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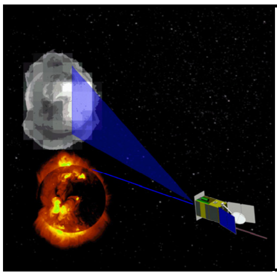
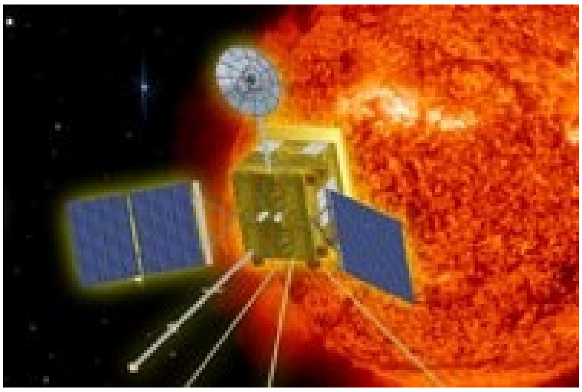


Istituto di Fisica dello Spazio Interplanetario

Experiment Interface Document
EIDB

SCENARIO
NSWD
(Neutral Solar Wind Detector)

SOLAR ORBITER



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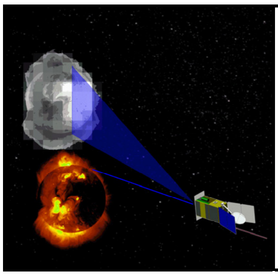

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ACRONYM LIST

ADC	Analog to Digital Converter
AIT	Assembly Integration and Test
AI&V	Assembly Integration and Verification
AMU	Atomic Mass Unit
APE	Analog Proximity Electronics
APID	APplication IDentifier
ASIC	Application Specific Integrated Circuit
BOL	Beginning Of Life
CBE	Current Best Estimation
CCEM	Ceramic Channel Electron Multiplier
CDMU	Command Data Management Unit
CEM	Channeltron Electron Multiplier
CM	Common Mode
CoG	Centre of Gravity
CoM	Centre of Mass
CR	Collection Rate
DAC	Digital to Analog Converter
DC	Direct Current
DHSU	Data Handling Support Unit
DM	Differential Mode
DMA	Direct Memory Access
DOF	Degrees Of Freedom

DPU Data Processing Unit

DS Document Specification

DSP Digital Signal Processor

EBL Electron Beam Lithography

EGSE Electric Ground Support Equipment

EM Electro Magnetic

EM Engineering Model

EMI Electro Magnetic Interferences

EMC Electro Magnetic Compatibility

EM/STM Engineering Model/STructural Model

ENA Energetic Neutral Atoms

EOL End Of Life

FEE Front End Electronics

FIFO First In-First Out

FM Flight Model

FOV Field Of View

FPGA Field Programmable Gate Array

FS Flight Spare

GF Geometrical Factor

HBR High Bit Rate

HK HousKeeping

HPU Hub Processor Unit

HV High Voltage

HVPS High Voltage Power Supply

ICD Interface Control Document

ICDR Instrument Critical Design Review

I/F InterFace

IFE Instrument Front End

IFOV Intrinsic Field Of Veiw

IPDR Instrument Preliminary Design Review

IQR Instrument Qualification Review

ISRR Instrument Science Requirements Review

LAN Local Area Network

L-CAM Limb Camera

LCL Latching Current Limiter

LSB Least Significant Bit

LUT Look Up TableMBR Medium Bit Rate

MCP Micro Channel Plate

MGSE Mechanical Ground Support Equipment

MICD Mechanical Interface Control Document

MLI Multi Layer Insulation

MoI Moment of Inertia

MSB Most Significant Bit

NSWD Neutral Solar Wind Detector

OBDH On Board Data Handling

PA Product Assurance

PAEX Pluto Atmosphere Escape Experiment

PCB Power Control Box

PDR Preliminary Design Review

PDU Power Distribution Unit

PEEK PolyEthereEtherKetone

PG Pulse Generator

PHA Pulse Height Analysis

PMI Piccola Media Impresa –(Italian Small/Medium size enterprise category)

PRS Pseudo Random gate Sequence

PSD Power Spectrum Density

PTI Product Tree Item

QA Quality Assurance

QM Qualification Model

RIE Reactive Ion Etching

RPA Retarding Potential Analyser

RTOS Real Time Operating System

RTU Remote Terminal Unit

S/C SpaceCratft

SCENARIO Solar Corona ENA Radiation Imagine Observer

SEL Single Event Latch-up

SMD Surface Mounted Devices

SMM Structural Mathematical Model

STM Structural Thermal Model

SYS System

TBC To Be Confirmed

TBD To Be Defined

TBW To Be Written

TC TeleCommand

TDC Time to Digital Converter

TM Telemetry

TMM Thermal Mathematical Model

TOF Time Of Flight

TRP Temperature Reference Point

TV Thermal Vacuum

UORF Unit Optical Reference Frame

UPA Ultrasonic Piezo Actuator

URF Unit Reference Frame

UVS Ultra Violet Spectrometer

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1 Introduction

1.1 Background

This document provides the Technical Information Update Document (TIUD) of the Neutral Solar Wind Detector (NSWD), to be flown on board Solar Orbiter. NSWD consists of a neutral atom sensor able to detect and characterize (in terms of velocity and direction) the energetic neutrals flowing together the ionised particles within the solar wind, between ~0.05 keV/nuc and ~5 keV/nuc. This may be a stand-alone instrument (indicated as high priority augmentation payload in the Solar Orbiter PDD), but it is also suitable for inclusion in the solar wind particle package SWA.

1.2 Scope

The purpose of this TIUD Part B is to document the Instrument Teams (IT) response to the technical requirements of the TIUD Part A, in terms of compliance, detailed specification and special requirements that have to be taken into account for the participation to the Solar Orbiter mission.

1.3 Document concept and architecture

This TIUD-B is structured as the ESA provided TIUD-B template to ensure consistent definition standards. Chapter 1 and 2 reflects the Preliminary Design Document (PDD) provided for the NSWD sensor. Chapters from 3 to 9 describe technical details as required.

1.4 Document Outline

Refer the TIUD Part B template structure.

2 Key Personnel and responsibilities

2.1 Organisation and Responsibilities

2.1.1 Instrument Team organisation

The NSWD instrument will be realised with a common Italian effort of four scientific Institutes and one national PMI space firm, namely:

- Istituto di Fisica dello Spazio Interplanetario (IFSI), INAF, Roma (Italy)
- Istituto di Struttura della Materia (ISM), CNR, Roma (Italy)
- Istituto di Nanotecnologie e Fotonica (IFN), CNR, Roma (Italy),
- AMDL Srl, Roma (Italy)

and by the international participation of:

- Physikalisches Institüt, University of Bern (UniBe), Bern (Switzerland)
- Centre d'Etude Spatiale des Rayonnements (CESR), Toulouse (France)
- Finnish Meteorological Institute (FMI), Helsinki (Finland)
- Centrum Badan Kosmicznych PAN (Poland)

morever, Thales Alenia Space Italia .- Milan (former LABEN) will be involved for the NSWD qualification activities in support of INAF and AMDL.

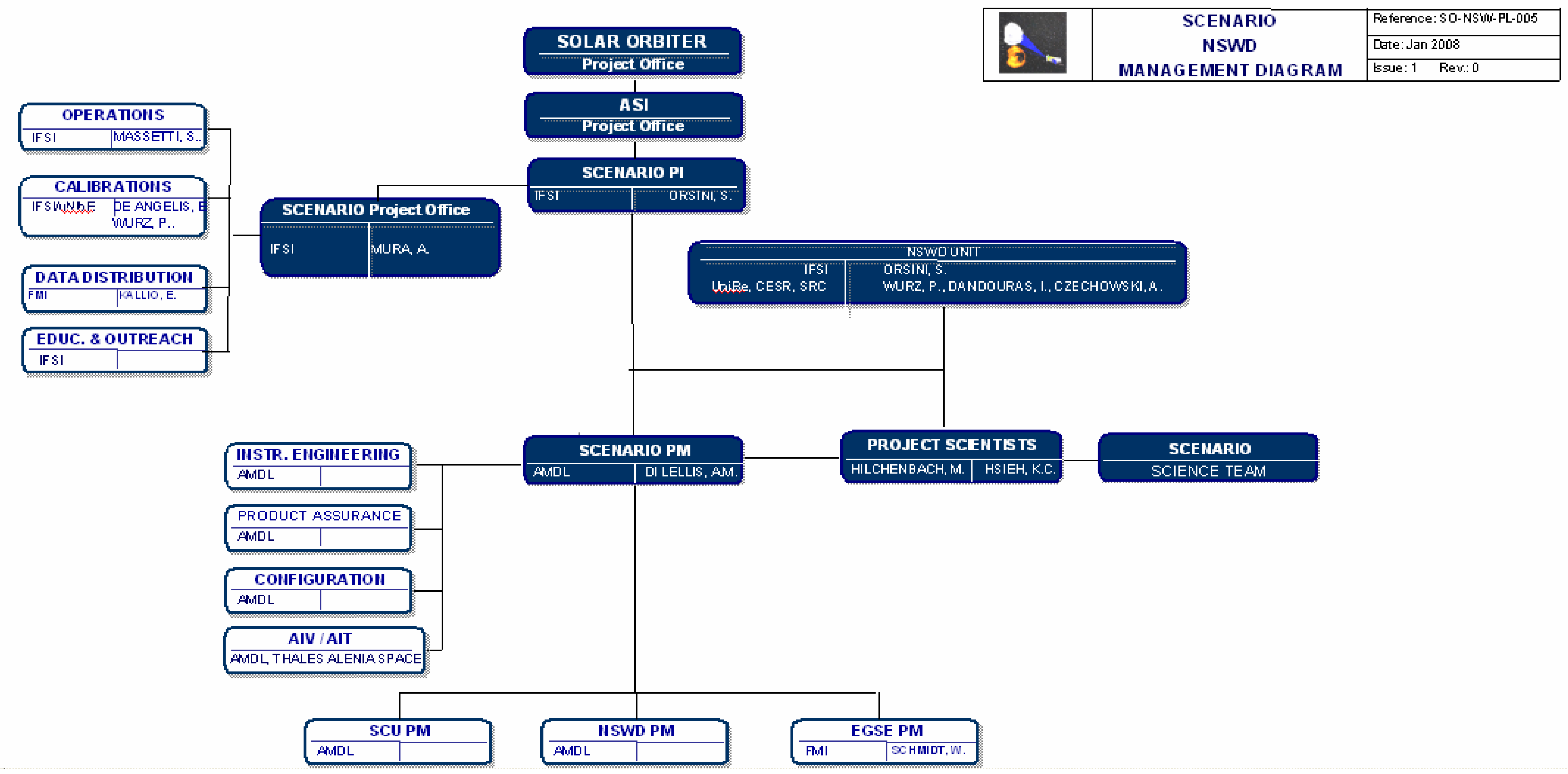

Figure 2.1. SCENARIO Functional Organigramme

2.2 Principal Investigator and Co-I, institutes and responsibilities

2.2.1 Institute Responsibilities

The Instrument flight models and the ground systems will be developed with the following responsibilities of the Institutions as listed below.

Table 2.1. SERENA Institutes and Responsibilities

GROUP	ROLE	Responsibility
IFSI, Italy (with the contributions of AMDL, IFN, ISM, CESR, CBK-PAN)	PI PM	SYSTEM CU, NSWD, FGSE
FMI, Finland	CO-I	EGSE

2.2.2 Support Facilities

The Assembly and Integration of the various units at system level will take place at IFSI (Area Ricerca Tor Vergata, Italy), as far as the deliverable units are concerned namely: STM, EM, (QM/FS), FM models. Also the functional test activities for all these models will be based at IFSI. The qualification activities (EMC, Vibrations) will be supported by Thales.

The IFSI institute is owner of a clean room facility of class 10.000, where space experiments may be tested and tuned. This facility is one of the eight clean rooms located in the “Area di Ricerca di Tor Vergata”, close to the Sensors and Microsystem Institute that uses the other ones and takes care of their maintenance.

The clean room includes the Thermal-Vacuum equipment (Italian, manufactured by Angelantoni Srl), able to contain half a cubic meter of useful space, and is fully automated for cycling tests. A precision optical bench test (pneumatically stabilized) and a class 100 laminar-flow table for mounting-dismounting optics and sensors is also available.

All of the IFSI latest experiments have been tested and qualified in this facility, that is: Mars96, PFS, Omega, Mars Express Aspera-3 and Venus Express Aspera-4 (for what concerns the Italian contributions to these projects).

For verification and calibration aspects of each unit, refer to the Engineering Plan of this proposal.

In this context we just remind that each sensor unit will be manufactured and calibrated under local Co-Pi responsibility. However, the PI team system calibration manager will be responsible to quick re-calibrate each delivered sensor unit, when connected to the other units at system level. This activity will be performed at the IFSI AIV facility, where a 1000 litre Ultra High Vacuum camera will be available with an ion beam source between 0.1 - 5 keV source. This Camera was already formerly used for ESA Cluster / Cis-2 analyzer testing activity (Di Lellis, 1993)

2.2.3 Key Personnel

Table 2.2. Key personnel address list

Position	**Name**	Affiliation	e-mail
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3 Instrument description and spacecraft interfaces

3.1 Scientific objectives

3.1.1 Introduction

The proposed NSWD - SCENARIO (Neutral Solar Wind Detector - Solar Corona ENA Radiation Imagine Observer) will detect and characterize the neutral component of the solar wind in the inner heliosphere for the first time. The proposed observation will directly contribute to three of the four scientific goals of the Solar Orbiter presented in the AO:

- Determine the properties, dynamics and interactions of plasma, fields and particles in the near-Sun heliosphere;
- Investigate the links between the solar surface, corona and inner heliosphere;
- Explore, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun’s magnetized atmosphere.

