# SN-II - Implementation Design Study of Space Weather Instruments

**7th European Space Weather Week, Brugges**

**15. Nov. 2010 – Astrium Friedrichshafen & University of Göttingen**

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# Content

## 1. Introduction

- Frame of ESA's SSA programme
- Objectives of the running two-phase ESA study

## 2. Strategy for the running study

- Technical requirements derived from Customer Requirements Document CRD
- Consulting/contributing groups
  - Independent Scientific Experts
  - Instrument Providers
  - Mission Project Teams

## 3. Outlook towards instrument implementation

- Implementation of piggy-backs on planned missions
- Definition of high level rqmts for existing gaps as dedicated mission(s)

## 4. Instrument selection processes → Uni Göttingen

- Analysis of CRD
- Instrument selection process

## 5. Conclusion → Uni Göttingen

# 1. Introduction (1/4)

- Customer requirements for space weather products have been identified in form of the CRD as part of the Space Situational Awareness (SSA) preparatory programme
- Products mainly consist of environment measurements or are derived from such data
- Measurements which can be performed from ground will be flagged
- There are very few (operational) in-space measurement sources in the field of science that could form part of an independent European Space Weather measurement network
- The SSA spacecraft-borne sensors to be developed on a < 10 year time scale are being considered
- Space weather SWE monitoring instruments will be flown on already planned ESA , European partner or non-European spacecraft.

# Frame of ESA's SSA programme

- **Common SSA Integration Framework** Cosif

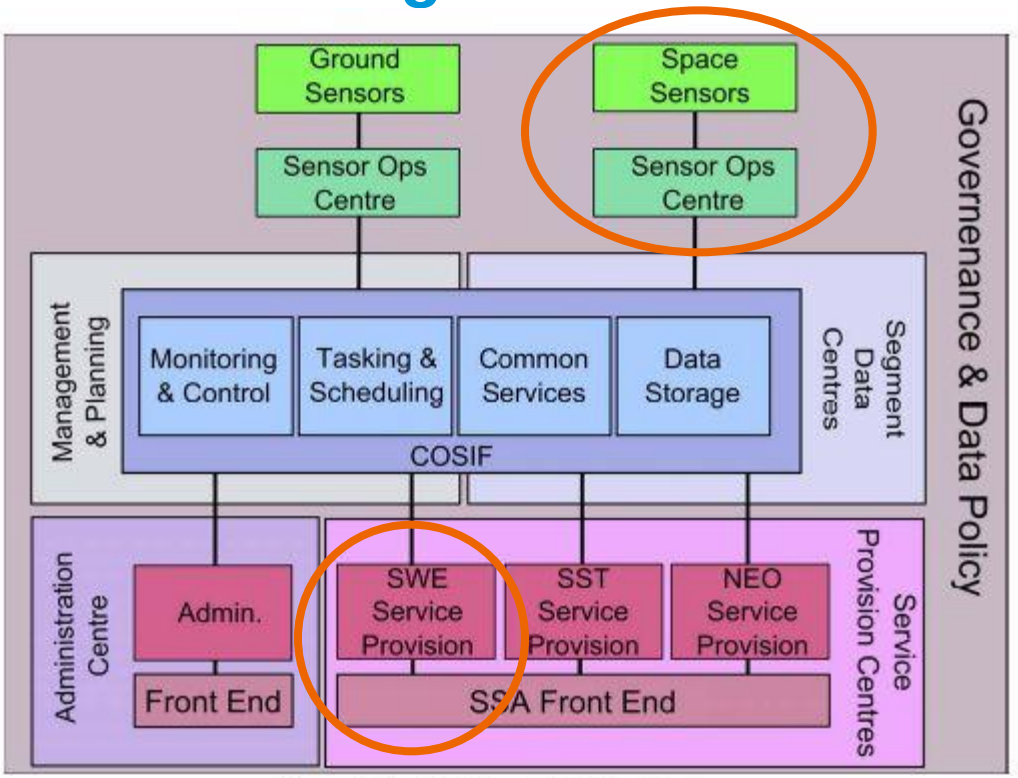



Figure 1: Simplified Overall SSA Architecture

The full Space Situational Awareness (SSA) system will enable Europe to detect, predict and assess risks from space and take actions

