5. EMC DESIGN REQUIREMENT

SECTION 5 CONTENTS

5.1 ELECTROSTATIC

5.1.1 Susceptibility

i) - The E field instrument EFW is very sensitive to electrostatic anomalies and will require that all spacecraft surfaces meet the EID Section 5.1.1 specification.

ii) - The magnetic search coils are protected against electrostatic charge by a conducting thermal envelop which is grounded to the spacecraft structure and designed in such a way that it prevents current loops in the material.

5.1.2 Exposed voltage

There is normally no exposed voltage on the WEC units. However the E field sensors (WEC 1 to 4) have a maximum bias floating voltage of ± 100 V only exposed when deployed.
In addition, when WHISPER is in active mode, a pulse of 50 to 200 volts peak to peak is present on the shield of two long booms.

5.1.3 Non conductive area

i) packages mounted on the spacecraft deck :

The mechanical boxes will be externally conducting. No non-conductive area will be exposed to the environment.

ii) external packages and equipment :

The search coil envelop (thermal blanket) will be conductive and grounded to the spacecraft structure.

The surface of the wire boom is made of silver copper bread covering an aluminium foil (internal shield) with a coverage of 60%.

The shells for the deployment unit canister are made of aluminium alloy.

The surface of the E-field spheres is made of aluminium coated with a carbon deposit.

5.2 ELECTROMAGNETIC CLEANLINESS REQUIREMENTS

5.2.1 Susceptibility

i) The magnetic susceptibility measured at the location of the search coils unit is:

$5 \cdot 10^{-3}$	$nT\ Hz^{-1/2}$	at	1 Hz.
10^{-4}	$nT\ Hz^{-1/2}$	at	50 Hz
$5 \cdot 10^{-6}$	$nT\ Hz^{-1/2}$	in the range	1 kHz to 2.5 kHz
10^{-5}	$nT\ Hz^{-1/2}$	at	4 kHz

The allowable line levels at the search coils location expressed in nT are TBD.

The corresponding total magnetic noise calculated in each instrument range is:

Wave Form Unit	0.1 - 20 Hz	13 pT rms
	0.1 - 200 Hz	16 pT rms
Spectrum Analizer	8 - 64 Hz	3.2 pT rms
	64 - 512 Hz	0.4 pT rms
	512 - 4096 Hz	0.6 pT rms
EFW	0.1 - 10 Hz	10 pT rms
	0.1 - 200 Hz	15.5 pT rms
	0.1 - 5000 Hz	18 pT rms
WBD	10 - 10 kHz	2.5 pT rms

ii) The electric susceptibility of the EFW experiment is :

$1 \cdot 10^{-7}$	$V\ m^{-1}\ Hz^{-1/2}$	at	10 Hz
$1 \cdot 10^{-8}$	$V\ m^{-1}\ Hz^{-1/2}$	at	1 kHz
$1 \cdot 10^{-9}$	$V\ m^{-1}\ Hz^{-1/2}$	at	100 kHz

iii) The WBD (WEC 10) and STAFF (WEC 8/2) inputs susceptibilities are :

$2 \cdot 10^{-6}$ Vrms (TBC) between 10 Hz and 600 kHz in the analysis bandwidth (ref to the experiment description).

iv) As the WHISPER experiment (WEC 9/1) is using two sensors of the electric field experiment, the threshold level of the sounding experiment is defined by the electric field experiment sensitivity. The requested levels are similar to those of previous experiment like GEOS, ISEE or VIKING, that is to say :

$0.13\ 10^{-6}$ V $Hz^{-1/2}$ in the range 4 kHz - 200 kHz at the location of the sensors.

A few lines, in limited number, can exist up to 2.10^{-5} Vrms.

It is requested that the DC/DC converter lines are located above 100 kHz.

5.2.2 Emission

The voltages transmitted via the long boom shields in active mode are 50, 100 and 200 Volt peak to peak with a pulse duration of 1 ms or 0.5 ms and a repetition cycle between 13 ms and 120 ms. The transmitted frequency within the pulse duration will be between 4 kHz and 80 kHz.

EMC tests will be performed on the electronic units and stacks of the WEC at an early stage of the design to allow for eventual design changes.

5.2.3 Frequency Plan

a) EFW - WEC.5

Digital section :	3686.4 kHz
	38.4 kHz
	36.0 kHz
Power supply	4194.304 kHz
	2097.152 kHz
	1048.576 kHz
	524.288 kHz
	262.144 kHz
	131.072 kHz
	65.536 kHz

b) STAFF/mwf - WEC.8/1

normal mode (10 Hz analysis) sampling rate:	25 Hz
high bit rate mode (200 Hz analysis) sampling rate:	450 Hz
calibration mode calibration signals:	7 Hz sinus
	200 Hz sinus
	0 - 4 kHz noise
internal clock of the ADC	2 MHz

STAFF/spa - WEC.8/2

Frequency clock of the computers:	32 MHz
Data sampling rate:	16 kHz

c) WHISPER - WEC.9/1

Pilote clock	(F0)	16 MHz
Zoran clock	(F0)	16 MHz
Micro C clock	(F1/3)	8 MHz
Synthesizer clock	(F0/32)	500 kHz
Sampling clock 1	(F0/48)	333.333 kHz
Sampling clock 2	(F0/96)	166.666 kHz
Sequence rate (40/3 = 13.333 ms)		75 Hz

Transmitter:	pulse of 1.024 ms	976.5625 Hz
	or 0.512 ms	1953.125 Hz

emitted frequency = N x 500/512 = N x 0.9765625 kHz
1 kHz bandwidth (N = 83 to 4, sweeping)

d) DWP - WEC.9/2

Processor master oscillator	5	MHz
Processor clock output (full speed)	17.5	MHz
Processor clock output (half speed)	8.75	MHz
UART master oscillator for EFW interface	2457.6	kHz
Sample clock master oscillator	2304	kHz
A to D converter clock to EFW	36	kHz
DWP internal sampling clock	900	Hz
Sampling clock to EFW & STAFF/WA (HBR mode)	450	Hz
Sampling clock to WHISPER	75	Hz
Sampling clock to EFW & STAFF/WA (norm mode)	25	Hz

e) WBD - WEC.10

WBD VCXO frequency	(F0)	14.045399	MHz
F0/7		2.006486	
F0/14		1.003243	
F0/28		0.501622	
F0/56		0.125405	
F0/64		0.219459	
S/C USO divided by 19	(F1)	220.752	kHz
F1/512		431	Hz
WBD Power Converter (from WEC PWR)		131.072	kHz

f) PWR - WEC.11

DC/DC Converter running frequency	262.144 kHz

5.3 MAGNETOSTATIC

5.3.1 Susceptibility

The WEC package is not susceptible to normal magnetostatic environment. The search coils would suffer from very large DC field (1000 Gauss) never encountered so far in any industrial or integration sites. However when they are not mounted on the boom, the search coils are preferably stored inside a mu-metal box as a part of the MGSE. The conditions (level and frequency) of a deperm of the search coils (WEC.6) is to be defined with the experimenter to avoid damaging the sensors.

5.3.2 Emission

i) The emission from EFW (WEC 1 to 4) is concentrated in the boom units which have motors for the deployment of the 50 meters wires. Theses motors use permanent magnets which are shielded with mu-metal. The resultant field strength has been low enough to be flown on ISEE, CREES and Viking. The latter mechanism had a post-deperm field of 0.5 nT at 1 meter and a post-integration field of 2 nT at 1 meter. While in a 0.4 Gauss ($4 \cdot 10^{+4}$ nT) field it had a 0.5 nT field induced. Stray fields tend to cancel due to the orthogonal placement of deployment units, while induced fields add. In addition, there is one TO5 relay in each boom unit for control of a high voltage signals. The deployment control unit is made with relay switches.

ii) Based on experience, the remanent DC magnetic field for the three magnetic search coils should be less than 0.2 nT at 1 meter after deperm and 0.10 nT at 1 meter for the magnetic preamplifier. A similar level of 0.1 nT should be aimed at by the WEC electronic sub units.

Non-magnetic class B connectors will be used on EM, flight and flight spare units.

5.3.3 Compensation technique foreseen

In the general sense we will use engineering rules to agree with the EID Section 5 parag. 5.1.1 specification.

Balanced printed boards or twisted multiplet wiring will be used for reducing the DC straight field of the WEC units when they are powered. Standard screening technique will be applied on the power supplies, the static shields, if used, will be connected to the structure through a low impedance strap.

Also the anti-symmetric location of the deployment units afford some compensation or cancellation.

5.4 GROUNDING

5.4.1 Grounding Concept

The grounding philosophy will comply with the requirements given on to figure 5.4 of EID part A document. Refer to the WEC grounding diagram drawing N° P.00507. (Fig. 5.4/1)

The primary power lines will be isolated from the spacecraft structure by DC resistance > 1 Mohm in parallel with a capacitance < 1 nF per line. The same principle will be used for the isolation between the primary and the secondary power lines.

The structures will not be used as return path for the DC power distribution of the WEC.

All power connections will be floating.

Signals grounds will be referenced to the ground via the same single point where the relevant secondary power supply is connected. They will be connected via the handling interface connector. The ground will be isolated from the structure by a DC resistance > 1 Mohm in parallel with a capacitance < 1 nF per stack or unit.

5.4.2 shielding and bonding

WEC.8 and WEC.10 having a magnesium structure will use gold coating for bonding at internal and spacecraft i/f.

5.5 EMC REVIEW BOARD

The P.I.s representatives of the wave experiment confirm that they will participate in, contribute to, and comply with decisions of the EMC board.

The CRPE and the Observatory of Meudon, which had already contributed to the evaluation of the IABG site for the Ulysses and the Viking tests, have been nominated as members of the EMC board for WEC.