In order to fulfil the listed tasks, *in situ* analysis of the solar wind electron and ion populations is not sufficient; hence, we propose this further investigation of the solar wind ‘zero-charge state’, as a fundamental tracer for understanding the solar wind evolution from the corona to the spacecraft vantage point. Furthermore, the solar wind neutral component travels unperturbed along tens of solar radii, preserving the same properties of the solar wind at the generation point. Hence, this signal will yield important clues about the way the solar wind evolves with heliocentric distance from the Sun: such properties may be derived from the detection of the neutral solar wind at the Solar Orbiter location. Given the strong complementarity between SCENARIO and Solar Wind Analyzer (SWA) instrument in investigating the solar wind expansion and the environmental effects on its dynamics, we strongly request that SCENARIO could be eventually integrated in the SWA package. This merging is also suitable for an essential system resource savings: basically SCENARIO is a particle instrument operating in same energy ranges like all SWA analyzers; hence, it looks natural to include SCENARIO within this package by sharing a common DPU system.

3.1.2 SCENARIO Scientific Objectives

- Radial evolution of solar wind structures in the inner heliosphere

The SWA *in situ* measurements will allow estimates of solar wind (SW) evolution from a single vantage point; hence, only mixed temporal evolution will be monitored (or a mixture of temporal and spatial evolution during the non corotational phase), at a given distance from the Sun, with the goal to ‘…

provide observational constraints on kinetic plasma properties for a fundamental and detailed theoretical treatment of all aspects of coronal heating'. A crucial and fruitful complement to such measurements would come from SCENARIO SW remote sensing capability, which will give a concrete chance to expand our knowledge about SW evolution (flux intensity, energy and temperature) by means of multi-point analysis along the SW expansion path.

- Influence of CMEs on the structure of the inner heliosphere

Continuous measurements of the Neutral Solar Wind (NSW) will open a possibility to directly study the dynamics of major transient processes in otherwise inaccessible regions of propagating coronal mass ejections (CMEs). Indeed, SCENARIO will be able to observe a critical part of the energy distribution that will determine whether suprathermal tails exist in the distribution close to the Sun (15÷20 R_S) during quiet times, or just during CME events.

- Solar wind microstate evolution with radial distance

The capability of SCENARIO to detect neutral atoms coming from below 20 R_S represents a unique possibility to access to information about the kinetic state of the plasma below the Alfvén radius. This distance is also crucial for discriminating between Alfvénic turbulence propagating modes, since MHD turbulence is completely different moving across this radius.

- Acceleration and heating mechanisms that lead to coronal hole – associated fast solar wind

Remote sensing via SCENARIO measurements will allow determining spatial evolution of fast solar wind along its path inside the inner heliosphere. Thus, parallel temperature profiles versus radial distance, when compared to both SWA *in situ* measurements and coronograph data (which will be effective in perpendicular temperature estimates, see D'Amicis et al., 2007), will provide useful information on both fast streams acceleration and heating mechanisms.

- Sources of slow solar wind, and what is its temporal and spatial evolution

Similarly, remote sensing of the slow solar wind via SCENARIO measurements would allow determination of dynamics along its path inside the inner heliosphere. Hence, if SWA measurement will provide information about the location of slow solar wind sources (taking profit of the time-varying s/c position relative to Sun surface), SCENARIO will consistently support investigations about its spatial evolution.

- Sources and the global dynamics of eruptive events (CMEs) and what are their effects on the inner heliosphere

This objective may be studied by combining remote sensing the early stage of CME in UV by the coronograph on SolO and optical observations on Earth, and *in situ* measurement of energetic particles accelerated by the CME-driven shock by SWA and particle detectors located on Solar Orbiter as well as Solar Sentinels. To reach a fuller understanding of this propagating and expanding phenomenon, however, SCENARIO data will be crucial, because only direct sampling of the CME-associated ion population via ENA can we discern the evolution of the shock before it passes by the *in situ* particle detectors.

- Nature of coronal hole boundaries, how do they evolve and how do they project into the inner heliosphere

The evolution of SW shock boundaries is usually monitored by *in situ* plasma measurements, taking advantage of spacecraft motion and/or temporal variations, but nevertheless only one point in space. SCENARIO, on the other hand, by measuring plasma at a distance via ENA, will permit a third kind of investigation of the temporal development of coronal hole boundaries. In fact, the angular resolution of the neutral flux can yield information about the solar wind properties at different distances. Hence, thanks to the NSW flow direction angular scanning, possible locations of SW regimes upstream as well as downstream the shock boundary will be monitored at the same time.

Other Scientific Objectives are: *In situ* characterization of the Solar Wind; Distribution and intensity of the inner source ENA radiation from other heliospheric sources

3.1.3 Required performances of the SCENARIO experiment

Summary table for Scientific Performance Requirements

Scientific Objective	**Expected flux (cm^{-2} s^{-1})**	**Energy range (keV)**	**Energy resolution (dE/E)**	**Minimum FOV (°)**	**Angular resolution (°)**	**Time resolution (m)**
Radial evolution of solar wind structures in the inner heliosphere	$10^3 \div 10^4$	0.5 ÷ 2	25 %	~10×10	~2	≤60
Influence of CMEs on the structure of the inner heliosphere	$10^3 \div 10^6$	1÷5	25 %	~5×5	~1	≤10
Solar wind microstate evolution with radial distance	10^3	0.5 ÷ 2	25 %	~10×10	~2	≤60
Acceleration and heating mechanisms that lead to coronal hole –associated fast solar wind	10^3	1 ÷ 5	25 %	~5×5	~1	≤60
Sources of slow solar wind, and what is its temporal and spatial evolution	10^4	0.5 ÷ 2	25 %	~10×10	~2	≤60
Sources and the global dynamics of eruptive events (CMEs) and what are their effects on the inner heliosphere	$10^3 \div 10^6$	2 ÷ 5	25 %	~5×5	~1	≤60
Nature of coronal hole boundaries, how do they evolve and how do they project into the inner heliosphere	10^3	0.5 ÷ 2	25 %	~5×5	~1	≤60
***In situ* characterization of the Solar Wind**	10^4	0.5 ÷ 5	25 %	N/A	N/A	≤60
Distribution and intensity of the inner source	10^4	0.5 ÷ 2	25 %	~10×10	~2	≤60
ENA radiation from other heliospheric sources	N/A	0.5 ÷ 5	25 %	N/A	N/A	N/A

3.2 Performance overview

With reference to the above scientific goals, the NSWD instrument on the Solar Orbiter would have the following parameters:

- Energy/nuc range: 0.1 to 5 keV/nuc.
- Energy resolution: 25%.
- Field of view of the NSWD should be centered at about 15° off the spacecraft-Sun-centre line to avoid direct sunlight; FOV: 12° x 5°.
- Angular resolution 1° x 5°.

Instantaneously, the NSWD optical bench technology can provide a 1D FOV which could be accommodated across the plane of the S/C–Sun axis orbit. The bi-dimensional FOV can be reconstructed by scanning the instantaneous FOV within the plane, by a micro stepping motion of the bench. Thanks to the additional DOF (Degree Of Freedom) proper dwell time can be adjusted, thus compensating the S/C motion in some extent.

3.3 Instrument main characteristics

The neutral sensor concept is based on shuttered nanogratings, which can gate the incoming neutral particles impinging on the detector entrance with a definite timing. Thanks to this approach neutral atoms can be processed and discriminated from ions with appropriate electrostatic deflectors, and preserve high directional information up to the stop detector. The grating/shuttering mechanism as derived from SERENA in BepiColombo finds justification also in the NSWD for the necessity to keep very high directional scanning, to limit the UV background, and to provide a broad time correlation. These objectives well fit also with the idea to use the shutter as miniaturized scanner element able to provide a sliding 1° x 5° IFOV scanning out of 12° x 5° FOV in order to explore with high angular accuracy the neutral distribution along the aberration direction, defined by the S/C motion.

3.3.1 Functional description

Detecting and characterizing neutral atoms in the energy range of interest, 0.1 ÷ 5.0 keV, in an environment of intense photon, electron and ion fluxes, require 1) highly effective suppression of photons, electrons, ions and 2) a means to ascertain that the particle detected is indeed a neutral atom of the known energy. Before we describe the instrument SCENARIO in detail to meet these demands, we note that our unique approach is made possible by a piezo-driven, high-frequency shuttering, multiple nano-slit system, which has its heritage traced to the instrument SERENA on ESA BepiColombo mission to Mercury. The shuttering slits provide, in addition to photon suppression, a precise START mark for the time-of-flight (TOF) measurement for each incident energetic neutral atom (ENA). The technique of neutral-ion conversion surface has its heritage traced to LENA on NASA’s IMAGE. The electrostatic analyzer (ESA) can be switched on and off at fast frequency, to provide a second time coincidence. The MCP stop signal will be used with these two correlated signals to complete a triple-coincidence TOF measurement. The technique of conversion surface has its heritage traced to LENA on NASA’s IMAGE. This triple-coincident TOF system, located behind a series of charged-particle suppressing electrostatic lenses, provides a sliding 1° × 5° IFOV scanning out of 12°×5° FOV in order to explore with high angular accuracy the neutral distribution along the aberration direction, defined by the S/C motion.

The NSWD sensor consists of the following subsystems (see Figure 3.1):

- Cover (not shown)
- Lens group #1 –5kV lens
- Lens group #2 +5kV lens
- Parallel plate collimator, balanced biased +5kV –5kV
- Shuttering system
- Lens group #3 +5kV lens
- Conversion Surface
- Parallel grids ESA +3kV
- MCP detector
- 2D Anode system (not shown).

The cover protects the instrument when not in operation. The ion/electron suppression system consists of three groups of non-obstructing lens and a parallel plate collimator. Lens group #1 is at –5kV and shall suppress the incoming low-energy SW electrons. Lens group #2 is at +5kV potential; this lens group suppresses the incoming low-energy SW ions. The parallel plate

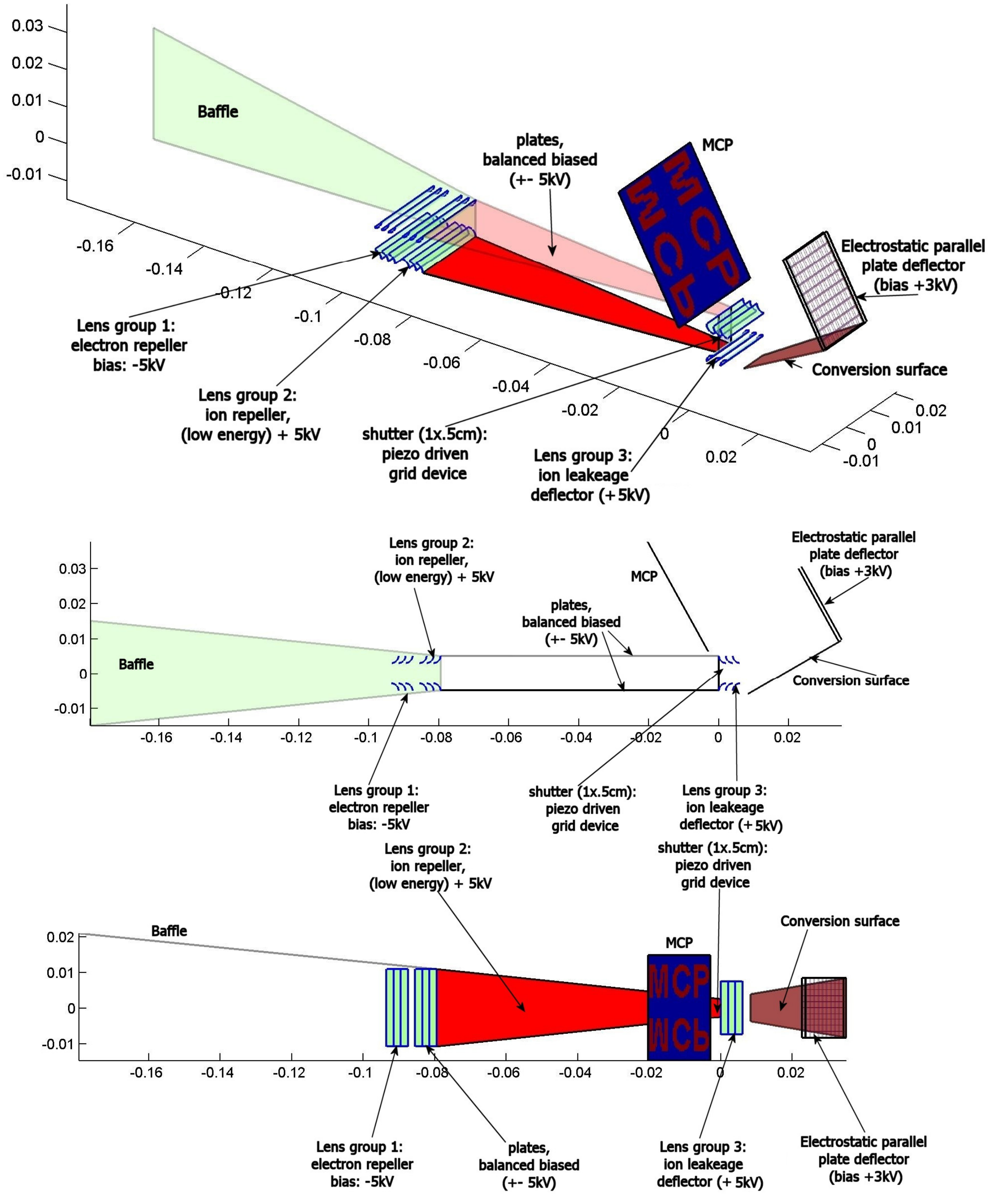
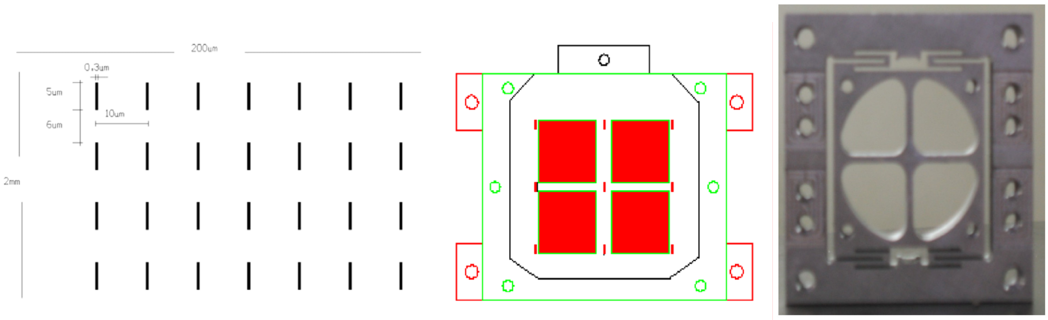


Figure 3.1. SCENARIO elements. From top: 3D view, lateral view, top view.