# 1. Introduction (3/4)

- As a result of a competitive tender ESA has recently placed a contract with Astrium GmbH to perform an activity called, ‘Implementation design study of Space Weather instruments’:
  - Consider the requirements of the CRD and investigate:
    - Instruments needed to satisfy these requirements
    - Required location(s) of the measurements
    - Characteristics of the instruments and of spacecraft already planned to be flown in suitable orbits
    - Degree to which the planned spacecraft can satisfy the requirements
    - Cost and Development Planning for piggy-back candidates

# 1. Introduction (4/4)

## Objectives of the running two-phase ESA study

**Phase 1**: Instrument characterisation & mission analysis

- derivation of technical rqts from CRD
- investigation of instruments satisfying CRD
- reasoning of proper place in space
- investigation of potential candidate platforms
- derivation of rqts of dedicated mission(s) for gap(s)

**Phase 2**: Preliminary mission design

- implementation design on the basis of instrument ICDs and platform I/F rqmts
- ground segment definition & data dissemination
- mission project teams of planned and running projects will be involved via ESA for piggy-backing of instruments

# 2. Strategy for the running study (1/6)

## Technical requirements derived from CRD

- **Phase 1**:
  CRD contains the customer rqmts for the SWE segment:

| | |
|---|---|
| ionosphere/thermosphere observations | LEO |
| magnetosphere observations | HEO or MEO |
| solar wind observations | L1 |
| solar observations | GEO or L1 |
| microparticle environment | |

→ addressing high-level user rqmts and identify services of this segment as part of the applicable baseline for all SWE segment design definition activities

→ all engineering activities and segment specifications will have to satisfy the CRD

# 2. Strategy for the running study (2/6)

## Consulting/contributing groups

- **Phase 1**:
  To cope with this wide and complex field several dedicated groups have to be consulted in order to avoid duplications or gaps:
  - Independent Scientific Experts
  - Instrument Providers
  - Mission Project Teams

# 2. Strategy for the running study (3/6)

- **Phase 1**:
  Implementation opportunities of piggy-backs on planned missions:

  - starting point: mission/platform list given by ESA
  - complemented by platforms available within a timeframe of < 10 years in which the spacecraft development shall be concluded
  - Instrument Short-List mated with Mission Short-List results in selection of piggy-backs and mission candidates which will be investigated in Phase 2: Preliminary Implementation Design

# 2. Strategy for the running study (4/6)

- **Phase 1**:
  Definition of high level rqts for dedicated mission(s) for filling existing gaps
  - identify launch opportunities on which small satellites can fly as secondary passenger
  - most probably the gap(s) will be for instruments typically positioned in an orbit around L2
    but:

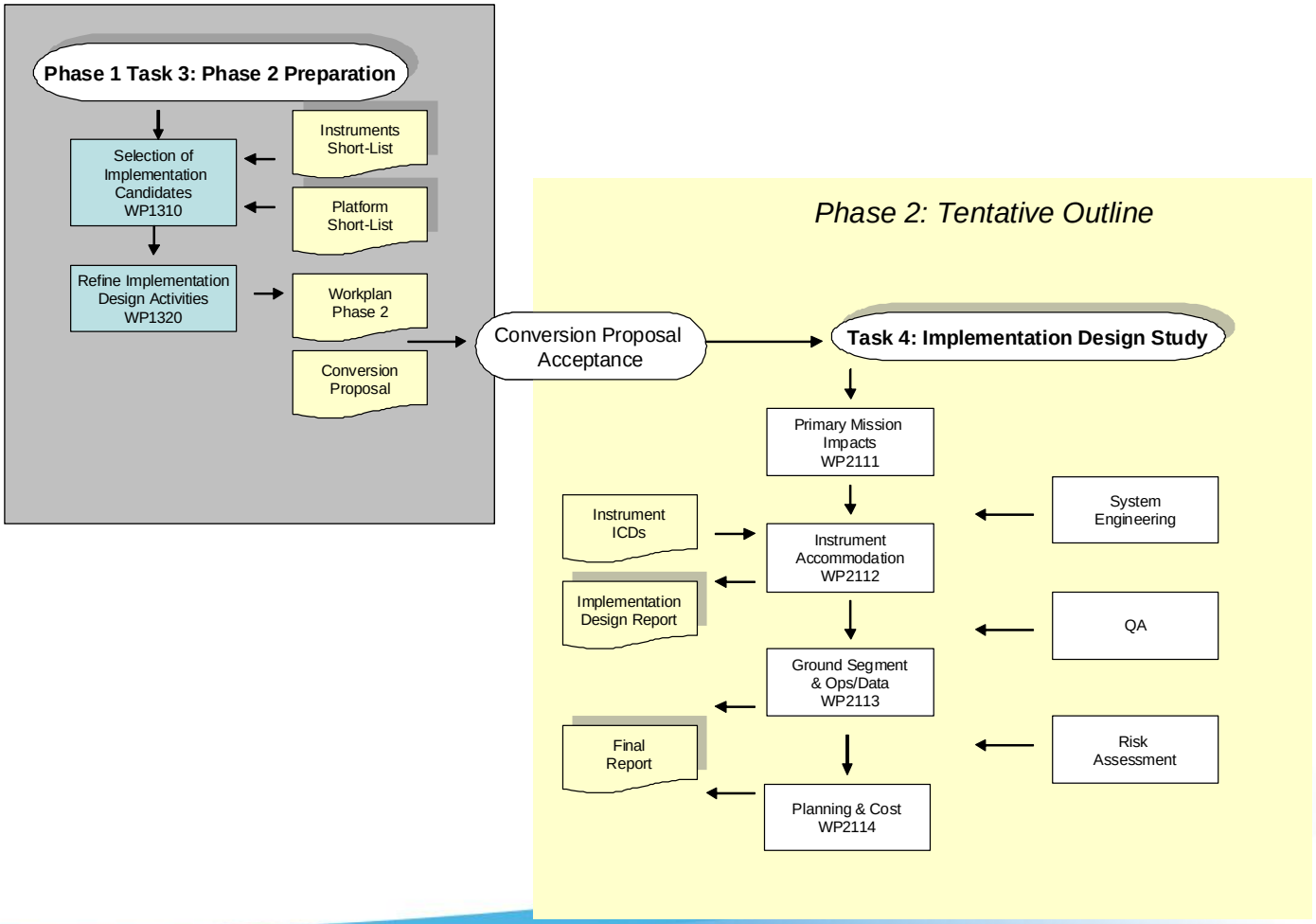
- Most probable gaps:
  - solar wind observations — no L1 mission
  - magnetosphere observations — only few missions
  - solar observations — Imager Coronagraphs/Flux Meters: large & heavy, need high accuracy pointing → untypical for piggy-back options

# 2. Strategy for the running study (5/6)

## Mission List (detail)

| Mission | ESA | Eumetsat | EC | DLR | CNES | CSA | ISA | JAXA | NASA | CNSA | NOAA | Roscosmos | commercial | Expected Launch | End of Operation | Main purpose |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ISS** | X | | | X | X | X | | X | X | X | | X | | 1998 | 2020+ | Manned space |
| **MSG-4** | X | X | | | | | | | | | | | | 2010 | 2017 | high stability spin axis, earth pointing, earth observation from GEO |
| **MTG** | X | X | | | | | | | | | | | | 2017-19 | 2020+ | high stability high pointing earth observation from GEO |
| **EDRS** | X | | | | | | | | | | | | | 2013 | 2020+ | Telecommunications |
| **Galileo IOV** | X | | | | | | | | | | | | | 2010 | 2020+ | Navigation |
| **Galileo FOC** | | | X | | | | | | | | | | | 2013 | 2020+ | Navigation |
| **Galileo-2** | | | X | | | | | | | | | | | 2025 | 2020+ | Navigation |
| **MetOp-C** | | X | | | | | | | | | | | | 2015 | 2020 | Multi-instrument earth observation mission |
| **Post EPS** | X | X | | | | | | | | | | | | 2018 | 2020+ | Multi-instrument earth observation mission |
| **Proba-3** | X | | | | | | | | | | | | | 2012 | 2014 | demonstration of foramtion flying techniques / solar coronagraphy |
| **Proba V** | X | | | | | | | | | | | | | 2012 | 2017 | Vegetation mapping, Spot 4/5 follow-on |
| **Hispasat** | | | | | | | | | | | | | X | 2012 | 2020+ | Telecommunications |
| **Heinrich Hertz** | | | | X | | | | | | | | | | 2015 | 2020+ | Research on telecommunications |
| **Alphasat I-XL** | | | | | | | | | | | | | X | 2012 | 2020+ | Telecommunications |
| **Sentinel-1** | X | | | | | | | | | | | | | 2011 / 2013 | 2020+ | C-Band SAR mission |
| **Sentinel-2** | X | | | | | | | | | | | | | 2013 | 2020+ | High Resolution Land Imaging Mission (VIS/NIR/SWIR) |
| **Sentinel-3** | X | | | | | | | | | | | | | 2013 | 2020+ | Ocean Mission |