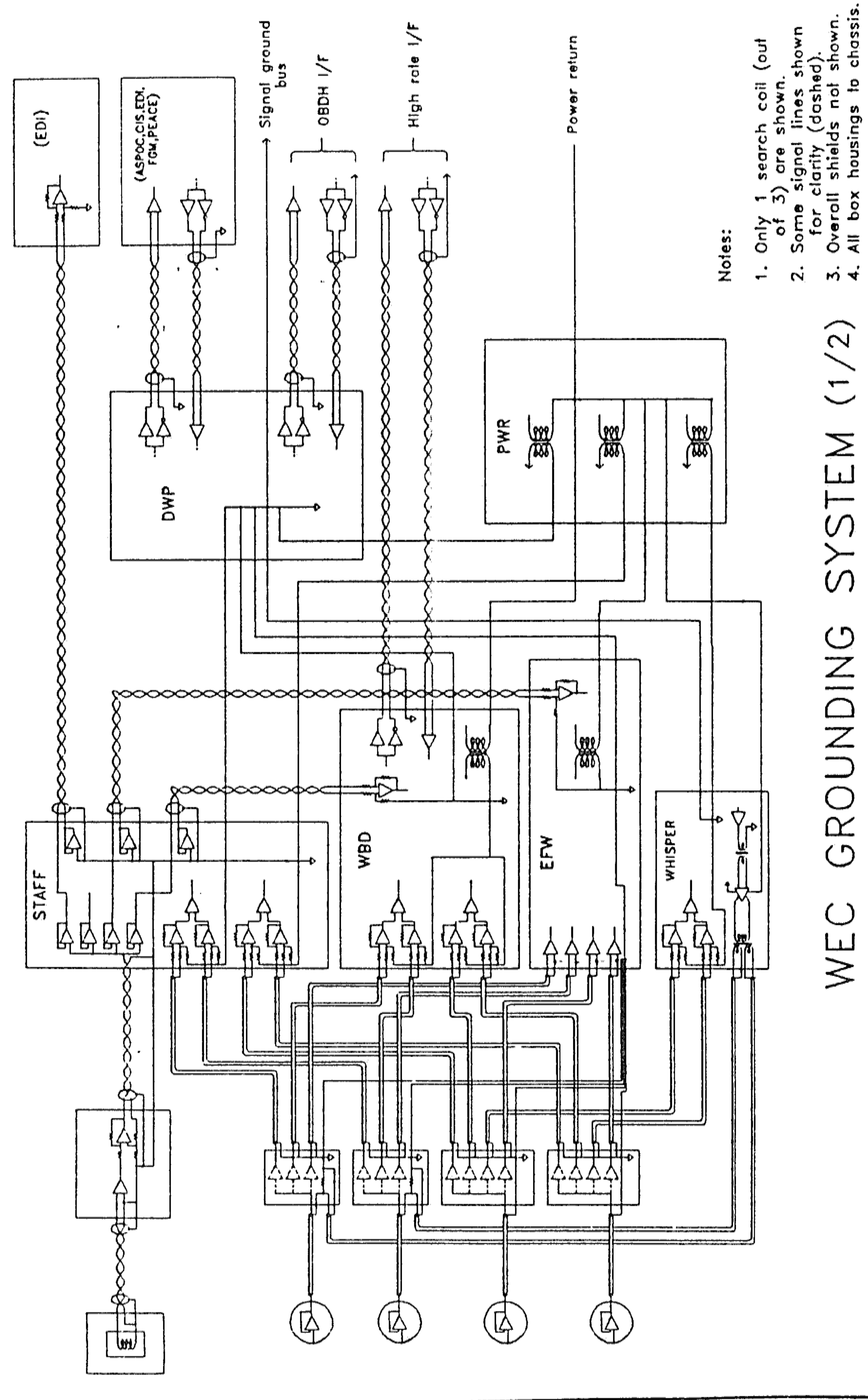

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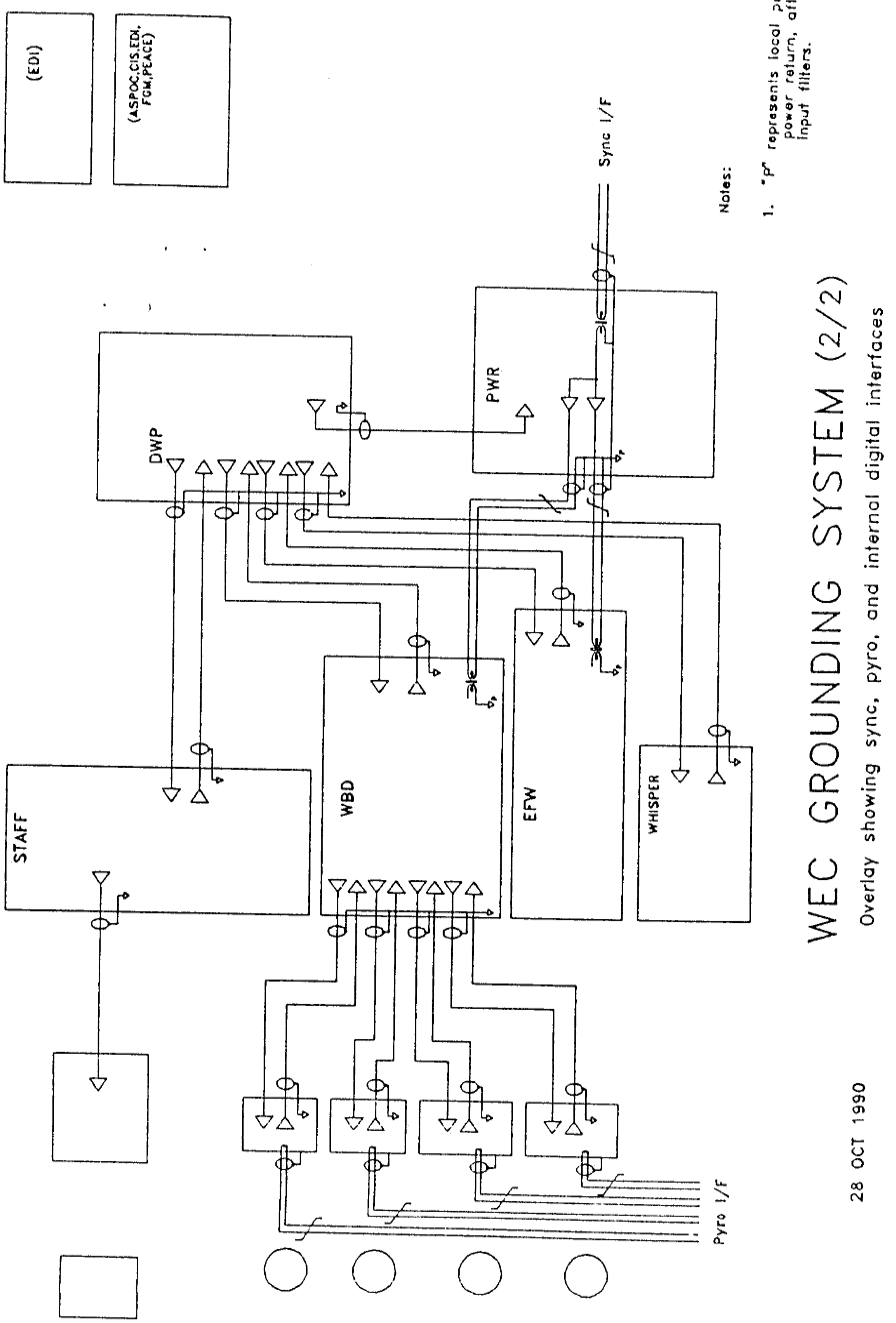
Fig. 5.4/1.1 WEC Grounding concept

Fig. 5.4/1.2 WEC Grounding concept



6. CLEANLINESS DESIGN REQUIREMENTS

SECTION 6 CONTENTS

6.1 CHEMICAL CLEANLINESS AND RADIATION TOLERANCE

Using past experience and approved lists, all materials used will be chosen to limit the total mass loss of the volatile agents TBD.

6.1.1 contamination sensitive areas

i) The E-field spheres (WEC 1 to 4) are very sensitive to contamination. The acceptable class during the spacecraft integration is 100.000. The spheres, when integrated on the spacecraft, are protected by the deployment units which are designed to guarantee that the surface of the spheres remain undamaged.

ii) The search coil unit (WEC 6) is delivered with a permanent thermal blanket which requires constant care all along the spacecraft integration for keeping good their thermal optical properties.

When used during ground tests, the search coils are protected by a transparent box made of makrolon, which is used for handling them in the test site and for their exact positioning inside the mu-metal shielding enclosure used during spacecraft integration (see section 9).

iii) All other units require standard handling procedures.

All electrical connectors will have protecting covers.

6.1.2 Radiation sensitive areas:

The sensitive elements of the WEC will consist of FETs, analog to digital converters, micro-processors, multiplexers.

6.1.3 Acceptable limits:

Nominal values which will be used for defining the radiation protection levels will be dictated by the previous experience of the experimenters in this domain and by specific documentation procured by the Space Agencies such as the JPL/NASA publication "Total-Dose Radiation Effects, Data for Semiconductor Devices". Specific tests and evaluations will be made by the laboratories (or industry) for some components for which the radiation hardness is not known.

Typical levels of protection are:

Hard Rad and passive components	: 100 kRads
Soft components	: 10 kRads
Very sensitive components (analog FETs)	: 5 kRads

6.1.4 Protection concept

The WEC equipment will be designed to withstand the radiation environment defined in figures 6.1 and 6.2 of EID Part A section 6 as it is explained hereafter.

In principle the aluminium case of the units assumes two tasks:

i) to decrease the external dose to the level accepted by the passive and the Hard Rad components i.e. in the range of 100 kRads.

ii) to avoid the second effect of Bremsstrahlung inside the high Z materials used in spot shielding, by reducing the energy of the incident particles.

These procurements are called the first level of protection.

The second level of protection is made by internal spot shields or by high Z materials (lead, tantalum).

A critical analysis of the components will be performed by the relevant experimenter for each unit, for defining the levels of protection and the appropriate methods. The criteria of protection will be to guarantee a minimal Ratio Design Margin (RDM) of 2 in normal conditions and 3 for the spot shieldings.

$$RDM = \frac{\text{acceptable level of radiation (Rads(Si))}}{\text{level of protection (Rads(Si))}}$$

For the spot shielding, RDM = 3

Taking into account the figure 6.1 of the EID and of an asssumed protection of the spacecraft structure of 2.7 g cm-2 from the experiment platform and 1.35 g cm-2 from the payload belt (i.e. 1 and 0.5 mm of aluminium) the protections listed in the following table will be envisaged. The CLUSTER conditions are not so drastic. Then, the most sensitive components can be protected by the printed boards if they are located at the centre of the unit. A printed board is almost equivalent to the similar thickness of aluminium. It is also possible to locally embed the components in epoxy or solithane products filled with tungsten carbide, aluminium oxide or zicron oxide.

kind of component	level of protection (note 2)	case thickness (Al)	spot shield thickness (note 1)
passive hard Rad	<=100 kRads	1 mm	
soft	10 kRads	1 mm	2.9 mm (Al or epoxy) or 0.7 mm (Pb) or 1.0 mm (Fe)
very sensitive	5 kRads	1 mm	4.0 mm (Al or epoxy) or 1.0 mm (Pb) or 1.4 mm (Fe)

Note 1 : supposing that the active surface of the components is encapsulated by a Kovar of 0.2 mm thick externally coated with 0.2 mm of solithane or similar potting material.

Note 2 : RDM = 3 included.

The sensitive active components will also be protected against latch-up with "watch-dog" circuits.

6.1.5 Cleaning items and procedures

Cleaning the spheres can be done but it bears the risk of removing the very thin coating of the spheres. To minimise this risk, cleaning will be performed only as a last resort and not routinely.

Cleaning procedure for the search coil thermal blanket is similar the one used for the spacecraft MLI surfaces.

The WEC electronic units may be cleaned on the outer surfaces with adequate agents.

7. EXPERIMENT SYSTEM LEVEL GROUND OPERATION INTERFACE

SECTION 7 CONTENTS

7.1 SPECIFIC EXPERIMENT SYSTEM LEVEL TEST

7.1.1 Specific type of tests

In order to cover all levels of system testing, three main type of tests will be designed as specified in EID part A section 7.

a) AFT

The Abbreviated Functional tests (AFT) will be run to verify quickly the integrity of the experiment each time this will be requested. No stimuli are used for these tests. They can be automatically performed by the CCS and only the Housekeeping telemetry is used. They will be also implemented in the WEC EGSE for testing the procedure.

b) SFT

The Functional tests level 1 (SFT1) will perform a more complete check-out of the WEC experiment after each transportation or dismounting/mounting operations, etc... The test is controlled by the CCS which has to send the commands, to control the stimuli and to get the telemetry. However, the data analysis is performed by the WEC EGSE which is connected to the CCS and is able to access the data. Internal calibration systems or external stimuli can be used.

The Functional Tests level 2 (SFT2) are similar to SFT1 but they will perform a more complete check-out of the experiment. External stimuli equipments will be used. Such tests will be requested a limited number of times:

i) For the first integration at the contractor site and at the launch site.

ii) On request if the other tests give a doubt on the integrity of one instrument. Different levels of complexity can be envisaged depending on the situation.

More specific tests are requested for checking the transmitter of WHISPER and the delays through the data system for WBD.

For the EMC check-out which are foreseen at system level for the EM, a simple subset of SFT1 will be used.

7.1.2 Performances to be verified

a) With AFT:

Only electrical integrity of the interfaces and verification that no instrument is obviously broken.

b) With SFT1:

Integrity of the DWP and electrical experiments, gain and frequency response of the magnetic channels if the antennas are inside the mu-metal box (ref to section 9.2.2.1.b).

c) With SFT2:

Bias voltages and currents of the electric probes, complete amplitude and frequency response of electric and magnetic instruments (ref to section 9.2.2.1.a). The specific tests for the WHISPER transmitter (ref to section 9.2.2.1.c) and Delay Verification for WBD can also be conducted.

7.1.3 Test schedules

The WEC will define test schedules which are compliant with EID part A Section 7. The following sequences are expected:

delivery to ESA	- visual inspection, acceptance - bench test
delivery to contractor	- acceptance - bench test - mechanical integration - first system level check-out as a complete SFT2, including the test of the transmitter, with WEC only (all other experiments OFF). - the other tests are made with all payload. They can be SFT2, SFT1 or AFT depending on the situation.
launch site	- bench test if the units have been dismounted for transportation. - SFT2, SFT1, AFT depending on the situation. It is assumed that the EGSE will be connected to the Control Centre and tested prior to system level integration.

7.2 EXPERIMENT STIMULI/CALIBRATION

7.2.1 Autonomous Functions

The Wave Experiment is a largely automated system. The DWP controls the modes of the experiments and can manage scheduled sequences defined by a limited number of commands.

7.2.2 Intrument Calibration

7.2.2.1 On Ground Calibration

a) EFW

The sphere deployment units permit a test probe to be inserted such that the sphere can be stimulated while in the un-deployed condition. This test set-up will be sufficient for most of the system tests. However, a complete checkout of the instrument will require that all four booms are deployed to a minimum length of 4 meters and that each sphere is placed in an electromagnetic shielding box. Stimuli provided by the EGSE stimuli unit, will now be connected to the spheres via a "finger" in the shielding box. Special hardware interface (TBD) may be necessary for the Delay Measurement/Verification requested by WBD.

b) STAFF

An internal calibration system is included in STAFF for checking the magnetic sensors and associated electronics but does not exist for the Electric experiment. Generated signals are low frequency sine waves and pseudo random noise up to 4 kHz.

Ground test stimuli are requested for SFT. An external signal can be injected in the magnetic antennas when they are inside the mu-metal box.

7.2.2.2 Inflight Ground Calibration

No inflight calibration sources.

7.3 GROUND OPERATIONS

7.3.1 Experiment constraints:

Some of the tests request a partial deployment of the long booms. Because the long booms will not retract, the deployment units must be removed from the vehicle after testing, to rewind the cable and recage the spherical sensor. This restoring procedure takes about two hours per mechanism, performed by a properly trained person.

In any case the transmitter of WHISPER shall not be switched ON when the booms are not at least partially deployed.

7.3.2 Environmental constraints:

When EMC tests are performed, a clean room with special EMC equipments is obviously needed.

At any moment, the search coil package must be kept away from strong magnetic fields (>1000 Gauss). For the routine operations it is preferred to keep the antennas inside the mu-metal box and connected to the spacecraft harness by a special cable (see drawing section 9).

No other constraints as soon as the satellite is in the normal environmental conditions as described in EID part A.

No special constraints in launch operations.

7.3.3 Late Exchange policy

N/A

7.4 EXPERIMENT PURGING

N/A

7.5 HIGH VOLTAGE CONTROL

The transmitter of WHISPER can generate a pulse up to 200 Volts peak to peak. Although this is not really a high voltage, WHISPER will be connected to the S/C high voltage pannel control and will have a "disable connector".