(A) **(B)** **(C)**

Figure 3.2. (A): Schematic view of the geometry proposed for the grids of the shuttering element of SCENARIO. See also Figure 2.3. (B): the whole SCENARIO shuttering element is made of 2 × 2 matrix. Each red area is filled by the grid in (a). (C): The actual ISC ultrasonic oscillator frame sample of ELENA.

collimator (balanced biased +5kV –5kV), further suppresses the ion/electron distributions of higher energy, not filtered by lens groups #1 and #2, thus limiting the ion/electron leakage impacting onto the following shuttering element.

The shuttering system consists of two identical sheets of nano-slits (see Figures 3.2 and 3.3). While one sheet remains stationary, the other, driven by a piezo oscillator, shuttles back and forth along the width of the slits. Grid openings are of the order of 100 nm or less to act as a filter for Lyman-alpha and other solar radiation. If the oscillator is put in high frequency mode, the alignment of the slits (with a typical duration of tens-hundreds of ns) marks and allows incidence of particles for TOF measurement. The lower limit on the TOF eliminates any photon-initiated signals in the MCP. The upper limit on the TOF sets the threshold of the ENA energy window. The slit dimension and the distance from the front aperture define the 1° x 5° IFOV. A system of piezo-electric actuators controls the relative rest position and distance of the grids. The relative alignment of the two grids can be also used to collimate the ENA flux with a 1°×5° resolution. Hence, the oscillator can be used at very low frequency to make an angular scan through the nominal FOV of 12°×5°.

In summary, the system allows, w.r.t. the neutral signal:

- to operate a slow sliding 1°×5° scanning within a 12°×5° FOV;
- optionally, to operate a fast (250 ns) shuttering along a 1°×5° specific direction;

and w.r.t. the UV environment:

- to blind the active detection system when operated in TOF mode;
- to filter Lyman-alpha and other solar radiation when operated in sliding mode.

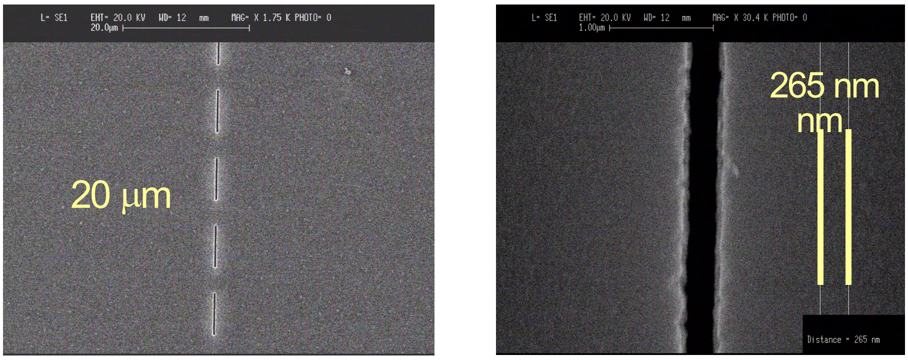


Figure 3.3 NSWD nanogratings samples: left side, first generation pattern; right side, fourth generation. Narrow slots (dark lines) are etched on a 2-inch diameter wafer, 2 µm Silicon nitride double side.

As a further ion suppression element, we include a lens group #3 (+5kV). This non-obstructing lens suppresses ions originated on or close to the shuttering system and introduces a further defocusing element of the high-energy ion/electron leakage.

After this group of lenses, only energetic neutral atoms are able to reach the conversion surface, which converts an impacting ENA to an ion and an electron, with efficiency of the order of 5%.

The emitted electrons are removed thanks to a +100V collector plate, not obstructing any particle path. The ions are emitted at approximately mirroring angles and enter in the parallel grids ESA. The ESA is a high transmittivity electrostatic analyzer, which can be operated in three basic modes:

- fixed biasing, providing the neutral energy dispersion within a range 100 eV ÷ 5 keV focusing the output beam on the MCP target without the need of stepping energy; all ions are deflected.

- on/off mode, to provide neutral energy dispersion combined with a TOF start information; ions are deflected depending on what time they enter the analyzer.

- stepping voltage, acting as a "low pass energy filter", to provide the integral energy distribution function; ions are deflected depending on their energy.

In all cases, deflected ions fly towards the MCP detector, which releases an electron pulse onto a multi-anode discrete system mapping the hit position on a 2D array. The MCP provides the STOP timing when ESA is operated in ON/OFF mode. The 2D Anode system utilizes a low-noise, low-power multi-channel front-end integrated circuits (ASICs), which process in parallel the multi-anode position detection system. Upon signal detection above the adjustable threshold, the circuits respond with sending out the energy- and position-information of the hit channel. Up to 128 channels for each chip are accommodated in a single device, thus providing more than 10×10 mapping.

Taking into account the instrument described elements, we estimate an overall geometrical factor of the order of 2 10^{-3} cm^2. Since the flux is highly collimated (generally expressed in cm^{-2} s^{-1}, see tables in the Scientific Objective Section), this number can be used as a reference to be directly multiplied times the fluxes to obtain count rates. If we include the FOV angle, the value is 4 10^{-5} cm^2 sr.

An external baffle plates can be foreseen to keep out solar UV. The direct solar radiation is blocked by the Solar Orbiter sunshield (making use of the aberration of particles up to 8°). For the suppression of scattered light within the collimator, the plates could be covered with sawtooth-like structures.

3.3.1.1 Optical concept

One of the major merits of the nano-grid shuttering geometry is the capability to block the UV light by default, thanks to the minimal width of the slit apertures (goal width <100nm) which may stops photons Lyman-α in a ratio better than 10^{-5} according to M. Gruntman (Applied Optics, v.36, No.10, 2203-2205, 1997). The residual transmitted photons are in principle not distinguishable from neutrals, but due to the regular grating structure they are focused on precise localized diffraction spots, which may be blinded on the detector, as shown in study case performed on one of the manufactured grating.

The leakage photons remain accumulated when detected (in a further reduction ratio of the order of 10^{-2}) in the first slot of the measured velocity distribution and therefore can be used as "marker" and easily stripped out from the statistics. A further UV light removal can be also achieved by coupling a second shutter moved by the same ultrasonic engine, but offering the opening state slightly

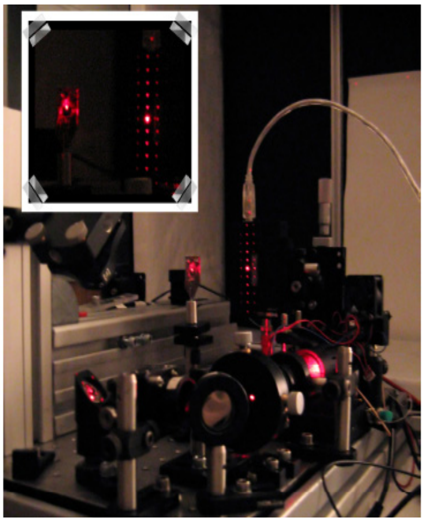


Figure 3.4. The test grating has 750nm wide apertures arranged in a regular pattern. In the final arrangement the ratio Lyman-alpha/(aperture-width) is of the order between one and one-half, therefore significant tests can be performed using ordinary light in the visible range, between 350nm and 700nm, due to the scaling properties of optical diffraction. Experiment set-up: Laser source 670nm Power Technology – mod PPMT- 10mW@670nm. Silicon detector Equipped with a condenser lens. CCD linear array Thorlabs - LC1-USB - USB 2.0 Line Camera.

later with respect to the main entrance shutter thus shadowing completely the MCP detector to the external UV environment.

All the NSWD operations are managed by an FPGA based microcontroller (Sensor Control Unit - SCU). It controls the switching of the power to the individual subsystem (e.g. HV blocks), samples the data, provides internal intermediate storage and data transfer to the external S/C SpaceWire interface or an external hosting DPU, being supposed at this time to be the DPU of the SWA package. NSWD will benefit of the inheritance from the SERENA BepiColombo design of the system control and power distribution unit.

3.3.2 Software description

The on board management and data processing are performed by a combination of H/W (FPGA) and S/W, resident in the SCU. The NSWD specific Data Handling System (DHS), consists of a VHDL coded based microcontroller which operates as main high-reliability processor which will work as main NSWD IFE.

In general, the software will be divided into an execution and an application software. The execution S/W will provide the Real Time Operating System (RTOS) kernel, as embedded functionality for the processor.

More detail can be found in Section 4.6

3.4 Operational Modes

3.4.1 Instrument operation concept

In order to achieve an efficient use of both the observation time and the telemetry/telecommand (TM/TC) allocation, several autonomous functions will be implemented. Al thought NSWD will not be able to execute time tag commands, when it has been switched in one of the science modes or in a diagnostic mode, it will not require further commands for operating and producing science data. The instrument modes will run automatically according to pre-defined configurations, procedures and timelines: this means that the instrument will organise the internal operation (functionally and timely) by itself, independent from the S/C. The functional sequences will be commanded by TC packets as a self consistent task for instrument operation. These sequences will be performed by means of several types of TCs.

3.4.2 Operational modes description

The SCENARIO sensor shuttering system may be set into at least three different configurations:

- rest position (high transparency mode, low angular resolution);

- low-frequency (used as a collimator, with azimuth angular scanning within 12°, high angular resolution);
- high-frequency (used as START signal).

The electrostatic mirror (located just after the ionizing surface) can operate according to three different approaches:

- fixed (highest voltage, for maximum efficiency);
- stepping (for resolving energy steps of energy resolution of about 25%);
- on/off (electronic gate at high frequency), to provide triple-coincidence ToF measurements.

Besides these basic, both the ESA and the shutter system can be set in "calibration" mode: for example, closing the shutter, and switching off the ESA voltage, to study the background/noise signal.

3.4.3 Telemetry modes

For each of the operative modes described in the previous sections, NSWD can use two basic telemetry modes: raw mode and binning mode. In raw mode, each particle targeting is processed separately and results in a telemetry event of 4 bits (angular scanning) + 12 bits (ToF1) + 2 bits (Coincidence) + 7 bits (128 Chs., MCP anode information). Considering an average countrate up to100 s^{-1}, the telemetry bitrate is up to 2500 b/s; considering an extreme event, with a countrate of 1000 s^{-1}, the highest telemetry bitrate is 25000 b/s.

In triple coincidence mode, additional 12 bits ToF information is foreseen, but the angular scanning is disabled (angle is resolved by means of the MCP anode information). Hence, the telemetry bitrate is (12+12+2+7)x100=3300 b/s.

In binning mode, a matrix of up to 128 ToF or energy channels, and up to 12 angular channel is transmitted, i.e. a maximum of 128x12=1536 channels. Assuming 8 bits for each channel (log compression), and for a nominal resolution time of 60 s, this results in a maximum bitrate of 205 b/s. Different configuration of the bin matrix can be used, resulting in different bitrates. The nominal mode foresees 16 energy channels x12 angular sectors x16 bit/channel. With a time resolution of 60 s, the bitrate is 50 b/s.

3.4.4 Compliance with S/C resources

The power consumption would be about 6 W in nominal mode. The required telemetry rate is about 100 bit/s in Nominal science mode without having applied the savings supported by several compression routines already available for the team.

3.5 Compliance with spacecraft dynamic environment

The instrument points 15° off the S/C-Sun axis in the plane of the orbit. The field of view is 12° (along the orbital plane) x 5° (out of the plane). NSDW should be S/C face pointing towards the Sun, with an offset angle of 15°. An alternative, possible accommodation would be the +Y panel, in a position behind the sunshield and with an unobstructed field of view of ± 6°, 15° off the S/C - Sun axis in the Sun-Satellite plane and about ± 5° out of the plane (see Figures 3.5 and 3.6).

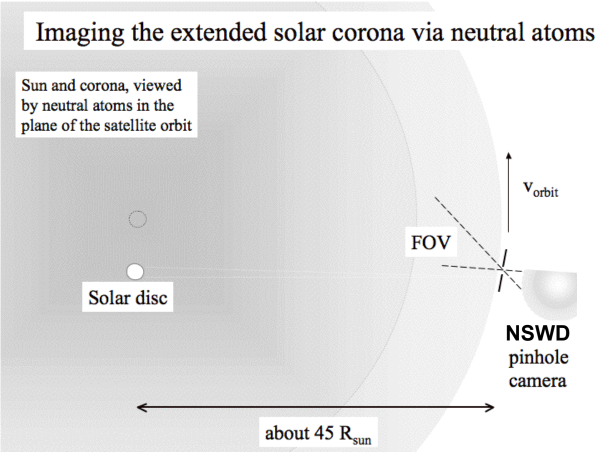


Figure 3.5. NSWD FOV orientation. Instrument schematics and field of view of the Neutral Solar Wind Detector. The aberration causes the shift of the "neutral solar wind" image of the corona off the Ly-α corona (shown for v_{sw} = 400 km/s, v_{orbit} = 65 km/s).

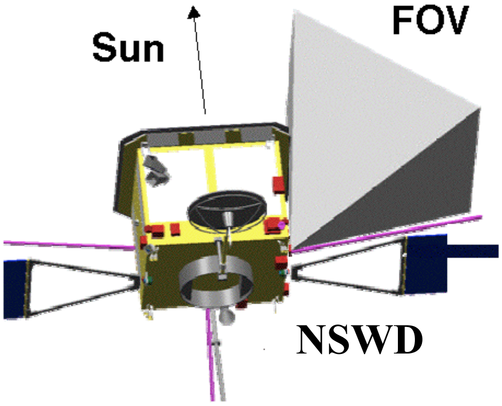


Figure 3.6. Potential instrument location on Solar Orbiter and field of view of NSWD.

