THE ELECTRONIC AND SOFTWARE DESIGN OF THE ORA OCCULTATION RADIOMETER

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1. INTRODUCTION

The OCCULTATION RADIOMETER (ORA) is a satellite borne instrument designed by the Belgian Institute for Space Aeronomy (Brussels, Belgium) in collaboration with Oxford University (U.K.).

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Instrument developer :	D. Nevejans /	BISA
Co-investigator :	F. Taylor /	Univ. Oxford.

Its purpose is to measure aerosol and trace gas densities in the Earth's atmosphere by means of an optical occultation technique. Therefore ORA will measure the solar radiation in 10 narrow bandwidth wavelength domains during a short period each time the satellite is entering and leaving the eclipse.

Eight domains were selected in the visible and near-ultraviolet part of the solar spectrum at : 250, 340, 385, 435, 442, 600, 943 and 1014 nm. Two additional bands were chosen in the near-infrared. This choice will allow the determination of ozone, nitrogen dioxide, water vapour, carbon dioxide, aerosols and dust particles from 20 km up to 100 km altitude.

The flight Model of the ORA instrument has been delivered to ESA (European Space Agency) in August 1989 and will be integrated on the EURECA (European Retrievable Carrier) satellite.

EURECA is a free-flying, low Earth orbiting reusable platform to be launched by the American Space Shuttle. It is to be considered as an unmanned SPACELAB follow-on and as a test bed for technologies required for future space stations. The projected orbit altitude is approximately 500 km. After at least 6 months EURECA will return to an orbit at 250 km altitude for retrieval by the Space Shuttle.

The original intention was to have EURECA launched for the first time in early 1983 for a microgravity mission, but due to a shuttle accident this launch has been postponed by 3 years. Launch is now scheduled for 16 May 1991. The ORA experiment will participate in this flight as a science add-on experiment having no microgravity requirements. It will use the sun pointing capability of EURECA, its power supply, its data handling system (DHS) and its telecommand and telemetry system.