# 2. Strategy for the running study (6/6)



# 3. Outlook towards instrument implementation (1/2)

- **Phase 2**:
  Implementation Design
- Implementation design for each instrument and each mission wrt impact on S/Ss
- Involvement of platform/mission manager via ESA
- Feasibility of implementing piggy-backs wrt I/Fs

# 3. Outlook towards instrument implementation (2/2)

- **Phase 2**:
  Preliminary ground segment structure for SWE application

- What is needed:
  - info on orbits, receiving stations, location of control and data processing centers
  - time delays between data acquisition and delivery at processing center
  - objectives and constraints for SWE ground segment for a precursor system (up to 2019) and an operational system beyond 2019
  - network and procedure for timely distributing of data

# 4. Instrument selection processes

The SWE instrument selection process in Phase 1 of this project will define those SWE instruments to be studied for flight implementation in Phase 2. The selection process bases on instruments that

- provide optimal technical and science performance with respect to the SSA SWE-CRD specifications and to available or identifieed as to be required flight opportunities, including

- dedicated instruments flown on previous missions or currently in operation

- baseline instruments best suited to be modified accordingly

- instruments currently under design (e.g., those in the ESA GSTP)

# 4.1 Relevant References (1 of 2)

- ESA SSA Space Weather Segment Customer Requirements Document

- defines requirements related to the monitoring of the Sun, the solar wind, the radiation belts, the magnetosphere, the ionosphere, the thermosphere, and the microparticle environment, addressing the high-level user requirements.

  - CRD identifiers: SWE-CRD-BBB-XXXX

  BBB: three letter service identifier (S/C design, S/C operation, human space flight, launch operation, transionospheric radio link, SSA space surveillance and tracking, general data service, non-space system operation)

XXXX: identification number for each segment

# 4.1 Relevant References (2 of 2)

- Related documents:

- SSA-SWE-SOW-SNII (Statement of Work "Implementation design study of Space Weather Instruments")

- ESA lists of space weather assets and GSTP projects

# 4.1 Relevant References (1 of 2)

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# 4.2 Identification of SWE Instruments from CRD Analysis (1 of 3)

**CRD to SWE Instrument Compliance Matrix**

| CRD Specification (according to SSA-SWE-SYS-CRD-1001r4IO_SSA and update of October 4, 2010) | Requested Measurement | SWE Effects | Identified required instrument type | Compliannce with SoW baseline instrument set |
|---|---|---|---|---|
| SCD-1512, SCO-1549, 1554, 1569, SST-1749 | >1 MeV proton energy spectrum, upper bound ~300 MeV. Highest priority to E>3 MeV. 1554: 1 MeV-400 MeV | Dose, NIEL, SEEs, solar cells | **Geo-space high energy proton radiation monitor** | High energy particle spectrometer, 30 sec., 5 kg, 5 W, 100 bps, directional measurements |
| SCD-1513, 1549, SCO-1570, SST-1749 | >1 MeV ion energy spectrum. Highest prior. To E>10 MeV | Dose, NIEL, SEEs | **Geo-space high energy ion radiation monitor** | Missing |
| SCD-1514, SCO-1555, 1571, 1572 | 0-30 keV electron spectrum, highest priority to E>100 keV, spectra along orbit range 50 keV-8 MeV | Dose, NIEL, charging | **Geo-space electron low energy and high energy detectors/monitors** | Medium to high energy particle spectrometer. 30s, 5 kg, 5 W, 100 bps |
| SCD-1515, SCO 1553 | >30 keV and < 1 MeV ion energy spectrum | Surface degradation, component sensitivity (e.g., CCDs) | **Geo-space ion low energy detectors** | Missing |
| SCD-1516, SCO-1553, 1568 | Thermal and suprathermal electron energy spectrum 0-30 keV | Charging, current collection | **Geo-space electron low energy detectors** | Plasma spectrometer and Langmuir density probe, 1 min., 1 kg, 1 W, EMC, <1 kbps |
| SCD-1517 | Thermal ion density and temperature | Charging, current collection, surface erosion | **tbd** | NA |
| SCD-1518,1521, 1526, SCO-1556, 1589, 1591, SCH-1604, LAU-1619, 1625, 1631, TIO-1648, NSO-1769, GEN-1696, 1697, 1698 | UV and soft X-ray spectrum | Charging, current collection, surface degradation, floating potentials, TEC variations | **Geo-space or L1 radiometers** | UV- and X-ray flux monitors, 1 min., <1 kg, 0.1 W, pointing, <1 kbps |
| SCD-1519, SCO-1540, 1541, LAU-1618, GEN-1715, 1716 | Atmospheric density | Drag, nowcast of drag, forecast for other planets | **tbd** | NA |
| SCD-1520 | Dose | Radiation damage and skin dose | **Geo-space high energy radiation monitor** | High energy particle spectrometer, 30 sec., 5 kg, 5 W, 100 bps, directional measurements |
| SCD-1523, SCO-1567 | Atomic oxygen density | Surface erosion in LEO | **tbd** | NA |