3.6 Instrument data sheet

	Parameter	**Units**	**Value/Description**	**Remarks**
General	Reference P/L	NSWD	SO-NSW-RS-002	EIDB
	Type of optics	N/A	Pin Hole	
	Type of camera	N/A	TOF Chamber	Time shuttered
Instrument optics	Aperture (longest dim)	mm	25	Rectangular aperture of 10x25 mm^2
	Focal length	mm	130	TOF length
	Focal number	N/A	N/A	
	Field of view		12° × 5°	12° along orbital plane
	Pixel IFOV		1° × 5°	
	Spectral range	keV	0.1 ÷ 5	
	Filter bandwidth	nm	N/A	
	Energy/ToF Channels	#	16÷128	Nominal mode
	Geom. Factor	cm^2	2×10^{-3}	
	Geom. Factor	cm^2 sr	4×10^{-5}	
	Dynamic range	cts/ cm^2 sr*keV	$10^3 \div 10^7$	
Instrument performances	Pixel lines	#	16	used for Energy
	Pixels per line	#	8	used for Azimuth in low angular resolution, when not operating the grid scanning.
	Pixel pitch	m	1500	
	Peak quantum efficiency	%	>50%	E.g. Burle 'Long Life' MCPs
	Exposure time	s	60	
Instrument resolution	Energy resolution	dE/E	25%	
	Angular resolution	µrad/px	1500	
Instrument physical properties	Mass, total (protection baffle NOT included)	g	1559	Including 20% Cont., (excluding DPU hopefully provided by SWA package)
	Mass, optics	g	339.7	
	Mass, box	g	556.3	
	Mass, electronics	g	600	
	Dimension (box)	mm^3	200 × 115 × 75	
	Baffle length	cm	7.5	Shadowing direct solar view.
Instrument power requirements	Average power	W	6.6	On Primary (DC-DC 75% efficiency)
	Installed Heater Power	W	N/A	
Instrument Data requirements	Time/imaging sequence	s	60	Science Mode: Nominal Mode
	Data rate to Orbiter OBDH	bps	50+50	Science Mode: Nominal Mode, 12 Pix × 16 Ene_chs × 16 bit / 60 s + HK & Conting: 50 b/s+50 b/s

4 Interface definition

4.1 Definition of Instrument Identification and Labelling

The instrument is labelled as NSWD.

4.2 Definition of Instrument Lifetime, Maintainability and Fault Tolerance

The instrument will survive for all the phases (launch, cruising, and for all the nominal operation of the mission). At presence, NSWD, being an argumentation payload in the AO proposal package, does not foreseen any redundancy, in order to save s/c budget resourced.

4.3 Definition of coordinate system for instrument and instrument units

4.3.1 S/C reference coordinate system

In the following pictures the outlined shape of the NSWD box is given. The Unit Reference Point (URP) is located onto the centre of the front-left fixation hole. The two connectors in the back panel map on the left side (DB9) the communication SpaceWire I/F to the hosting DPU candidate electronics, supposed to be at this time the SWA package DPU. On the right there is the Power I/F connector (DB15) which houses both the input Main & Redundant power lines. On the right side of the same panel is also located the ground reference stud. On the front panel is visible the neutral particles opening. The yellow dotted line represents the preferred side of an obstacle baffle to the solar illumination.

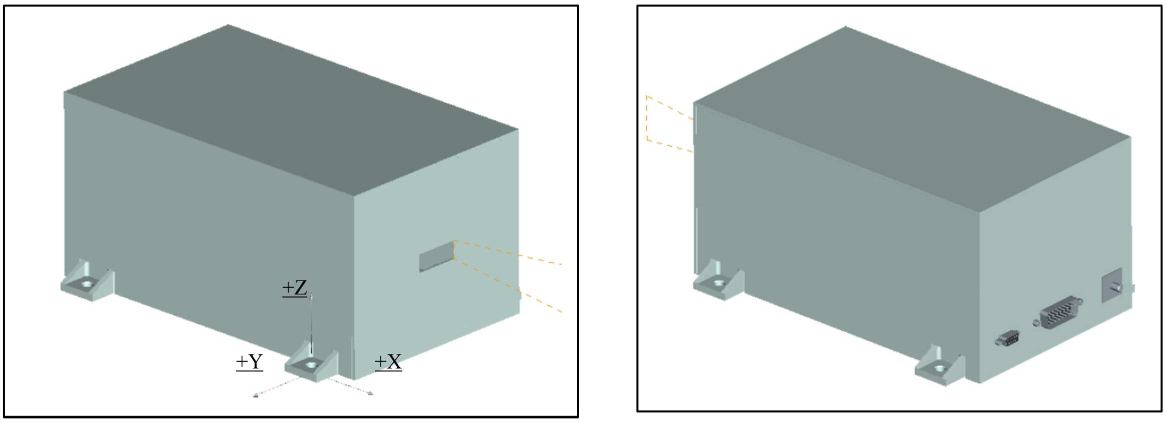


Figure 4.1. NSWD box view for the baseline mounting plate parallel to the payload deck S/C plane.

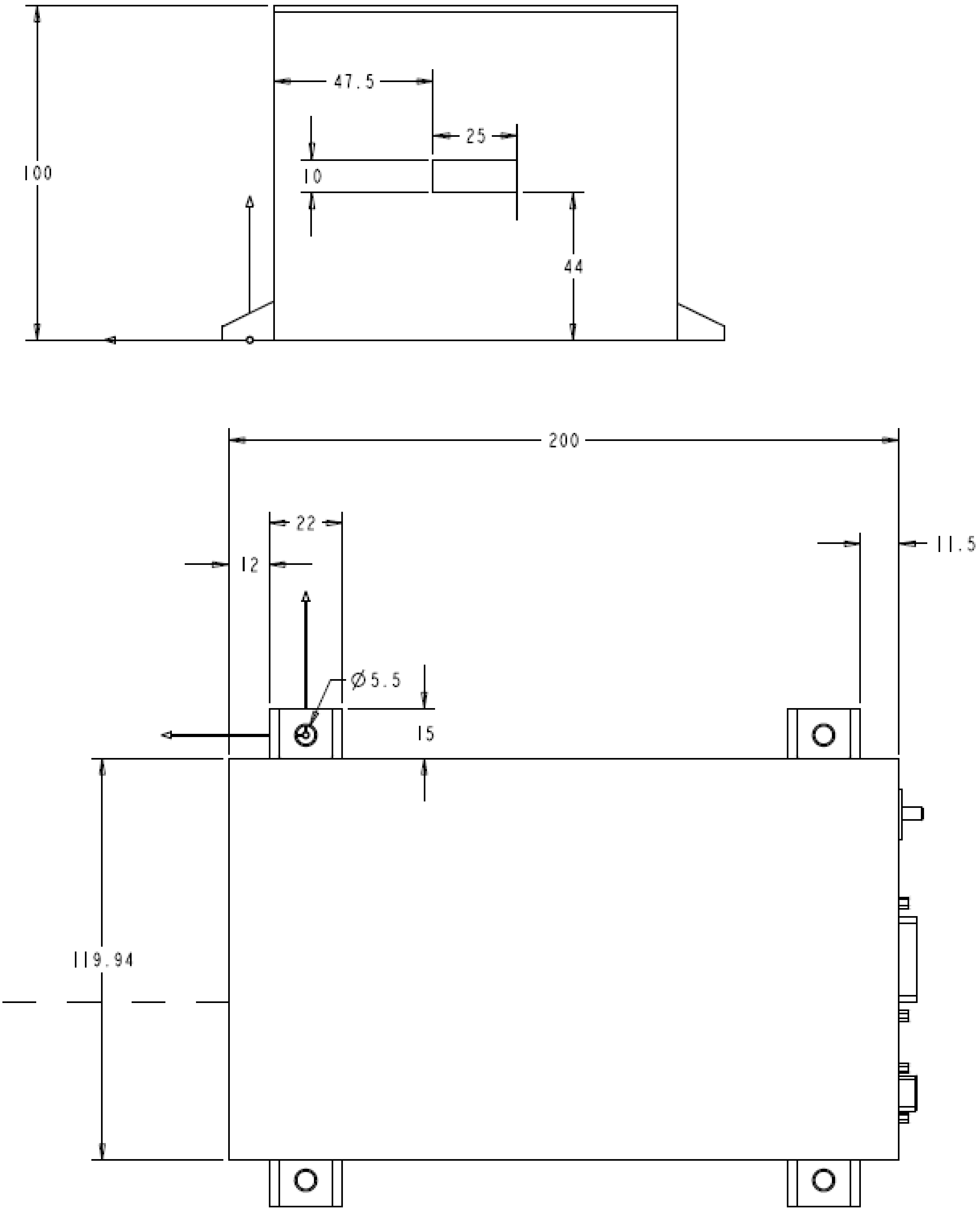


Figure 4.2. NSWD box views**.**

4.3.2 Configuration requirements

4.3.3 Instrument arrangement

Aluminium alloy box with the following dimensions:

- X_{URF} direction: 200.0 mm
- Y_{URF} direction: 120.0 mm
- Z_{URF} direction: 100.0 mm

4.3.4 Instrument aperture

- Plane of location: YZ
- Y dimension: 25 mm
- Z dimension: 10 mm

The aperture surface will be covered with a baffle system designed to reject most part of the incoming radiation as portrayed in Figure 4.3.

4.3.5 Instrument Alignment

The instrument points 15° off the S/C-Sun axis in the plane of the orbit. The field of view is 12° in the S/C orbit plane and about ±2.5° out of the plane. The pixel intrinsic field-of-view (IFOV) is 1° × 5° and the whole instantaneous one-dimensional FOV is composed by 12 pixels in the sun-satellite plane and offset by 15° thus giving a 9° to 21° degrees coverage. This global view can be also scanned, when the sensor optics is running in High Angular resolution mode, by controlling the nanoshutters alignment.

The NSWD sensor foresight has to be co-aligned to other remote sensing instruments, with accuracy within 0.25°. The aperture must be unobstructed at

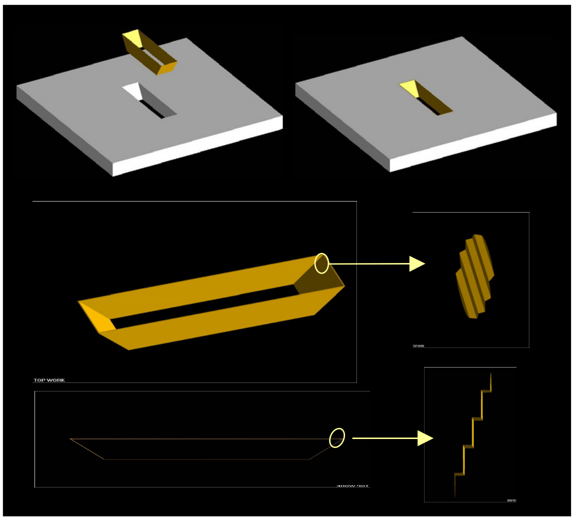


Figure 4.3. Design of the NSWD baffle to be hosted around the opening of the instrument

all times. The NSWD optics will be internally aligned to such main NSWD aperture. The pointing and alignments accuracy shall be referenced to this opening and will be within 0.25°.

4.3.6 Mechanical Environment

The NSWD box will be a self-consistent assembly. Structural model analysis will be performed to identify the main structural relevant points.

4.3.7 Structural Design

From a mechanical point of view, the instrument can be divided in four main modules:

- Collimation Bank,
- Ultrasonic Oscillator,
- Deflecting Plates,
- Detecting Device,

plus several electronics board of shape and size listed in the next table.

4.3.8 NSWD Mass properties

NSWD UNIT				
ITEM	**Q.ty**	**MASS**	**Contingency**	**Mass incl. Cont.**
		[g]	**20% [g]**	**20% [g]**
SENSOR MECHANICHS				
Lens group 1	1	30.0	6.0	36.0
Lens group 2	1	30.0	6.0	36.0
Plates Bearing	4	3.5	0.7	4.2
Plates Guides	4	6.8	1.4	8.2
Plates	2	55.0	11.0	66.0
Ultrasonic Oscillator	1	40.0	8.0	48.0
Lens group 3	1	30.0	6.0	36.0
Conversion Surface	1	2.8	0.6	3.4
ESA Grid + Bearing	1	25.0	5.0	30.0
MCP 1 Stop detecor + Anode	1	60.0	12.0	72.0
NSWD BOX				
Base	1	132.0	26.4	158.4
Box Top Cover	1	42.0	8.4	50.4
Later wall 1	1	65.0	13.0	78.0
Lateral wall 2	1	65.0	13.0	78.0
Connector Box wall	1	48.0	9.6	57.6
Aperture wall	1	39.0	7.8	46.8
Locking Screws				
M3x6	24	22.8	4.6	27.4
Bearings				
High Voltage cards bearing	24	31.2	6.2	37.4

Sequencer/Communication Card	4	5.2	1.0	6.2
Encoder/decoder & Control	4	5.2	1.0	6.2
Prox Electronics bearing	4	5.2	1.0	6.2
Ultrasonic Oscillator bearing	4	3.0	0.6	3.6
ELECTRONICS				
HIGH VOLT Cards ($30x75x15mm^3$)	5	175.0	35.0	210.0
Piezo Driver ($50x150x10mm^3$)	1	75.0	15.0	90.0
Encoder/decoder & Control (50x150x10mm^3)	1	75.0	15.0	90.0
DC-DC Power Supply & Sequencer ($160x100x15mm^3$)	1	150.0	30.0	180.0
Proximity electronics ($150x15x5mm^3$)	1	25.0	5.0	30.0
CONNECTORS				
15 pin MALE	2	15.0	3.0	18.0
9 pin mini MALE	3	10.5	2.1	12.6
TOTALS				
TOTAL OPTICS	N/A	283.1	56.6	339.7
TOTAL BOX	N/A	463.6	92.7	556.3
TOTAL ELECTRONICS	N/A	500.0	100.0	600.0
TOTAL NSWD BOX		**1272.2**	**254.4**	**1526.6**
BUFFLE*				
Ext Collimator – body	1	12.5	2.5	15.0
Ext Collimator – plating	1	14.5	2.9	17.4
TOTAL SCENARIO		**1299.2**	**259.8**	**1559.0**
*Required if S/C body is not providing sun shielding in the instrument FOV				

Table 4.1. NSWD Mass budget

4.3.9 Mechanisms Design

In the frame of the technologies developed for the SERENA, instrument on-board the ESA BepiColombo MPO S/C, the NSWD will host an ultrasonic oscillator of similar characteristics. The highest NSWD transferred momentum by the ultrasonic shutter is:

2.65 10^{-7} Kg m s^{-1}

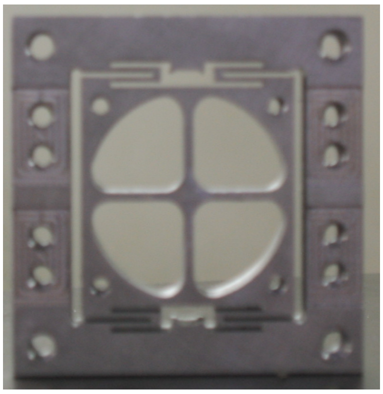


Figure 4.4. ISC ultrasonic oscillator frame sample**.**

Presently, CNR-ISC has investigated a compact structure to include the grid frame carrier as piezo engine pre-loading structure, thus minimizing dimension and weight. In this version multilayer piezo stacks, cofired with ceramic encapsulation and with extreme lifetime, have been chosen to combine ultra-high performance with long lifetime in a few mm^3 part. Several tests are running in house to optimize the performances and the mechanical oscillation stability, and for examining the vibration disturbances that the devices may introduce during its operations.

