ADM-Aeolus Project

System Requirements Document

for Phases B, C/D, E_1

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DOCUMENT CHANGE RECORD

ISSUE/REV.	DATE	CHANGE
01	31 August 2001	All
02	28 June 2002	p.16 MNT-13: deleted measurement extent over 7 & 25 km p.17 MNT-22: max. standard deviation of Bias increased to 0.4 m/s. Assumption of up to eight ground observation with dry snow for satellite bias measurement added. p.17 MNT-23: max std deviation of Slope Error increased to 0.7%. p.18 OPS-11: transition time changed to 15 min p.18 OPS-12: Deletion of sentence 'Loss of nominal operations during orbit shall be minimised. In particular such ' p.20 OPS-40: requirement for use of single ground station added p.20 OPS-43: exchanged with wording as agreed during negotiation p.21 GSR-2: max. mass increased to 1150 kg p.21 GSR-3: max. volume redefined p.21 GSR-10: min. reliability changed to 0.85 p.24 STR-10: equation defining of margin of safety corrected p.36 COM-15: additional statement to ensure transmission of telemetry without need to switch on board antennas p. 36 COM-16: sentence added about the polarization assumption of the ground station p.37 COM-26 added, stating explicitly assumptions on link budget parameters related to the ground stations; min elevation angle for Kiruna changed to 4 degrees p.48 Reference Atmospheric Model: Assumption on maximum ground wind speed stated
02 rev. b	01 Nov 2002	p. 14 Bit/Byte numbering convention corrected p. 15 MNT-9: possibility to perform measurements from decaying orbit added; note removed p. 21 GSR-2: mass requirement reformulated p. 24 STR-3: wording on margins corrected p. 25 STR-12: Aeolus Structure/Thermal Model is only Structure Model p. 28 MEP-18: reformulated p. 31 AOS-1: condition 'in the case of full fuel tanks as well as in the case of partially filled fuel tanks' added p. 34 DHS-15: margin philosophy reformulated
03	30 Aug 2004	p. 7, SD-15: deleted (CR-001) p. 7, RD-5 to –10: removed references to launchers that are not considered for Aeolus, and renumbered p.11: data reception station scenario updated (PDR AI 6559) p. 12, 13, 15, 16 & 17: 'geoid' replaced by 'ellipsoid' in sect. 3.4.1, requirement MNT-5, MNT-14 and section 4.4 performance assumptions (PDR RID 6606) p. 16, MNT-11: add 70 km pixel size for altitudes above 12 km, and note updated accordingly (PM-2) p. 16, MNT-13: change on-board averaging from 700 m to 1 km, and note updated accordingly (PM-2) p. 18, OPS-2: reformulated (PDR) p. 20, OPS-40: ground station scenario updated (PDR AI 6559) p. 21, GSR-2 & 3: delete Tsyklon from launcher list p. 27, MEP-14: deleted (PDR AI 6632)

		p. 28, MEP18: add thermal knife actuator (PDR AI 6632) p. 37, COM-20: EIRP changed to 63.7 dB (PDR AI) p. 37, COM-23: replace 'chosen ground station' with 'specified ground station' (PDR) p. 37, COM-26: PDT ground stations: nominal X-band ground station characteristics moved to Annex B p. 38, SWR-3: remove last sentence and ref. to SD-15 (CR-001) p. 38, SWR-5: wording changed according to CR-001 p. 38, SWR-13 and -14: times relaxed from 50 / 100 ms to 125 ms (as requested in ASW PDR-1) p. 40, EMC-8: added to reflect agreement on ESD testing from contract negotiations (AE-NI-ESA-SY-51) p. 42, Data Product Definitions: refined formulation, and statement added that duplicate data need to be deleted when data streams from different ground stations are merged in a single data processor p. 42, PRC-1, 2 & 3: reformulate according latest product guidelines (PDR AI consistency) p. 42, PRC-5: processing time changed to 5 minutes p. 42, PRC-51: new requirement for data driven processor p. 42, PRC-52: new requirement to define order of processing Annex B: added with data of the nominal X-Band data receiving stations
03.1	17 Sep 2010	Change to implement Continuous Mode: Deletion of some outdated text and addition of brief explanatory text in section 3.2 (p.10) Modification of requirements: MNT-10: Pixel Spacing: continuous pixels with 1% data gaps allowed MNT-11: Wind Observation Pixel Size: increase from 50 to 100 km below 14 km, from 70 km to 140 km (TBC) above 14 km altitude MNT-13: averaging distances changed to 3 km and 7 km EPS-3: margins after Platform Qualification Review reduced to 5 %

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1 Introduction / Scope

The Atmospheric Dynamics Mission ADM-Aeolus is the second Earth Explorer Core Mission. The mission objective of ADM-Aeolus is to provide global observations of wind profiles with a vertical resolution satisfying requirements of the World Meteorological Organisation (WMO). Accurate wind profiles would eliminate a major deficiency in the Global Observing System. The ADM-Aeolus mission will demonstrate the impact of these data on operational weather forecasting and on climate research. It could be considered a prototype for future operational wind satellites.

