Call for Submission of Letters of Intent to Propose Instruments for the Solar Orbiter Mission

Neutral Solar Wind Detector (NSWD) for Solar Orbiter

The Neutral Solar Wind Detector (NSWD), to be flown on board Solar Orbiter, 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.

The NSWD primary scientific objectives may be summarized as in the following:

- observation of neutral solar wind flux;
- velocity, density and temperature of the neutral solar wind;
- comprehension of solar Ly-α corona, i.e. deduction of solar wind plasma velocity distributions anisotropy perpendicular and along the solar magnetic field lines from neutral solar wind observations;
- study of the solar wind acceleration region via the detection of the neutral solar wind hydrogen atoms and investigation of the temporal and spatial details of the solar wind using the co-aligned movement of the Solar Orbiter spacecraft with respect to the solar rotation;
- observation of the fast and slow neutral solar wind in different solar conditions, potentially including transitions regions and CMEs;
- resolution of the "inner source" pick-up ion puzzle thought to originate from solar wind plasma - dust interaction in the solar atmosphere region within 0.2 AU.

1 Names and responsibilities of the institutes associated with the submission

Associated Institutions *(key persons are underlined)*

Europe:

- **Istituto di Fisica dello spazio Interplanetario IFSI / INAF, Via Fosso del Cavaliere 100, 00133 Roma, Italy**
  Dr. Stefano Orsini, Dr Roberto Bruno, Dr. Raffaella D'Amicis, Dr. Elisabetta De Angelis, Dr. Stefano Massetti, Dr. Anna Milillo, Dr. Alessandro Mura
- **AMDL s.r.l.,** v.le Somalia 133, 00199 Roma, Italy
  Dr. Andrea M. Di Lellis
- **Istituto di Fotonica e Nanotecnologie (IFN), CNR, via Tiburtina, 00100 Roma, Italy**
  Dr. Roberto Leoni
- **Istituto dei Sistemi Complessi (ISC), CNR, Via Fosso del Cavaliere 100, 00133 Roma, Italy**
  Dr. Stefano Selci
- **ENEA, via E. Fermi, 00044 Frascati (Roma), Italy**
  Dr. Vincenzo Zanza
- **Max-Planck-Institut für Sonnensystemforschung, Max-Planck-Str. 2, 37191 Katlenburg-Lindau, Germany**
  Dr. Martin Hilchenbach, Prof. Eckart Marsch, Dr. Joachim Woch
- **Finnish Meteorological Institute, Erik Palménin aukio, FI-00560 HELSINKI, Finland**
  Dr. Esa Kallio, Dr. Walter Schmidt
- **Physikalisches Institut, Space Research & Planetary Sciences, Sidlerstrasse 5, CH - 3012 Bern, Switzerland**

Prof. Peter Wurz, Dr. Karin Bamert

- **IRF - Swedish Institute of Space Physics, Box 812, 98112 Kiruna, Sweden**
  Prof. Stas Barabash, Dr. Martin Wieser
- **Osservatorio Astronomico di Torino, Strada dell' Osservatorio, 20, I-10025 Pino Torinese (TO), Italy**
  Prof. Ester Antonucci
- **Space Research Centre, Bartycka 18 A, 00-716 Warsaw, Poland**
  Dr. Andrzej Czechowski
- **Centre d'Etude Spatiale des Rayonnements CESR, 9, av du Colonel Roche, 31028 Toulouse cedex 4, France**
  Dr. Iannis Dandouras
- **KFKI - Research Institute for Particle & Nuclear Physics, Konkoly Thege Miklós út 29-33, -1121 Budapest, Ungary**
  Prof. Karoly Szego
- **Department of Physics, The Auroral Observatory, Faculty of Science, University of Tromsø, N-9037 Tromsø, Norway**
  Prof. Ruth Esser

Japan:

- **Department of Earth and Planetary Science, Faculty of Science, Kobe University, Nada, Kobe 657-8501, Japan**
  Prof. Ingrid Mann

US:

- **University of Arizona, PAS 565, Tucson, AZ 85721, USA**
  Prof. Ke Chiang Hsieh, Prof. J. Randy Jokipii, Prof. Joe Giacalone, Dr. Jozsef Kota
- **University of Hawaii, Institute for Astronomy, 2680 Woodlawn Drive, Honolulu, HI 96822, USA**
  Prof. Shadia Rifai Habbal
- **JHU/APL, MP3 E132 11100 Johns Hopkins Road, Laurel, MD 20723, USA**
  Dr. Stefano Livi
- **Experimental Space Plasma Group, University of New Hampshire, Durham NH 03824, USA**
  Prof. Eberhard Möbius, Dr. Harald Kucharek
- **National Space Science and Technology Center, SD50, 320 Sparkman Dr., Huntsville, AL 35805, USA**
  Dr. Robert B. Sheldon
- **Astronautics and Space Technology Division, Viterbi School of Engineering, 854 Downey Way, RRB-224, MC 1192, University of Southern California, Los Angeles, CA 90089-1192, USA**
  Prof. Mike Gruntman
- **Department of Atmospheric, Oceanic and Space Sciences, The University of Michigan, Space Research Building, Ann Arbor, MI 48109-2143, USA**
  Prof. Thomas H. Zurbuchen
- **Interplanetary Physics, NASA/Goddard Space Flight Center, Greenbelt, Maryland 20771, USA**
  Dr. Michael R. Collier

Key-persons e-mail list:

Europe:
stefano.orsini@ifsi-roma.inaf.it, amdl@iasf-roma.inaf.it, roberto@ifn.cnr.it,
Stefano.Selci@ism.cnr.it, zanza@frascati.enea.it, hilchenbach@mps.mpg.de, esa.kallio@fmi.fi,
peter.wurz@phim.unibe.ch, stas.barabash@irf.se, antonucci@to.astro.it, ace@cbk.waw.pl,
Iannis.Dandouras@cesr.fr, szego@rmki.kfki.hu, ruth.esser@phys.uit.no

Japan:
mann@diamond.kobe-u.ac.jp

US:
Hsieh@physics.arizona.edu, shadia@IfA.Hawaii.Edu, Stefano.Livi@jhuapl.edu,
Eberhard.Moebius@unh.edu, Rob.Sheldon@msfc.nasa.gov, thomasz@umich.edu,
michael.r.collier@nasa.gov

Major Responsibilities

Principal Investigator	Stefano Orsini	IFSI/INAF, Roma, Italy
Project Scientist	Martin Hilchenbach	MPS, Katlenburg-Lindau, Germany
Project Scientist	K. C. Hsieh	University of Arizona in Tucson, AZ, USA
Project and Program Manager	Andrea M. Di Lellis	AMDL, Roma, Italy

Hardware Providers

IFSI/INAF (+ AMDL; + IFN, ISC, ENEA): *Sensor Responsibility*

OTHER PROVIDERS
(i.e.: fmi, Uni of Bern, irf, cesr, jhu/apl, unh, msfc): *Specific hardware participation from other providers within the team will be decided after a devoted team meeting to be held before March 2007.*

2 NSWD brief description and scientific objectives

Scientific Objectives

Neutral hydrogen is indicative of the behaviour of the main solar wind component formed by protons out to at least 2-3 solar radii. In fact, beyond this distance the characteristic time for charge exchange between hydrogen atoms and protons becomes comparable to the coronal expansion time scale causing the neutrals to decouple from the charged solar wind. Hence, they retain information on the three-dimensional coronal distribution of hydrogen at the level where they are generated.