Mathematical models have been implemented for defining and optimizing the part stresses and study the frequency response. ISC has refined the mechanical simulation of the structure of ultrasonic payload. Examples of such simulation are provided below.

4.3.10 Mounting Attachment and Handling

The instrument will be fixed to the S/C payload deck by 4 attachment lugs with M5 screws (see Figure 4.2). Design of the lugs, tolerances in holes position and dimensions, feet planarity, are intended to comply with EID-A Mounting Points Loading requirements.

The reference hole is also defined in Figure 4.3. No thermal isolation is needed at the interface.

4.3.11 Aperture Cover

A NSWD covering mechanism, housed close to the main aperture entrance will protect sensor during the ground and the launch operations. The design of the cover will be finalised in a later stage.

4.3.12 Electrical Connectors Mechanical Accommodation

NSWD hosts two connectors which are visible to the front panel (see Figure 4.2). Namely:

- a 15 pins male for Main & Redu power supply I/F (Baseline - DEM15PZNMBK52).
- a 9 pins Male for Main SpaceWire I/F (Baseline – DEM9PZNMBK52)

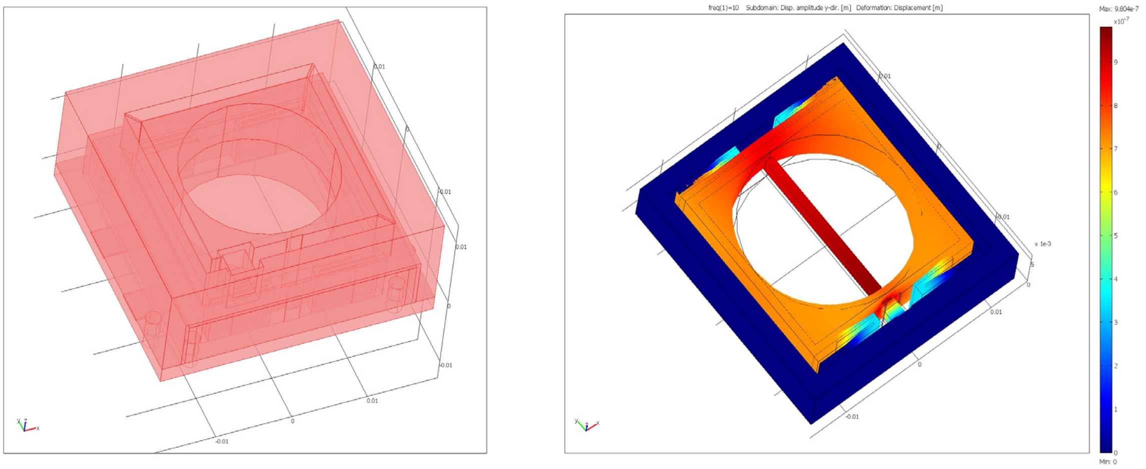


Figure 4.5. ISC ultrasonic oscillator: (left) complete frame, (right) structural analysis**.**

4.3.13 Purging Interfaces

NSWD hosts on set of MCPs devices in “Chevron” configuration, which require purging with 99.99% clean dry nitrogen gas, when NSWD is out of its shipping container. The aperture cover mentioned in par. 4.3.13 will also work as a sealing system for the purging gas flow. A purging system adapter (Swagelok tube male fitting 1/4") will be available. The Nitrogen consumption is foreseen to be of 4 l/h ± 1l/h

4.3.14 Description of S/C Dynamic Environment

The baseline SOLO orbit is appropriate for the NSW velocity distribution reconstruction and in particular for the H allowing with the remote sensing the three-dimensional coronal distribution reconstruction. There are no further specific requirements for the operational foreseen scenario.

4.4 NSWD Thermal Design and Interface Description

4.4.1 Sensor Thermal Control Definitions and Responsibilities

The NSWD sensor box shall be collectively thermally controlled. The sensor shall accept a medium temperature range: operational over the mission profiler between -20 and +40 °C, non-operational between -40 and +50 °C. Thermal control of NSWD will be provided internally according to the location of sensor and thermal resistances between sensor parts and the spacecraft.

The sensor does not require any cryogenic interface.

4.4.2 Thermal environment

The thermal environment will be that provided by the Solar Orbiter mission profile and by the instrument accommodation within the S/C in this respect the following thermal aspect are discussed in some detail in the next paragraphs.

4.4.2.1 Sensor Thermal Design

The aperture of the sensor shall be protected during the mission operations from a direct sun view by a baffle protruding from the front panel (unless the S/C body provides a similar shielding). Apart for the environmental contributed heat, NSWD houses two thermal relevant parts namely

- the ultrasonic oscillator
- DC-DC converter supply

for which an appropriate heat drawing will be provided. All of these heat-generating devices will be coupled to the sensor case in order to optimise the transfer of the heat flux to the attachment lugs.

4.4.2.2 Thermal Interfaces – Temperatures and Energy Budgets

The main heat loads on the sensors can be simplified as follows:

Environmental-direct Sun view (w.o. any baffle protection):

Incoming radiation (max foreseen) 2.7 W/cm^2

Sensor aperture area: 2.5 cm^2.

Overall environmental max thermal input: 6.75 W

The above figure is derived from a direct Sun observation, which is considered a forbidden attitude for the sensor. In the correct attitude, only the Corona is in view of the instrument and the above figure scales to:

Overall environmental max thermal input < 60mW

Internal heat generation:

- Piezo actuator - power consumption: 1.2 W
- DC/DC converter - thermal dissipation: 2 W
- Other electronics elements: 4.9 W
- Overall thermal input: 8.76 W

4.4.3 Compliance to Thermal Interfaces Requirements

The NSWD with its ultrasonic engine will be full qualified for this application according to the SOLO mission thermal interface requirements.

4.4.4 Thermal Hardware Interfaces

NSWD will not require any internal S/C controlled thermistor, but the NSWD box reference point temperature shall be provided with an accuracy of ± 2.5°.

4.4.5 Thermal Mathematical Models

The sensor will be divided into sub-units, according to the thermal behaviour of each component. Each sub-unit will be simplified by a discrete number of nodes allowing the creation and analysis of the thermal model of the sensor. By the PDR, a first NSWD thermal model will be assessed with a limited number of nodes while a more refined model will be developed before the STM delivery.

4.5 Electrical Design and Interface Requirements

4.5.1 Electrical Power Design and Interface Requirements

4.5.1.1 Definitions

The NSWD primary power is a $+28V_{DC}$ (Min +26.4V – Max +29V) regulated bus form SOLO S/C. NSWD is powered by the S/C *Power Distribution Unit* (PDU) via the Latching Current Limiters (LCLs) thus having a maximum current limitation and automatic disconnection in case of overload.
All NSWD parts will survive to a Main S/C bus power standing levels and to fluctuations between 0V and +32V or instantaneous short circuit of the primary bus. Instrument will receive power from the primary and redundant S/C power bus through separate connectors and power cross strap will be provided in the NSWD local power interface unit.
The NSWD current, drawn with all the operated modules, will not exceed **1.0A** at a S/C bus voltage of $+26.4V_{DC}$ at the end of life. The average power will be **6.6W,** in nominal mode.

4.5.1.2 Power Conversion and Distribution Architecture

The NSWD +28VDC power input will be down converted to the needed lower voltage buses by means of DC-DC modules not synchronised running with a free internal pulse width modulation clock.

For EMI reduction, each internally routed primary bus will be preliminary filtered by common mode (CM) / differential mode (DM) Balun / L-C filters. Balun filters will be realised by ferromagnetic toroid coils, for magnetic cleanliness, no open ferrite will be used for implementing the filtering circuits.

For the switch control and for power limiting shown in the above block diagram we foresee a circuit as it follows:

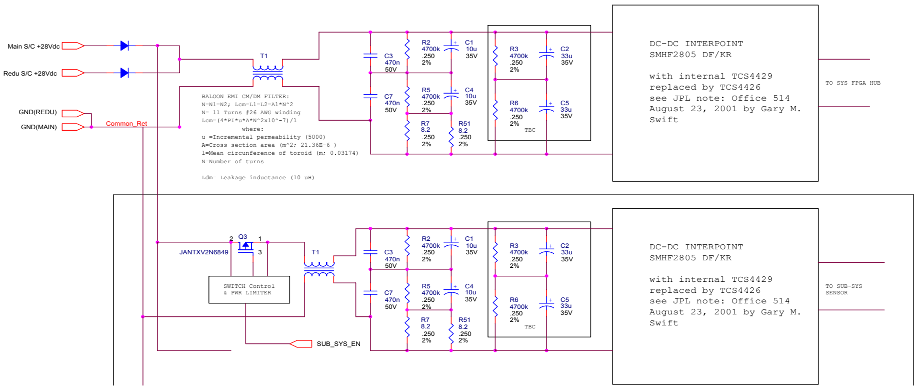


Figure 4.6. NSWD power distribution block diagram**.**

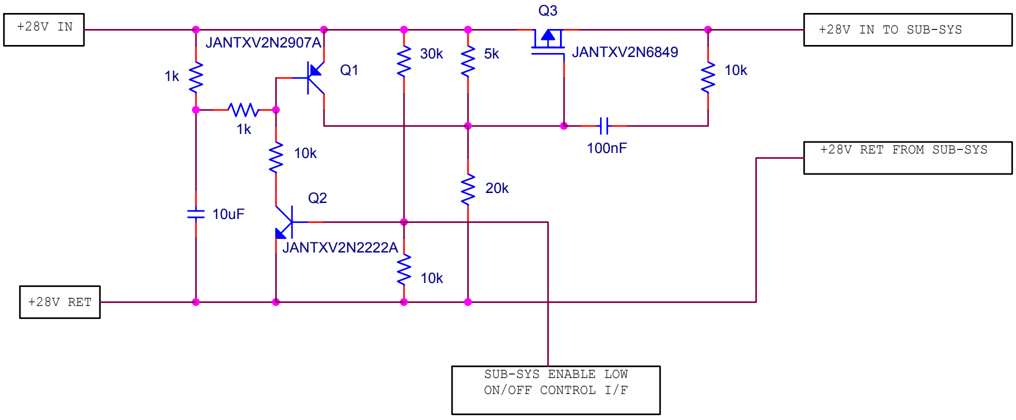


Figure 4.6. SWD Sub-System power control diagram.

4.5.1.3 Required Power Interfaces (lines)

The NSWD will require both the main +28V_{DC} power bus and the +28V_{DC} redundant bus for operation. NSWD will not be directly interfaced to the *Pyro interface* and *Transistor switches* power buses of the MPO S/C.

4.5.1.4 Power Interface Characteristics

The NSWD overall in-rush current will be compliant with MPO LCL class 2 devices. At power on only the NSWD system FPGA based controller will be activated. Following the reception of a dedicated ON/OFF command from the S/C SpaceWire I/F the addressed sub-unit will be powered.

4.5.1.5 Budgets

The following CBEs for the different modes in which sensor heads are operated is foreseen. Power estimations are referred at the primary bus assuming 75% of DC-DCs converter average efficiencies.

Table 3.4.1 - Summary Table of the CBEs NSWD power needs

	MODE NOMINAL [W]	**MODE LO FREQ / HIGH ANGULAR RES**	**MODE HI FREQ [W]**	**MODE DIAGNOSTIC [W]**
	AVERAGE* PEAK**	AVERAGE PEAK	AVERAGE PEAK	AVERAGE PEAK
TOTAL	6.6 7.2	7.2 8.0	8.1 9.0	3.8 4.7

AVERAGE*: The value presented is the foreseen maximum average. In nominal mode the ultrasonic engine is in OFF state

PEAK**: All peaks are concerning short peaks, i.e.: peaked power demanding lasting less than 100ms.

4.5.1.6 Long Peak estimations

Long peak estimations of power concerns only the following operations on NSWD subsystems parts.

4.5.1.6.1 *Not recurrent and performed in BOL conditions*

NSWD Cover protections opening	
NSWD	6.0

Note * During NSWD cover opening ultrasonic engine is in OFF state.

4.5.1.6.2 *Recurrent and performed in BOL/EOL conditions*

N/A

4.6 Instrument Software Architecture

4.6.1.1 Instrument Software Description

The on board management and data processing are performed by a combination of H/W (FPGA) and S/W, resident in the main controller. The NSWD specific Data Handling System (DHS) consists of:

A VHDL coded based microcontroller which operates as main high-reliability processor which will work as main NSWD IFE.

In general, the software will be divided into an execution and an application software. The execution S/W will provide the Real Time Operating System (RTOS) kernel, as embedded functionality for the processor.

This part of the S/W will be in charge to provide the drivers for all the H/W resources of the system, real-time scheduling and synchronization, and to support the S/C interface.

The application S/W will be the sensor and system specific code, developed for providing the science data acquisition, processing and formatting in the NSWD framework.

An additional small software kernel for performing a safe and emergency mode, named ‘diagnostic mode’, will be implemented as a third stand alone element.

4.6.1.2 Detailed Instrument Software Description

At NSWD switch on, after performing the system booting and I/O peripherals and memory checks, controller will enter into the Stand-By mode. This is a PROM like based mode not changeable in which only the uplink command processing and the downlink housekeeping reporting are provided.