# 4.3 Identification of SWE Instruments from CRD Analysis (2 of 3)

| | | | | |
|---|---|---|---|---|
| SCD-1524, 1525, SCO-1546, 1547, 1573, 1574, LAU-1620, GEN-1722, 1723 | Micro particle flux | Impact effects, periods of increased intensities (e.g., meteorid streams), surface degradation | **Geo-space or L1 micro particle detector** | Micro-particle detector, 15 deg., 2 km/s in range 0-50 km/s, 2s, 6 kg, 10 W, <1 kbps |
| SCO-1531, 1532, 1546, 1548, SCO-1552, 1564, 1583, 1584, 1585, 1586, 1588, 1589, 1591, SCH-1592, 1593, 1594, 1596, 1599, 1600, 1601, 1607, 1610, 1611, LAU-1619, 1631, TIO-1659, NSO-1760 | Real-time SWE monitoring (magnetic storms, SEPS, CMEs, flares, coronal holes, meteor streams), incl. far-side of sun and forecast and probability estimates of SWE events (magnetic storms, SEPs, CMEs, flares, meteor streams, dose, charging) | Effects on S/C, prediction, TEC forecast, all SWE conditions, long-term, short-term | **L1 or geo-space solar X-ray, EUV, VIS imager, magnetograph, micro-particle detector, particle detectors. L1 solar wind plasma instrument and magnetometer, particle detectors.** | X/EUV imagers, 90°, 5 min., 10 kg, 10 W, high accuracy pointing, <1 kbps |
| SCO-1549, 1555, 1558, 1560, 1584, 1588, SCH-1592, SCH-1599, 1600, 1603, NSO-1751, 1752, 1753, GEN-1713, 1714 | S/C radiation monitoring in magnetosphere and heliosphere, E 1-400 MeV p in rad. belt | Radiation effects, cosmic ray fluxes and spectra | **L1, L5 and geo-space medium to high energy radiation monitors.** | High energy particle spectrometer, 30 sec., 5 kg, 5 W, 100 bps, directional measurements |
| SCO-1566, 1584, SCH-1599, 1600, 1601, SCH-1604, LAU-1619, 1623, 1625, 1629, 1631, 1632, NSO-generally, NSO-1751, 1762, 1763, 1764, 2600, GEN-1700, 1701, 1702, 17031704, 1705, 1706 | Solar wind monitoring and particle monitoring at 1 AU (1 MeV to >100 MeV p and ions, 2-50 MeV electrons) | Magnetospheric disturbance level, forecast, storm detection, TEC forecast, GICs | **L1 solar wind plasma instrument, magnetometer, high energy particle detectors for p, ions and electrons.** | Solar wind plasma monitor (0 eV-2 keV, 2 x 10 channels with 10%), 3D Magnetometer (1e-3 nT, 1 min., 1 kg, 1 W, EMC, <1 kbps), high energy proton, ion and electron particle detectors or compact radiation monitor |
| SCO-1561, 1563, TIO-1633, 1634, 1635, 1636, 1637, 1639, 2466, 1640, 1641, SST-1657, 1658, NSO-1753, 1754, 1755, 1770, 1771 | Altitude dependent TEC, scintillations, TIDs, irregularities, blobs | Navigation and communication impacts | **Geo-space GNSS receivers** | GNSS dual freq. receiver in radio-occ. Mode, 1 TECU, >100 e-density profiles/day, 10 kg, 10 W, pointing, <1 kbps |
| SCH-1592, 1596, 1607, LAU-1614, 1628, 1631, 1648 | SEP forecast for increased fluxes of 30-200 MeV particles | Radiation hazards to astronauts | **L1, L5, geo-space solar monitoring devices, solar wind instrument, magnetometer and high energy radiation monitors.** | Missing |