In the solar corona up to 2-3 solar radii, neutral atoms are closely coupled to the emerging solar wind plasma and give rise to the prominent solar Lyα corona mainly by resonant scattering of chromospheric HI Lyα photons. From the measurement of the Lyα spectral line profile, the hydrogen velocity distributions in the solar corona have been deduced (e.g. Kohl et al., 1996; Cranmer, 1998; Marsch et al., 1999). These distributions generally reflect that of the proton one up to about 2-3 solar radii. Above this altitude, because of the low coronal density, the neutral solar wind (NSW) decouples from the ionised component and escapes into space. Contrary to charged particles, neutral particles can cover long distances on ballistic trajectories through space, undisturbed by magnetic field. They constitute an unique *in situ* trace particle population of the solar wind plasma within a few solar radii where it is generated (Allen et al., 2000). The understanding of the corona and hydrogen plasma interaction beyond 3 solar radii derives from the comparison between the neutral and the proton component of the solar wind. In fact, the former carries the coronal information while the latter carries information on the wind evolution after decoupling from the neutrals.

The *in situ* measurements of the NSW velocity distribution performed far from 3 solar radii (e.g. at the Solar Orbiter position) allow remote sensing of the three-dimensional coronal distribution of hydrogen from the level where the neutral and charged component decouple. Hence, such observations represent a powerful diagnostic technique enabling one to infer the degree of anisotropy, if any, in the neutral and charged coronal hydrogen from 3 solar radii. This diagnostic would then provide an extremely valuable test for deciding whether the ion cyclotron process is indeed acting on protons, since this would result in a broader velocity distribution, indicative of more effective heating, across the magnetic field than along the field direction, corresponding to the radial direction in polar coronal holes. Moreover, the proposed NSW measurements would also represent a unique remote diagnostics to infer the velocity distribution along the magnetic field direction, information that is not accessible via spectroscopic measurements of the coronal hydrogen emission; in fact being the field direction approximately perpendicular to the UV Coronagraph line-of-sight, the parallel velocity cannot be easily detected. This component, actually detectable by the NSWD, is indeed essential to establish the degree of anisotropy of the hydrogen velocity distribution in the corona (Hilchenbach, 2001).

The previous considerations are related to a boundary limit for evaluating the source properties of the neutral distribution as observed at the Solar Orbiter position. In fact, even if the neutral and charged component decouple at approximately 3 solar radii, a neutral undergoes further collisions with a mean free path rapidly increasing with the radial distance. It will then be necessary to integrate along the lines of sight at different angles from the Sun, looking at the distribution function at each point and the probability that a neutral in that distribution will reach the detector. Figure 1 shows the mean free path of a neutral particle travelling at 700 km/s as a function of the heliocentric distance. From the figure, it is clear that only a small fraction of the neutral particles generated at 3 solar radii would be observed by Solar Orbiter, since their mean free is not sufficiently long. Conversely, the majority of the neutrals generated at heliocentric distances ≥ ~18 solar radii would fly unperturbed and eventually be detected by Solar Orbiter (D'Amicis et al., 2006). It follows that the proton velocity distribution at ~18 solar radii would be 'frozen' within the generated neutrals and adiabatically transferred up to the Solar Orbiter position. On the other hand, in order to reconstruct the distributions from ~18 back to 3 solar radii, it is necessary to feed-back

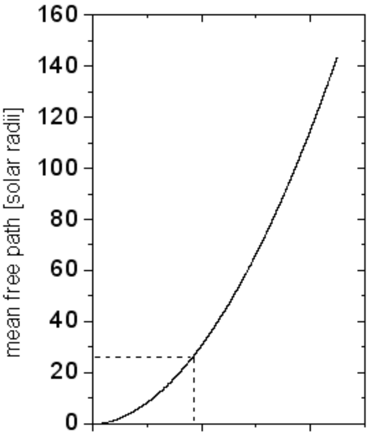

Figure 1. *Mean free path of a neutral particle traveling at 700 km/s. Neutral particles can reach the Solar Orbiter location (48 solar radii) only if the sum of the radial distance at which they are generated and the mean free path is ≥ 48 solar radii. It means that x + y ≥ 48 solar radii. Hence, only neutral particles generated at an heliocentric distance ≥ 18 solar radii could be detected by Solar Orbiter without any previous interaction (D'Amicis et al., 2006).*

the data with theoretical models of the solar wind evolution.

The heliocentric distance of ~18 solar radii is rather important since it represents the distance at which the corona stops corotating with the surface of the sun and the wind becomes super-Alfvénic. This distance was firstly evaluated by Pizzo et al. (1983) and Marsch and Richter (1984) who, using Helios *in situ* observations, set the value between 10 and 30 solar radii. This distance acts as a filter for the Alfvénic turbulence since only outward propagating modes will be able to escape from the Sun. Inward modes, being faster than the wind bulk speed, will precipitate back to the Sun if they are generated before this point (see ample literature reported in Bruno and Carbone, 2005). Thus, MHD turbulence is completely different moving across the Alfvén radius. Having information through the NSW about the kinetic state of the plasma around 18 solar radii and comparing it to *in situ* plasma measurement would be extremely valuable to understand wave-particle processes which are fundamental for solar wind heating and acceleration.

The neutral atom flux is expected to be about 100-1000 atoms $cm^{-2} s^{-1}$ at 0.21 AU, and it could be up to 10^6 atoms $cm^{-2} s^{-1}$ in a CME. At Earth orbit NSW fluxes of about 10^4 atoms $cm^{-2} s^{-1}$ have been observed (Collier et al., 2001), because of neutralization of solar wind along its movement away from the Sun. The NSWD should also measure energetic neutral atoms emitted from various coronal sources, and thus enable images of these coronal emission regions to be constructed from rays of neutral atoms with different velocities. Nevertheless the NSWD candidate entrance system must block radiation emerging from the solar disc. The UV scattered in the solar corona, i.e. $L\alpha$, must be suppressed by a factor of more than 10^{-12}. The entrance system must reduce ions and electrons of the solar wind plasma by a factor of about 10^{-9} whilst transmitting neutral atoms.

While the most important aspect of the planned measurements will be the remote sensing of the velocity distribution along the magnetic field direction and therefore deduce the distributions in the acceleration region of the solar wind, other fields of interest are CMEs and, possibly, the "inner source" and solar wind-dust interaction, which has been identified as important contributor to NSW at 1 AU (Collier et al., 2003). For the investigation of the solar wind-dust interaction, the orbit of Solar Orbiter is well suited with a perihelion of 0.21 AU. The connection between this "inner source" of the pick-up ions and the interplanetary dust cloud near the Sun remains an open question. The interactions of solar wind ions with the surface of the interplanetary grains provide one mechanism to explain the "inner source". If the ions traverse the grains, emerge neutralized and slowed down, then they can be ionised and become pick-up ions. The flux of the pick-up ions from the inner source is fairly high (few tons/s for oxygen ions picked up within 1 AU). It is therefore possible that the non-ionised fraction of the particles emerging from the grains may form a detectable part of the neutral solar wind. These particles would typically lag behind the solar wind by an amount dependent on the energy lost while traversing the grain.

The NSWD primary scientific objectives may be summarized as in the following:

- observation of neutral solar wind flux;
- velocity, density and temperature of the neutral solar wind;
- comprehension of solar Ly-α corona, i.e. deduction of solar wind plasma velocity distributions anisotropy perpendicular and along the solar magnetic field lines from neutral solar wind observations;
- study of the solar wind acceleration region via the detection of the neutral solar wind hydrogen atoms and investigation of the temporal and spatial details of the solar wind using the co-aligned movement of the Solar Orbiter spacecraft with respect to the solar rotation;
- observation of the fast and slow neutral solar wind in different solar conditions, potentially including transitions regions and CMEs;
- resolution of the "inner source" pick-up ion puzzle thought to originate from solar wind plasma - dust interaction in the solar atmosphere region within 0.2 AU.

NSWD preliminary information such as mass, power, bit rate, electromagnetic cleanliness, viewing requirements, etc.

Energetic Neutral Atom (ENA) detectors have been flown on SOHO, Cassini, IMAGE, Mars Express, and Venus Express. Time-of-flight instruments are for example flown on Ulysses, SOHO and ACE.

