end of the period under analysis mainly due to poor board connections. Temperature is follow up by the four RAS in the same way.

The communication link works well and the images captured by triggering COS messages are clear and can be stored with the corresponding format on data base.

Screens proposed improve the handshake of information, in fact the programming and the query. The communication via modem and the local and remote query of the historical data base is performed satisfactory as it also the file transfer.

The next steps in the RAS development will be the inclusion of a dose rate meter and the encryption of the transmitted data information besides the authentication.

From the system point of view should follow the implementation of an automatic remote query process, so that the data provided by this query can become a part of an SQL data base on a UNIX server which runs on WWW (World Wide Web) server. A query mechanism would be defined exploiting the possibilities of the interface between the WWW server and an application provides by CGI (Common Gateway Interface).

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