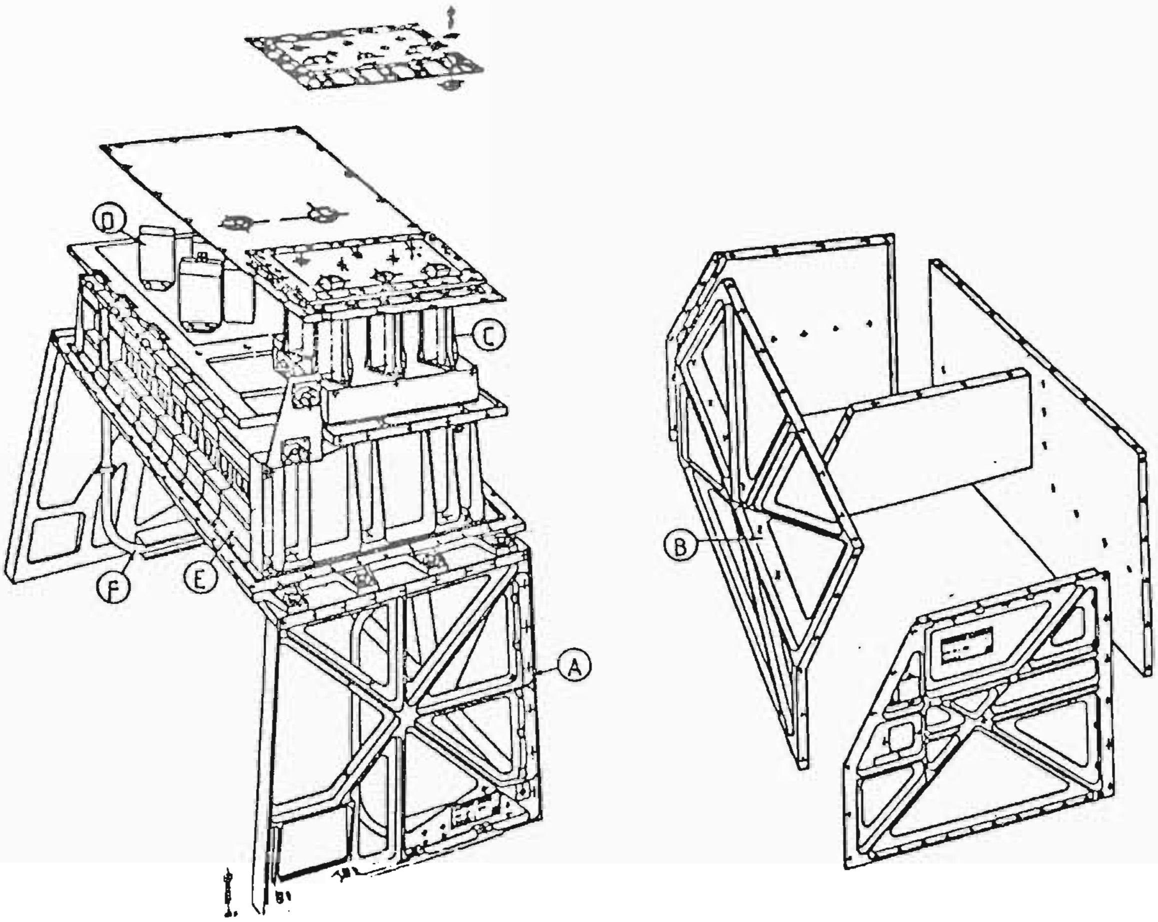
BRIEF ORA HARDWARE OVERVIEW

The OCCULTATION RADIOMETER consists of 3 major parts located within an aluminium structure or box (B) mounted on top of a bridge structure (A) :

* Eight similar optical modules (C) destinated for measurements in the visible and near-ultraviolet part of the solar spectrum, each consisting of :
  - an interferential filter having a bandwidth of about 10 nm
  - a lens system limiting the field of view to $\pm$ 2°.
  - an UV-enhanced Si or a GaP photodiode.

* An optics block for the infrared measurements (D) composed of a chopper motor, mirrors, 2 gas cells (one filled with carbon dioxide vapour and another with waper vapour) and 4 PbS detectors.

* The main electronics block (E).



The dimensions and the mass of ORA and of the bridge structure have the following values :