The neutral sensor concept is based on micro-valve choppers, 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, without interacting at all with any impacting surface thus preserving a high directional information up to the stop detector. This technique developed for the neutral atom camera ELENA in the frame of the BepiColombo (e.g.: Mura et al., 2006) can allow an angular resolution better than 1.8° within a large 1-D FOV (e.g. 76°, in the ELENA case) and cover an energy range from 5keV down to a few eV (Figure 2, top).

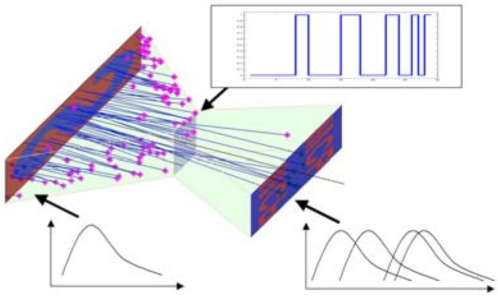

***Figure 2** (Top) NSWD Sensor concept. (Bottom) ELENA prototype grid sample: left side, first generation pattern; right side, fourth generation. Narrow slots (dark lines) are etched on a2-inch diameter wafer, 2 μm Silicon nitride double side.*

The timing performance of the micro-valve choppers, which in last extent determine the Time-of-Flight (TOF) of the particles, are optimised basing the design on the state-of-the art of ultra-sonic oscillator (operated at frequencies up to 100 kHz) and high resolution gating nano-grids (Figure 2, bottom).

The collimated particles released by the entry chopper are then flown in a TOF chamber and finally detected by a 2-dimensional array (based on Micro Channel Plates - MCPs - and discrete anodes sets), allowing the reconstruction of both velocity and direction of the incoming particles.

The MCPs "see" a sequence of pulses generated by the oscillation of the mask with respect to a fixed collimator. Randomisation of the mask pattern could be also considered to improve the duty cycle, by associating the "opening/closing" state to pseudo-random sequences (PRS) of ones and zeros, according to the technique described in Wilhelmi and Gompf (1970). With PRS mode the chopper gate can be considered open up to ~ 50 % of the time.

As a reference, such a NSWD instrument on the Solar Orbiter would have the following parameters: Energy/nuc range: 0.05 to 5 keV/nuc, velocity resolution about 0.05, mass resolution being a secondary objective. The field of view of the NSWD should be cantered at about 25° off the spacecraft-Sun-centre line, the field of view half-cone measures up to 20°. A primary deflector can be housed in front of the gating chopper thus contributing in a first raw removal of the charged particles background. Then the TOF section within the sensor body can provide a longer fine discrimination path in which charge particles gated together with neutral can be rejected to the requested 10^{-9} ratio, deflecting and trapping the ion and the electrons out of the FOV neutral path. The collimator plate length, distance and potential would determine the cut-off of the charged-particle transmission (goal: about 40 - 100 keV/q). It can be achieved by means of high voltage biased plates within the instrument itself without protruding large external collimators. In this respect sensor could be confined in a simple parallelepiped box with about 1 cm^2 hole entrance. The first compartment can be also accommodates the baffle plates keeping out solar UV. The direct solar radiation is blocked by the solar orbiter sunshield (making use of the aberration of particles up to 8°, see Figure 3). For the suppression of scattered light within the collimator, the plates could be covered with sawtooth-like structures.

In this respect, 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^{-7}. The residual photons, even though transmitted and not distinguishable from neutrals, remain accumulated when detected (in a 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. By the way 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 later with respect to the main entrance shutter thus shadowing completely the MCP detector to the external UV environment.

As far as heat flow due to irradiation external mesh overlaid on the hole entrance can be foreseen for protecting and minimizing the IR transmission. Various types of metallic meshes may be used as IR semi-reflectors with almost any Γ reflectivity in the range $| \Gamma | \approx 0\text{-}1$ while residual trapped heat can be conducted by the mesh to the housing box.

Instantaneously, the ELENA BepiColombo 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.

Data Handling

The NSWD could benefit also of a second inheritance from the SERENA BepiColombo design for what is concerning the system control and power distribution unit, namely SCU. Such a board support S/C I/F and data handling computation services suitable at particle package level consisting in one board containing the following functional blocks:

- Hi Rel FPGA based Control Unit (Spacewire hub, Leon2)
- Hi Rel SRAM 512x2 kB EDAC Protected
- HI Rel local power converter and power distribution switches
- Rad Tolerant EEPROM 128x2 kB EDAC Protected
- Rad Tolerant 200 MIPS DSP Based DPU Compressor

Orbit, operations and pointing requirements

The instrument points 25° off the S/C-Sun axis in the plane of the orbit. The field of view is an half cone of about 20° in the sun-satellite plane and about +/- 10° out of the plane.

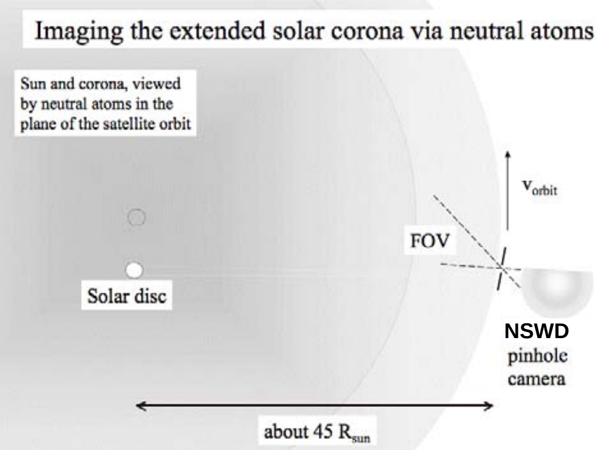

***Figure** 3. Instrument schematics and field of view of the Neutral Solar Wind Detector.*
The aberration causes the shift of the "neutral solar wind" image of the corona off the Ly-α corona (shown for v_{sw} = 400 km/s, v_{orbit} = 65 km/s) (Hilchenbach et al. 2005).

Accomodation

The instrument should point 25° off the S/C - Sun axis in the plane of the orbit. A possible accommodation would be the +Y panel, in a position behind the sunshield and with an unobstructed field of view of +/- 20°, 25° off the S/C - Sun axis in the Sun-Satellite plane and about +/- 10° out of the plane (see Figure 4).

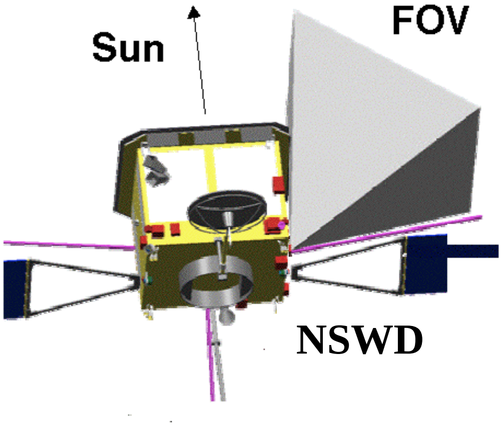

***Figure 4.** Potential instrument location on Solar Orbiter and field of view of NSWD.*

Interface and physical resources requirements

The NSWD can be built for a mass of 1.3 kg, including 0.2 kg for a shared DPU. The power consumption would be about 2 W. The required telemetry rate is less than 0.32 kb/s. It is envisaged to use a common DPU and it is possible to share mechanical structure elements with e.g. SWA.

INSTRUMENT SUMMARY

Unit	Mass (kg)	Power (W)	Volume (cm^3)	Data rate (b/s)
Structure	0.330			
Electronics	0.430	2		
Harness	0.040			
Connectors	0.020			
Sensor (MCP+collimator)	0.280			
DPU**(shared)**	0.230			
Total	1.33	2	2560	320 b/s

Table 1: NSWD resource requirements

Cleanliness, ground operations and other requirements

At S/C level a class-10000 clean room shall be enough. The instrument is envisaged to operate autonomously and commanding is only required to update lookup table for voltage settings and data classification schemes.