The atmospheric wind will be measured by the single payload of the Aeolus satellite, the Atmospheric Laser Doppler Instrument (ALADIN). This is a direct detection lidar operating in the ultra-violet spectral region. It emits a short but powerful laser pulse toward the atmosphere, from which a small portion is scattered back by the air molecules and by cloud and aerosol particles. A telescope in ALADIN collects this backscattered light and directs it to an optical receiver, which measures the Doppler shift of the received signal.

This Doppler shift is a direct measure of the difference velocity between the scatterers and the ALADIN in the direction of the laser pulse. If the measurement geometry and the residual satellite velocity are accurately known, the wind velocity in the projection of the line of sight to the Earth's surface can be derived (except for a small temperature correction, which has to be applied later). The altitude information is obtained by time of flight measurement between the outgoing laser pulse and the received backscatter signal.

The ADM-Aeolus system comprises the satellite with the ALADIN payload, the launcher and a ground segment for the control and supervision of the satellite, and for the reception and processing of the measurement data to Level 1b.

This document provides the requirements for the ADM-Aeolus system. All numbered requirements shall be verified and tracked.

In the rest of this document, the acronym ADM is suppressed in favour of the mission name Aeolus. The term 'Satellite' is used in this document for the complete space segment, thus the spacecraft and the ALADIN payload.

2 Documents

2.1 Applicable Documents

The following documents are considered as expansions of this document, providing more details of the requirements, to the extent specified herein. This System Requirements Document takes precedence over any other technical requirement.

The process for defining and agreeing technical requirements, which do no yet exist, is defined in the Statement of Work (AE-SW-ESA-SY-003).

In case of conflicts between this document and the applicable documents, the conflict shall be brought to the attention of ESA for resolution.

AD-1 Aeolus Satellite to Ground Interface Control Document AE-IF-xxx-SY-006

AD-2 Aeolus Operations Interface Requirements Document AE-RS-ESO-SY-001

AD-3 Aeolus Product Assurance Requirements AE-RS-ESA-PA-002

AD-4 Aeolus Spacecraft to Launcher Interface Document (Launcher A) AE-RS-ZZZ-RO-003

AD-5 Aeolus Spacecraft to Launcher Interface Document (Launcher B) AE-RS-ZZZ-RO-004

AD-6 Aeolus Satellite Design Specification AE-RS-ZZZ-SC-005

AD-7 Aelous Level 1b Processor Definition AE-RS-ZZZ-GS-002

AD-8 Aeolus Satellite/Ground Interface Document AE-RS-ZZZ-SY-006

AD-9 Contractor PA Requirements AE-RS-ZZZ-PA-001

AD-10 Airborne ALADIN Demonstrator Interface Control Document AE-RS-ESA-SY-003

2.2 Standards

The following standards shall be used in executing the work. They are applicable only as called up in this document.

SD-1 IEC standard 825-1: Safety of Laser Products, Geneva, International Electrotechnical Commission, 1993

SD-2 Space Environment Standard ECSS E-10-04

SD-3 Safety Standard ECSS-Q-40

SD-4 Cleanliness and Contamination Control Standard PSS-01-201

SD-5 Mechanical Engineering Standard ECSS-E-30-00 Part 2-3

SD-6 Thermal Control Standard ECSS-E-30-00 Part 1A

SD-7 Space Engineering Electrical and Electronic Standard ECSS-E-20A

SD-8 Specifications for Solar Cells ESA PSS-01-604

SD-9 Packet Telemetry Standard PSS-04-106

SD-10 Telemetry Channel Coding Standard PSS-04-103

SD-11 Packet Telecommand Standard PSS-04-107

SD-12 Telecommand Decoder Specification PSS-04-151

SD-13 Radio Frequency and Modulation Reference Document RD-04-105 iss. 2.4

SD-14 ESA Ranging Standard PSS-04-104

SD-15 deleted

SD-16 CCSDS Time Code Formats CCSDS-301.0-B-2 issue 2

SD-17 Advanced Orbiting Systems, Network and Data Standards CCSDS-701.0-B-1

SD-18 Software Engineering Standard ECSS-E-40 B (Draft)

SD-19 ESA Pointing Error Handbook (EHB.DGD.REP.002)

SD-20 European Space Debris Safety and Mitigation Standard, issue 1 (Draft)

SD-21 IEEE Standard for Binary Floating-Point Arithmetic, ANSI/IEEE Std 754-1985 (IEEE 754), Institute of Electrical and Electronics Engineers, 1985

SD-22 Software Product Assurance ECSS-Q-80 B (Draft 3 April 2000)

2.3 Reference Documents

RD-1 ADM-Aeolus Mission Requirements Document AE-RP-ESA-SY-0001

RD-2 Final Report phase A of the Earth Explorer Atmospheric Dynamics Mission, Feb. 2000

RD-3 The Four Candidate Earth Explorer Core Missions: Atmospheric Dynamics Mission, ESA SP-1233 (4), July 1999

RD-4 Department of Defence World Geodetic System 1984 – Its Definition and Relationship with Local Geodetic Coordinate Systems, DMA Technical Report 8350.2, US Department of Defence, 1987