8. EXPERIMENT DESIGN VERIFICATION

SECTION 8 CONTENTS

8.1 EXPERIMENT DESIGN VERIFICATION CONCEPT

8.1.1 Experiment Verification Plan

8.1.1.1 Model philosophy

The design verification concept is generally compliant with EID Part A Section 8. The testing and verification for the WEC has a number of stages or levels. These are :

Single box
- applying to verification, calibration and test on a single box

Stack
- applying to verification, calibration and test on a stack of boxes which will be mounted on the spacecraft as a single unit.

Consortium
- applying to verification, calibration and test on the complete set of packages which comprise the instruments of the WEC.

The philosophy behind the design verification and testing is that individual boxes will be environmentally tested as far as possible, locally to their production. In some cases this has to be tested at stack level. After this the units will be integrated and tested at Consortium level. This is likely to be within UK for EM and France for Flight Models. The final stage is for joint delivery of a complete WEC set of instruments to ESA.

A verification plan shall be prepared which complies with the requirement of EID Part A section 8.1.2.

8.1.1.2 Calibration and transfer function

unit :	1/4	5	6	7	8	9	10
Electric	X	X + W			X + W	X + W	X + W
Magnetic		W	X + W	X + W	X + W		X + W
Mechanic			X				

Tab 8.1/1 WEC calibration plan (EM, FM & FS)

Unit level = X
Wec level = W

8.1.1.3 Verifications Matrix

unit :	1/4	5	6	7	8	9	10	11	WEC
Physical properties	A+T	A+T	A+T	A+T	A+T	A+T	A+T	A+T	A
Structural	A	A	A	A	A	A	A	A	
Strength	T	T	T	T	T	T	T	T	
Sine	T	T	T	T	T	T	T	T	
Shock	T	T	T	T	T	T	T	T	
Random	T	T	T	T	T	T	T	T	
Acoustic	A								
Pressure	A	A	A	A	A	A	A	A	
Leakage	A	A	A	A	A	A	A	A	
Thermal properties	A	A	A	A	A	A	A	A	
Thermal balance	A	A+T	A+T	A	A	A	A	A	
Thermal vaccum	T	T	T	T	T	T	T	T	
Climatic	A	A	A	A	A	A	A	A	
Radiation Sensitivity	A	A	A	A	A	A	A	A	
Emc interferences	T	T	T	T	T	T	T	T	A
Grounding/bonding	T	T	T	T	T	T	T	T	A
DC magnetic	T	T	T	T	T	T	T	T	A

Tab 8.1/2 WEC Verification Matrix

A = Analysis
T = Test

8.1.2 **Experiment Test Matrix**

The WEC and experiment unit qualification and acceptance test matrixes are given in table 8.1/3.x and 8.1/4.x. These are compliant with EID part A section 8.1.3.

Legend of the Tab 8.1/3.x and 8.1/4.x :

Unit Qualification = X
Stack Qualification = S
Wec Qualification = W

unit : **WEC 1, 2, 3 & 4**	SM	EM	F1
Visual inspection		X	
Dimensions		X	
Physical properties		X	
Functional test (CPT)		X	
Low level sine		X	
Sine vibration		X	
Strength test		X	
Shock test		X	
Low level sine		X	
Random vibration		X	
Low level sine		X	
Functional test (LPT)		X	
Thermal vacuum		X	
Functional test (CPT)		X	
Grounding/bonding/isolation		X + W	
EMC conducted interference		X + W	
EMC radiated interference (AC)		X	
DC magnetic properties		X	
Purging rate verification			
Visual inspection		X	

Table 8.1/3.1.a Qualification Test Matrix : EFW WEC 1/4

unit : WEC 5	SM	EM	F1
Visual inspection		X	
Dimensions		X	
Physical properties		X	
Functional test (CPT)		X	
Low level sine		X	
Sine vibration		X	
Strength test		X	
Low level sine		X	
Random vibration		X	
Low level sine		X	
Functional test (LPT)		X	
Thermal vacuum		X	
Functional test (CPT)		X	
Grounding/bonding/isolation		X + W	
EMC conducted interference		X + W	
EMC radiated interference (AC)		X + W (TBC)	
DC magnetic properties		X	
Purging rate verification			
Visual inspection		X	

Table 8.1/3.1.b Qualification Test Matrix : EFW WEC 5

unit : **WEC 6**	SM	EM	F1
Visual inspection		X	
Dimensions		X	
Physical properties		X	
Functional test (CPT)		X	
Low level sine		X	
Sine vibration		X	
Strength test		X	
Shock test		X	
Low level sine		X	
Random vibration		X	
Low level sine		X	
Functional test (LPT)		X	
Thermal vacuum		X	
Thermal balance		X	
Functional test (CPT)		X	
Grounding/bonding/isolation		X + W	
EMC conducted interference		X	
EMC radiated interference (AC)		X	
DC magnetic properties		X	
Purging rate verification			
Visual inspection		X	

Table 8.1/3.2.a Qualification Test Matrix : STAFF WEC 6

unit : **WEC 7**	SM	EM	F1
Visual inspection		X	
Dimensions		X	
Physical properties		X	
Functional test (CPT)		X	
Low level sine		X	
Sine vibration		X	
Strength test		X	
Shock test		X	
Low level sine		X	
Random vibration		X	
Low level sine		X	
Functional test (LPT)		X	
Thermal vacuum		X	
Functional test (CPT)		X	
Grounding/bonding/isolation		X + W	
EMC conducted interference		X	
EMC radiated interference (AC)		X + W (TBC)	
DC magnetic properties		X	
Purging rate verification			
Visual inspection		X	

Table 8.1/3.2.b Qualification Test Matrix : STAFF WEC 7

unit : **WEC 8**	SM	EM	F1
Visual inspection		X	
Dimensions		X	
Physical properties		X	
Functional test (CPT)		S	
Low level sine		S	
Sine vibration		S	
Strength test		S	
Shock test		S	
Low level sine		S	
Random vibration		S	
Low level sine		S	
Functional test (LPT)		S	
Thermal vacuum		S	
Functional test (CPT)		S	
Grounding/bonding/isolation		S + W	
EMC conducted interference		X + W	
EMC radiated interference (AC)		X + W (TBC)	
DC magnetic properties		S	
Purging rate verification			
Visual inspection		X	

Table 8.1/3.2.c Qualification Test Matrix : STAFF WEC 8

unit : **WEC 9**	SM	EM	F1
Visual inspection		X	
Dimensions		X	
Physical properties		X	
Functional test (CPT)		S	
Low level sine		S	
Sine vibration		S	
Strength test		S	
Shock test		S	
Low level sine		S	
Random vibration		S	
Low level sine		S	
Functional test (LPT)		S	
Thermal vacuum		X	
Functional test (CPT)		X	
Grounding/bonding/isolation		X + W	
EMC conducted interference		X + W	
EMC radiated interference (AC)		X + W (TBC)	
DC magnetic properties		X	
Purging rate verification			
Visual inspection		X	

Table 8.1/3.3 Qualification Test Matrix : WHISPER/DWP WEC 9

unit : WEC 10	SM	EM	F1
Visual inspection		X	X
Dimensions		X	X
Physical properties		X	X
Functional test (CPT)		X	X
Low level sine	X		X
Sine vibration	X		X
Strength test	X		X
Low level sine	X		X
Random vibration	X		X
Low level sine	X		X
Functional test (LPT)			X
Thermal vacuum			X
Functional test (CPT)			X
Grounding/bonding/isolation		W	W
EMC conducted interference		X + W	X + W
EMC radiated interference (AC)		X + W	X + W
DC magnetic properties		X	X
Purging rate verification			
Visual inspection		X	X

Table 8.1/3.4 Qualification Test Matrix : WBD WEC 10 unit

unit : **WEC 11**	SM	EM	F1
Visual inspection		X	
Dimensions		X	
Physical properties		X	
Functional test (CPT)		X	
Low level sine		X	
Sine vibration		X	
Strength test		X	
Shock test		X	
Low level sine		X	
Random vibration		X	
Low level sine		X	
Functional test (LPT)		X	
Thermal vacuum		X	
Functional test (CPT)		X	
Grounding/bonding/isolation		X + W	
EMC conducted interference		X + W	
EMC radiated interference (AC)		X + W (TBC)	
DC magnetic properties		X (TBC)	
Purging rate verification			
Visual inspection		X	

Table 8.1/3.5 Qualification Test Matrix : PWR WEC 11 unit

unit : **WEC 1, 2, 3 & 4**	FM1	FM2,3,4,FS
Visual inspection	X	X
Dimensions	X	X
Physical properties	X	X
Functional test (CPT)	X	X
Low level sine	X	X
Random vibration	X	X
Low level sine	X	X
Functional test (LPT)	X	X
Thermal vacuum	X	X
Functional test (CPT)	X	X
Grounding/bonding/isolation	X + W	X + W
EMC conducted interference	W	W
DC magnetic properties	X	X
Visual inspection	X	X

Table 8.1/4.1.a Acceptance Test Matrix : EFW WEC 1/4

unit : **WEC 5**	FM1	FM2,3,4,FS
Visual inspection	X	X
Dimensions	X	X
Physical properties	X	X
Functional test (CPT)	X	X
Low level sine	X	X
Random vibration	X	X
Low level sine	X	X
Functional test (LPT)	X	X
Thermal vacuum	X	X
Functional test (CPT)	X	X
Grounding/bonding/isolation	X + W	X + W
EMC conducted interference	X + W	W
DC magnetic properties	X	X
Visual inspection	X	X

Table 8.1/4.1.b Acceptance Test Matrix : EFW WEC 5

unit : **WEC 6**	FM1	FM2,3,4,FS
Visual inspection	X	X
Dimensions	X	X
Physical properties	X	X
Functional test (CPT)	X	X
Low level sine	X	X
Random vibration	X	X
Low level sine	X	X
Functional test (LPT)	X	X
Thermal vacuum	X	X
Functional test (CPT)	X	X
Grounding/bonding/isolation	X + W	X + W
EMC conducted interference		
DC magnetic properties	X	X
Visual inspection	X	X

Table 8.1/4.2.a Acceptance Test Matrix : STAFF WEC 6

unit : **WEC 7**	FM1	FM2,3,4,FS
Visual inspection	X	X
Dimensions	X	X
Physical properties	X	X
Functional test (CPT)	X	X
Low level sine	X	X
Random vibration	X	X
Low level sine	X	X
Functional test (LPT)	X	X
Thermal vacuum	X	X
Functional test (CPT)	X	X
Grounding/bonding/isolation	X + W	X + W
EMC conducted interference	X + W	X + W
DC magnetic properties	X	X
Visual inspection	X	X

Table 8.1/4.1.b Acceptance Test Matrix : STAFF WEC 7

unit : **WEC 8**	FM1	FM2,3,4,FS
Visual inspection	X	X
Dimensions	X	X
Physical properties	X	X
Functional test (CPT)	S	S
Low level sine	S	S
Random vibration	S	S
Low level sine	S	S
Functional test (LPT)	S	S
Thermal vacuum	S	S
Functional test (CPT)	S	S
Grounding/bonding/isolation	X + W	X + W
EMC conducted interference	X + W	X + W
DC magnetic properties	X	X
Visual inspection	X	X

Table 8.1/4.2.c Acceptance Test Matrix : STAFF WEC 8

unit : **WEC 9**	FM1	FM2,3,4,FS
Visual inspection	X	X
Dimensions	X	X
Physical properties	X	X
Functional test (CPT)	X (*)	X (*)
Thermal vacuum	X (*)	X (*)
Functional test (CPT)	S	S
Low level sine	S	S
Random vibration	S	S
Low level sine	S	S
Functional test (LPT)	S	S
Grounding/bonding/isolation	W	W
EMC conducted interference	X + W	W
DC magnetic properties	X	X
Visual inspection	X	X

Table 8.1/4.3 Acceptance Test Matrix : WHISPER/DWP WEC 9

(*) WEC 9.1 and WEC 9.2 thermal vaccum tested separately (TBC)

unit : WEC 10	FM1	FM2,3,4,FS
Visual inspection		X
Dimensions		X
Physical properties		X
Functional test (CPT)		X
Low level sine		X
Random vibration		X
Low level sine		X
Functional test (LPT)		X
Thermal vacuum		X
Functional test (CPT)		X
Grounding/bonding/isolation		W
EMC conducted interference		X + W
DC magnetic properties		X
Visual inspection		X

Table 8.1/4.4 Acceptance Test Matrix : WBD WEC 10

unit : **WEC 11**	FM1	FM2,3,4,FS
Visual inspection	X	X
Dimensions	X	X
Physical properties	X	X
Functional test (CPT)	X	X
Low level sine	X	X
Random vibration	X	X
Low level sine	X	X
Functional test (LPT)	X	X
Thermal vacuum	X	X
Functional test (CPT)	X	X
Grounding/bonding/isolation	X + W	X + W
EMC conducted interference	X + W	W
DC magnetic properties	X	X
Visual inspection	X	X

Table 8.1/4.5 Acceptance Test Matrix : PWR WEC 11

8.1.3 **Experiment Functional Performance Test**

The experiment functional performance test. Comprehensive and Limited Performance Test (CPT and LPT) shall be provided to demonstrate that the hardware and software meet their performance requirements within defined and allowable tolerances. These test will comply with EID Part A section 8.3.