Open Points and Critical Issues

The possible UV-suppression system via nano-shuttering system is being studied.
Increasing the detection efficiency is being studied.

3 Assessment of the hardware maturity and heritage (particular reference to the performance and survival of the detectors and front-end electronics)

The NSWD sensor is an innovative sensor, based on the design of BepiColombo SERENA/ELENA unit and on heritage and space-borne components got from CLUSTER/CIS, MARS EXPRESS/ASPERA-3, IMAGE/MENA. The sensor maturity is medium, since the design and preliminary testing activity (already funded by the Italian Space Agency) of its parent instrument ELENA are already in advanced process phase. The thermal criticality is low, all exposed components like collimators and UV grating systems are thermally tested, and can support local thermal excursions.

Experiment maturity quantification**: **3-4

4 Outline of the technological study programme required for demonstrating the validity of the proposed concept

The NSWD consists of several critical parts. In the frame of BepiColombo, the Italian Space Agency has already started funding the laboratory activities necessary for the sensor characterization. For this purpose, we are using a calibration facility from our partner institution

ENEA. Studies of the position imaging and TOF systems and experimental tests have been already carried. We are presently performing further test activities for validating the NSWD detection process.

The ability to produce fully miniaturized electronics will be demonstrated at the brassboard level prior to the NSWD CDR.

5 Solar Orbiter Neutral Solar Wind Detector Data Sheet

Name / acronym	**NSWD - Neutral Solar Wind Detector**

Objectives	*In situ* measurement of neutral solar wind atoms and determination of their velocity and temperature

General description	Neutral atoms are closely coupled to the emerging solar wind plasma and give rise to the prominent solar Lyman-alpha corona. The ratio of the densities of neutral hydrogen and protons is small, some parts per million, and the neutral atoms are therefore a trace particle population in the solar wind plasma. 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.

Reference P/L and/or heritage	Modification / improvement of flight H/W: BepiColombo/SERENA-ELENA, IMAGE/LENA - /MENA, ULYSSES/GAS

Parameter	**Units**	**Value / Description**	**Remarks**
Sensor / detector			
Type	N/A	*In situ* neutral particle detector	
mass range energy/mass	amu keV/nuc	hydrogen, helium, oxygen (mass resolution is 2nd objective) 0.05 to 5 keV/nuc	
Operating T	K	240 to 320 K	
Entrance system			
Type	N/A	Collimator / UV shield	
FOV	degree	40°x20° full cone	
Pointing	degree	25° off Sun-Satellite axis(in X-Y plane) (TBC)	
Pointing error	degree	0.5°	
Configuration			
Physical Units	No	1	
Location S/C		Panel (+Y)	
Physical			
Mass, total	kg	1.3	
Mass unit 1	kg	1.1	
Mass unit 2	kg	0.2	shared mass allocation for DPU

Dimension 1	cm	L x W x H 40 x 10 x 10	
Dimension 2	cm	L x W x H N/A	shared mass in central DPU
Power			
Average	W	2	
Peak power	W	3	
Stand-by	W	0.5	
Data rate / volume			
Average data rate	Bits/s	<320	
Peak data rate	Bits/s	N/A	
Data volume /orbit	KByte	estimate: $3*10^5$	
Own data storage	MByte	less than 0.1	
Thermal			
Heat load to radiator	W	estimate: smaller than 8 W (TBC)	
Operating T range	K	240 to 320	
Other requirements	N/A	N/A	
Cleanliness			
EMC requirements	N/A	Surface of detector (TBC)	
DC magnetic	N/A	not required	
Particulate	N/A	clean room, class 10000	
Miscellaneous			
Mechanisms	No.	TBD.	
Orbit requirements		N/A	
AIT/AIV requirements		N/A	

Development approach / schedule

Preferred model philosophy	e.g. EBB, EM, QM, FM + FS - yes
Estimated development time	EBB (1 yr), EM (1 yr), QM (2 yr), FM (1 yr), FS (1 yr). yes

Areas considered as critical.

Critical area /unit/ subsystem	**Remarks, proposed risk-mitigating measures.**
new sensor technology	detector efficiency requires new technology
	i.e. surfaces
	suppression of scattered UV photons (example: Ly-alpha photons) and solar wind ions by about 10^12 required

Technology readiness – Design maturity level.

Unit / subsystem	**TRL**	**DML**	**Justification and remarks.**
Detector	2/1*	4	Based on heritage / *New concepts are still looked into

Electronics	2	3	as plasma instruments
Entrance System	2	3/4	UV suppression / Ion filter

Technology Readiness Level (TRL):
1: basic principles observed and reported; 2: technology concept and application formulated; 3: analytical and experimental critical function, characteristic proof-of-concept; 4: components validated in the laboratory; 5: component and/or breadboard validation in a relevant environment; 6: system demonstrated in relevant environment (ground or space); 7: system prototype validated in space environment; 8: system flight-qualified through tests; 9: system verified by successful mission.

Design Maturity Level (DML):
1: existing HW; 2: existing + minor modifications; 3: existing + major modifications, 4: new, detail design available; 5: new, preliminary design available, 6: new, conceptual design available.

6 Selected References

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Rome, September 13th, 2006

The NSWD proposer

dr. Stefano Orsini

APPENDIX

SOLO PHASE/A-B1 Support Financial Plan

IFSI / INAF

ITEM	1st Quarter 1st year	2nd Quarter 1st year	3rd Quarter 1st year	4th Quarter 1st year	5th Quarter 2nd year	TOT
Travels	6 kE	6 kE	6 kE	6 kE	6 kE	30 kE
Manpower	10 kE	10 kE	10 kE	10 kE	10 kE	50 kE
Products	25 kE	10 kE	10 kE	5 kE		50 kE
External Serv.	5 kE	10 kE	10 kE	5 kE	5 kE	35 kE
Total	**46 kE**	**36 kE**	**36 kE**	**26 kE**	**21 kE**	**165 kE**

KEY-PERSONS CVs

Major Responsibilities

Name	**Orsini, Stefano**
Address	Istituto di Fisica dello Spazio Interplanetario (IFSI)/INAF Via del Fosso del Cavaliere, 100 I-00133 Roma, Italy Phone: (39) 0649934612 Fax: (39) 0649934383
E-mail	Stefano.Orsini@ifsi.rm.cnr.it
Position	NSWD PI
Responsibility	Instrument Delivery
CV	Laurea in Physics at the University of Rome ‘La Sapienza’ in 1976. Research Scientist at the Istituto di Fisica dello Spazio Interplanetario of the Italian National Research Council (IFSI-CNR), Roma, Italy (from 1982). Has experience in solar-terrestrial relationship studies, mostly related with magnetosphere/upper ionosphere magnetic field, plasma and Energetic Neutral Atoms (ENA). Presently, (in view of MARS EXPRESS, VENUS EXPRESS, BepiColombo, and Solar Orbiter) he is investigating the interaction of the solar wind with planetary surfaces and gas environments as a clue for understanding the planets evolution and surface composition. Has published about 70 papers on refereed journals, 20 papers on Conference Proceedings and has given about 220-contributed and 20-invited presentations in international conferences. *Main activities*: 1977-1981: Co-investigator (scientific data analysis) of the ISEE-2 / EGD experiment; 1984-1988: Co-investigator (GSE-S/W) of the INTERBALL / OPERA experiment; 1988-1999: Co-investigator (Software Manager and Scientific Data Analysis) of TEMAG experiment on board TSS-1 and TSS-1R (Tethered Satellite System), launched in 1992 and 1996; 1991-1997: Principal Investigator of the ISENA experiment, launched on board the ill-fated argentinian satellite SAC-B in late 1996; 1998 – Today: Co-I as Italian Leading Investigator of the ESA Mars Express / ASPERA-3 experiment; 1999-2002: Scientific Responsible of the Italian Auroral Observatory ‘ITACA’ (NyÅlesund, Svalbard, Norway), network ‘MIRACLE’ (FMI, Finland); 2000 – 2003: Member of the ESA BepiColombo Science Advisory Group as contact scientist for a Neutral Particle Analyzer on board the Mercury Planetary Orbiter.; 2001 –Today: Deputy Coordinator of the ESA Topical Team ‘Electromagnetic and other geophysical techniques for *in situ* and orbital planetary exploration’; 2002 – 2003: Member of the ESA Solar Orbiter Payload Working Group; 2002 – Today: Member of the ESA Physical Sciences Working Group; 2002 – Today: Science Advisor of the ESA AURORA Program; 2002 – Today: Co-I as Italian Leading Investigator of the ESA Venus Express / ASPERA-4 experiment, PI of the ESA BepiColombo SERENA particle package.