RD-5 Rockot User's Guide, Issue 3, Rev.1, Apr. 2001

RD-6 Dnepr User's Guide, Issue 2, Nov. 2001

RD-7 Vega User'sVEGA User's Manual, VG-MU-1-C-001-SYS, Issue1, rev.0 May 2003

3 Background, Assumptions and Definitions

3.1 Summary of the Mission Objectives

The Atmospheric Dynamics Mission ADM-Aeolus is designed to provide global observations of wind profiles in clear air in the troposphere and lower stratosphere. The aim is to demonstrate that these data will substantially improve the Global Observing System (GOS) and that the assimilation of the wind profiles in the numerical weather prediction models will lead to a significant improvement of weather forecasting skills. The mission would also provide data needed to address some of the key concerns of the World Climate Research Programme (WCRP) i.e. quantification of climate variability, validation and improvement of climate models and process studies relevant to climate change. The newly acquired data would also help realise some of the objectives of the Global Climate Observing System (GCOS).

The Atmospheric Laser Doppler Instrument (ALADIN) will measure the atmospheric wind profiles. ALADIN is a Direct Detection Doppler Lidar (D3L) operating in the ultra-violet spectral region (355 nm). The instrument determines Doppler shifts of the backscatter from laser pulses fired at an angle toward the Earth and thereby the wind component along the horizontal line of sight can be determined. The height can be deduced from the time delay between emission of the laser pulse and reception of the backscatter signal. Being mounted on a polar-orbiting satellite, ALADIN will provide a near global coverage of wind profiles.

Aeolus will determine only a single wind velocity component. These wind profile measurements will be assimilated into numerical forecasting models to improve the quality of the global three-dimensional wind fields. To make full use of the data, the global wind profile data must be made available to the weather prediction centres in near real time.

The Mission Requirements Document [RD-1] gives more detail on the science objectives and scientific requirements of the Aeolus mission. The mission objectives as well as the implementation as derived in the Phase A study is described in the ESA report for the mission selection [RD-2]. The space and ground segment as derived in the Phase A is described more detailed in the ADM Phase A Final Report [RD-3].

3.2 Outline of the Measurement Principle

ALADIN is a Doppler wind lidar. The basic operating principle of a lidar is analogous to that of a radar (see Fig. 3-1): short light pulses from the lidar transmitter laser are sent towards the atmosphere. A small portion of these light pulses is scattered back by the atmosphere, either by the air molecules ('Rayleigh scattering') or by aerosols or cloud droplets ('Mie-scattering'). The backscattered light is collected by the lidar receiving telescope and directed it to the receiver, which converts the received photons into electrical signals. The altitude of the scattering layer from which the lidar signal is received, is obtained by range gating the received signal and time of flight measurement.

If the backscatterers have a relative velocity to the lidar along the laser propagation axis (which defines the line-of-sight of the lidar), the received frequency will be slightly different from the transmitted laser pulse (Doppler-effect). Thus by measuring the frequency shift between the transmitted light pulse and the received backscatter signal, one can obtain the difference

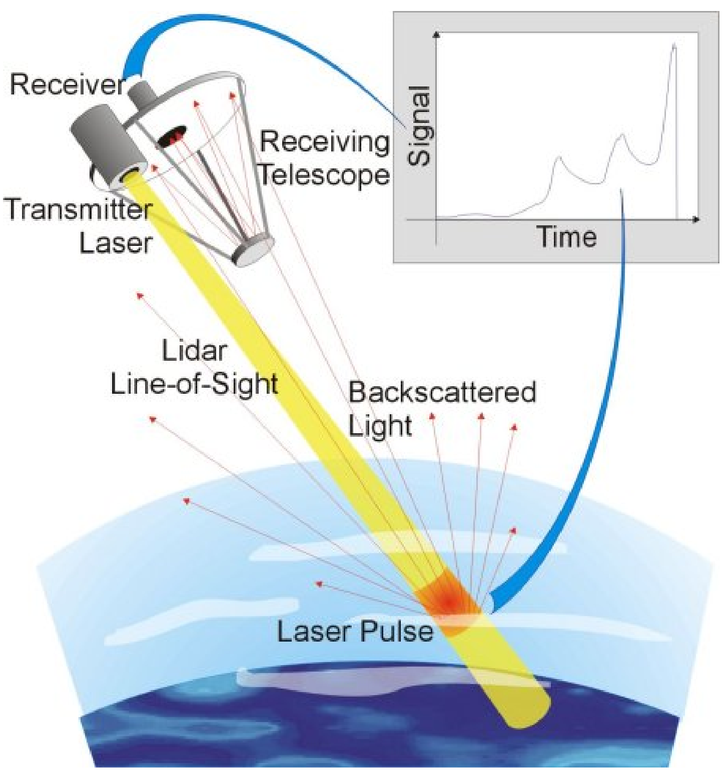


Fig. 3-1: Basic lidar measuring backscatter signals from the atmosphere

velocity along the line of sight. This difference velocity is caused by atmospheric winds (as projected onto the line of sight of the lidar), but also by the satellite ground track velocity as projected onto the line-of-sight. Thus one component of the horizontal wind velocity can be determined from the Doppler shift, if the satellite ground track component is sufficiently well known (see also [RD-1] for the scientific justification of the single wind component measurement).