Conversely Nominal (science) instrument modes procedures will reside in EEPROM. The EEPROM content at the mode switching will be copied into RAM where the S/W will be run. Code, fixed table and operative tables (context) will be always checked against appended checksums and regularly verified by a periodic task (typical period: few seconds). Each S/W module will have a module header containing information for identification and verification. The modules can be changed by ground uploading and can be verified by downloading.

The instrument modes can be executed and configured by telecommands (TCs) to achieve a defined instrument state.

The combination of the RTOS and the Application S/W residing on FPGA controller will be very simple, and reliable; it will be essentially devoted to:

- handle and verify the Ground TCs routing to the peripherals;
- collect and transmit -according to predefined polling sequences- science and housekeeping data from the sensors;
- provide controller and sensor monitoring.

4.6.1.3 Functional Requirements for System Provided Software Resources

NSWD will not internally support a mass memory device. Therefore, because of such an on-line data handling philosophy, the acquired data will be quasi-immediately transferred or shortly delayed depending of the internal data handling and compression for different data types. NSWD will minimize complex procedures (for handling and loading storing contexts) which require cumbersome ground or S/C operations. Conversely, the trajectory which brings up NSWD from its OFF state to any science mode or the diagnostic mode will be governed by a simple sequence of TCs which will have embedded all the specific configuration parameters available in the SOLO system database.

4.6.1.4 TC Packet Structure and Content

4.6.1.4.1 *TC Data Packet Structure and Contents*

TC Data Packets sent by the S/C will be received by NSWD IFE. The controller unit will decode the target destination of the addressed subsystem.
The following types of command are foreseen:
at Controller Level:

- Mode Control
- Telemetry Control
- Time Synchronization
- Diagnostic: Memory Dump, Memory Load, I/O Read Write, Processor Jump, EEPROM Context/Code Saving.

at Sensor specific Level:

- Mode Control
- Memory Load (configuration) Data for setting parameters e.g. MCP HV, Cover On, Discriminator Levels etc.

4.6.1.5 TM Packet Structure and Content

4.6.1.5.1 *TM Data Packet Structure and Contents*

Different streams of data will be generated by the sensor head

For example:

- NSWD controller (in its nominal science mode) produces a histogram data set of 12 Azimuthal Angles * 16 Energy levels * 16 bit counter in 60 s which correspond to about 50b/s bit rate.

Such data packets will be transmitted via the point to point SpaceWire downlink the S/C or the hosting DPU. Depending on the operating mode of the sensor, the contents of the data packets change from raw count rate data to a mixture of count rate data and analogue measurement data needed for calibration purposes.

Packetizing and compression into real TM packets for transmission to the S/C is assumed to be performed by the NSWD hosting DPU. Refer to par. 4.6.2.

4.6.1.5.2 *Contents of the HK packets*

HK packets contain analogue measurement data and digital status data. Digital status data include: last received command, operating mode, settings for HV supplies, timing settings, multiplexed values of LUTs etc. Analogue measurements include: high voltage monitors, low voltage monitors, and temperature sensors.

4.6.1.6 TM Parameter Description

See Section 4.6.4

4.6.1.7 Instrument Autonomy

In order to achieve an efficient use of both the observation time and the telemetry/telecommand (TM/TC) allocation, several autonomous functions will be implemented. NSWD will not be able to execute time tag commands; anyway, when switched in one of the science modes or in a diagnostic mode, it will not require further commands for operating and producing science data. The instrument modes will run automatically according to pre-defined configurations, procedures and time lines: this means that the instrument will organise the internal operation (functionally and timely) by itself, independent from the S/C. The functional sequences will be commanded by TC packets as a self consistent task for instrument operation. These sequences will be performed by means of several types of TCs.

After power-on, a start-up procedure will check the main functionality of the instrument control unit in order to ensure the nominal tasks foreseen in the stand-by mode i.e. the telecommand processing and instrument monitoring.

In a nominal situation, the sequence of events is the following:

1. After NSWD switch-on by S/C, the instrument enters the stand-by mode, including a boot procedure and RAM check.
2. In the stand-by state, it waits and it processes the initialisation TCs formatted in the TC packet.
3. By default, the first operation TC to be executed corresponds to a start of a default science mode, so that the instrument goes to the science state and produces science data.
4. The transfer to the science state consists of the following steps:
   - The controller reads the current configuration from its EEPROM and interprets only the parameter that are required to format and handle the sub-system activities.
   - The controller switches these subsystems on which are set to be active in the current configuration.
   - If the controller has checked that the initialisation of the sub-systems is OK, it enters the science state.
5. Upon reception of a no operation or configuration TC, the controller is

ready for a new reconfiguration and mode operation or waits for switch-off TC (i.e. switch off the sub-systems) in the stand-by state.

Any science modes will be selected by optionally configuration TC(s) and a operation TC, by using a pre-defined configuration table in EEPROM. The configuration tables will be located in the EEPROM, but for one located in the PROM, which describes the Diagnostic mode.

Error detection will be performed by a health or self check, by instrument monitoring or by a watch-dog. The watch-dog will detect S/W endless loops. The instrument monitoring by the S/C should be done by a watch-over function of the instrument at regular intervals.

An instrument check will be performed during the start-up procedure after power on. Furthermore, a diagnostic modes will be used for detailed instrument tests. The diagnostic modes produces test pattern and/or detailed H/K for verification purposes. In case of error a corresponding flag word will be placed in the operational HK, and the global error flag will be set until acknowledged by a special TC.

Each telecommanding will be acknowledged in the operational H/K and the instrument status will always be provided to the S/C in each instrument mode.

The current status of the instrument will always be kept in the before power-off. This status can only be cleared by a special TC.

4.6.1.8 Instrument Specific Software

No request.

4.6.2 Telemetry Description

4.6.3 General

NSWD will produce two main Telemetry (TM) streams. The science TM represents the scientific performance of the instrument. The other main part consists of all the additional information necessary to evaluate the instrument operation.

Spacecraft operations during all the active mission phases will be carried out with an ‘off-line’ approach. NSWD will not have the capability for time-tagged execution of telecommands.

The telemetry evaluation on ground will be mainly off-line, with limited possibility of quasi-real-time control. Hence, anomalies will be detected with a delay. NSWD will be able to detect instrument failures and, in case of a critical one, it will be put into a Diagnostic mode.

The NSWD science data will be processed on-line and transferred to the S/C mass memory, where they will be buffered for subsequent transmission to the ground segment.

Because of no processing of the science TM data at the ground control centre, any information that is needed to carry out nominal and contingency operations on NSWD will be included either in Housekeeping TM packets or in Report TM packets (TBC).

4.6.4 Science Telemetry

NSWD will transmit the science data (including calibration data and test pattern) in small and self consistent TM packets in order to prevent loss of large amount of data due to transmission failures. In the frame of the on-line data handling philosophy, the acquired data will be quasi-immediately transferred, or shortly delayed, depending on the internal data handling and compression of the different data types.

Related to the TM behaviour, the on-board data handling can be divided in: data acquisition, and data transfer to the S/C. A self-consistent data set (e.g. Mass histogram) will be collected on ground.

The science data for the different data channels are separated in different TM packets identifiers. One data acquisition from each unit sensor constitutes of a complete set of parameter information and science data which is transferred by a common application identity (APID) and split in several TM packets (Transfer Units). The result of some data acquisitions causes the transfer of a first packet, in which all the relevant parameters of the acquisition are embedded. Then several data is appended to this packet and to the following TM packets, according to the TM packets granularity (Transfer Units) established by the S/C protocol.

The TM packet contains the following information (TBC):

- Type of packet
- Size
- Time-stamp(s)
- Sequence number of the Packet in the acquisition frame
- Acquisition unit number
- Mode
- Data compression type
- Binning summing parameter
- Spectral mask
- Gain selection
- Integration time
- Inter-frame delay
- Inter-scan delay
- Calibration devices status

4.6.5 Other Telemetry

There will be other TM packets, which are different from the Science data TM packets. These are: Housekeeping, Report (TBC), Diagnostic and Memory dump TM packets (TBC), which will be produced independently from the

Science data TM packets. Additional packet types are TBD.

4.6.5.1 Housekeeping TM packet

The acquisition of the HK, together with a health check, will be cyclically performed in each instrument state and mode. After each acquisition, a Housekeeping TM packet will be generated, which represents the health and safe working of the instrument.

The following information (TBC) and housekeeping are contained in this packet:

- Size
- Timestamp
- Temperature values
- Voltages and currents
- Sub-system and interface status
- Telecommand execution status
- Current instrument status

4.6.5.2 Report TM packet

The instrument will report TC acceptance and executions, a progress of the internal autonomous function and a detection of anomalies. Each of them could be signalled by a separate Report TM packet. The content is TBD. In alternative, reporting could be provided in a dedicated sub-field of the NSWD HK packet.

4.6.5.3 Diagnostic and memory dump TM packets

In defined Diagnostic modes the instrument produces specific Diagnostic TM packets. These packets can be data produced, for instance, by an over-sampling of specific Housekeeping in the instrument. A detailed content is TBD. On TC request, a memory dump can be performed. In this case, the content of the memory will be transferred by a Memory dump TM packet.

4.6.6 Telemetry Packet Structure

The telemetry packets will conform to the structure defined in EID-A, The internal data structure of the Science TM packets and the other TM packets are TBD.

4.7 Electromagnetic Design

4.7.1 Instrument EMC Design Concept

In order to control the NSWD instrument from the EMC point of view, and in order to ensure its compatibility with SOLO mission requirements, a dedicated EMC Control Plan will be established and updated throughout the design and testing activities. The EMC control plan will contain all the needed assessments/analysis for demonstrating that the instrument is compliant (until

test procedures) with the EMC requirements, the design rules, the frequency control plan, and the model-testing concept.
The following paragraphs summarise the criteria and precautionary measures to be followed in the NSWD design.

4.7.1.1 Conducted and Radiated Emissions

The main sources responsible of conducted and radiated emissions are the DC/DC converters located in the NSWD DPU. The input filter to the main SOLO S/C +28 V input will be designed both to withstand conducted noise present in the main power lines avoiding susceptibility problems and to reduce the emission noise to levels fulfilling the relevant EMC requirements. Double Π arrangement could hence envisage for input filter of the DC/DC converter.

Other sources are the signals in the interface between the sensor modules and the controller. Uses of shielding, amplitude and bandwidth limitation balanced lines are the design criteria employed to reduce the strength of fields emitted from the interface circuits.

The following guidelines will be adopted to reduce electro-magnetic emissions:

- input filter design with a safety margin of 20 dB
- cables shielding
- balanced lines to transmit/receive signals inside the instrument
- voltage and current amplitudes transitions control
- rise and fall time control to reduce frequency emission spectrum

4.7.1.2 Conducted and Radiated Susceptibility

The conducted and radiated susceptibility depends mainly on the levels of the electro-magnetic fields surrounding the instrument, on the noise generated in the power bus and their coupling to the detectors depending on layout, grounding concept, shielding, filtering and signal processing.

Each sensor assembly is mounted inside the sensor head housing, which works like a Faraday shield for the majority of E-fields. Two means of coupling are envisaged:

- the interconnection between the detectors located in the particles focal plane assembly and the proximity electronics closely mounted in the bottom sensor boxes;
- the sensor heads optical aperture

While standard shielding and filtering approach is used for the former, correct design of the baffles, in terms of longitudinal w.r.t. diameter dimension and electrical coupling to the structure, will be adopted for the latter [e.g.: 60 dB reduction is obtained with 2:1 design rule].

Conducted noise coming from the main power is filtered to levels not causing interference's on secondary power supply voltages at the instrument input by proper design of the input filter arranged in common and differential mode configuration.

The hereafter design criteria will be used for low noise detection:

- baffles with 60 dB EM fields reduction
- cables shielding
- preamplifier located as close as possible to the source, with RC input filter to avoid operational amplifier input stage rectification, and with sufficient gain to ignore contributions of other sources, put downstream in the analog chain, from the overall noise figure
- balanced lines to transmit/receive interface signals
- cable shields grounded at the signal source end only
- increase physical separation among susceptible circuits
- multi-points ground and/or ground plane to minimise high frequencies susceptibility
- shields not used as return path for signal or power
- no grounding loop to avoid grounding current
- ground star points of sensor module connected to chassis at sensor level to avoid interferences from grounding loop current via capacitive coupling

4.7.1.3 Specific EMC Requirements

4.7.1.3.1 *Electrostatic*

Charge accumulated on an object usually leaves the object by one of two ways, leakage or arcing. Since it is mandatory to avoid arcing, leakage is the preferred way to discharge an object. Charge can leak off an object trough the air, due to humidity. The higher the humidity, the faster the charge will leak off the object. The charge on an object can also be counteracted by using an ioniser to fill the air with an opposite charge.

Static Sensitive Parts: Suppliers of parts, components, or assemblies, which are or contain static sensitive parts, will provide anti-static protection for such parts for the entire time they are under the supplier’s direct control.

Packaging: All static sensitive parts will be delivered to suppliers in anti-static packaging materials and shall be similarly protected during storage at the suppliers.

Workstations: All supplier workstations will include antistatic protection, such as grounded wrist straps, antistatic lab coats, grounded soldering irons, and grounded tabletop surfaces as a minimum.

Work in progress: Work in progress will be stored and transported in antistatic carry tubs or other protective packaging materials. These containers will be clearly marked to indicate that they contain static sensitive parts.

Touch labour tasks: All engineers and technicians performing touch labour tasks on the static sensitive hardware will be advised of the importance of adhering to the static control procedures and of their critical rules in protecting the hardware.

4.7.1.3.2 *Magnetostatic*

The use of magnetic materials shall be minimised in the design of the system. As a general guideline, hard magnetic materials such as ferromagnetic (permanent magnets) or stainless steel alloys should be avoided as possible. Ferrite for implemented filtering coils will be considered only in toroidal shape.