8.1.4 **Proposed Program for Limited Life-Time Elements**

Only pyro of WEC1/4 can be considered as limited lifetime elements.

A limited lifetime programme will be established which is compliant with EID Part A section 8.3.3.

A register of limited life materials shall be maintained at each establishment.

The expiry date of limited life materials shall be recorded as part of the control procedure for these materials. Where no date is provided an expiry date (current date + 1/2 shelf life) shall be marked on the container and used as the effective expiry date for the control procedure.

9. EXPERIMENT GROUND SUPPORT EQUIPMENT

SECTION 9 CONTENTS

9.1 ELECTRICAL GROUND SUPPORT EQUIPMENT

9.1.1 General Concept

The Electrical Ground Support Equipment (EGSE) to be used for the wave experiment relies heavily on the experience gained from earlier missions (GEOS 1&2, ISEE, AMPTE, VIKING, CRRES). Wave data consists of several interrelated data streams all processed on board the Cluster spacecraft by the same DWP (i.e. that provided as part of DWP). These streams correspond to the model payload experiments: Search Coil Magnetometer, Electric Field, Wide Band Data, and Sounder. Later in the mission EGSE are required to be used as work stations for flight operations. Because of this and because of the complexity of wave data, the EGSE will be formed around a work station (e.g SUN 3/160, but exact type TBD). The work station (& operating system) will be chosen so that common software can be easily shared between, and developed by the various institutes comprising the wave experiment consortium. The use of a similar minicomputer for integration and in flight operations will allow some pretesting of the data processing and display programs to be used in flight operations. Past experience has shown that timely exploitation of early orbit data requires analysis programs to be error free well before launch. All of the support software will be chosen to best fit the common interests of the institutes involved. At this stage it would seem that the operating system may be UNIX (same as the CCS), the high level language (fortran or C) and a common graphics environment will be selected later (GKS?).

Three complete EGSE units will be purchased to support the wave experiment consortium integration on Cluster. The EGSE has to check the functional operation of both the wave experiment component units and the whole wave experiment at different levels of integration during a number of ground tests (e.g. Acceptance test, Electric & Magnetic Cleanliness, Thermal-Vacuum) . For some of these tests an interface simulator will emulate the operation of the spacecraft On-Board Data Handling (OBDH) system and Central Checkout System (CCS). Unit level testing of experiment units will also need simulation of the wave experiment DWP (using non-flight DWP circuits) as well as providing power and synchronisation/ sun pulses (etc) to the flight hardware (provisions included in the interface simulator). A simulation circuit card corresponding to the DWP function will be included in the work station.

Each of the wave experiment sensor units require stimulation and calibration signals at levels of signal to noise as similar as possible to those expected during flight operations. Consequently it is planned to have a crate of stimulation signal generators located as close to the sensors as is permitted in unit and system level tests.(and as far away from the EGSE as possible). Some local intelligence (microprocessor) will reside in this stimulation crate so that the interconnection to the EGSE will be via simple serial lines. For some tests it will also be possible to control the stimulation crate directly from the CCS via this serial line. While unit level tests involve a direct EGSE connection to the experiment, system level tests are indirect via the CCS. In these tests control files (Telecommands) will be generated to initialise the experiment mode(s) and also to sequence/ control stimulation sources. Data will be retrieved from the CCS by reading the stored data base. Some continuous monitoring of housekeeping channels will check for critical values being out of limits.

Displays of alpha-numeric and 2-D and 3-D graphics will be implemented for maximum experimenter appreciation of experiment operation. Since not all of the experimenters involved in the wave experiment will be present at every integration test it is important that institutes can gain access to the EGSE via public networks (in addition to the network access direct to the CCS).

Five levels of EGSE testing have been identified in fig 9.1 based on a combination of the wave experimenters own requirements and the ESA requirements of supporting unit level tests, system level tests, and flight operations. (PLP/410C/EID section 9). With full functional simulators of the interface and DWP the transition from one level of testing to the next should be transparent to the experimenter (in the way in which he interacts with his experiment unit.). Note that some experiment units will have been individually tested at an earlier stage where those institutes have used a simpler EGSE system (e.g.IBM PC + stimulator). In these cases when moving to the wave consortium tests listed below the PC becomes a terminal on the workstation, and the stimulation card is fitted into the stimulation crate. This migration of hardware and software ensures maximum capability of units and builds on experience gained during testing.

a) EGSE Self Check.

Operation of the work station with the simulators of both the interface and the wave experiment DWP allows self checking of these three major components of the EGSE. As the work station will support assembly and compilation of the experiment DWP code, this configuration will allow pre-testing and debugging of on board software.

b) Unit Level Test of Experiment Component

Since all wave experiment units (wave sensor and analysis units) interface on board the spacecraft with the wave DWP, testing of them separately requires the use of the DWP simulator for communication with the work station. In this test (and the next three types of test below) the experiment units are actively stimulated and calibrated with signals provided by the stimulation crate. Stimulation signal generators can be sequenced through a preset series of operations in conjunction with the aims of the specific unit level test.

c) Unit Level Test of Wave Experiment

In these tests the wave experiment includes the DWP so the EGSE has to simulate the on board data handling system. The EGSE now has to decommutate the data into the component wave experiment streams for subsequent separate displays.

d) System level Test

When the wave experiment has been integrated onto the spacecraft the EGSE interfaces directly with the CCS reading data files or entering control files. The CCS provides access to an archive data base of unprocessed whole packets as sent by the wave experiment.The work station controls the stimulation crate via serial lines as before.

e) Flight Operations

Once launched the EGSE interfaces directly with the ground segment in much the same way as in (4). It is envisaged that the EGSE can operate as a work station either at the ground data handling facility or remotely via networks at the home institutes. It is expected that the software interface to the ground segment will be similar to that with the CCS.

9.1.2 Interface Simulator

A separate access to wide band data is requested for checking at integration. Otherwise compliant with EID part A 9.1.2.

9.1.3 Central Check-out System

During some system level tests the CCS should directly control the sequence of stimulation signals. A RS232 serial line is required from the CCS to the stimulation crate. Otherwise compliant with EID part A 9.1.3

9.1.4 Operations Centre

EID part A 9.1.4 T.B.D
+
It is required that the EGSE work stations can be accessed remotely by the wave experiment consortium institutes.

9.1.5 EGSE Interfaces

Both RS232 and Ethernet interfaces will be available. Compliant with EID part A 9.1.5

9.1.6 Housekeeping Monitor and Command Data Base

A listing of the housekeeping and command data base shall be provided for acceptance at the same time as the experiment, compliant with EID part A 9.1.6.

9.1.7 Control Files

A listing of the control files for system test and operations including procedures shall be provided for acceptance at the same time as the experiment, compliant with EID part A 9.1.7.

9.1.8 Software

All EGSE software will be produced to the recognised standard ESA PSS-05-0, compliant with EID part A 9.1.8

9.1.9 Hardware

Compliant with EID part A 9.1.9

9.1.10 Maintenance

Compliant with EID part A 9.1.10, but at Kourou where full maintenance might not be possible a complete spare unit will be provided

9.1.11 Documentation

Compliant with EID part A 9.1.11

9.1.12 Stimulation of the Experiment

Compliant with EID part A 9.1.12

9.1.13 Schedule

Compliant with EID part A 9.1.13

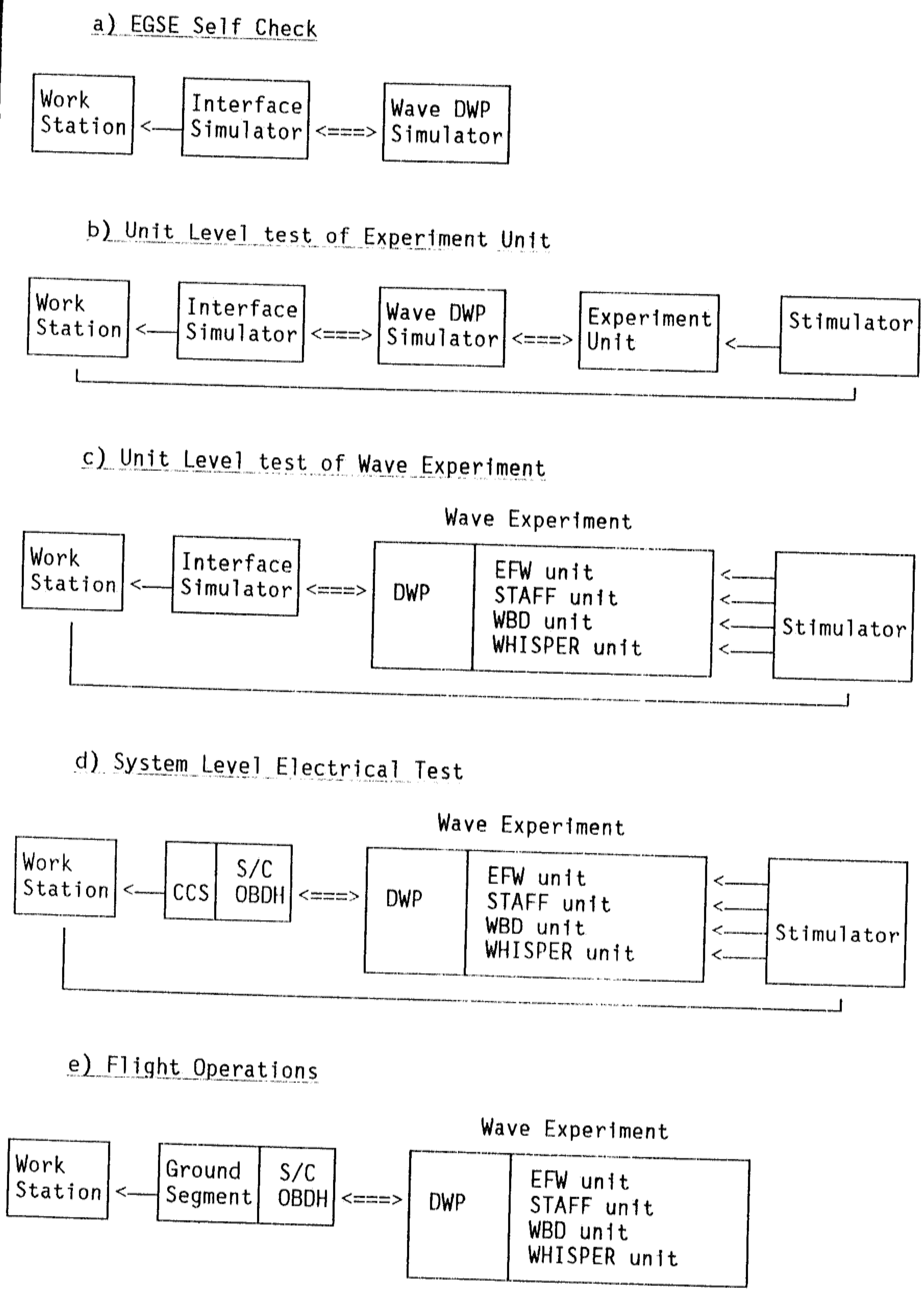


Fig. 9.1/1 EGSE TEST

9.2 MECHANICAL GROUND SUPPORT EQUIPMENT

9.2.1 General

The WEC will comply with the Programme Office requirements as defined in EID Part A Section 9.2.1.

9.2.2 MGSE Identification

9.2.2.1 description of the main characteristics

a) **EFW description of the main characteristics**

The EFW MGSE (WEC 1 to 4) has two features used at different levels of the integration:

i) the spheres being inside their canister, four test probes are used to have a physical contact with the spheres through holes practised on the deployment units. Fig. 9.2/1.a

ii) the spheres being removed from their canister and still connected to a free length of wire boom extended with care in the integration room, they are placed inside a shielding box located at the vicinity of the spacecraft. Fig. 9.2/1.b

The stand-off devices which support the extended wire booms will be procured by EFW.

THe EFW plasma simulator (Faraday cage) is made up of four hinged plates A, B ,C, D and two side plates E (see Fig. 9.2/1.c). It is fully electrical isolated as all external surfaces are of 6 mm PVC (TBC) sheet with 1 mm Al sheets attached to the inside of the four plates. The side plates have 2 mm Al frames with "fixed nuts" and unbrako scews holding the bottom plate C and the back-plate B in position. Both side-plates have slits for the wire-boom and stud.

Sphere support F is attached to the side-plates by four srews. A relay box G is used for routing of the stimuli signals via RC network to the sphere, or driving the entire aluminium cage at potentials up to 85 Volts.

During transport, the four hinged plates are folded as indicated in the Fig. B. The two side plates are used to cover a 15 m cable for connection to the EFW stimuli box (Fig. 9.2/1.c).

Size of the EFW simulator: fully assembled: 81 x 53 x 51 cm
dis-assembled : 80 x 53 x 17 cm

Total weight: 33.5 kg

b) **STAFF description of the main characteristics**

The MGSE of the search coils (WEC 6) is made of a mu-metal shielding box (also used as a self storage, see 6.1). The shielding box is used during the comprehensive performance test (CPT), during System Functional Test (SFT) and when performing the EMC conducted noise investigation at the spacecraft level. Then the search coils are connected to the spacecraft boom harness through one hi-rel extension cable provided by the STAFF experiment. Fig: 9.2/2 gives the test set up configuration. This requires to have an easy access to the magnetic preamplifier (WEC.7) during the flight integration.