The atmospheric return signal of each laser pulse is detected by a high resolution spectrometric device, using direct conversion of incoming photons into electrical signals. The returns from the molecular (Rayleigh-) scattering and from the aerosol (Mie-) scattering will be observed, and both will give useful wind information in different altitude regimes.

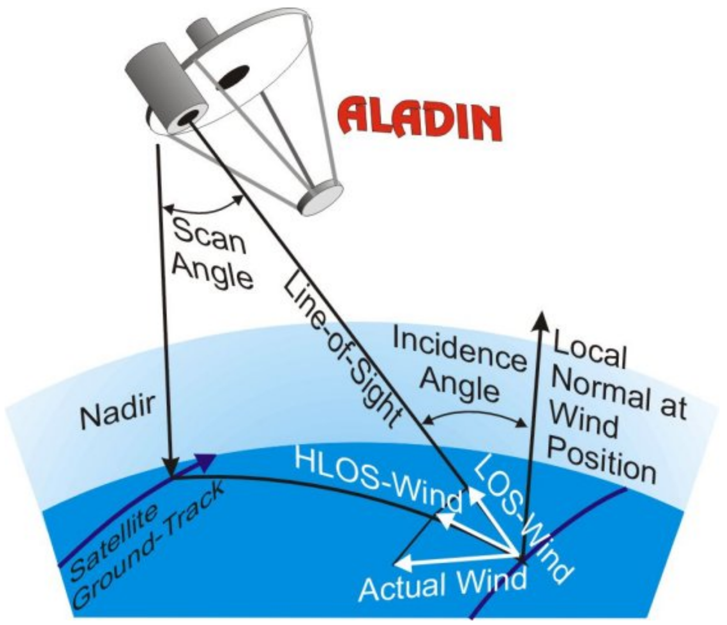


Fig. 3-2: Basic geometry of a spaceborne wind lidar with fixed line-of-sight

The instrument has a single fixed viewing direction, fixed at an angle of about 35° with respect to the Nadir of the satellite and looking orthogonal to the ground track velocity vector of the satellite (see Fig. 3-2). The satellite will implement yaw steering such that the ground will have an apparent zero velocity along the line-of-sight of the instrument.

To measure the wind velocity with the required accuracy, the signal-to-noise ratio of the received signal must be on the order of 500. To achieve such a high value, signal averaging over many laser pulses is required.
Each observation is subdivided into individual measurements which are downlinked to ground for further processing. However, to limit the data bandwidth, and to improve the overall measurement performance, individual laser signals can be co-added on board to form a measurement. The original baseline has been modified to ease the development of the Transmitter Laser. In the new baseline, the laser emitts pulses with about 50 Hz pulse repetition frequency which is half the repetition rate compared to the original baseline, but without interruption. As before, the receiver co-adds a number of pulses to form measurements with reduced noise, which are downlinked in block for further processing. For implementation reasons, small data gaps can exist between the data blocks. On-ground, the measurements are further averaged to extract the wind profiles with the required accuracy. Due to the continuous stream of measurements, the averaging distance can be kept variable depending on the actual atmospheric conditions.

On-ground processing to the received measurement data includes the following blocks for the molecular and the aerosol channels:

- Subtraction of background radiance from all altitude samples;
- Evaluation of the frequency shift between the emitted laser pulse and each altitude sample (called the LOS Doppler shift); for the Rayleigh channel, the observed frequency shift depends on the spectral width of the Rayleigh backscatter line, which in turn depends on the atmospheric temperature at the scattering altitude. As the atmospheric temperature is unknown at this stage, the determination of the LOS Doppler shift can be performed assuming a fixed temperature (like 0°C), and applying a temperature correction later during the level 2 processing, when better assumptions on the actual atmospheric temperature are available.
- Determination of the Doppler shift resulting from the projection of the satellite velocity vector onto the line-of-sight, called satellite-induced Doppler shift. This Doppler shift is determined from pointing data determined by the attitude control sensors, and corrected for biases from the ground return that is occasionally included in the ALADIN backscatter data. The satellite-induced Doppler shift is subtracted from the LOS Doppler shift to result in the wind-induced Doppler shift.
- The wind-induced Doppler shift is projected onto the local horizontal plane at the measurement location and converted into the horizontal wind velocity at the measurement altitude.

The wind measurements obtained from the individual measurements are still very noisy. To reduce the random noise, the wind measurements are averaged to form a wind observation, resulting in a representative wind profile over the specified pixel length.

3.3 Mission Assumptions

3.3.1 Launcher

The selection process for the launcher is defined in the Aeolus Statement-of-Work (AE-SW-ESA-SY-003).

3.3.2 Environment

The environment encountered during the launch preparation activities, launch and ascent is defined in the Aeolus Satellite to Launcher Interface Documents [AD-4] and [AD-5].

The applicable environment encountered in orbit, including the solar and earth electromagnetic radiation, high energy particles, meteorite and debris environment, is defined in ECSS E-10-04 [SD-2].