4.7.1.3.3 *Frequency Selection*

The highest frequency in the system shall be twice of the NSWD compressor processor frequency. The NSWD frequency control plan will be issued and updated throughout the instrument design and test phases

4.7.1.3.4 *MCPs detectors and ultrasonic oscillator power-up sequence*

In particular, it is important to follow a correct power-up sequence in order not to damage the MCPs detectors which are present in all the NSWD sensors and to put in the correct oscillation state the ultrasonic engine. The right sequence will be provided by the manufacturer, but the power supply and reference voltages have to be present before any other as general rule. Another precaution is that the front-end electronics has been designed and proven to be free of transients (e.g. due to high voltage de-coupling capacitors discharges).

4.7.2 Grounding Scheme

The NSWD instrument is compatible with the S/C system of the distributed single point grounding scheme in accordance with the following guidelines:

- the main power bus return is connected at one point (not in the instrument) to the S/C ground structure;
- secondary power supply returns are grounded via a single point to the ground plane (chassis = structure) by low impedance removable bar;
- ground plane is not employed for signal return;
- structure is isolated from primary and secondary returns.

The primary power bus is isolated from the secondary power bus with a DC resistance higher than 1 M□ and an AC capacitance path, in parallel, lower than 50 nF.

The connections from the star points to chassis (metallic structure) are made by using removable jumpers external to the enclosure.

The metallic housing is isolated from the corresponding ground points, when external jumper is removed, by a resistance higher than 1 MΩ with a maximum capacitance of 50 nF in parallel.

The signals are exchanged between sensor heads and DPU by using the following interface circuits:

- single ended source with differential receiver
- balanced source with differential receiver

- single ended source with isolated load.

4.7.3 Performance Requirements

The emission and susceptibility shall be verified by analysis and test. The test results or the reference to the test results shall be introduced here. Any deviation or any waiver agreed with ESA shall be listed here.

5 Operational Interfaces

5.1 Instrument Modes

5.1.1 Instrument Operations Concept

Following the power-up of the instrument, the HW-SW initialisations and tests are carried out. The test results can be provided by requesting specific boot report TM. The controller is put into STAND-BY state. The reception of dedicated ON/OFF command from the S/C SpaceWire I/F to the power control register will allow to control and power any sub-system.

The power up of the controller will follow the trajectory hereafter stated:

- If a “diagnostic” power-up is commanded, the controller unit will be switched into a survival mode with minimum performances and operability of the unit. In this condition, no usual science telemetry will be provided by the experiment. Only diagnostic dump for health checking will be provided and transmitted.

- If a “Nominal” power-up is commanded, the controller will be kept into its nominal state for autonomous S/C I/F and TM dumping. Nominal rate sampling from the activated sensor head will be performed according to the normal operations TM polling tables.

- If a “Raw(burst)” power-up is commanded, the system will perform the standard booting procedures for switching into raw mode.

In Figure 5.1 is shown how the main controller processor controlling the NSWD I/Fs can switch from STAND-BY by dedicated TC to any of the following modes:

- DIAGNOSTIC MODE
- STAND-BY MODE
- NOMINAL SCIENCE MODE
- RAW/BURST SCIENCE MODE
- CAL MODE

The default logic for the NSWD mode transitions is that they are ground commanded. The transition from one mode to another mode (except power off /on) always goes via STAND-BY Mode.

5.1.1.1 DIAGNOSTIC MODE

Regardless of the Sensor head powering condition, the “diagnostic” mode is the basic mode for performing diagnostic and testing operation on the power-up. The controller will be switched into a survival mode with minimum performances and operability of the unit. Only diagnostic dump for health checking will be provided and transmitted.

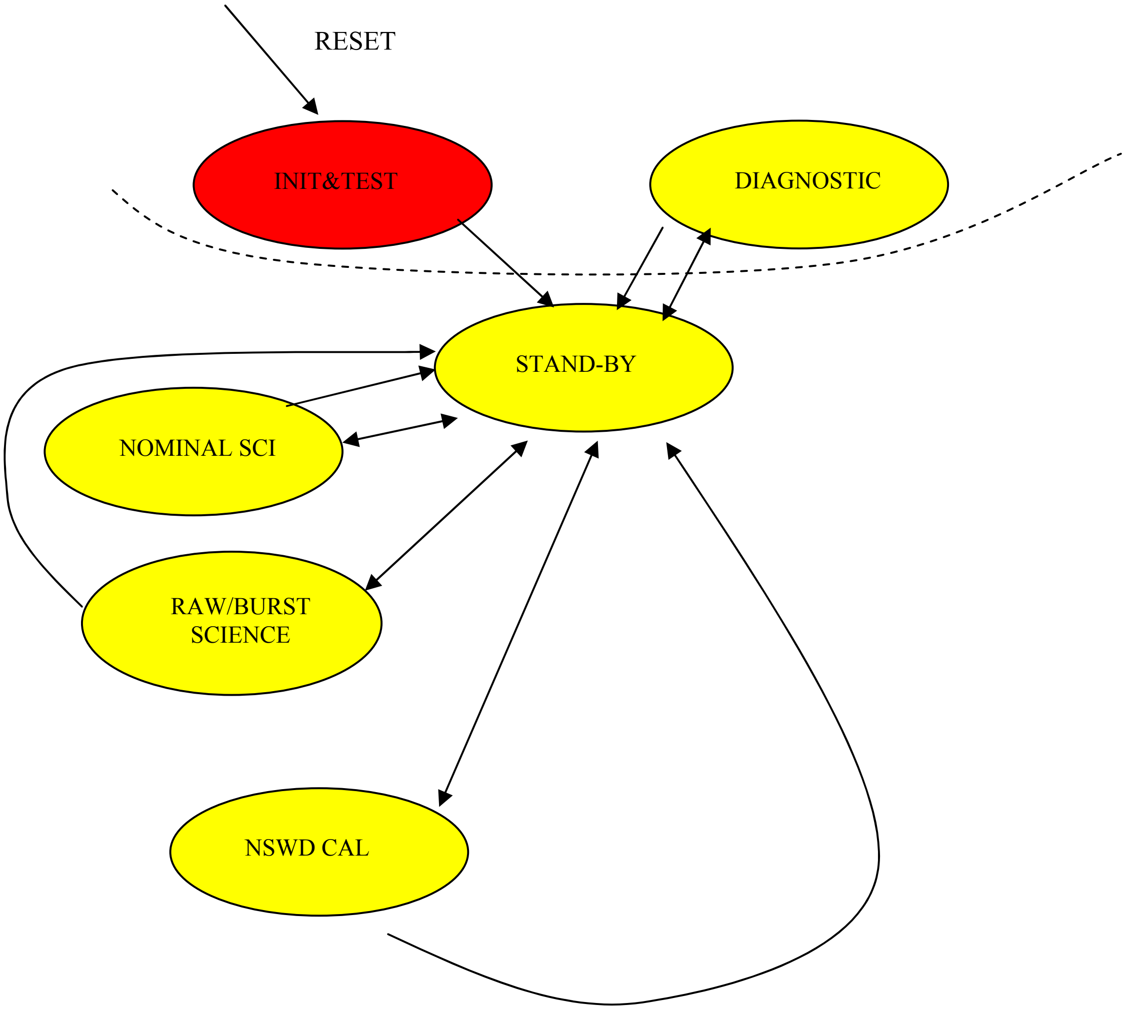


Figure 5.1 NSWD Mode Transitions

5.1.1.2 STAND-BY MODE

This is the default mode, in which NSWD is switched following a reset or a power-up. From this mode, the controller can be switched to any other scientific or diagnostic mode by means of dedicated TCs. Only housekeeping telemetry will be supported while in this mode

5.1.1.3 NOMINAL SCIENCE

This scientific mode is the nominal one and shall be normally used for all types of scientific observations. The sensor will be activated active to produce science data. TM will be produced by collecting from the sensor head fixed quantity of data according to the predefined TM allocation table.

5.1.1.4 RAW/BURST

This scientific mode is an upgrade of the nominal science case. It takes into account of specific condition in which a more relevant bandwidth of the SOLO Spacewire TM is made available for NSWD to have the possiblity to transmit raw events. TM will be produced collecting from the sensor head fixed quantity of data according to the predefined TM allocation table.

5.1.1.5 NSWD CAL

This scientific mode is fully devoted to support calibration or diagnostic purposes.

5.1.2 NSWD Calibration approach

A specific facility providing a beam of Energetic Neutral Atoms is located in the ENEA Research Centre of Frascati in Rome-Italy. The Scientific Technical Unit of Fusion at the FTU (Frascati Tokamak Upgrade) has realised this equipment to test and calibrate Energetic Neutral Atoms analysers finalised to the plasma temperature study. In the last years, collaboration with the IFSI/INAF was started to the goal of a realisation of an ENA instrument to the study of ENA generation in the planetary environments. This facility has the characteristics summarised in the following table. This facility although is ideal for test with neutrals is not located in a clean room. Therefore only NSWD DM an EM model can be tested in this facility, while FM and FS calibration will be performed at the University of Bern Ion facility. Refer also to Engineering Plan, section 2.4.4.2.1.

Facility carachteristics	
Energy range	300eV-110keV
ION SOURCE	
filament	tantalum
If	0-30A
Is	0-2A
Vs	200V
HV	0.3-10kV
species	H - He - D
MASS SELECTION	
Magnet	0-2.5 kGauss
ACCELERATOR	
V accel.	0-100 kV
FOCALIZATION	
electrostatic lenses	
NEUTRALIZATION	
charge exchange	neutralization cell
IONS SUPPRESSION	
deflection plates	

Table 5.1. NSWD test facility characteristics at ENEA

5.2 In flight operations considerations

5.2.1 NSWD: TLM & Power budgets Vs Operational modes.

The power consumption of NSWD is mainly related to the oscillation frequency of the Piezo-electric engine that can be parked, varied continuously or operated at fixed frequency. The ToF resolution is strictly related to the frequency. If the chosen frequency is too low, the ToF resolution will be very coarse; if the frequency is too high, a STOP signal may occur after a subsequent START signal occur, thus causing erroneous ToF targetting. The shuttering element may also be operated at very low frequency (angular scanning). In this case, the energy resolution may be obtained by using the ESA as low-pass energy filter or as an on/off electronic gate.

For each of the operative modes, NSWD can use two basic telemetry modes: raw mode and binning mode (see table in Section 4.3). In raw mode, each particle targeting is processed separately and results in a telemetry event of 4 bits (angular scanning) + 12 bits (ToF1) + 2 bits (Coincidence) + 7 bits (128 Chs., MCP anode information). Considering an average countrate up to100 s^{-1}, the telemetry bitrate is up to 2500 b/s; considering an extreme event, with a countrate of 1000 s^{-1}, the highest telemetry bitrate is 25000 b/s.

In triple coincidence mode, additional 12 bits ToF information is foreseen, but the angular scanning is disabled (angle is resolved by means of the MCP anode information). Hence, the telemetry bitrate is $(12+12+2+7)\times100=3300$ b/s.

In binning mode, a matrix of up to 128 ToF or energy channels, and up to 12 angular channel is transmitted, i.e. a maximum of $128\times12=1536$ channels. Assuming 8 bits for each channel (log compression), and for a nominal resolution time of 60 s, this results in a maximum bitrate of 205 b/s. Different configuration of the bin matrix can be used, resulting in different bitrates (see table in Section 4.3). The nominal mode foresees 16 energy channels ×12 angular sectors ×16 bit/channel. With a time resolution of 60 s, the bitrate is 50 b/s. Examples of TLM and Power budget vs. operative mode are given in Table 5.2

Op. Mode / freq.	Power (mW)	Telemetry (b/s)	Energy x Ang. Chs
Rest.	6607	40	16x8
Slow (Angular scanning)	7206	50	16x12
Fast	8140	~3300	N/A (raw mode)

Table 5.2. Operative modes, power and telemetry.

5.3 Ground operations requirements

5.3.1 Specific Experiment System Tests.

After integration on S/C there could be the necessity of verifying the boresight alignment and co-alignment with the other experiments. However due to the not stringent pointing requirements no specific procedures are addressed, but only knowledge of the plane of the NSWD unit window respect to the system reference cube.

5.3.2 Experiment Stimuli

The instrument do not require stimuli unit after integration on the S/C.

5.3.3 Purging Requirements

The instrument purging equipment is the equipment used to purge the optics enclosure with dry, filtered 99.99% nitrogen gas (contamination control). It is expected that this unit will be used principally by the S/C contractor during AIT. The present requirement is for a 4 liters/h supply.

5.3.4 Mission operations

5.3.5 Instrument deliverables to the ground segment

An upgraded science processing version of the NSWD Electrical Ground Supporting Equipment (EGSE) used for all the instrument verification and testing will be delivered at the SOLO Ground Operation Center to monitor the NSWD downlinked TLM and distributed on the local network. Such a unit will be essentially a workstation equipped with a LAN I/F

5.3.6 Instrument inputs to the ground segment

NSWD will support the Mission Operation Center (MOC) with all the necessary information (e.g. Context table, calibration table, command sequences) for correctly performing the instrument once in space. The NSWD science Team will also support the SOLO Mission Science Data Center (SMS-DC) with all the procedures and information to allow the Center to manage the real time production of level-1 like data, quick-looks and all the science report that can routinely produced without a specific off-line analysis provided by NSWD Scientific Team off-line.

5.3.7 Mission products

Neutral atoms are closely coupled to the emerging solar wind plasma and give rise to the prominent solar Lyman-alpha corona. Direct observation of the neutral atoms, their flight pass and their density and velocity distribution will help to refine the understanding of the Lyman-alpha corona, i.e the solar wind acceleration region. Beyond 3 solar radii, the neutral atoms become more and more decoupled from the plasma. The neutral solar wind constitutes an *in situ* trace particle population within the solar wind plasma being observable from Perihelia to Aphelion of the Solar Orbiter orbit. In this respect the NSWD will produce the following major products:

- 2-Dimensions Neutral beams distributions up to a maximum instantaneous coverage of 12° x 5° and 1°x 5° highest accuracy.
- 2-D Velocity distribution as derived from the particles energy (range 100 eV – 5 keV).

5.3.8 Instrument team support to operations

NSWD Team will support the Mission Operation Center (MOC) in all the critical phases as the instrument commissioning in space. The team will also support the MOC providing all the time line operation sequences for correctly operating the instrument within the given operation scenario stated by all the actors of the SOLO Operations. NSWD Team will also participate to the plenary meetings and NSWD dedicated audiences to define the general Mission Operation Scenario and the detailed plan of any specific NSWD operation impacting with the mission control and TLM budgets.