276. mm x 336 mm x 270 mm and 13.6 kg for ORA

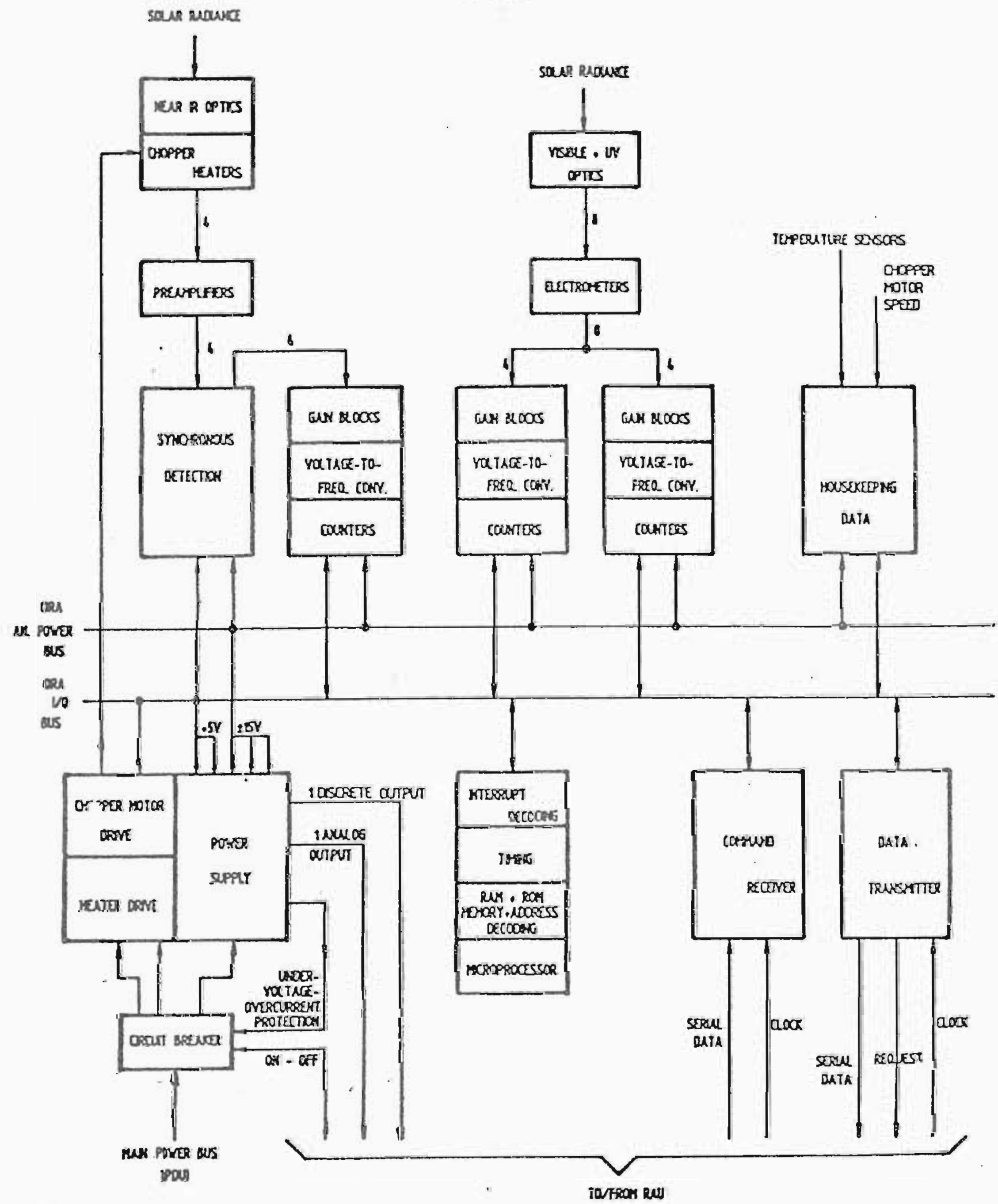
and

265. mm x 437 mm x 307 mm and 3.7 kg for the bridge.

THE ORA ELECTRONICS HARDWARE

The main electronics block of ORA consists of the following modules :

* A processor board integrating an 80C86 microprocessor together with 16 Kbytes of Erasable Programmable Read Only Memory (EPROM), 32 Kbytes of Random Access Memory (RAM), address decoding, an interrupt controller, programmable timers and a real-time multitasking operating system.



The 80C86 and the associated peripheral chips of the 82C** series have been selected because of the availability of MIL standard versions from at least two vendors and because of the existence of a real-time multitasking operating system compatible with the 80C86 (VRTX-86 from Ready Systems).

* A command receiver board accepting commands formatted into TC packets arriving from a Remote Acquisition Unit (RAU) connected to EURECA's DHS.

* A data transmitter board sending data formatted into TM or TC packets to a Remote Acquisition Unit (RAU) connected to EURECA's DHS.

* A synchronous detection board containing 4 synchronous demodulators which demodulate the chopped signals of the near-infrared optics preamplifiers and deliver them to an Analog-to-Digital Converter board.

* Three integrating Analog-to-Digital Converter boards each consisting of 4 programmable gain stages (gain programmable in 15 1.5 dB steps), 4 voltage-to-frequency converters and 4 16-bit counters.

* An housekeeping signals board consisting of two multiplexers for 14 analog inputs each and two analog-to-digital converters similar to the ones used for the optical channels.

  The analog inputs are produced by thermistor networks measuring temperatures in critical parts of the instrument, such as : detectors, gas cells, chopper motor, heat pipes, etc...