3.3.3 Operational Concept

Aeolus will be operated by ESOC. The Mission operations proper commence at separation of the Satellite from the launcher and continue until disposal at the end of the mission. The satellite will be designed such that the mission operations are robust and low cost.

Mission operations include the following tasks:

Mission Planning will operate the satellite according to a High Level Operations Plan to be provided by ESA. ESA will detail mission operations in a Flight Operations Plan.

Satellite status monitoring by means of processing the housekeeping telemetry such that the status of all satellite sub-systems can be monitored. Monitoring includes attitude monitoring.

Satellite control taking control actions by means of immediate or time tagged telecommands following the Flight Operations Plan, and responding to monitoring anomalies.

Orbit determination and control using tracking data both provided by the sensors of the attitude and orbit control system and by ground tracking and implementing orbit manoeuvres to change the satellite velocity such that required orbital conditions are achieved.

Attitude determination based on the processed attitude sensor data in the satellite monitoring.

On-board software maintenance, integrating software images received from the Satellite manufacturer (pre-launch and post-launch), including the instrument, into the telecommand process.

The operations support activities for Aeolus will be conducted according to the following concept::

All Satellite operations will be conducted by ESA according to procedures laid down in the Flight Operations Plan.

Satellite control during the operational phase will be ‘off-line’. Real time operations will be reduced to a minimum. For command and control, only one Ground Station (Kiruna) will be used. The satellite will therefore provide on-board capabilities, which relieve the ground system from the burden of programming operations, of assessing the performance in real time, and of conducting corrective actions on short notice in case of on-board anomalies. The contacts between the Mission Operations Control Centre and the satellite will therefore primarily be used for pre-programming of those autonomous operations functions on the spacecraft, and for housekeeping and payload data collection for off-line status assessment. Anomalies will normally be detected with a delay.

The scheduling of the Kiruna station passes will be coordinated with other Earth Explorer missions. Satellite compatibility with the ESA stations is ascertained by the Satellite to Ground Interface Document [AD-8].

During the operational phase, two or more ground stations will be used to acquire the instrument data stream to avoid blind orbits and to allow data processing with a minimum delay.

Alternative downlink and processing strategies will be used:

1. Global mission: Data will be dumped once per orbit to the nominal receiving stations Svalbard, Gatineau and Prince Albert. The full orbit worth of data will be processed to level 1b within 5 min.

2. Global plus Regional Mission: a network comprising of the nominal stations and a number of additional stations at mid latitudes will be used. Data will be processed as they become available from segments of the orbit.

3.3.4 Ground Processing Assumptions

To serve the operational weather prediction centres, the measurement data from Aeolus must be downlinked, processed and delivered in near real time (max delay 3 hours from sensing to delivery). The data downlink is performed on a dedicated separate channel. Data are transmitted from the receiving stations to a processing center, and there processed to Level 1B (corrected and fully calibrated engineering data with all ancillary data required for further processing).

Further processing to Level 2 is performed by assimilating the Level 1B data in numerical weather forecasting models with all other available meteorological observations. This task is not covered in this document.

3.3.5 Mission Phases

Launch and Early Orbit Phase (LEOP), with:

Internally powered pre-launch phase during the count down;

Launch and separation of the satellite from the launcher;

Acquisition phase, including:

- attitude rate reduction, attitude acquisition,
- appendages deployment (if any),
- delivery of power from the solar array.

S-band link acquisition;

Orbit correction phase, in which manoeuvres from the injection orbit to the nominal orbit are performed to correct for any launcher dispersion errors;

Initial satellite checkout

Commissioning Phase with:

Platform functional checkout, in which the satellite basic functions and health are verified;

ALADIN switch on and functional checkout to verify the health of the instrument;

Aeolus initial performance characterisation, in which the various performance parameters of ALADIN and satellite subsystems are determined,

Ground segment data acquisition and final commissioning,

In-orbit verification of performance and performance stability.

The Commissioning is assumed to take 3 months.

Operational Phase, during which the Aeolus operates nominally. Modification of operating parameters or software may occur from time to time. This phase will have the following modes:

Nominal operation, where the instrument operates continuously with a possible commandable offset and measures along the slant line-of-sight to collect wind data, or performs internal characterisation and calibration measurements, which are needed to achieve the specified performance.

End-to-end calibration, where the instrument line of sight is pointing to Nadir with a commandable offset by depointing the satellite. This allows calibrating the level 1b products by measuring a known Doppler shift of the backscattered signals resulting from the projection of the satellite ground track velocity onto the instrument line-of-sight.

Orbit control, to maintain the selected orbit.

End of Life Phase with:

Satellite passivation by disposing of all remaining fuel, if it can be demonstrated that it will burn up during re-entry in the atmosphere and does not pose any hazard, or

Satellite de-orbiting to allow a controlled re-entry in the atmosphere.

In case of on-board failure detection during any of the above mission phases, the on-board control system will attempt to recover to operational status by switching to redundant units, where that is possible. If this is not possible, Aeolus will enter its **Safe Mode**. In such a case, the following sequence is foreseen:

Automatic transition to a sun-pointing survival mode;

Ground diagnosis during subsequent ground station passes;

Recovery to the Operational Phase under ground control.