Name	**Di Lellis, Andrea Maria**
Address	AMDL S.r.l., Via Giovanni Angelici 33, 00149 Roma, Italy Contact Office for BepiColombo c/o INAF-IASF Mobile: (+39)338.9699199 Phone: (+39)06.4993 4958 Fax: (39) 0649934383
E-mail	amdl@rm.iasf.cnr.it
Position	NSWD Project Manager
Responsibility	NSWD Design & Manufacturing
CV	**Education**. Laurea in Physics (Summa cum laude) at University of Rome “La Sapienza”, Dec the 18th 1987. ASI Fellowship: Interplanetary medium and magnetosphere plasma, c/o CNR-IFSI: 1989-1990. **Training.** *First Company experience*: owner of a small company for laboratory R&D and supporting space programs: 1990-1995. *CNR –IFSI Research position:* III liv: 1996-1998. *ESA certications*: as ESA PSS-01-708 21: May 1998. *Second company experience*: owner of AMDL Srl- Rea/CCIA Rome/I 903737 – company operating in the Space R&D 1998-2004. *ASI certifications:* as expert for planetary exploration, Bando n. 7/2000 prof. n.3. **Profile:** Development of space instrumentation for earth and planets plasma magnetospheres, remote sensing of planets and comets atmospheres and surfaces, *in situ* planets science. Flight software and processing electronics for on-board data handling. CCD cameras for telescopes and development of ground support equipment for experiments control. Data handling and numerical analysis of observation data. Science Monte Carlo simulations analysis and technical simulation for optimization of key observational parameters and space instrumentation design. Management of international projects, industry control, quality assurance. Formal space programs commitments: Co-I ESA Cluster 1 – CIS: Cis-2 4 x DPU Design & On-Board S/W. Co-I ESA Cluster 2 – CIS: Cis-2 4 x DPU Design & On-Board S/W. Co-I Soviet Union Mars-96 – PFS: FFT DPU Design & On-Board S/W. Co-I ESA MarsExpress – PFS: FFT DPU Design & On-Board S/W. Co-I DARA-NASA Equator-S mission –ESIC: DPU Breadboard, On-Board S/W Design, GSE. TM ESA Rosetta – VIRTIS: Virtis FGSE ground simulators H/W & S/W control. ESA INTEGRAL mission - IBIS esperiment: EM & QM operation manager. ESA Herschel mission: SPIRE & HIFI ground simulators H/W & S/W control. TM ESA Smart-1 mission – AMIE Camera: Power Supply & S/C I/F board Designer. Co-I NASA-ASI Mars Sample Return 2003 Ma_FluX: Program Manager. Co-I NASA-ASI Mars Sample Return 2003- MARE-Dose: Instrument designer & Experiment Manager. Co-I ESA-China Republic – Double Star Mission - Ion Composition esperiment: On-Board S/W. TM NASA-Dawn mission VIR Experiment: On board SW Compression and ground EGSE PM ESA/BEPICOLOMBO/SERENA: Project Manager, Control System Unit, ELENA design.

Name	**Hilchenbach, Martin**
Address	Max Planck Institut für Sonnensystemforschung Max Planck Str. 2 37191 Katlenburg-Lindau Germany
E-mail	hilchenbach@mps.mpg.de
Position	Co-I
Responsibility	NSWD Project Scientist
CV	**Education**: Dr. rer. nat. in physics at the University of Innsbruck in 1986; **Employment**: Research staff at MPS **Relevant experience in Space missions**: Planetary and space plasma physics: instrumentation hardware and data analysis, L-CoI for SOHO/CELIAS/STOF, PI for ROSETTA/COSIMA, Co-I for EXOMARS/MOMA, Co-I for BEPICOLOMBO/BELA. Order of fifty publications in peer-reviewed scientific journals, and forty publications in conference proceedings and books in the fields of space plasma and planetary sciences.

Name	**Hsieh, Ke Chiang**
Address	Department of Physics University of Arizona 1118 E. 4th Street, PO Box 210081 Tucson, AZ 85721, USA
E-mail	hsieh@physics.arizona.edu
Position	NSWD Co-I
Responsibility	NSWD Project Scientist

Name	**Barabash, Stas**
Address	Swedish Institute of Space Physics (IRF) Box 812 SE-981 28 Kiruna Sweden Phone:+46-980-79000
E-mail	stas.barabash@irf.se
Position	NSWD Co-I
Responsibility	TBD
CV	Director of the Solar System Physics and Space Technology program at IRF, professor of experimental space physics (2002). Wide experience in space instrumentation, project management, data analysis, and theory. PI for ESA Venus Express/ASPERA-4, Swedish Astrid-1 / PIPPI, Swedish Munin / DINA, Co-PI (with PI responsibilities) for ESA Mars Express / ASPERA-3, Co-PI for ESA CSSAR Double Star – Polar/NUADU, ESA SMART-1/D-CIXS, Co-I for Soviet Phobos-2/ASPERA, Russian Mars-96/ASPERA-C,Soviet Interbal-Auroal/PROMICS-3,Soviet Interbal-Tail/PROMICS-3. Co-PI of the BepiColombo SERENA package, as responsible of the MIPA unit.

Name	**Collier, Michael R.**
Address	Building 21 Room 246 Code 673, Laboratory for Geospace Science NASA/Goddard Space Flight Center Greenbelt, Maryland 20771, USA Phone: 301-286-5256 fax: 301-286-1433
E-mail	Michael.R.Collier@nasa.gov
Position	NSWD Co-I

Responsibility	TBD
CV	Dr. Collier received his B.Sc. in Physics in 1988, M.S. in Physics in 1990, and Ph.D. in Space Physics in 1993, all from the University of Maryland at College Park. Since 1998, he has served as a Civil Service Scientist at Goddard Space Flight Center in Greenbelt, Maryland. His research interests include low energy neutral atom imaging from ionospheric outflow, from the solar wind and from the magnetosheath, diffuse soft X-ray emission due to solar wind charge exchange, interplanetary magnetic field scale lengths and flux ropes, and the study of suprathermal and superthermal particles in the interplanetary medium and at planetary magnetospheres. He has published over 50 articles on these topics as author or co-author. He serves as Deputy Lead-Co-I for the Magnetospheric MultiScale Fast Plasma Instrument and as Instrument Scientist for the Low Energy Neutral Atom (LENA) imager on the IMAGE spacecraft. He has participated as a member on a number of instrument teams including the Wind Magnetic Field Investigation, the Wind SWICS/MASS/STICS package, and the Voyager Low Energy Charged Particle experiments.