* A motor and heater control board which controls the thermal environment and the chopper motor of the near infrared part of ORA.

  It manages the power supplied to 6 heaters heating the gas cells and detectors and supplies the 2 windings of the chopper motor with the appropriate waveforms required for synchronous operation.

Total power consumption for ORA is 25 Watt @ 28 Volt if all heaters are operating.

THE ORA ON-BOARD SOFTWARE

The major part of the ORA on-board software is written in the C language and compiled and linked by means of the HP 64000 Hosted

Development System Cross compiler running on Hewlett-Packard workstations under a UNIX operating system.

Some time critical routines, such as the interrupt routines, were written in 8086 assembler using the HP 64000 cross assembler on the system mentioned above.

The different modules of the on-board software were built on top of a real-time, multitasking operating system : the VRTX operating system from Ready Systems. This OS was selected since it was specifically intended for microprocessors in embedded applications requiring a real-time multitasking executive.

VRTX is entirely written in position-independent code (4 Kbytes) and can be positioned anywhere in the address space of the ORA microprocessor. Furthermore VRTX does not require any additional hardware for its operation.

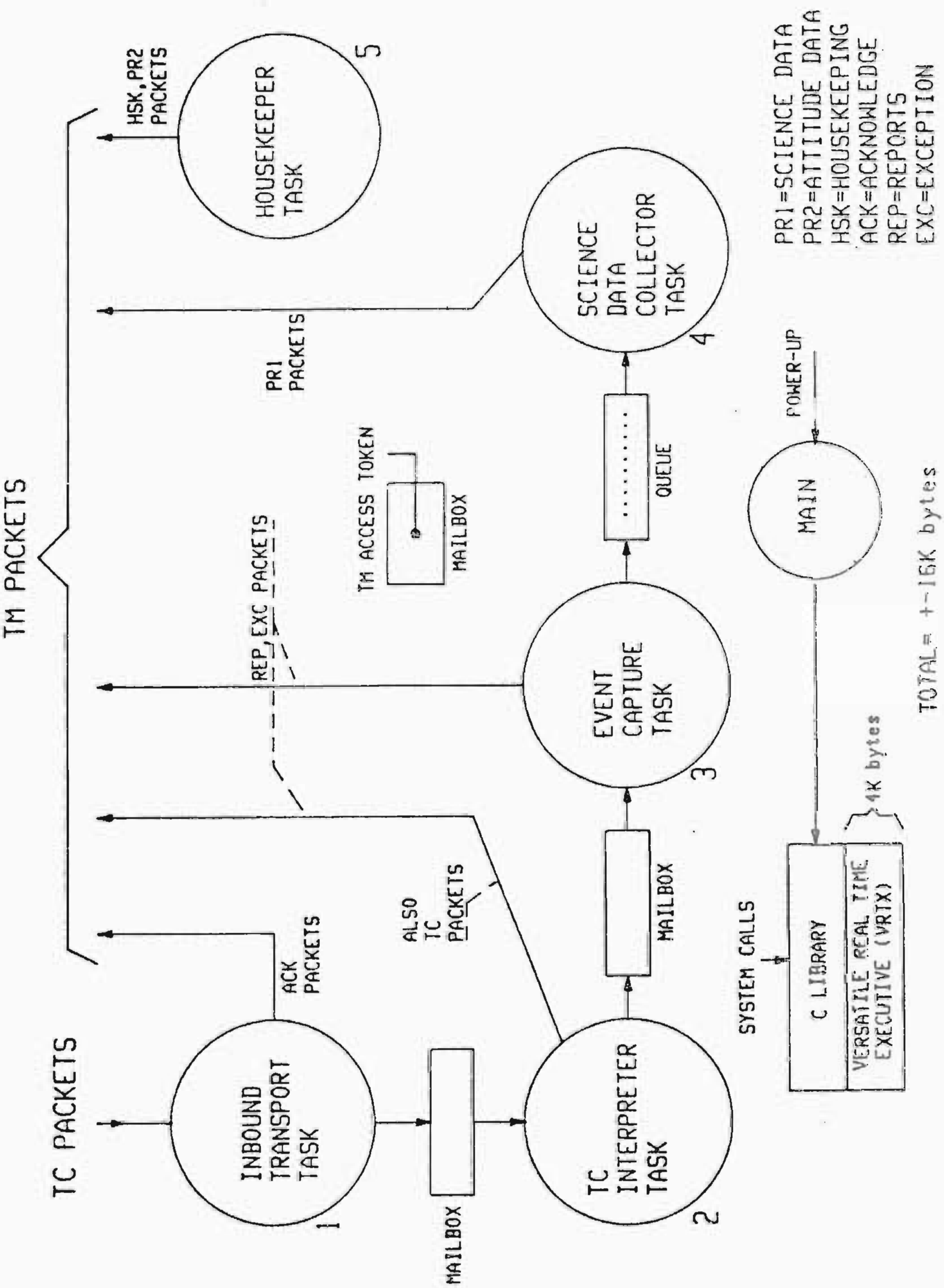
In order to interface VRTX with ORA software modules written in the C programming language a library of C functions performing system calls to VRTX has been established.