3.4 General Terms and Conventions

3.4.1 Definitions

LOS (Line-Of-Sight)

is defined by the laser pulse propagation direction. It corresponds to the line drawn between the instrument and the observed atmospheric target.

Range Resolution [δr]

is the extend of the target range along the LOS, as given by the signal integration time δt of the lidar receiver electronics by

$$\delta r = \tfrac{1}{2}\, c \cdot \delta t \ .$$

Measurement Range [r]

is the distance along the LOS between the instrument and the center of the range gated atmospheric target. The range gate is set at a time

$$t_r = 2r/c \ ,$$

where $c = 3{\cdot}10^8$ m/s is the velocity of light.
The signal is collected from the target range extending from r-½δr to r+½δr.

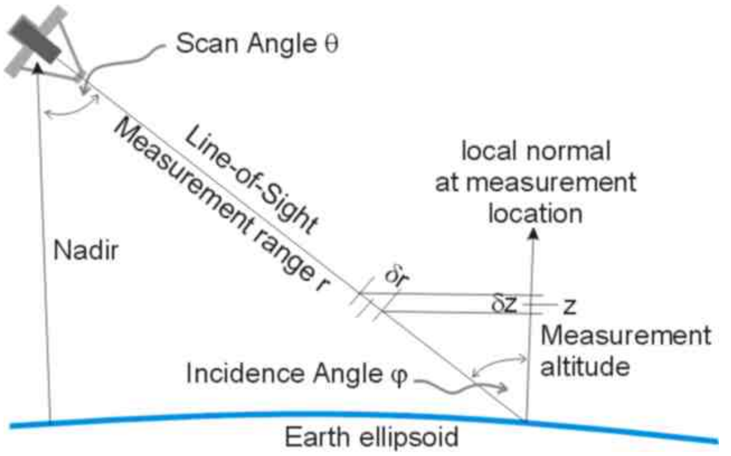


Fig. 3-4: Terms describing the Aeolus measurement geometry

Altitude resolution [δz]

is the extend of the measurement target along the local normal to the reference Earth ellipsoid at the point where the LOS intersects the ellipsoid, and is given by

$$\delta z = \delta r \cdot \cos(\varphi) \ ,$$

where φ is the angle between the LOS and the local normal.

Sample Altitude [z]

is the vertical distance between the center of the atmospheric target and the reference Earth ellipsoid at the point where the LOS intersects the ellipsoid. The measurement target extends from z-½δz to z+½δz, as determined by the range gating of the receiver.

LOS Doppler shift [$\delta\nu_{LOS}(z)$]

is the difference between the centroid of frequency of the transmitted ν_0 laser pulse and that of the received signals from aerosol and molecular scattering from the sample altitude z.
The determination of the Doppler shift from the molecular scattering contribution depends on the assumption of the atmospheric temperature at altitude z. As this is in general unknown, a fixed atmospheric temperature of 0°C shall be assumed for the derivation of the Doppler shift from the molecular backscatter signal.

Satellite-induced Doppler shift [$\delta\nu_S$]

is the Doppler shift resulting from the projection of the satellite velocity vector onto the LOS. For ideal yaw steering of the satellite, this satellite-induced Doppler shift vanishes. However, small pointing errors can result to major contributions to $\delta\nu_{LOS}(z)$, which need to be determined and subtracted.

HLOS Doppler shift [$\delta\nu_H(z)$]

is the LOS Doppler shift $\delta\nu_{LOS}(z)$, corrected for the satellite-induced Doppler shift $\delta\nu_S(z)$, and then projected perpendicularly to the LOS direction on the local horizontal plane at the wind observation location. For an incidence angle φ, it is

$$\delta\nu_H(z) = (\delta\nu_{LOS}(z) - \delta\nu_S) / \sin(\varphi) \quad .$$

HLOS Wind [$v_H(z)$] (or simply Wind)

is a measure for the wind between altitude z-δz/2 and z+δz/2 (as indicated by the average sample altitude z). It is directly proportional to the HLOS Doppler shift $\delta\nu_H(z)$, and is given by

$$v_H(z) = \delta\nu_H(z) \cdot \lambda_0/2 \quad ,$$

where $\lambda_0 = c/\nu_0$ is the wavelength of the transmitted laser pulse.

Wind Measurement

Height bins from various laser pulses (typically between 10 and 100 pulses) are on-board co-added before the data are downlinked. These downlinked data points can be processed to result in a wind measurement. However, a wind measurement needs in general additional averaging in the on-ground processing to reduce noise before wind can be derived with the required accuracy.

Wind Observation

A wind observation leads to the production of an altitude-assigned wind speed value $v_H(z)$ with the specified performance characteristics. It is obtained from several wind measurements (typically between 70 and 7), and represents an averaged wind speed over the distances defined by the spatial representation and the altitude resolution.
It should be noted that the wind derived from the molecular backscatter signal needs an additional correction to account for the actual atmospheric temperature at sample altitude z. This correction is not included in the defined level 1b product.

Spatial representation or Pixel Size

is the horizontal range of a zone over which return signals are combined and processed to represent the average wind speed of this horizontal zone.

3.4.2 Reference Frames

All reference frames shall be right-handed and orthogonal.