The characteristics of the shielding box are:

material : the external enclosure is made of soft iron painted with black paint compatible for vacuum tests. The three internal enclosures are made of mu-metal .

size : about 40 x 40 x 40 cm
weight : about 35 kg

electrical equipment : 6 internal calibration loops connected to BNC connectors .

c) **WHISPER description of the main characteristics**

The **WHISPER MGSE** has two features used during the Comprehensive Performance Test (CPT), during System Functional Tests (SFT) and when performing EMI/EMC investigations at the spacecraft level :

i) Check the sounding pulse transmitted to the long booms.

ii) Provide a dummy load when the long booms are not deployed.

It will be used in addition to the EFW MGSE for testing the WHISPER unit. It consists in three main items: two dummy loads and a probe.

The **WHISPER Dummy Loads** provide a convenient way of testing or continuing testing the whole experiment, with its transmitter in an active state, when the long booms are not deployed or during EMI/EMC investigations. There are two types of dummy load to match the different requirements of the successive levels of testing:

- the actual WHISPER Dummy Load is dedicated to the CPT test and to EMI/EMC investigations.

- the WHISPER Small Dummy Load is designed to support the AFT tests.

The WHISPER Dummy Load takes place in the WEC harness between the WHISPER transmitter output and WEC13 cable to WEC3-WEC4 unit. The dummy load provides three different types of load, resistor, capacitor and a more complex, more realistic, load synthesised with a pair of two twisted wires shielded cable. It allows again direct connection to the long booms without change in the current installation. The load is manually switched.

The WHISPER Dummy Load package is shown on figure 9.2/3.a. It consists in a standard 445.5/132.5/351 mm rack, two extension cables and two savers.

The WHISPER Small Dummy Load provides a two capacitors load which respectively simulates the loads corresponding to the two transmitting booms. It consists in a saver-sized box with an "input" and an "output" connector. It takes place in the WEC harness according to the drawing on figure 9.2/3.b, between the WHISPER box transmitter output and the EY boom pair WEC3-WEC4. The box is coloured in red. A red tag with "NON FLIGHT UNIT" written is attached to it.

The **WHISPER Probe** allows to check over the amplitude and the shape of the sounding signal during the integration phases. It works as an high impedance input and switching interface between the long boom cables braids and the display units (the Stimuli Box and an oscilloscope).

The WHISPER Probe set consists in the following items:

- for each transmitter long boom, a signal clip including a serial insulator capacitor hooks the cable outer braid while a ground clip including a serial insulator capacitor too hooks the related EFW deployment unit ground stud. A three meters long cable conveys the sounding signal to the WHISPER Probe box.

- the Probe box is a mobile plug-in unit stowed in the WHISPER STAFF Stimuli Box and under its software control. Its switching possibilities allow either the individuals braids signal components or the differential one to be monitored.

- the Probe Box and braid monitor plug in unit in the Stimuli Box are connected via a 20m long power and signal cable.

The WHISPER probe functional diagram is shown figure 9.2/3.c. The signal clip is built from an alligator clip. Clip contacts consist in an metal half cylinder which internal surface is made of conductive foam. Clip contacts are soldered perpendicularly to the first clip jaws. Their dimensions, 2mm internal and 6mm external diameter, 30mm length, fit WEC3 and WEC4 cable size. The ground clip structure is similar to the signal clip one. But clip contacts are soldered as a prolongation of the original clip jaws. Their dimensions, 6mm internal and 10mm external diameter, 40mm length, fit experiment ground stud size.

d) **Other Units**

No specialised MGSE is required for the other WEC equipments. They will be delivered with carrying cases which will meet the Programme Office requirements as defined in EID Part A Section 9.2.5.

9.2.2.2 Utilisation and deployment plan :

TBD

9.2.3 Test fixtures and configuration

The experiment test fixtures provided by the WEC experiments for the vibration tests or other tests will comply with the requirements defined in EID Part A Section 9.2.3.

9.2.4 Environmental cleanliness and safety

The design of the WEC MGSE will ensure the levels of environmental cleanliness and contamination control required for the spacecraft safety and will comply with the safety aspects and the load factors as defined in the EID Part A Section 9.2.6.

9.2.5 Transport containers

The WEC experiments will be delivered in transport containers or carrying cases which will meet the requirements defined in the EID Part A Section 9.2.5.