VRTX provides the following range of real-time features to the ORA software :

* Multitasking and real-time response
* Priority-based time-sliced or interrupt driven scheduling of tasks
* Intertask communication and synchronization by means of mailboxes and queues
* Dynamic memory allocation.

VRTX also maintains a time which is reset to zero when it is initialized. This timer allows VRTX to support time-sliced round-robin scheduling of equal priority tasks, specific clock-related system calls, as well as time-out support for some system calls.

At power-up the 80C86 microprocessor is reset and starts executing module "main" which is intended primarily for :



TC PACKETS
TM PACKETS
INBOUND TRANSPORT TASK
1
MAILBOX
ACK PACKETS
TC INTERPRETER TASK
2
ALSO TC PACKETS
MAILBOX
EVENT CAPTURE TASK
3
REP, EXC PACKETS
TM ACCESS TOKEN
MAILBOX
QUEUE
SCIENCE DATA COLLECTOR TASK
4
PR1 PACKETS
HOUSEKEEPER TASK
5
HSK, PR2 PACKETS
POWER-UP
MAIN
SYSTEM CALLS
C LIBRARY
VERSATILE REAL TIME EXECUTIVE (VRTX)
4K bytes
TOTAL= +-16K bytes
PR1=SCIENCE DATA
PR2=ATTITUDE DATA
HSK=HOUSEKEEPING
ACK=ACKNOWLEDGE
REP=REPORTS
EXC=EXCEPTION

* defining interrupt vectors
* setting up the VRTX Configuration Table
* initializing devices
* creation of tasks, mailboxes and queues
* starting multitasking

In total 5 tasks are being scheduled by VRTX :

* The "inbound-transp" task which handles the reception of TC packets and takes care of data integrity during transport of TC packets from DHS to ORA.
* The "tc-interpreter" task which analyzes the commands packed within the received packets, checks their syntax and executes them.

* The "event-capture" task responsible for capturing events, such as : sunrise and sunset, snapshots and gainadjustment.

* The "science data collector", which collects the science data TM packets produced by the event- capture task and sends them one by one to the telemetry channel.

* The "housekeeper" task "housekeeper" which measures temperatures and controls the thermal environment of the infrared optics.

As mentioned before these tasks communicate with each other by means of mailboxes and queues provided by the VRTX operating system.

PACKETIZED TC AND TM ON EURECA

Telecommanding and telemetry on EURECA both make use of the concept of packets.

Commands sent to ORA are packed into TC packets having a primary header of 6 bytes and a data field of variable length less than

230 bytes long. The primary header contains such information as: packet identification, packet sequence control and packet length.