Name	**Czechowski, Andrzej**
Address	Space Research Centre Polish Academy of Sciences Bartycka 18A PL 00-716 Warsaw, Poland tel. (48)22 840 37 66 ext. 313 fax (48)22 840 31 31
E-mail	ace@cbk.waw.pl
Position	NSWD Co-I
Responsibility	TBD
CV	Educated at Department of Physics and Mathematics, Warsaw University and Physics Faculty, Moscow State University, graduate studies at the Institute for Theoretical Physics, Warsaw University, PhD 1975, habilitation 2005. Main research interests: theoretical heliospheric physics, including solar wind, energetic neutral atoms and anomalous cosmic rays; interplanetary/interstellar dust. Member of CELIAS/SOHO team. About 80 publications in physics and space sciences.

Name	**Dandouras, Iannis**
Address	Centre d’Etude Spatiale des Rayonnements 9, Avenue du Colonel Roche 31028 Toulouse Cedex 4, France Phone:+33(0)561556676 fax:+33(0)561556701
E-mail	Iannis.Dandouras@cesr.fr
Position	NSWD Co-I
Responsibility	TBD
CV	Dr. Dandouras received his B.Sc. in Physics from the University of Athens, Greece (1980) and his Ph.D. in Space Physics from the University of Toulouse, France (1988). Since 1989 he is *Chargé de Recherche* at CNRS, at the CESR laboratory (Toulouse). His research interests include solar wind-magnetosphere coupling, terrestrial magnetosphere dynamics, magnetosphere-exosphere interaction, the dynamics of the magnetospheres of the outer planets, and the development of magnetospheric imaging techniques. He is involved as a Deputy PI in the Cluster 4-spacecraft mission (CIS-Cluster Ion Spectrometry experiment), in the Cassini mission to Saturn (Co-I of the MIMI-Magnetospheric Imaging Instrument experiment), in the Double Star 2-spacecraft mission (Deputy PI of the HIA experiment), and in the Stereo mission (Co-I of the IMPACT experiment). He is a member of several working groups (ESA CSDS IWG, ESA

	Cluster SOWG, ESA DSDS IWG), and of the French Cluster Data Center Steering Committee. He has been also member of the CDPP (*Centre de Données de la Physique des Plasmas*) Implementation Working Group, and of the French Space Weather Working Group (PNST). Dr. Dandouras has been a visiting scientist at the SSL (Univ. of California, Berkeley), in 1989, and at the Univ. of Washington, Seattle (numerous stays since 1983).

Name	**Gruntman, Mike**
Address	Astronautics and Space Technology Division USC Viterbi School of Engineering 854 Downey Way, RRB-224, MC-1192 University of Southern California Los Angeles, CA 90089-1192, USA tel. 213-740-5536 fax 213-821-5819
E-mail	mikeg@usc.edu
Position	NSWD Co-I
Responsibility	TBD
CV	Present affiliation: Professor and Chair of Astronautics, Chair of the Astronautics and Space Technology Division, Viterbi School of Engineering, University of Southern California, Los Angeles, California. Research interests: Dr. Gruntman is Principal Investigator and Co-Investigator in several projects in space science and space technology. His interests include space physics and space instrumentation, astronautics, space mission and spacecraft design, microsatellite technology and applications, spacecraft propulsion, space sensors, heliospheric and magnetospheric physics, space plasmas and environment, particle and photon analyzers and detector systems, ion and neutral particle beams, atomic collisions, particle interactions with surfaces, aerospace education, and aerospace history. Gruntman authored and co-authored more than 200 publications (including one book). He studied and published on the neutral solar wind since late 1970s.

Name	**Habbal, Shadia Rifai**
Address	Institute for Astronomy University of Hawaii 2680 Woodlawn Drive Honolulu, HI 96822, USA phone: 1 808 956 6531 fax: 1 808 956 4604
E-mail	shadia@ifa.hawaii.edu
Position	NSWD Co-I
Responsibility	TBD
CV	Dr. Habbal received her MSc in Physics from the American University of Beirut in 1970, and her PhD in Physics from the University of Cincinnati in Ohio in 1977. She has published over 90 papers in refereed journals. She has served as Editor for the Journal of Geophysical Research, and has edited three books. She has over 90 publications in refereed journals. Her research expertise is in solar physics, with particular emphasis on the solar wind and its origin at the Sun. Her research uses observations, data analysis and modeling in a complementary manner. She has been leading eclipse expeditions since 1995. Her current interest in eclipse observations is in finding spectroscopic signatures of very fine dust grains, in the form of siicon nanoparticles, in the corona. She worked at the Harvard-Smithsonian Center for Astrophysics for 22 years. She then accepted a chaired faculty position in solar-terrestrial physics at the University of Wales, Aberystwyth, UK. She then moved to the Institute for Astronomy at the University of Hawaii in early 2005, where she currently holds the post of faculty chair. She

	has served on a number of advisory panels in the US and in the UK, and has played an active role in the scientific justification for the Solar Probe mission.

Name	**Kallio, Esa**
Address	Finnish Meteorological Institute (FMI) Space Research Unit P.O.BOX 503, FIN-00101 Helsinki, Finland Phone: (+358)-9-1929 4636 Fax: +358 9 1929 4603
E-mail	esa.kallio@fmi.fi
Position	NSWD Co-I
Responsibility	TBD
CV	Co-I of ASPERA-3/MarsExpress, ASPERA-4/VenusExpress and ICA/Rosetta. Expertise: i) Numerical and analytical global modelling of the solar wind interaction with Mercury, Venus, Mars and Saturnian moon Titan; ii) modelling of the energetic neutral atoms, ENAs.

Name	**Leoni, Roberto**
Address	Istituto di Fotonica e Nanotecnologie/CNR Via Cineto Romano 42 00156 Roma, Italy Phone: +39 06 41522 239 Fax: +39 06 41522220
E-mail	roberto@ifn.cnr.it
Position	NSWD Co-I
Responsibility	NSWD nanotechnology manufacturing
CV	Laurea in Physics, 1979. *Position:* Senior Researcher at IFN. *Field of activity:* Superconducting devices, electron-beam lithography and thin-film technology. *Teaching:* Solid State Physics, 2000-2001, 2001-2002 and 2002-2003, Dep. of Physics, Univ. Roma TRE. He is involved in superconducting and with ultra-small tunnel junctions (about 0.01um^2 area). He uses the technological tools of the Microfabrication Facility of the IFN to develop devices for experiments concerning the electron cooling effect, on-chip electronic microrefrigerators, normal-metal hot electron bolometers (N-HEB) and Single Electron Transistors (SETs). He is responsible of the Electron Beam Lithography facility of the IFN and is author and co-author of about 100 scientific publications on International Journals. *Research Projects*: Programma Nanotecnologie, Italy; RSFQubit (RSFQ Control of Josephson Qubits), EU.

Name	**Livi, Stefano**
Address	Johns Hopkins University Applied Physical Lab. 11100 Jonhs Hopkins Road, Laurel, MD 20723-6099 USA Phone: (443) 778-8413 fax: (443) 778-0386
E-mail	Stefano.Livi@jhuapl.edu
Position	NSWD Co-I
Responsibility	TBD
CV	**Education**: PhD in Physics (Summa cum laude), 1982, University of Florence; PhD in Astrophysics (Summa cum laude), 1986, University of Rome. **Employment**: Ph.D. student at MPAe, 1981-1982; Postdoc at MPAe, 1982-1984; Staff scientist at MPAe, 1984-1987; Senior scientist at MPAe, 1987-1999; Principal staff physicist at MPAe, 1999-2000; Senior professional staff at Johns Hopkins University – Applied Physics Laboratory, 2000 – today **Relevant experience in Space missions**:

	Principal Investigator: STROFIO (NASA PIDDP) Lead-Investigator: CAMMICE/MICS (Polar); MIMI/LEMMS (CASSINI); ISENA (SAC-B); ROSINA/RTOF (Rosetta); Co-Investigator: MSIS (AMPTE) ; TAUS (Phobos) ; UVCS (SOHO) ; CELIAS (SOHO); Rapid (Cluster); MICS (CRRES); CEPPAD (POLAR); EPD (Galileo); Rapid (Cluster-II); ASPERA-3 (Mars Express); IMPACT (Stereo)