EFW MGSE CONFIGURATION

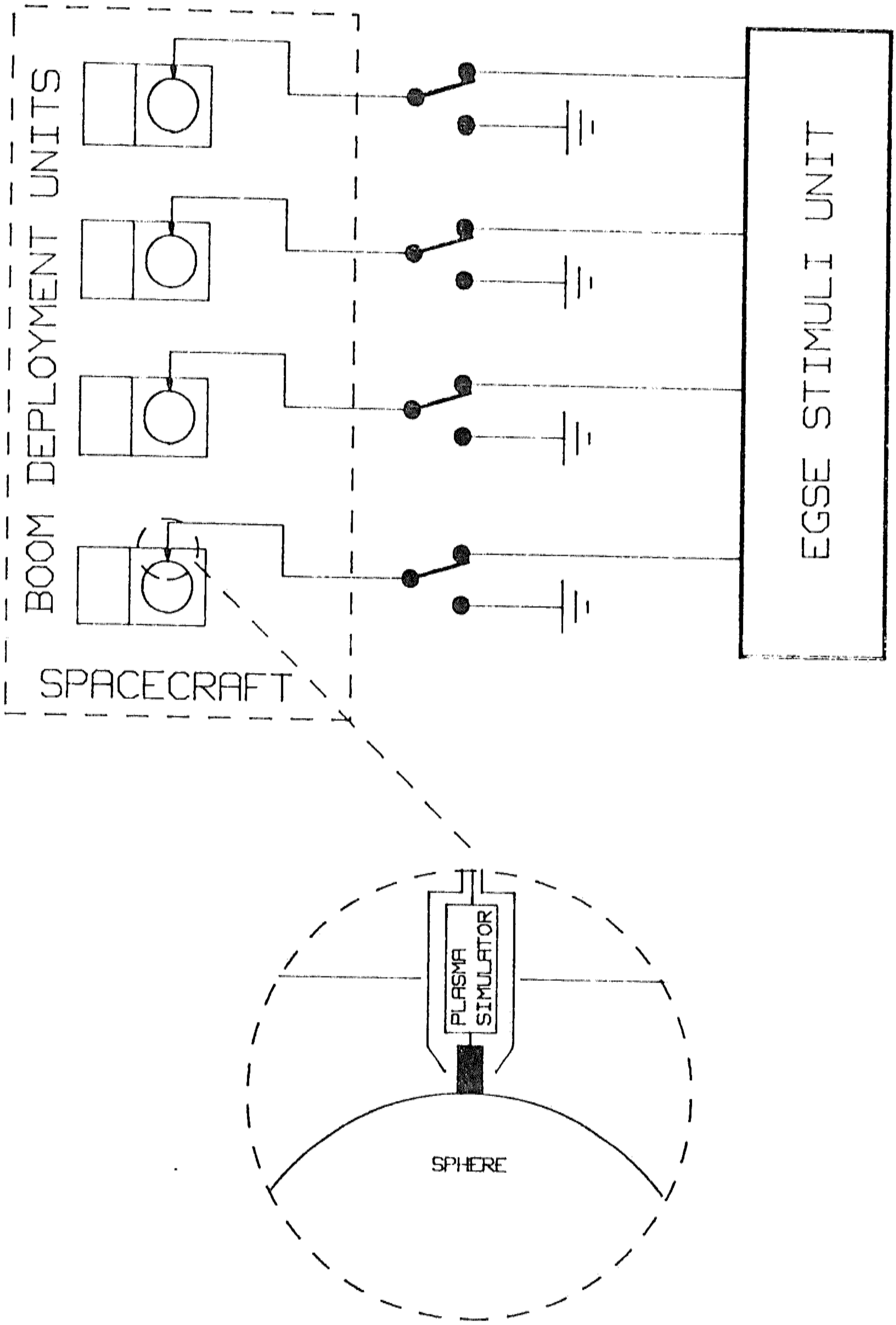


Fig 9.2/1.a EFW - Stimuli connections inside the spacecraft

EFW MGSE CONFIGURATION

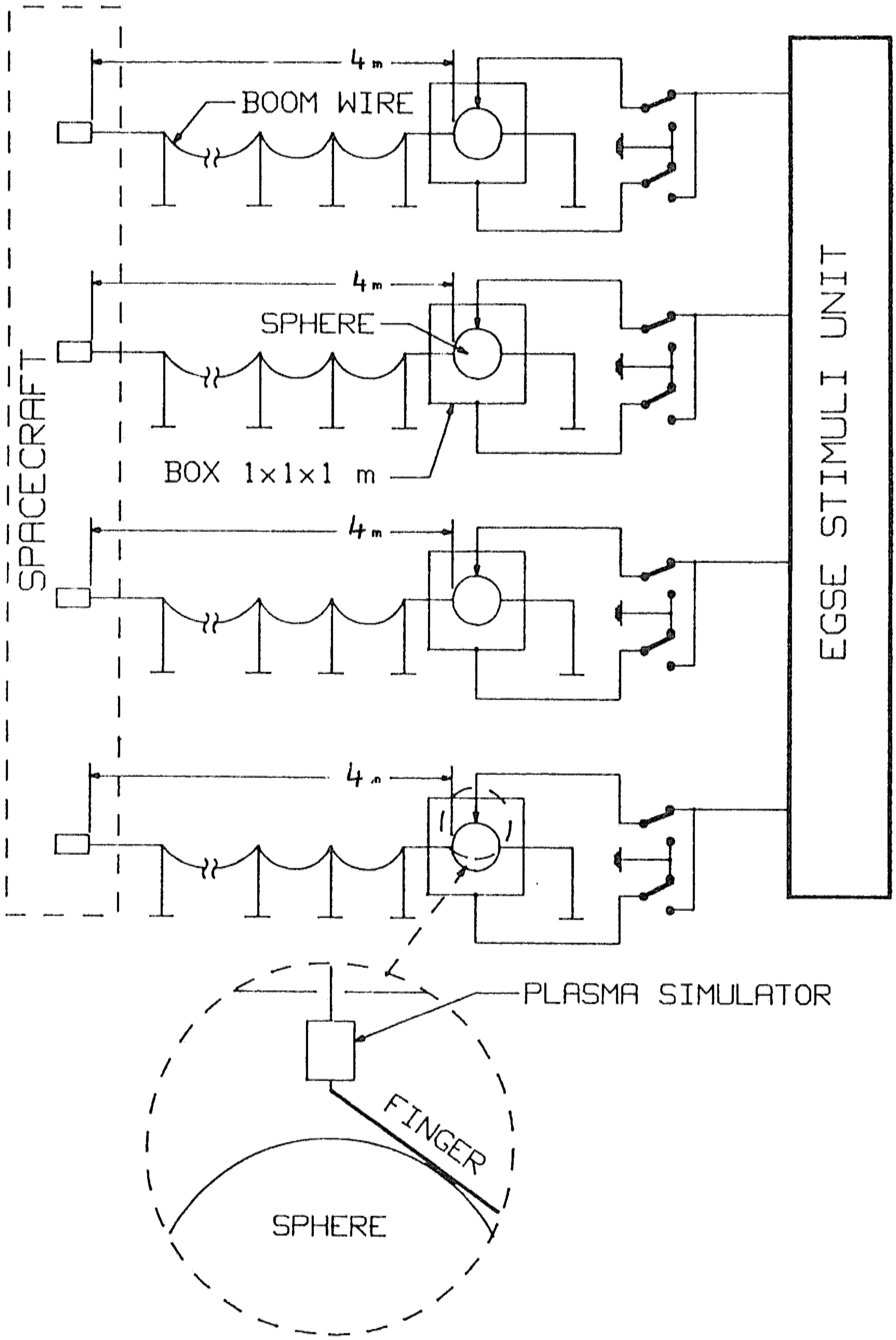


Fig 9.2/1.b EFW - Stimuli connections outside the spacecraft

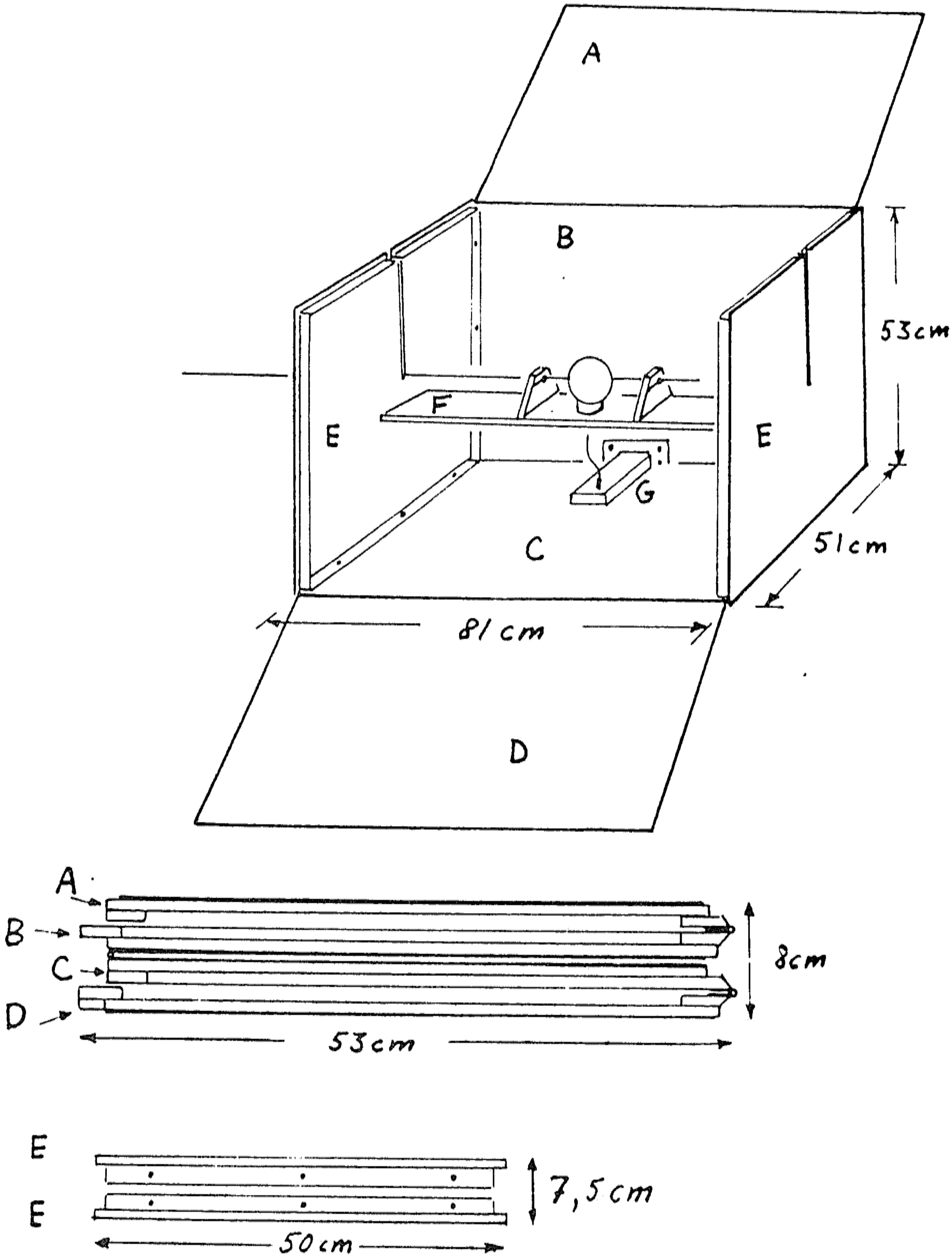
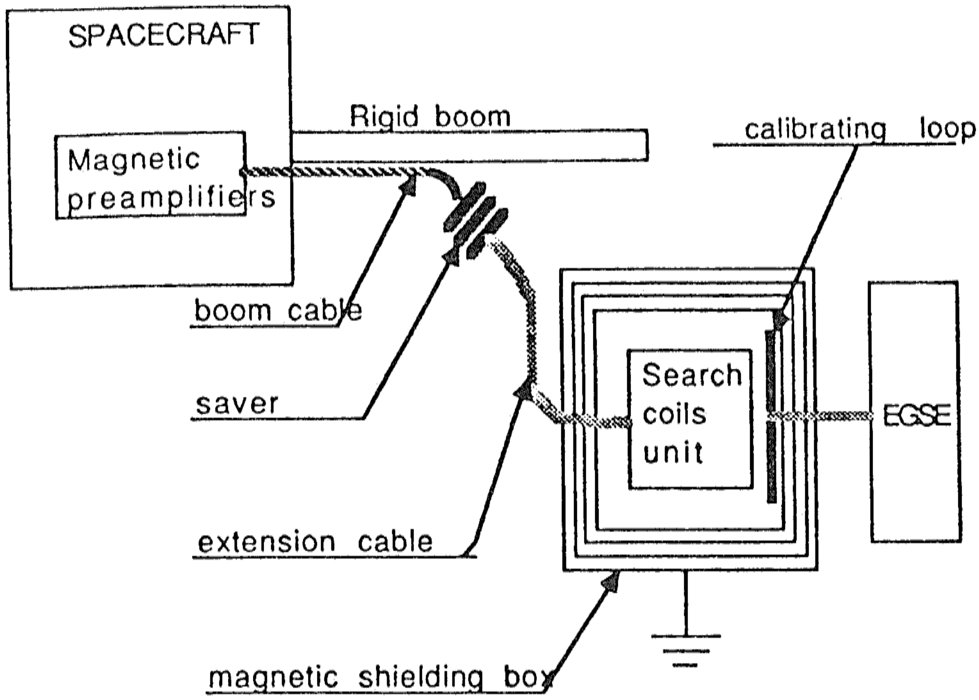
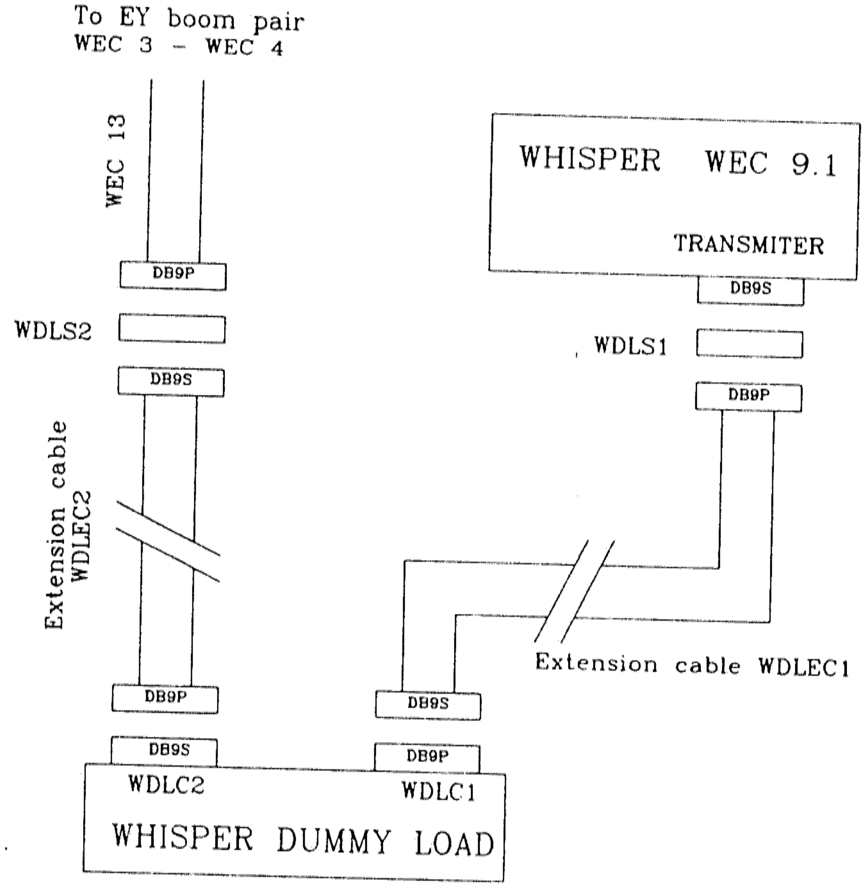


Fig 9.2/1.c EFW Plasma simulator



STAFF MGSE CONFIGURATION

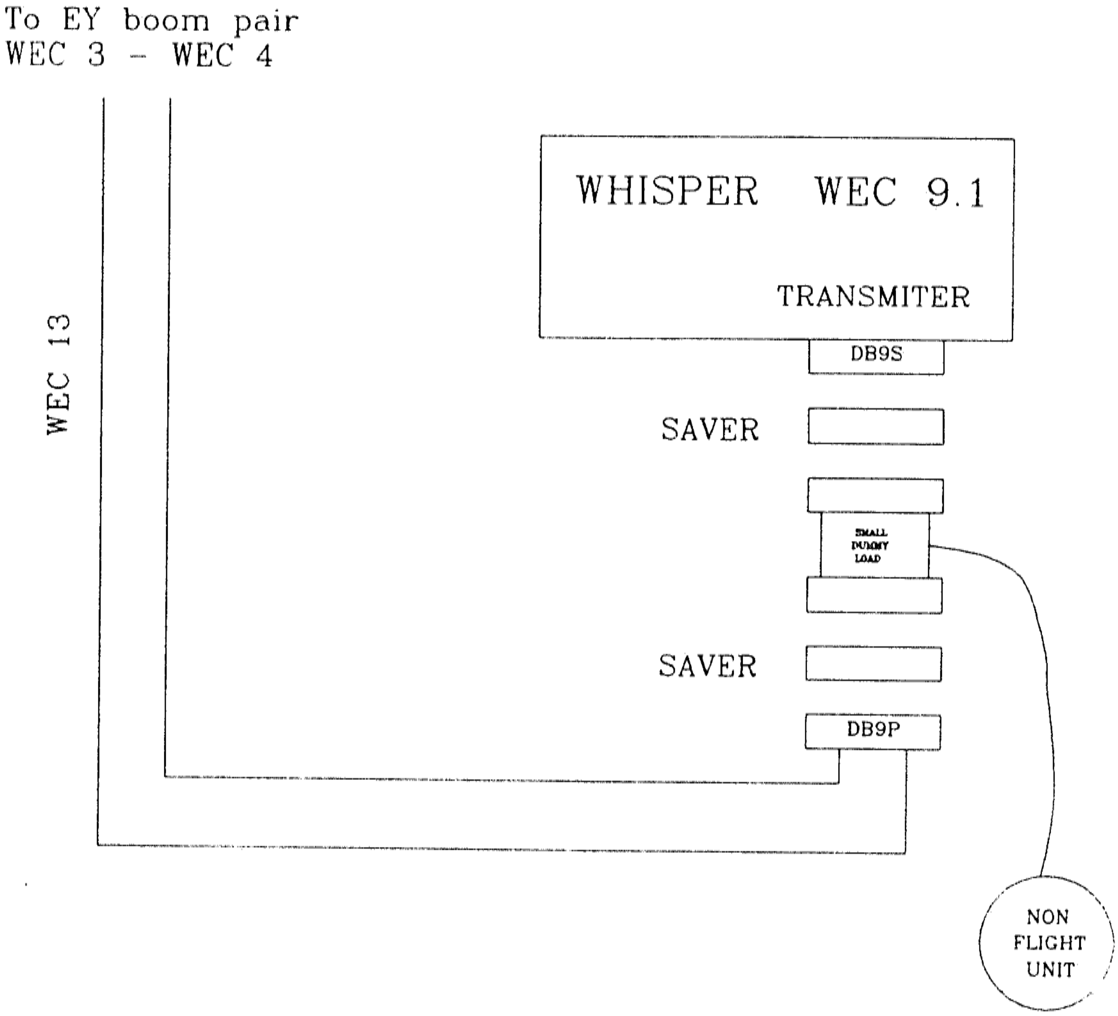
Fig. 9.2/2 Test set up of magnetic search coils



Part list :

WHISPER Dummy Load Box : 3U/84/360 standard rack (TBC)
WDLC1 : connector type Cannon D 9 contacts pin
WDLC2 : connector type Cannon D 9 contacts pin
WDLS1 : saver non magnetic for type Cannon D 9 contacts connector
WDLS2 : saver non magnetic for type Cannon D 9 contacts connector
WDLEC1 : extension cable (4m)
WDLEC2 : extension cable (4m)
WEC 13 : cable from WHISPER to WEC 3 - WEC 4

Fig. 9.2/3.a : WHISPER Dummy Load package.



Part list :

WEC 13 : cable from WHISPER to WEC 3 - WEC 4

Size = TBD x TBD x TBD

Fig. 9.2/3.b : WHISPER Small Dummy Load package.