Telemetry packets have a variable length of less than 518 bytes in total and contain a primary header, a secondary header (a time tag) and a data field. Very long TM packets with lengths up to 65536 bytes can even be segmented into pieces each having the same primary header.

THE ORA TC COMMANDS

The packets sent to ORA are of 2 types :

* ORA Instrument Specific TC Packets sent from ground to control the measurements performed by ORA

* TC packets sent by the EURECA DHS to set time, to send attitude data and file contents, etc.

Each ORA specific command, as analyzed by the "tc-interpreter" task, is an ASCII string packed within a TC packet and has the format :

```
XY[=[[p1][,[p2][,[p3],....]]]];
 with   XY = mnemonic code (a string of 2 ASCII characters)
        pi = parameter i (an ASCII string representing a
                  decimal value between 0 and 65535 or hexa-
                  decimal value between 0000 and FFFF
      [..] = enclosing optional parameters
         ; = command terminator.
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This encoding of commands in ASCII strings had a tremendous influence on the development and testing of the OCCULTATION RADIOMETER. Commands are very readable and can be composed in a flexible way by the operator of the ORA Electrical Ground Support Equipment (EGSE) as if he was typing on a PC's keyboard.

THE ORA TM PACKETS

The following telemetry (TM) packets types have been defined :

* Instrument Private Data Packets of type 1 containing data concerning captured events
* Instrument Private Data Packets of type 2 containing a copy of EURECA attitude data
* Housekeeping Data Packets containing housekeeping data concerning the health of the ORA hardware
* Memory Dump Packets containing a copy of the contents of a block of ORA memory
* Acknowledge Packets used as software handshake by the inbound packets transport layer of the ORA software to acknowledge received TC packets
* Exception Packets to indicate abnormal behaviour of ORA
* Report Packets to report successful progress in the execution of the ORA software.

The telemetry channel is also used to send TC packets from ORA to the DHS to request DHS services.

THE PROTOCOL BETWEEN EURECA'S DHS AND ORA

The exchange of TM and TC packets between the EURECA DHS and ORA is defined by the DHS-bus protocol. This protocol corresponds to the ISO/ANSI Reference Model of Open Systems Interconnection (OSI).

The ISO/ANSI model for OSI has 7 layers, but only 4 of them are implemented in the DHS-bus protocol :

layer 7 : the application layer, which defines the commands and telemetry contents

is performed in ORA by the "tc-interpreter" task for inbound data and by all tasks sending data for outbound data.