The **Inertial Reference Frame** shall be the J2000 equatorial coordinate system and is defined as follows:

the origin O_{J2000} is at the center of the earth,

the X_{J2000} axis is at the intersection of the mean ecliptic plane with the mean equatorial plane at the date of 01/01//2000 and pointing positively towards the vernal equinox,

the Z_{J2000} axis is orthogonal to the mean equatorial plane at the date of 01/01/2000 and pointing positively towards the north,

the Y_{J2000} axis completes the right handed reference frame.

The **Earth-fixed Coordinate System** shall be the most recently defined International Terrestrial Reference Frame (ITRF).

The satellite shall use a single coordinate system for the instrument and the platform. Preferably, this shall be the **Local-Horizontal / Local-Vertical** (LVLH) reference frame, which is oriented as follows:

the Z_m axis is along the nadir vector, pointing at the Earth,

the Y_m axis is along the negative orbit normal vector,

the X_m axis completes the right –handed reference frame.

As **reference Earth ellipsoid**, the WGS-84 model shall be used [RD-4].

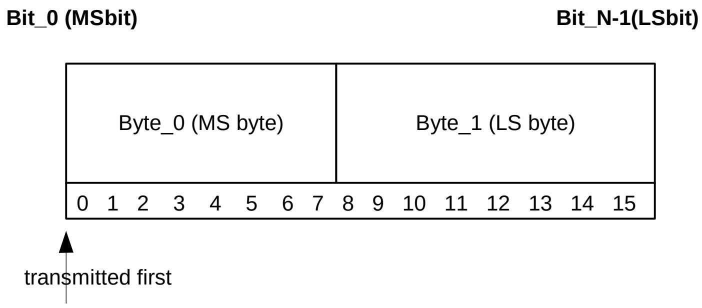
3.4.3 Bit / Byte Numbering Convention, Data Representation

In all project specific documentation including commented code, the following convention shall be applied:

Bit 0 in a byte shall be the most significant bit,
and bit 0 shall be transmitted before but 1;

Byte 0 in data fields shall be the most significant byte,
and byte 0 shall be transmitted before byte 1.

Fig. below shall apply



During file transfer, within any data type structure, bytes shall be transmitted in ascending order, i.e. byte 0 before byte 1 etc.

In case of conflict of this convention with manufacturers documentation, the appropriate project specific documentation shall identify the conflict and shall provide appropriate means of performing ready cross references.

4 Measurement Requirements

4.1 Measurement Principle

MNT-1: **Instrument Type:**
Atmospheric winds shall be observed using a Doppler wind lidar instrument, which emits bursts of short duration pulses generated by a frequency-tripled Nd:YAG laser (emitted wavelength near 355 nm) towards the atmosphere and determines the frequency shift of the backscattered radiation.
The atmospheric return signal of each laser pulse shall be detected by a high resolution spectrometric device, using direct conversion of incoming photons into electrical signals.

MNT-2: **Instrument Detection Channels:**
The instrument shall exploit the molecular and aerosol backscatter signal.
Note: for many atmospheric conditions, the aerosol scattering will be dominant in the lowest parts of the troposphere, while at the upper troposphere and the lower stratosphere the molecular scattering is dominant. However, thin clouds at high altitude are frequently present and will produce a strong aerosol return also from high altitudes. Thus, both the molecular and the aerosol signals must be observable in the full altitude range.

MNT-3: **Eye Safety:**
The optical fluence generated by Aeolus shall meet the eye-safety standard [SD-1] for an observer, who tracks Aeolus with an 80 mm diameter telescope from the ground and is located in a spot in the center of the transmitted laser pulse from ALADIN.

MNT-4: **Pointing Properties of the Instrument:**
The instrument shall have a single fixed LOS. This LOS is fixed at an angle of about 35° with respect to the Nadir of the satellite and looking orthogonal to the ground track velocity vector of the satellite.

MNT-5: **Pointing Properties of the Spacecraft:**
The satellite shall implement a yaw steering in such a way that the laser pulse nominally sees the ellipsoid with an apparent null velocity along the Line of Sight.

4.2 Orbit Selection Requirements

MNT-6: **Orbit Type:**
The orbit shall be a frozen sun-synchronous dusk-dawn orbit (18:00 local nodal crossing time for ascending or descending node).
Note: this orbit provides the best thermal environment and highest average power from the solar arrays.

MNT-7: **Orbit Repeat Cycle:**
The orbit repeat cycle shall be less than 35 days.
Note: The wind measurement itself does not require any particular orbit repeat cycle, but some repeatable data grid may be useful. For simplification of mission planning and satellite operations, however, an orbit repeat cycle is required.

MNT-8: **Accuracy of Station Passes:**
Station passes shall be with a time error of less than 10 s.

MNT-9: **Orbit Altitude:**
The altitude shall be selected taking into account the measurement performance and the engineering constraints (in particular the required fuel for orbit maintenance and duration of the eclipse), and the orbit repeat cycle.
In order to achieve the mission lifetime as specified in GSR-8, it is acceptable to perform measurements from a decaying orbit at the end of the mission lifetime.