# 4.3 Identification of SWE Instruments from CRD Analysis (3 of 3)

| | | | | |
|---|---|---|---|---|
| SCH-1601, 1610, 1611, LAU-1615, 1616, 1619, LAU-1624, 1629, 1631, TIO-1643, 1644, 1645, 1648, SST-1659, NSO-1760, 1765, GEN-1687, 1686, 1699 | Solar disc imaging (X or EUV or VIS) and magnetograms, far-side imaging/maps, H-alpha, radio-telescopes | Solar activity forecast (solar wind, CMEs, flares, particles) | **L5, L1 and geo-space imagers complemented by ground-based networks.** | See imagers. Magnetograph, VIS imager missing |
| SCH-1602, TIO-1659, NSO-1766, GEN-1689, 1690, 1691, 1695 | Wide-angle corona | CMEs, corona and solar wind conditions | **L5, L1 or geo-space coronagraph.** | Wide angle coronagraph, 10°, 30 min., 10 kg, 20 W, high accuracy pointing, straylight removal, <1 kbps |
| TIO-1646, GEN-1711, 1712 | Environment monitoring of local magnetospheric magnetic and electric fields | | **Geo-space electric field devices and magnetometers.** | Plasma spectrometer and Langmuir density probe, 1 min., 1 kg, 1 W, EMC, <1 kbps. Magnetometer as specified. |
| NSO-1772, GEN-1707, 1708, 1709, 1710, | Auroral imaging from space too ? | Polar conditions | **Tbd if desired from space.** | Missing |
| GEN-1692 | Stereo images of CMEs, CIRs | | **L5, L1, L4, geo-space coronagraph observations.** | Imagers as specified |
| GEN-1693 | Far-side maps | | **Geo-space or L1 magnetograph.** | Missing |
| GEN-1694 | Ly-alpha monitor | | **Geo-space or L1 monitor** | Missing |

**Generally requested needs for instruments and other CRD specs:**

1) SEG-1504 (needed information on origin of data)

2) SEG-1506 (accuracy specs)

3) SEG-1638, 1597, 1506, LAU-1621, 1622, 1626 (information provision to users, availability of data)

4) SEG-1677 (event based alarm mode, NA to all types of instruments)

5) SCD-1507, 1508, 1509, 1510, SCO-1557, 1588, LAU-1617 (statistical environment characterization for ionizing rad., plasma, microparticles, UV, dose, SEE, charging, anomalies, micro-particle impacts , post-analysis tools and information, NA to all types of instruments)

6) SCD-1511 (long-term solar cycle predictions (NA to a number of instruments and observations)

etc.

# 4.4 Identification process of potential SWE instrument providers (1 of 2)

- Long-list of international available SWE instrument resources established
- SWE Science advisory team (SAT) formed (9 members from Europe)
- SWE Instrument Expert Team (IET) formed (8 members from Europe)

# 4.4 Identification process of potential SWE instrument providers (2 of 2)

- Review process of SWE instrument resources by UGOE, Astrium, ESA, SAT, IET
- Review yielded a reduced long-list of potential SWE instrument providers (PIP list comprises ~ 60 institutions)
- Announcement of dedicated project workshop at ESA/ESTEC and request for statements of interest sent out on October 29

# 4.5 Selection process of SSA SWE SN-II Phase 2 instruments (1 of 2)

- **November 4: Requested timeline for SOIs**
- **November 10: Requested timeline for instrument questionnaire response**
- **Instrument proposal feedback was very successful**
- **Review of SWE project instrument proposals by UGOE, Astrium, ESA, IET members until November 21**

# 4.5 Selection process of SSA SWE SN-II Phase 2 instruments (2 of 2)

- **Successful proposals will participate in the SWE instrumentation workshop at ESA/ESTEC on November 30, December 1**
- **Final review process of SWE instrument presentations w.r.t.**
  **- CRD analysis results**
  **- Instrument/mission technical requirement to CRD analysis results**
- **Announcement of selected Phase 2 SWE instruments by about December 17**