<u>layer 6</u> : the presentation layer, which transforms the data format used by the lower layers to the data format accepted by the application layer
is transparent in the DHS-bus protocol.

<u>layer 5</u> : the session layer, which starts, maintains or ends the connection between 2 applications
is transparent in the DHS-bus protocol.

<u>layer 4</u> : the transport layer, which takes care of data fragmentation and reassembly and ensures data integrity during transport between session entities
is performed in ORA by the "inbound-transp" task for inbound data and is transparent for outbound data (no data integrity ensured).

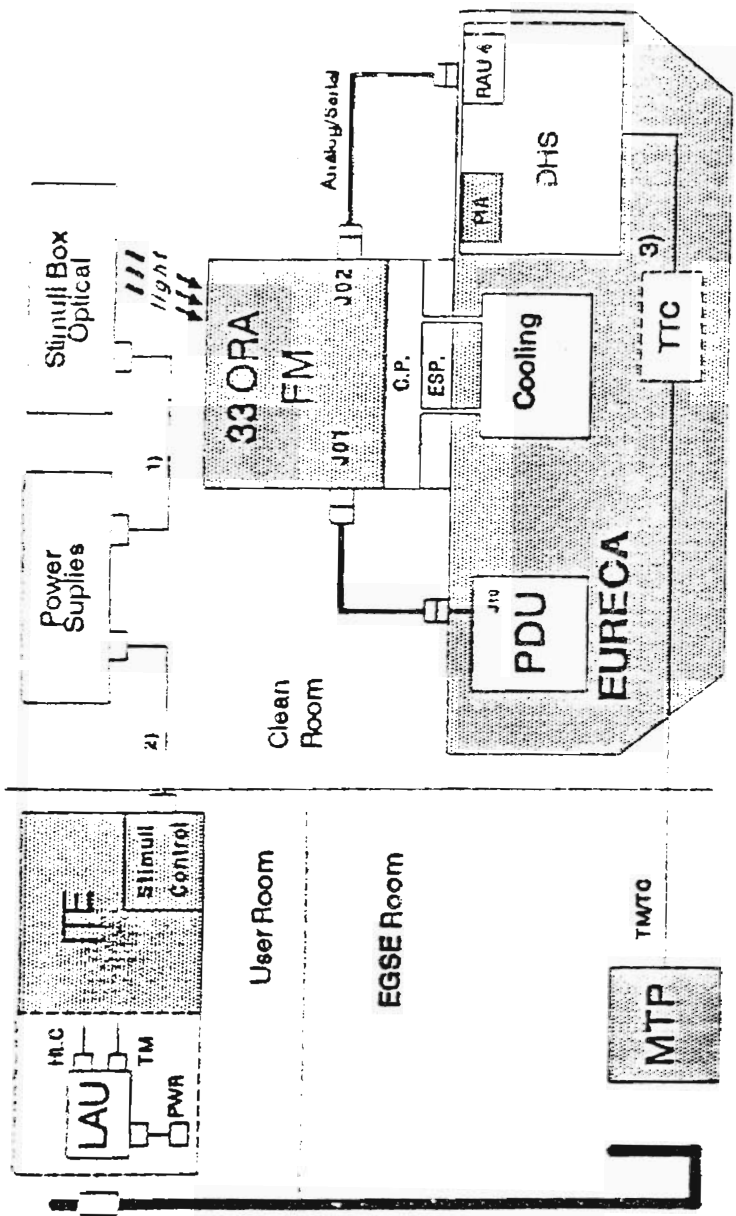
<u>layer 3</u> : the network layer, which routes data from the transport layer to the selected network node or vice versa
is transparent in the DHS-bus protocol.

<u>layer 2</u> : the datalink layer, which divides data to or from the network layer into separate blocks and checks transmission errors
is performed in ORA by function recv-tc-packet for inbound data and function send-tm-packet for outbound data.

<u>layer 1</u> : the physical layer, which is composed of all mechanical, electrical and signaling facilities required to transfer raw data over the physical communication medium
consists at the ORA side in the Command Receiver Board and the Data Transmitter.

<u>BRIEF OVERVIEW OF THE TEST CONFIGURATION OF ORA ON EURECA</u>

The software tests of ORA flight model as mounted on EURECA are performed in the following way.



ORA FM EURECA Test Configuration

ORA receives 28 Volt from the Power Distribution Unit (PDU) and is communicating with the Remote Acquisition Unit (RAU) of

EURECA. EURECA itself is sending telemetry to and receiving telecommands from a Master Test Processor (MTP). This computer, which controls the whole test sequence, is connected via a Local Area Network (LAN) to the Instrument Test Equipment (ITE) of the ORA, a dedicated computer for check-out of our instrument

During the test sequence the MTP asks the ORA ITE to run a particular test. The result is that the ITE makes a request to the MTP to send the appropriate TC command packets to EURECA, where they are forwarded via the Data Hadling System (DHS) and the RAU to ORA.

Meanwhile ORA is transmitting TM packets which go the other way around : they go from ORA to the RAU, from the RAU to the DHS from EURECA to the MTP and from the MTP via the LAN to the ORA ITE. Finally they are stored in history files on the ITE's disc.

In order to test the software at the highest possible level a stimuli box can be placed on top of ORA. This stimuli box contains several light sources with the appropriate spectral output for simulating the same kind of events ORA will try to capture during orbit : sunrise, sunsets, etc. This stimuli box and its power supplies are remotely controlled via a fiber optic link from the ITE