Name	**Mann, Ingrid**
Address	Department of Earth and Planetary Sciences, Faculty of Science Kobe University, Nada, Kobe 657-8501, Japan Phone/Fax: 81-78-803-5741
E-mail	mann@diamond.kobe-u.ac.jp
Position	NSWD Co-I
Responsibility	TBD
CV	**Present affiliation:** Professor at Faculty of Science, Department of Earth and Planetary, Sciences, Kobe University, Japan **Education:** Diploma in Physics, Ruhr - Universität, Bochum, Germany 1987, PhD (Dr. rer.nat.) in Physics, Ruhr - Universität, Bochum, Germany, 1990, Habilitation, Universität Braunschweig, Braunschweig, Germany 1997 **Research Interests:** Dust and small bodies in the solar system and in extra-solar planetary systems, physics of the interplanetary and interstellar medium. **Professional Experience:** German and US teaching and basic research institutions, ESA and NASA space centres. Guest researcher in Sweden, USA and Japan, international scientific collaborations, participation in space missions, expert groups and review panels. **Research Record:** Order of eighty publications in peer-reviewed scientific journals, publications in conference proceedings and books, invited presentations on international conferences in the fields of astronomy, space and planetary sciences. **Relevant experience:** Research on dust and dust-plasma interactions near the sun. **Interest in the project:** Dust gas interactions and the possible generation of neutrals by dust and by dust interacting with the solar wind.

Name	**Marsch, Eckart**
Address	Max-Planck-Institut für Sonnensystemforschung (MPS), 37191 Katlenburg-Lindau, Germany
E-mail	marsch@mps.mpg.de
Position	NSWD Co-I
Responsibility	TBD
CV	**Education**: Dr. rer. nat. in theoretical physics at the University of Kiel in 1976; Habilitation (Astronomy and Astrophysics), University of Göttingen in 1990. **Employment**: Senior research staff (C3) at MPS and Extraordinary Professor at the University of Göttingen **Relevant experience in Space missions**: Analysis and theoretical interpretation of data from the Plasma Instrument and Magnetometer on the Helios mission, Co-Investigator of the Charge and Element Analysis System (CELIAS) on the ESA/NASA mission SOHO, Co-Investigator of the Solar Ultraviolet Measurements of Emitted Radiation (SUMER) for the ESA/NASA mission SOHO, Co-Investigator of the Sun Earth Connection and Heliospheric Investigation (SECCHI) for NASA's STEREO mission, 1999 - 2000

	Proposal coordinator for the Solar Orbiter mission selected by ESA in 2000, 2004 - 2005 Chair of the Science Definition Team (SDT) for Solar Orbiter.

Name	**Möbius, Eberhard**
Address	Space Science Center & Department of Physics, University of New Hampshire, Morse Hall, 39 College Rd., Durham, NH 03824, (603) 863-3097, USA
E-mail	Eberhard.Moebius@unh.edu
Position	NSWD Co-I
Responsibility	TBD
CV	Eberhard Möbius received his Diploma in Physics in 1973 and his Ph.D. in Physics in 1977 from the Ruhr-Universität Bochum in Germany. After working as research scientist at the Max-Planck-Institut for extraterrestrial Physics in Garching, Germany for 12 years, Dr. Möbius joined the Space Science Center and the Department of Physics of the University of New Hampshire (UNH) in 1990 as faculty member. Dr. Möbius' research is centered around the acceleration of particles in and their transport through space with the help of state-of-the-art instruments on spacecraft. He is also involved in the studies of interstellar gas outside the solar system, a sample of cosmic material that is distinct from the sun and its planets, and its interaction with the heliosphere. He is a Co-investigator on thermal and energetic ion and neutral instruments for the NASA Advanced Composition Explorer (ACE) and FAST missions, the ESA/NASA Cluster and SOHO missions, and for the upcoming NASA Solar Terrestrial Relations Observatory (STEREO) and Interstellar Boundary Explorer (IBEX) missions. Dr. Möbius has served on several science and technology definition teams and commissions for NASA. He has served in committees and in editorial functions for IAGA, COSPAR and AGU. He is very active in graduate and undergraduate teaching as well as public outreach and was awarded the Arthur K. Withcomb Professorship (1998-2000). Dr. Möbius has authored and co-authored over 200 publications in refereed journals on topics in laboratory plasma, magnetospheric, solar and heliospheric physics as well as on ion mass spectrometer instrumentation.

Name	**Selci, Stefano**
Address	Istituto di Struttura della Materia/CNR, Via del Fosso del Cavaliere, 100 I-00133 Roma, Italy Phone: (39) 0644934167
E-mail	Stefano.Selci@ism.cnr.it
Position	NSWD Co-I
Responsibility	NSWD nanotechnology AIV
CV	Senior Scientist at ISM-CNR (Rome-Italy), previously researcher at the University of Rome "Tor Vergata", author of more 80 international papers, is mainly devoted to characterization of semiconductor materials, in particular quantum confined systems, performed in full collaboration with theoreticians to develop first-principle _unnellin of radiation-matter interaction. In particular the study of the optical response of semiconductors systems using optical spectroscopy is grounded on a large experience gained with fundamental works on semiconductor clean surfaces (Phys.Rev.Lett. 52, 1145 (1984)) while the use of scanning probe microscopies (STM), is a well consolidated activity that produced, among other results, the first scanning _unnelling microscope realized in Italy (Science 245, 1226 (1989).

Name	**Sheldon, Robert**
Address	NASA/MSFC/NSSTC/VP62 Huntsville, AL, USA

E-mail	rob.sheldon@msfc.nasa.gov
Position	NSWD Co-I
Responsibility	TBD
CV	**Education** Ph.D., Physics, (Space Physics) University of Maryland, 1990 M.A. Religion, Westminster Theological Seminary, 1985 M.S., Physics, University of Maryland, 1982 B.S. Physics, Wheaton College 1981 **Positions Held** Senior Scientist Consultant (USRA) 2003-present Visiting Associate Professor, 2002-2003, Wheaton College Associate Professor, Univ. of Alabama in Huntsville,1998-2002 Senior Research Associate, Boston University, 1997-1998 Research Associate, Boston University, , 1995-1997 Research Associate, University of Bern, Switzerland, 1992–1995 Research Assistant, University of Maryland, 1986–1990 High School Physics Teacher, Silver Spring Academy, 1988-1989 Part-time Computer Programmer, LTK Engineering, 1983-5 Teaching Assistant, University of Maryland, 1981-2, 1985-6 Research Assistant, IBM Watson Research Center, 1981. **Awards and Professional Services** Convener for the Huntsville 2000 Workshop (attendance 85). NASA Group Achievement Award for AMPTE Mission Operations (1990) UMd Ralph D. Myers Teaching Award for Grad Lab Teaching Assistant (1986) **Teaching** Has taught at undergraduate, graduate levels. Co-directed several graduate students. **Relevant Experience** • Currently developing new space instrumentation for NASA exploration of the Moon and Mars, including ultra high resolution TOF mass spectrometers potentially exceeding R~3000. • Participated extensively in the invention, design, calibration, and software analysis of Wind/MASS, ACE/SWIMS, SOHO/MTOF series. Heavily involved in calibration for Wind/STICS, Wind/SWICS, ACE/STICS, POLAR/CAMMICE, CLUSTER/IES, IMAGE/LENA instruments. Detailed analysis of AMPTE/CHEM data. • Analysis and first detection of ENA signal in POLAR/CEPPAD data. • Developing innovative high energy detectors for radiation belt studies for imaging loss-cone pitchangles at very fast time resolution. • Designed and proposed a 100MHz shutter TOF instrument using coded masks for neutral atom imaging.