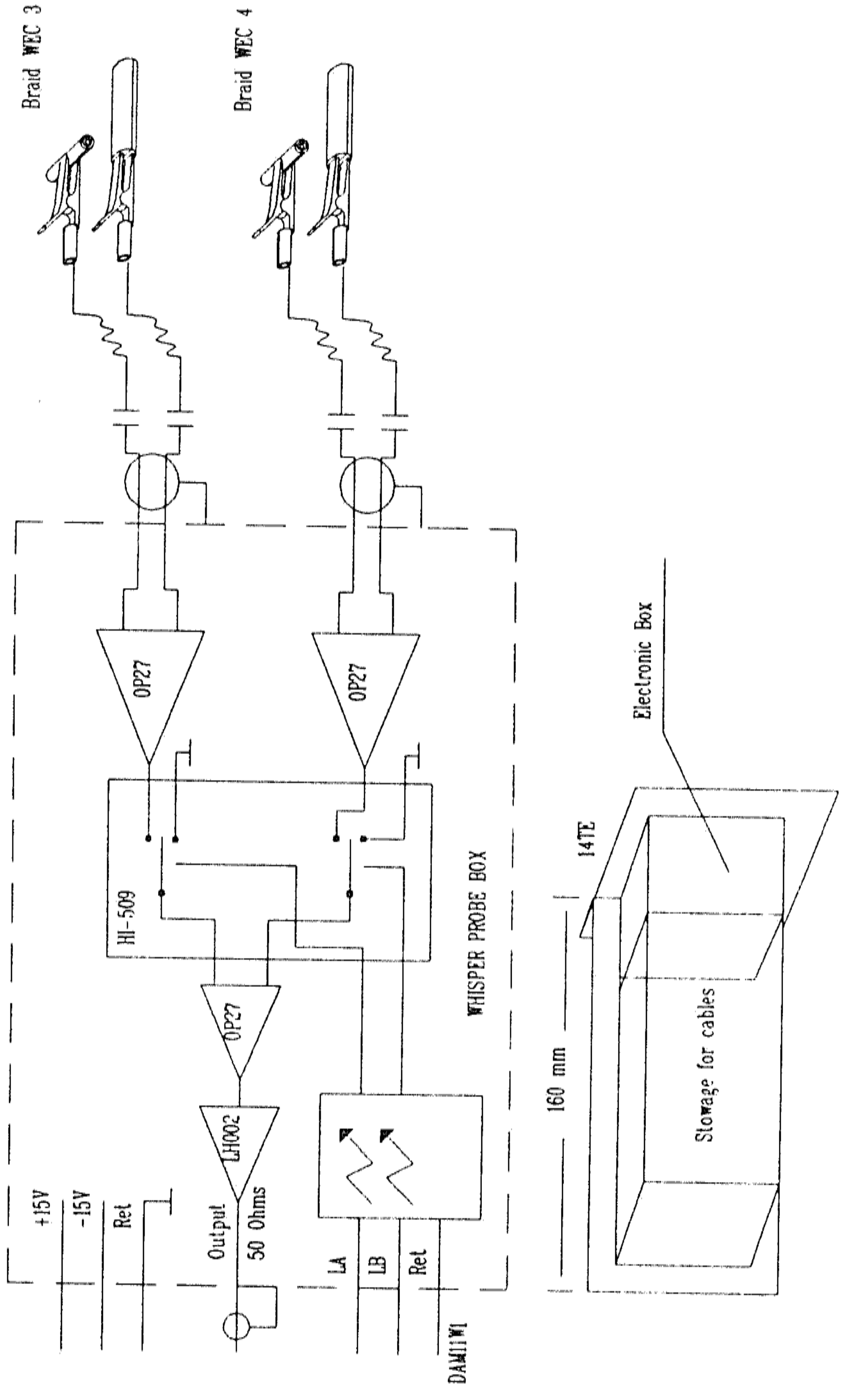


Fig. 9.2/3.c : WHISPER Probe functional diagram.

10. FLIGHT OPERATIONS

SECTION 10 CONTENTS

10.1 FLIGHT OPERATION CONCEPT

10.1.1 Modes description

The flight operations of the Wave Experiment are separated into different phases:

10.1.1.1 Long booms deployment phase

The first mission phase for the WEC involves the deployment of the four 50 meters booms. Since the exact scenario depends upon spacecraft dynamics and operational constraints, the following is considered only a suggestion.

1) Spin up spacecraft to 20 RPM.
2) Deploy boom pair Y1 and Y2 to 20 m radius.
3) Deploy boom pair Z1 and Z2 to 20 m.
4) Spin up spacecraft to 30 RPM, causing top hats to release.
5) 4 x one hour tests during 48 hours.
6) Deploy boom pair Y1 and Y2 to 35 m.
7) Deploy boom pair Z1 and Z2 to 35 m.
8) 4 x one hour tests during 48 hours.
9) Deploy boom pair Y1 and Y2 to 40 m.
10) Deploy boom pair Z1 and Z2 to 40 m.
11) Spin up spacecraft to 24 RPM.
12) Deploy boom pair Y1 and Y2 to 50 m.
13) Deploy boom pair Z1 and Z2 to 50 m.

The deployment is realised at a speed of 1 cm/s +/- 40 %. Deploying a boom pair is accomplished by enabling boom deployment power and sending a pair of commands to the EFW microprocessor. It will measure out the commanded length of wire on each boom (to 5 cm accuracy). The deployment is controlled by the processor of EFW but also partially by the spacecraft which has to switch the DWP ON, to power the deployment motors and to control the spacecraft dynamics. The procedure can be stopped at the s/c level in case of difficulties. The exact strategy is TBD. If desired and spacecraft power is adequate, all four booms may be deployed simultaneously in the normal or spacecraft backup modes, so long as the requirements and limitations described in Section 2.3 are satisfied (i.e. top hat release and peak wire tension). Near Real time facilities as a survey of the telemetry and some telecommand facilities are mandatory for this phase.

Science diagnostics are performed to determine the effects of the spacecraft on the environment as measured from several distances. Data will be collected from the AC and DC electric field instruments during each science stop. The duration of the science stop may range from several hours to a few days depending upon the complexity of tests to be performed.

An optional procedure proposed by WEC (TBC by ESA Cluster PO) is that one pair of booms is left to 35 m and the other pair is fully deployed for a period of up to six months.

10.1.1.2 Initial turn-on operations:

The main purpose of the turn-on phase is to perform the preliminary check-out of the experiment and to evaluate the EMC quality of the spacecraft in flight. It will be requested to have the Wave Experiment in operation with only one of the other experiments, one after one, and progressively with all of them. A detailed turn-on plan shall be established. Direct telemetry transmission is requested during the first check-out of the WEC in order to use the EGSE system for quick but complete evaluation of the experiment performances.

10.1.1.3 Routine operations:

In the normal flight operations the Wave Experiment is conceived as a largely automated system since the DWP controls the modes of the whole experiment. In order to fulfil the requirement of a global WEC power consumption of less than 11.75 Watts, the WEC Scientific Board has defined global modes of operation. Four of them are described below as examples (see power figure in section 3). It has to be noticed that those mode combinations are not the only ones possible, and that other modes will eventually be defined before and after launch.

mode	A	B	C	D
EFW	nominal	nominal	nominal	nominal
STAFF/mwf	nominal	nominal	nominal	nominal
STAFF/spa	nominal	reduced	nominal	OFF
WBD	nominal	OFF	OFF	nominal
WHISPER	OFF	active	passive	passive
DWP	nominal	nominal	nominal	nominal

Duty cycle modes consisting in alternate sequences of different combinations of basical modes will be defined by a small number of telecommands, the scheduling being managed by the DWP. The choice of the operational modes and the use of high speed or low speed telemetry rate will be made on the basis of scientific interest. Specific regions of Cluster orbit will be identified as being of

primary interest (the polar cusp, the auroral zone, or the magnetic equator, for example) and the WEC modes will be scheduled for these regions. Orbit prediction will be requested one or two weeks in advance and a magnetospheric field model will be needed to identify time intervals corresponding to the regions of interest.
The schedule will be established by agreement of the WEC scientific board and/or decision of the SWT. The operational modes can also depend upon the available power or telemetry inside WEC. Some operations of EFW (i.e. changing the offset) may alter the nature of the signal transmitted to the other boxes (i.e. WHISPER). These considerations will be taken into account for the preparation of the FOP at WEC level. The DWP will have the possibility to check that the on-board required modes are consistent with the main constraints.

For the wide band operations using DSN coverage and in order to provide as much flexibility as possible, it is proposed to simply provide a list of the regions, the approximate percentage of the total available wide band coverage that should be devoted to each region, and the preferred instrument configuration. This will enable the CLUSTER Project mission operations staff to integrate these requirements into the operation schedule.

The nominal mode used for single spacecraft operations will be the real time mode. Hence, DSN coverage will be required for the majority of these operations. In the event of irreconcilable scheduling conflicts with the DSN, the recorded mode can be used as a back-up mode. This affects the available analysis bandwidth, however, so operations should be planned for enough in advance to resolve ground tracking conflicts.

The wideband coverage stated in EID part A is for two spacecrafts, each scheduled to acquire wideband data for 30 minutes intervals once per orbit. It is believed that this level of coverage does not allow an adequate probability of detecting many events of interest. Hence, the WBD group has placed a request with the ESA Programme Office that the wideband coverage be increased to 2 hours for each spacecraft per orbit.

Since collection of real time data is permitted from only one spacecraft at a time, multi spacecraft operations could use the 100 kb/s burst-mode capability, which could allow high-rate data to the OBDH tape recorder via the Wave Consortium data handling unit. Though not part of the selection baseline, a request for a dedicated WBD burst mode (ref also to sec 3.3.4) has been placed with the ESA Programme Office and is currently under consideration.

The dedicated WBD burst-mode requires that the wideband receiver be commanded to an instrument state which uses the 10 kHz bandwidth with 4-bit A/D conversion at a sample rate of about 25 ksamples/s.

For all multi spacecraft operations, data acquisition of a minimum of 30 minutes once per week has been requested.

10.1.2 Nominal and back-up modes

A preliminary list of the nominal and back-up modes will be established in a later phase of the project.

10.1.3 Ressources

TBD

10.1.4 Constraints

The special requirements concern especially the need of real time operations during the early orbit phase (deployment and turn-on).

When the spacecraft get out of eclipse, the temperature of the magnetic preamplifiers has to be checked before a new switch-on.

It is very important not to switch ON the transmitter of WHISPER before the emitting booms have been at least partially deployed.

It is reminded that the EFW instrument requires a tilt of the spin axis towards the Sun with an angle larger than d/l where d is the high of the s/c above the radial boom plane and l is the length of a boom.

10.2 DATA PROCESSING AND MISSION PRODUCT

TBD

11. PRODUCT ASSURANCE

This section is a reprint of the Product Assurance Plan for the Cluster Wave Experiment Consortium, as issued by WECTCO december 90.

SECTION 11 CONTENTS

11.1 INTRODUCTION

The members of the WEC (Wave Experiment Consortium) recognise the need for stringent controls on product assurance to ascertain optimum progress of the programme. Therefore they will aim at compliance with all safety requirements related to interfaces with the spacecraft as described in EID part A section 11. They also will try to respect all the reasonable aspects of the PA philosophy and procedures for their own equipments and, at least, for all the internal WEC interfaces. The present document is a Product and Quality Assurance Plan which covers only the general aspects of the problem for the Wave Experiment. It describes general rules applicable by each experimenter. The details specific to one experiment will be described in separate sub plans produced by each experimenter.

The applicable and reference documents which could be useful for the WEC experimenters for Product Assurance Programme are listed in the EID part A sections 1.5 and 1.6.

The interfaces within the different elements of WEC will be described in 3 separate documents being the basic working documents for all hardware and software engineering within the WEC:

WEC Internal EID	- part 1:	Interfaces with DWP
	- part 2:	Interfaces with the WEC Power Supply
	- part 3:	Interfaces within the WEC units, excluding DWP and PWR

11.2 GENERAL PRODUCT ASSURANCE PLAN

11.2.1 General

Since the WEC has established a technical coordination office (WECTCO) responsible for all technical aspects of interfaces within the experiment, an effort will be made for defining a common structure of PA plan largely usable by all the groups of the WEC. However, each group is expressly responsible for the integrity of his experiment and the constraints are not the same for all of them. Mechanisms or externally mounted units have not the same safety requirements than electronic boxes. NASA rules have specific aspects which must be taken into account by the the USA experimenters. Therefore, it is envisaged to have a PA plan for each of the five experiments, plus one for the WEC Power Supply unit which will be written by the industrial contractor.

11.2.2 Organisation

The specific responsability of the Technical Coordination Board is applicable to the following actions:

- Coordination in the definition of the interfaces
  - with the spacecraft (special quality rules)
  - with other experiments (IEL)
  - internal to WEC (WEC EID)
- Coordination of the planning activity and reporting to ESA
- Preparation of the completed Wave Experiment and organisation of the WEC Integration/Acceptance procedures
- Direct participation to the testing activities at WEC level
- Support to AIV activities at S/C level
- Scheduling of activities of the consortium members as far as the results of those activities are to be provided to ESA or others.
- No action in the parts procurement activity

The responsabilities of the individual experimenters concerning the PA/QA activity is the following:

Each PI is requested to designate a cognizant Product Assurance representative who will manage all PA activities for his experiment. The WECTCO will also designate a PA engineer to coordinate what can be coordinated and, at least, to minimise the job of the different groups by avoiding repetition of common tasks. The WEC also may ask for use of ESTEC resources or for the help of National Agency for specific tasks for which in house expertises or facilities are not available.

All the quality assurance tasks shall be coordinated by the designated PA engineer, who will exercise these functions in close collaboration with the PI and the Technical Manager throughout the duration of the project. In order to do this :

He shall be authorized to make functionally-related decisions on all activities to assure quality.
He shall coordinate on the quality plan all the activities of the various groups that are cooperating in the study, development, construction, and testing of the equipment.

He shall be responsible for drafting and following up the complete quality plan system.

He shall assure technical and administrative management of all quality-related problems.

He has to track and to follow up manufacturing quality.
He participates in the processing of non-conformances/failures and analyzes incidents.