6 System level AIT

6.1 Instrument Model Philosophy and Deliverables

6.1.1 Instrument Model and Test Philosophy

Table 6.1: NSWD test matrix

Activity	TM[1]	STM	EM	FM	QM/FS	Responsible
Calibrations	A	N/A	N/A	A	A	PI
Visual Inspection	N/A	A	A	A	A	PI
Dimension verification	N/A	A	A	A	A	PI
Physical Properties	N/A	A	A	A	A	PI
Functional Test	A	N/A	A	A	A	PI
Low Level Sine	N/A	A	N/A	A	A	PI + Thales Alenia Space
Strength Test	N/A	TBD	N/A	TBD	N/A	TBD
Shock	N/A	TBD	N/A	TBD	N/A	TBD
Sine Vibrations	N/A	Q	N/A	AC	Q	PI + Thales Alenia Space
Low Level Sine	N/A	A	N/A	A	A	PI + Thales Alenia Space
Random Vibrations	N/A	Q	N/A	AC	Q	PI + Thales Alenia Space
Low Level Sine	N/A	A	N/A	A	A	PI + Thales Alenia Space
Functional Test	N/A	N/A	N/A	A	A	PI
Acoustic Noise	N/A	N/A	N/A	N/A	N/A	N/A
Functional Test	N/A	N/A	N/A	A	A	PI
TVAC	Q	N/A	Q	Q	Q	PI
Functional Test	A	N/A	A	A	A	PI
Grounding / Bonding / Isolation	N/A	A[2]	A	A	A	PI
EMC Conducted Emissions / Susceptibility	N/A	N/A	A	AC	Q	PI + Thales Alenia Space
EMC Radiated Emissions / Susceptibility	N/A	N/A	A	AC	Q	PI + Thales Alenia Space
DC Magnetic Properties	N/A	N/A	A	AC	Q	PI + Thales Alenia Space
Purging Rate Verification	N/A	N/A	N/A	N/A	N/A	N/A
Visual Inspection	N/A	A	A	A	A	PI

6.1.2 Instrument Spare Philosophy

Flight Spare will be manufactured and made available to SOLO Project on request within 6 months after the FM model delivery.

6.2 Ground Operations Requirements

6.2.1 Experiment System Tests

After integration on S/C there could be the necessity of verifying the boresight alignment and co-alignment with the other experiments. However due to the not stringent pointing requirements no specific procedures are addressed, but only knowledge of the plane of the NSWD unit window respect to the system reference cube.

6.2.1.1 Test Overview

All types of test which have to be performed e.g. ISTs, Specific Functional checks, abbreviated functional checks

6.2.1.2 Test Objectives

Test objectives for the different test types, e.g. (Instrument switch-On, Switch to Standby, command in measurement mode, command to self test mode

6.2.2 Experiment Stimuli

The instrument does not require stimuli unit after integration on the S/C. TBC

6.2.3 Purging Requirements

The NSWD unit houses Micro Channel Plates (MCPs) detector devices. Because of these sensors the unit needs a continuous purging with dry nitrogen (99,99% pure Nitrogen). This purging may be occasionally interrupted e.g. while moving in and out of a test chamber or to place the unit in a transport container provided that these operations are done in with a Cleanliness environment at class 100.000.
The purging equipment is the equipment used to purge the optics enclosure with dry, filtered 99.99% nitrogen gas (contamination control). It is expected that this unit will be 4 liters/h ± 1l/hour supply used principally by the S/C contractor during AIT. The present requirement is:
Purge rate:
4 ± 1 (liters/hour) supply

6.2.4 Applicable Constraints

Clean Room

MCPs can't be operated in atmospheric conditions. Conversely they need a pressure which is not exceeding 10^{-6} mbar, when they are powered by the HV supply.

NSWD will be designed to operate during the system integration and test campaign (including launch preparations) under the following maintained environmental conditions according to Eid-A:

- Temperature: 21°C ±3°C
- Relative Humidity: 50% ±10%
- Cleanliness: class 100.000
- Pressure: atmospheric conditions

Launch Thermal and Pressure Environment

It is assumed that during the launch operations the purging will be discontinued and the NSWD commissioning will be not scheduled before 20 days after the launch, thus allowing the internal outgassing to take place and to allow under the PI responsibility the first switching of the HV on the different subsystems.

In any case NSWD will be designed to survive in Launch mode the exposure to the following thermal flux during Launch according to Eid-A.

6.3 Electrical Ground Support Equipment

6.3.1 Concept

The Electrical Ground Support Equipment performs the following. The Ground Support Equipment (FGSE) interfaces directly to the sensor and is used to develop, test and verify the instrument. It will be essentially a PC Card providing the physical SpaceWire link I/F to the instrument. A user interface software will allow to drive the I/F card and to command and collect instrument data to verify their compliance to the NSWD system. Out of the SpaceWire link, the EGSE will support power supply I/F and any specific thermistor I/F to the sensors. After integration of the instrument into the spacecraft, the EGSE can be connected to the central checkout system via standard LAN.

The EGSE consists of a Laptop computer with both Microsoft Vista and Unix/Linux operating systems, and an interface box simulating the electrical interface of the spacecraft prior to S/C integration. The interface box uses standard USB protocol for connection to the computer. The instrument side will be supported via a dedicated Main and Redundant SpaceWire I/F.

6.3.2 Functionality:

- The EGSE allows configuring the S/C-simulator interface with the same functionality as the spacecraft and provides monitoring information about the interface connection status
- The EGSE provides the means to generate telecommands to the instrument via the S/C-simulator interface using the formats specified in the relevant data handling interface control documents.
- The EGSE reads and stores binary telemetry data from the instrument via the S/C-simulator interface or via the Central Checkout System, and provides basic monitoring tools and distributes sorted detector data to the FGSEs on request or via shared data storage resources.
- The EGSE provides logging of all telecommand and telemetry activities.
- The EGSE provides remote access to all its functions if the local network environment allows.

6.3.3 Model philosophy:

The central EGSE will be manufactured in 4 functionally equivalent models:

(a) Engineering model for NSWD and instrument verification, instrument integration into the S/C and support of EQM-program AIV activities.
(b) Flight model for NSWD verification and instrument verification, calibration and integration into the S/C, AIV support.

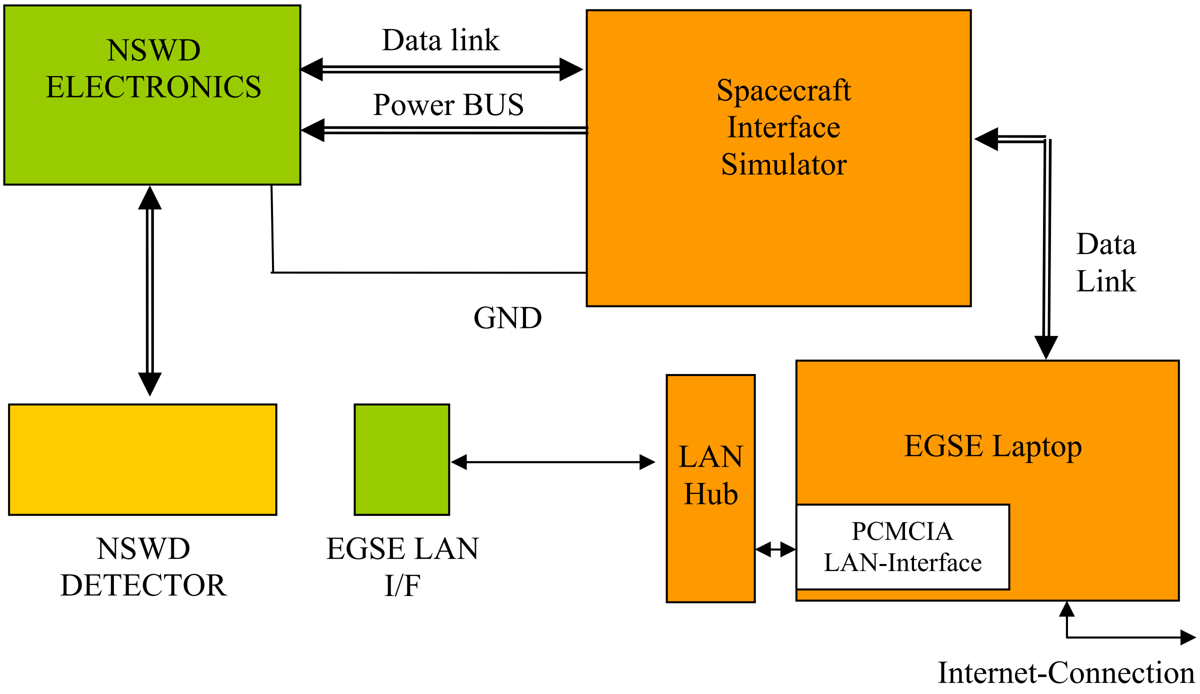


Figure 6.1. EGSE functional block diagram

(c) Flight Spare Ground Reference Model for operational support and additional ground calibration activities.
(d) Development Model at IFSI for project support and software development without interfering with the project program.

6.3.4 S/W Organization

The EGSE coarse structure is depicted in Figure 6.1. The EGSE is composed by three main layers, i.e. the H/W layer, an Intermediate tier, and the User level. Each layer foreseen layered data structures that communicates each other via data streams. On the other hand, interlayer communications takes place on TCP/IP. Thus the software composing each layer can run on a different machine connected to the others over a network. Moreover each layer can run on the same machine where other layer (layers) is (are) running, making the EGSE very flexible.

6.3.4.1 H/W layer module

The H/W layer takes into count of the interface to the H/W and it will be formed by three levels:

- the H/W properly named;
- the low level driver that will send/receive data and commands to/from the H/W;

- a high level interface that will do the system calls to the driver, will packetize/depacketize data in the TCP/IP framework and will offer some light server functions.

6.3.4.2 Intermediate tier module

The intermediate tier is at the same time a client for the H/W layer, while it is the server for the user layer. The client side will be able to connect to the relevant server, to decode both the ILT and Central Checking System (CCS) protocols and to stream data to the main server. The latter will be able to offer complete server functions to the next layer, using different data sockets (e.g. one for TC and HK, one for dumping, one for band consuming scientific data, etc.) in order to assure good performance in every use condition.

6.3.4.3 User interface module

The last layer provides the high level interface. The main features that will be available are:

- TC editor;
- HK visualization and statistics;

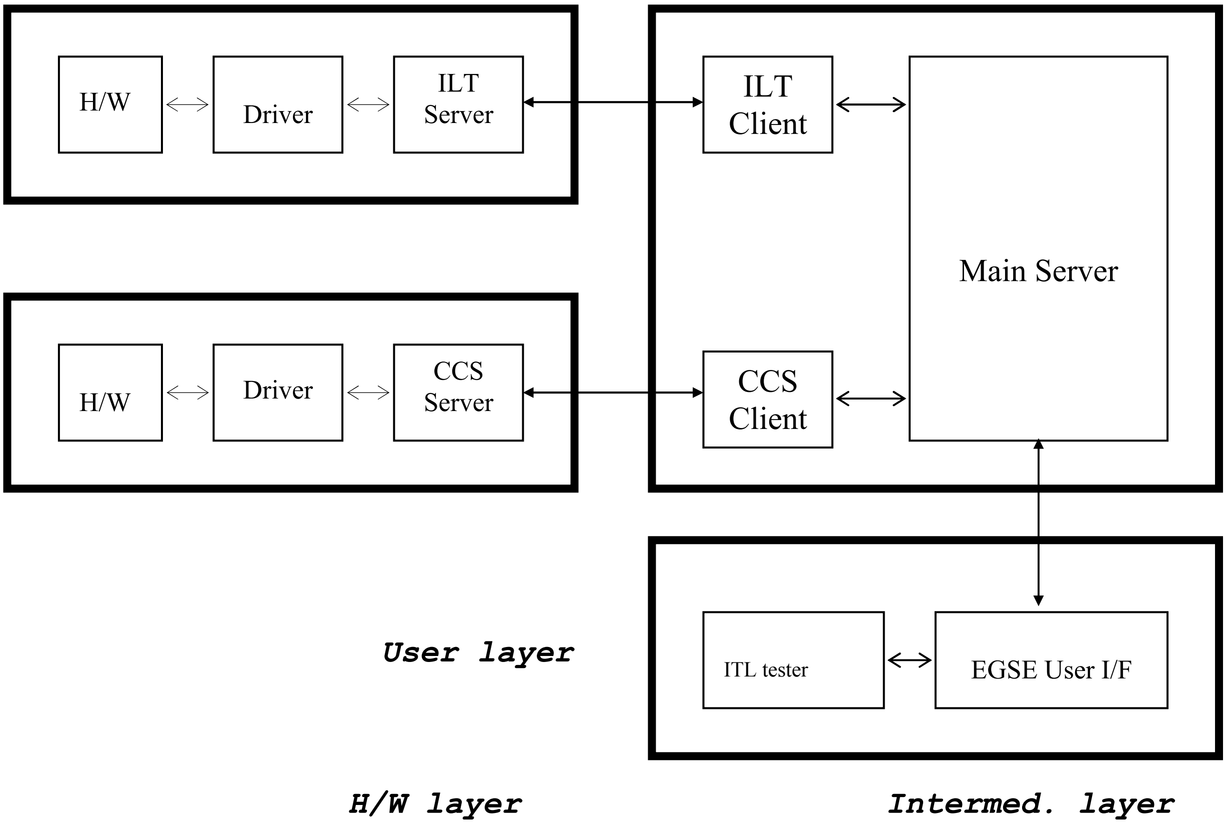


Figure 6.2. EGSE S/W coarse structure.

- dumping, Quick Looks of scientific data;
- PDS files generation and visualization.

A simpler user I/F is released in the early stage of the design, in order to have soon available a user interface, intentionally designed for EM tests. Then it is upgraded by scientific quick look to provide a full scientific consolle in a later stage.

7 Instrument Verification Plan

See dedicated document:

SO-NSW-PL-003, Issue 1 Rev 0.

8 Product Assurance Requirements

See dedicated document:

SO-NSW-PL-004, Issue 1 Rev 0.

9 Management Plan

See dedicated document:

SO-NSW-PL-005, Issue 1 Rev 0.