Name	**Szego, Karoly**
Address	KFKI Research Institute for Particle and Nuclear Physics of the Hungarian Academy of Sciences, Konkoly Thege Miklós út 29-33, H-1121 Budapest, Hungary Phone:+36 1 392 26 38 Fax: +36 1 395 91 51
E-mail	szego@rmki.kfki.hu
Position	NSWD Co-I
Responsibility	TBD
CV	Present affiliation: Head of Department, Department of Natural Sciences, Office of the Hungarian Academy of Sciences; scientific affiliation: KFKI Research Institute for Particle and Nuclear Physics, current position: scientific adviser. Education: Diploma in Physics, Roland Eötvös University, Budapest, Hungary, 1966; Ph.D. 1972; D.Sc. 1987. Professor, Roland Eötvös University, Budapest,

	Hungary, 1998. He is member of several national and international advisory boards. Awards: Diploma for International Cooperation, NASA, 1982; State Prize of Hungary, 1986; 'Token of Esteem' , Union of Soviet Socialist Republics, 1986; Award of the Union of the Hungarian Societies in Natural Sciences, 1991. Research activities in space physics: in the VEGA mission (1986) CoPI of the imaging experiment, and CoI in two charged particle analysers; he was CoI in two charged particle analysers (TAUS and HARP) of the PHOBOS mission (1988), was guest investigator in the Pioneer-Venus mission between 1990-1993. He is CoI in the CAPS experiment of the CASSINI mission, work package coordinator for the ROSETTA lander onboard software, CoI of the ROSETTA orbiter plasma consortium. His scientific contributions include: obtaining first images of a cometary nucleus, modeling its activity; exploration of the plasma regions around comets, Venus, and Mars, in particular the interaction of the shocked solar wind with the ionosphere of nonmagnetic solar system bodies. Number of publications in refereed scientific journals: 141.

Name	**Wurz, Peter**
Address	Physikalisches Institut - University of Bern Sidlerstrasse 5 CH-3012 Bern, Switzerland Phone: (++41 31) 631 44 26 Fax: (++41 31) 631 4405
E-mail	peter.wurz@soho.unibe.ch
Position	NSWD Co-I
Responsibility	TBD
CV	**Institution**: Space Research and Planetary Sciences Division, Physics Institute, University of Bern, Switzerland **Education**: Engineering school, Vienna, Austria, Department: Telecommunication and Electronics, 1980; M.S. Technical Physics, Technical University of Vienna, 1987; Ph. D. Technical Physics, Technical University of Vienna, 1990; Viena Docendi, University of Bern, 1999; Titularprofessor, University of Bern, Bern, Switzerland, 2003 **Professional Background**: Electronics Engineer, 1981–1983, Datentechnik; Austria; Software Engineer, 1983–1985, Datentechnik; Austria; Research Assistant, 1985–1990, Institut für Allgemeine Physik, Technical University of Vienna, Austria; Post-doctoral appointment, 1990–1992, Materials Science/Chemistry Divisions, Argonne National Laboratory, Chicago, USA; Research Associate, 1992–2000, Physics Institute, Department of Space Research and Planetary Sciences, University of Bern, Switzerland; Docent, 2000–present, Physics Institute, Space Research and Planetary Sciences Division, University of Bern, Switzerland. **Relevant Experience**: Dr. Wurz is Lead Co-Investigator for the RTOF instrument of ROSINA on the Rosetta mission (ESA), and is Co-Investigator on Charge, Element, and Isotope Analysis System (CELIAS) on SOHO (ESA/NASA), Low-Energy Neutral Atom (LENA) instrument on IMAGE (NASA), the ASPERA instruments on Mars Express and Venus Express (both ESA), and on the PLASTIC instrument on the STEREO mission (NASA), and on the LASMA instrument on Phobos-Grunt (Russian). Dr. Wurz is author of more than 150 scientific papers in the refereed literature and of 50 other publications, on topics related to plasma physics, space science, space science instrumentation, ion optics, electron-stimulated desorption, ion-sputtering, physical chemistry, and laser interaction with solids and particles**.**

Name	**Zanza, Vincenzo**
Address	CR ENEA Frascati Via Enrico Fermi 45

	00044 Frascati (Roma), Italy Phone: +39 0694005542 Fax: +39 0694005735
E-mail	zanza@frascati.enea.it
Position	NSWD Co-I
Responsibility	NSWD calibration, Instrument performance, verification support
CV	Laurea (cum Laude) in Physics at the University of Rome “La Sapienza” on 1974. Fellowship at Rome University, from 1975 to 1979, working on transport properties of dense fluids and on neutron scattering from liquids.On 1979, began its activity on the physics of magnetically confined plasmas at the Frascati laboratory of CNEN (now ENEA). Until around 1990, his research was mainly dedicated to Neutral Particle Analyzers. In this area he and his coworkers built the NPA diagnostic system for large fusion experiments such as Frascati Tokamak Upgrade (FTU), the Joint European Torus (JET) and Large Helical Device (LHD, Nagoya, Japan). The transport of neutral particles in hot plasmas, its influence on the global plasma confinement, and the dynamics of energetic ion tails generated by electromagnetic waves or fast ion beams was the main topic investigated in this period. In the following his activity spanned over many topics of the Physics of Tokamak plasmas. In particular:Plasma heating and confinement, Energy and momentum transport in tokamak plasmas, Plasma-wall interaction, Optical, Far Infrared and X-ray diagnostics. At present his activity is concerned with the propagation of electromagnetic waves in plasmas and with the polarimetry of the beam-induced radiation emitted from plasmas. He is author of about 40 papers on refereed journals and about 70 papers on Conference Proceedings.

Name	**Zurbuchen, Thomas**
Address	Dept. of Atmospheric, Oceanic, and Space Sciences University of Michigan, USA
E-mail	thomasz@umich.edu
Position	NSWD Co-I
Responsibility	TBD
CV	**Education** Ph.D., Physics (with highest honors), University of Bern, Switzerland, 1996 M.S., Physics, Mathematics, Astronomy (with highest honors), Univ. of Bern, Switzerland, 1992 **Positions Held** Associate Professor, 2003-present Senior Associate Research Scientist, 2002–2003 Assistant Research Scientist, University of Michigan, 1998–2002 Research Fellow, University of Michigan, 1996–98 Part-time Consultant in Space Industry (Oerlikon Contraves), 1992–94 Teaching Assistant, University of Bern, 1990–96 **Awards and Professional Services** Presidential Early Career Award (PECASE), 2004. Outstanding Research Scientist Award of the Univ. of Michigan College of Engineering, 2002. Swiss National Science Foundation, Young Researcher Award, 1996–97 Member, American Geophysical Union and the Swiss Society of Astronomy and Astrophysics Chair and convener of several conferences, including SHINE (3 times) Member of NASA Science and Technology Definition Teams **Teaching** • Graduate Level: Solar Terrestrial Relations, Plasma Physics, Space System Design, Space Instrumentation. • Undergraduate Level: Engineering Design Course, Solar Terrestrial

	Relations • Has graduated three Ph.D. students, three M.S. students. • Advises 8 Ph.D. students at various levels, ~10 part-time students at varying levels. **Relevant Experience** • Currently leads data center for composition instruments on ACE, Ulysses, and WIND, and develops new space instrumentation. Participated extensively in calibrations of Wind/MASS, ACE/SWICS, and ACE/SWIMS. Led UV-suppression tests for SOHO/CTOF and SOHO/MTOF. Participated in development of Wind/MASS. • Led design and construction of FIPS, a miniaturized mass spectrometer that is part of the MESSENGER payload to Mercury. FIPS launched, successfully tested out and en route for Mercury. • Technology developments on MEMS and new FPGA based circuits and instrument designs.