He has to approve repair and waiver requests. When a contractor is used, the PA engineer participates in the verification of the conformance of study documents to contract requirements and study rules applicable under this contract. The responsible persons presently nominated for PA activity are:

WEC		: B. de la Porte
	Address	: CNET/CRPE
		3 av de la République
		92131 Issy les Moulineaux - France
	Telephone	: 33 1 45 29 62 14
	Telex	: 200 570 F CNETION
	Telefax	: 33 1 45 29 60 52
	SPAN	: CRPEIS::DELAPORTE
EFW		: D. Klinge
	address	: ESTEC/SSD, postbus 999
		2200 AG - NOORDWIJCK the Netherlands
	telephone	: [31] 1719 83594
	telex	: 39098 NL ESTEC
	telefax	: [31] 1719 17400
	SPAN	: ESTEC1::SI1144
STAFF		: A. Meyer
	Address	: CNET/CRPE
		3 av de la République
		92131 Issy les Moulineaux - France
	Telephone	: 33 1 45 29 49 06
	Telex	: 200 570 F CNETION
	Telefax	: 33 1 45 29 60 52
	SPAN	: CRPEIS::MEYER

Have also to participate to the PA/QA activity for STAFF:

P. Chauveau	CNET/CRPE - Issy les Moulineaux
R. Knoll	Obs Meudon/DESPA - Meudon
D. Klinge	ESTEC/SSD - Noordwijck
M. Arnal	Industrial Contractor ALCATEL ESPACE -Toulouse
X. X	Other industrial contractors not selected yet

WHISPER : F.X. Sené, Technical Manager
Institute : LPCE/CNRS
Laboratoire de Physique et Chimie de l'Environnement
Address : 3A, Av. de la Recherche Scientifique
45071 ORLEANS CEDEX 02 FRANCE
Telephone : [33] 38 51 52 77
Telex : 760600 F CNETORL
Telefax : [33] 38 63 12 34
SPAN : CRPEIS::SENE

Have also to participate to the PA/QA activity for WHISPER:

Ph. Martin LPCE/CNRS - Orléans
P.B. Mogensen DSRI - Copenhagen
J.M. Batut Industrial Contractor AETA - Fontenay aux Roses

WBD : E.A. Kruse
Institute : Department of Physics and Astronomy
The University of Iowa
Address : Iowa City, IA 52242
USA
Telephone : 1 319 335 1891
Telex : 910 525 1398
Telefax : 1 319 335 1753
SPAN : IOWASP::KRUSE

DWP : H.St.C. Alleyne, Project Manager
Institute : University of Sheffield
Department of Physics
address : Sheffield S3 7RH
Telephone : (44) 742 768555 ext 4354
Telex : 547216 UGSHEF G
Telefax : (44) 742 728079

PWR : B. de la Porte
Institute : CNET/CRPE
Address : see above
Telephone :
Telex :
Telefax :
SPAN :

The WEC Power Supply is fully designed and manufactured by an industrial contractor: AETA. Then, the PA plan will be written by the contractor but controlled by the WEC PA engineer.

For the Contractor:

PA/QA responsible : J.M. Batut
Address : AETA (Applications Electroniques Techniques Avancées)
62-70 rue Blanchard
92263 Fontenay aux Roses - France
Telephone : 33 1 46 61 22 55

In addition, the French groups (WECTCO, STAFF, WHISPER) have obtained the support of a Quality engineer from CNES. He cannot have the role of PA representative for any experiment but he can offer punctual help for establishment of the Plan or other critical situation which could be encountered.

Support for WECTCO, STAFF, WHISPER: A. CAUMONT / CNES Toulouse

Within the U.K. the Rutherford Appleton Laboratory is providing limited PA support for all groups. This includes DWP.

Other supporting personnel would be added as necessary during the project.

11.2.3 **Product Assurance Plan**

The general rules of the Product Assurance Plan for the Wave Experiment are described in the different sections of the present document. Sine they are limited to the general problems, they are applicable to all the WEC experimenters. All the pars of WEC have not the same importance for PA activity and specific PA Plan shall be attached to the general Plan for the experiments having a certain level of criticality. The critical points can be identified as follows :

EFW

- Has a semi-direct interface with the main power lines of the spacecraft.
- Has deployable long booms needing handling precautions.
- Is sensitive to electrical emissions.
- Has electrical sensors (spheres) sensitive to cleanliness conditions.

STAFF

- Has a magnetic sensor (search coil) externally mounted. Stringent thermal design is needed. Handling precautions to be defined.
- Is interfaced with an other experiment (EDI).

- Is sensitive to magnetic emissions.

WHISPER

- Transmits a pulse at about 200 V on one long boom pair. Handling and safety precautions are needed.
- Has a semi-direct interface with the main power lines of the spacecraft.
- In active mode, generates electric disturbances.

WBD

- Has a semi-direct interface with the main power lines of the spacecraft.
- Has a direct interface with the telemetry system.

DWP

- Has a direct interface with the OBDH system.
- Has several interfaces with non WEC experiments.
- Is interfaced with all the other arts of the WEC for data collection, telecommanding and controls.

PWR

- Has a direct interface with the main power lines of the spacecraft.
- Is interfaced with all the other parts of WEC for power distribution.

11.2.4 Contractor and Supplier Surveillance

Only contractors with assessed capability with regard to quality control and traceability shall be used for manufacturing/processing of EM, FM, FS parts and assemblies. Contracts, purchase orders etc... shall include a statement indicating the requirement for quality control and traceability at the appropriate standard. A PA Contractor engineer shall be identified and he shall work in close relation with the experiment PA responsible. The Contractor shall have an autonomous quality inspection department independent of the manufacturing department. He should be able to demonstrate that he has set up a system to allow th rapid transmission of modifications and the simultaneous removal of outdated documents.

11.2.5 Status Reviews, Facility Reviews

Reviews shall be held to examine the status of the instruments, subsystems and ground support equipment at the appropriate stages in the programme. In general, the requirements of EID part A section 11.2.5 will be respected.

11.2.6 ESA Participation in Inspections and Tests

As requested in EID part A section 11.2.6, ESA will be invited to participate to all the important activities audit, surveys, source inspections, test observations or witnessing, mandatory inspection etc, at the facilities of the PI and his contractors and suppliers.

11.2.7 Product Assurance Progress Reporting

Reporting of the progress and status of the PA programme will be included in the regular project progress reports. The items which will be addressed are those described in the EID part A section 11.2.7. An effort will be made for producing short reports following a standard format.

11.3 QUALITY ASSURANCE

11.3.1 General

A Quality Assurance activity will be tailored by the experimenters according to the complexity of each instrument and to the need to assure compliance to formal requirements.

In order to obtain the relevant quality, general rules of design should be applied and critical studies should be performed during the design phase. Electrical schematic diagrams with part ratings, mechanical blueprints, rules of the art relevant to the construction and the technology used, all the parts and/or supplies used should be analyzed. These analyses should be conducted during design reviews and quality meetings. They could lead to the discovery of critical elements, i.e., technology or components as new, not validated or not yet used for space application, used to the limit of their performance or field ratings, whose reproducibility is still not guaranteed, presenting industrial risks in terms of procurements, for which problems or failures would have major estimated consequences. Critical elements, if any, shall be mentioned in the list of technology. In the project, quality actions in the study process shall impact among others like: the choice of parts and manufacturers, the rules on how to use parts, the choice of materials and assembly technology.

11.3.2 Procurement Controls

Specifications of EID part A section 11.3.2 will be respected as much as possible. However, the experimenters have not always the possibility to inspect the fabrication of the components. Some of them are available in "high reliability" type and are delivered with appropriate documentation (report of LAT, etc). It is usually preferable not to test them at reception.

11.3.3 Incoming Inspections

The compliance with applicable requirements of all items procured from outside sources will be verified by Incoming Inspection Procedure described in EID part A section 11.3.3.

11.3.4 Surveillance of Manufacturing/Integration, Mandatory Inspection Points

Manufacturing and assembly activities will be subject to surveillance as stated in the EID part A section 11.3.4.

Special attention shall be carried out for DWP and PWR units which have a general interest for the whole Experiment and comprises all the interfaces with the spacecraft. If a contractor is used, he will have to provide documents that allow to track and follow-up project quality and, if necessary, to report on faults or failures encountered. He must provide a room where the inspector representative can carry out all inspection operations promptly and under good conditions.

Manufacturing/assembly float charts will be established and Mandatory Inspection Points will be specified during the study phase of the Engineering Models.

11.3.5 Test Witnessing, Pre-Test/Post-Test Review

The test organisation will be witnessed by the quality assurance personnel. Pre and Post Test Reviews shall be organized at al the important stage of the test development. In the WEC Experiment, there are several levels of test activities: single experiment, stack and WEC levels. Although the tests of the single experiments are under the responsibility of the involved experimenter, the WEC technical coordinator shall be informed and could participate to the important phases of these tests and corresponding reviews.

11.3.6 Logbooks and Traceability

Logbooks will be established for all operations and tests as requested in EID part A section 11.3.. The log books attached to the different units are under the responsibility of the individual experimenters. The log book of the WEC testing equipment will be controlled by the Coordination Office.

11.3.7 Cleanliness and Contamination Control

Plan to be provided by each PI. It shall describe the precautions taken in each laboratory to avoid any contamination. In general, the WEC experiment is not very sensitive to contamination. The most sensitive part is the the spheres of the EFW experiment for which special precautions are envisaged.

The WEC integration will be made in a "clean room" (better than class 10 000 in quiet situation) and special procedures for experiments handling and room occupation will be specified.

11.3.8 Nonconformance Control

All the Non Conformance events shall be controlled by the PA engineers as described in EID part A section 11.3.8. Reporting forms distributed by ESTEC will be used as far as possible.

11.3.9 Metrology and Calibration

The PA responsible in each laboratory shall have to take care of the quality and accuracy of the equipments used for calibration or measurement of any parameter of the experiment. Verification or recalibration of equipments shall be carried out in the important circumstances which have to be identified in advance.

11.3.10 Handling, Storage, Packaging, Marking and Labelling

Transportation Control General specifications of EID part A section 11.3.10 shall be respected by the experimenters. Any equipment liable to be damaged during handling shall be transported or manipulated by special means adapted to the equipment. In particular, and wherever possible, parts and subassemblies should be handled with clean gloves. The parts and subassemblies must be stored in a laboratory environment so that they are protected against the risks of contamination (dusts, organic matter, volatile products) and hazard manipulations and shocks. An individual packaging - transparent if possible - is recommended as well as appropriate markings to limit handling. Each of the assemblies and subassemblies should be marked so that it can be identified. The marking shall be clear, concise, apparent, indelible, and not capable of attacking the materials serving as a support. This marking which individualises each product will be included in the manufacturing file, in particular on the element markings list, on the installation drawings for the subassemblies, on the Contractor inspection reports if applicable.

For shipment, each equipment shall be placed in an individual packing designed to assure protection against climatic and mechanical constraints and stressing during transport without any special precautions. Each packing shall include indications on the Project/Experiment/Unit name, the serial number, the shipment date, the preferred direction for handling and storage (up-down), the "fragile" statement or adequate marks.

11.3.11 Alerts

The experimenters will be attentive to the possible alerts coming from ESTEC.

11.3.12 Software Quality Assurance

The WEC PI's shall produce a quality assurance programme for software development in the limits of their possibility. DWP and EGSE are especially involved but all the other experiments are using micro processors.

11.4 RELIABILITY ASSURANCE

11.4.1 General

An analysis of the reliability will be made for all the parts of the Wave Experiment but not necessarily at the same level of details for all of them.

11.4.2 Failure Modes, Effects and Criticality Analyses

It is not intended to provide a complete FMECA for all the parts of the experiments.

The large number of interfaces within the WEC instruments will be made with a limited number of interface type, mainly analog or digital, well known for their good protection against the more usual disturbances (short/open circuit, inverted voltage).

A simplified Failure Mode Analysis is expected from each experimenter in order to identify the most critical failure modes of each experiment and to have an idea of their probability. These modes will be used at the WEC level for establishing a simplified analysis of the possible incidents with their consequences on the whole WEC experiment. One purpose of this analysis is also to demonstrate that failures cannot propagate to the satellite hardware.

A standard FMECA shall be performed for the elements of the experiment which are electrically, thermally or mechanically interfaced with the spacecraft or with other experiment. EFW and STAFF are involved for mechanical or thermal interfaces. DWP and PWR are involved for electrical interfaces.

11.4.3 Single Point Failure and Critical Items list

To be provided by the experimenters concerned

11.4.4 Numerical Reliability Assessments

It is not intented to provide a numerical reliability analysis. The effects of the Failure Modes only will be classified in different levels of severity affecting the experiment, the scientific mission, the spacecraft.

11.4.5 Worst Case Analysis

It is, in general, extremely difficult for a laboratory to perform a Worst Case Analysis. If, for some parts of the experiment, this is formally requested by ESA, at least all the information needed for the Analysis will be provided.

11.5 SAFETY ASSURANCE

11.5.1 General

WEC is not largely concerned with this activity. However some critical points can be identified and shall be subject to a Safety Plan:

- Connection of the EGSE to the spacecraft (if direct connection exists)
- Grounding problems. Precautions to be taken.
- Boom mounted unit (search coil). Handling precautions and procedures to be defined.
- Electric spheres cleanliness. Handling precautions and procedures to be defined.
- Long booms. Procedures for partial deployment and environmental precautions to be defined.
- External voltage for WHISPER. Safety precautions and procedures to be defined.

11.5.2 Applicable requirements

11.5.3 Safety Assurance tasks

Hazard Analysis to be provided by the experimenters concerned.

11.6 COMPONENT QUALITY, SELECTION AND PROCUREMENT

List of components, procedures for purchasing, etc...
are provided by the experimenters in the DATA-PACKAGE of the different reviews.

The EEE parts list and the quality levels will conform to the requirements in EID A.

The material and processes will be selected, controlled and lists will be provided to ESA as required in EID A.

11.7 MATERIAL AND PROCESS SELECTION AND CONTROL

To be provided

11.8 CONFIGURATION MANAGEMENT AND CONTROL

To be provided

12. MANAGEMENT

(To be issued)

13. PROGRAMME AND SCHEDULE

(To be issued)