4.3 Localisation Requirements

4.3.1 Horizontal Properties

MNT-10: **Pixel Spacing:**
Wind observations shall be continuous with eventual data gaps not exceeding 1%.

MNT-11: **Wind Observation Pixel Size:**
The pixel size of a wind observation shall be 100 km along the measurement ground track. At altitudes above 14 km, the pixel size can be increased up to 140 km.

MNT-12: **On-board Averaging:**
Wind measurement data shall be downlinked after on-board co-addition or averaging of individual atmospheric return signals over an adjustable horizontal length.
Note: The on-board co-addition of individual measurements is introduced mainly to reduce the downlinked data rate.

MNT-13: It shall be possible to adjust the extend of wind measurements to either 3 km or 7 km during flight by telecommand.

4.3.2 Vertical Properties

MNT-14: **Measurement Altitude Range:**
The instrument shall have the capability to take measurements in the altitude range from the reference ellipsoid to 30 km altitude.

MNT-15: **Minimum Number of Vertical Samples:**
A minimum number of 20 vertical samples shall be recorded and downlinked for each measurement.

MNT-16: It shall be possible to change the **altitude resolution** at different measurement altitudes in-flight by telecommand. The altitude resolution shall be adjustable in steps of multiples of 250 m. For the molecular and the aerosol backscatter channels, independent altitude resolution values shall be settable.

MNT-17: **Measurement Range Error:**
The measurement range shall be known with a 3-sigma error less than 50 m.
Note: this requirement defines the required timing accuracy between the outgoing laser pulse and the sampling clock of the receiver.

MNT-18: **Correction of Orbit Height Variations:**
Systematic orbit height variations during one wind observation shall be compensated between wind measurements with an accuracy of 20 m.
Note: the orbit height variations reach typically up to 25 m/s, so that a total height variation over a wind observation (measurement duration 7 s) can reach about 175 m, which could lead to some undesired correlation between different altitude layers. An adjustment of the range gating between wind measurements is required to compensate for this variation.

MNT-19: **A-posteriori Geo-Location:**
The a-posteriori absolute geolocation of the center of gravity any wind observation shall have localisation errors less than:

a) 2000 m for the horizontal error, and
b) 200 m for the assigned measurement altitude.

All localisation errors in this requirement are 95 % confidence errors as specified in [SD-19].
Note: the altitude assignment should not become the design driver for the pointing accuracy of Aeolus around the roll axis.

4.4 Performance Requirements

The performance requirements in this section apply to wind observations and shall be met:

throughout the operational phase of Aeolus,

assuming the following 'nominal' vertical sampling scheme for molecular and aerosol backscatter channels:

a) 500 m between the ellipsoid and below 2 km altitude,

b) 1km for altitudes from 2 km and below 16 km and

c) 2km for altitudes from 16 km up to 20 km,

any measurement extend as specified in MNT-13,

assuming the Aeolus Reference Atmospheric Model as defined in Annex A.

MNT-20: **Wind Dynamic Measurement Range:**
Full measurement performance shall be achieved for all wind speeds in the range from +100 m/s to -100 m/s. Wind speeds of up to ±150 m/s shall be detectable.

MNT-21: The **Random Error** of the observation is the r.m.s. error over one wind observation, as derived from variance of the measurement data used for this observation. The random error of the wind observations shall be less than

a) 1 m/s for the accuracy at an altitude between 0 and 2 km,

b) 2 m/s for the accuracy between 2 and 16 km.

MNT-22: The **Unknown Bias** is a slowly varying (changing over many observations, on a time scale between 1 min to 50 min) offset of the observed winds with respect to the true winds, determined at zero wind speed after correction using the results of any in-flight calibration.
The standard deviation of the unknown bias of the HLOS wind observations shall be less than 0.4 m/s.
Note: the time scale covers the time between two observations and the maximum time envisaged between re-calibration of the satellite-induced Doppler shift. It can be assumed that the ground return from up to eight observations over dry snow can be processed to retrieve the satellite induced Doppler shift

MNT-23: The **Slope Error** is a systematic error which is proportional to the measured wind speed.
The standard deviation of the slope error of the HLOS wind observations shall be less than 0.7 % throughout the full performance dynamic range.
Note: the slope error can lead to errors of up to ±0.7 m/s at the full performance dynamic range of Aeolus.

MNT-24: **Signal Strength Dynamic Range:**
The ground echo and cloud top returns shall be exploitable for Doppler estimation, assuming an atmosphere with no aerosol loading (i.e. no extinction from aerosol scattering).

5 Operational Requirements

5.1 Mode Requirements

5.1.1 Launch and Early Operations Phase (LEOP)

OPS-1 The satellite shall be capable to run an automatic sequence without ground intervention which will, as a minimum, undertake all deployments (including the solar array), initiate and complete attitude acquisition. The sequence shall be able to cope with a single anomaly event.

OPS-2 During LEOP, the satellite shall ensure that sun illumination will not cause any damage.

OPS-3 The satellite shall survive a duration of at least 5 days after launch without ground contacts in nominal and one-failure situations, without subsequent loss of mission.

5.1.2 Operational Phase

5.1.2.1 Nominal Operation Mode

OPS-4 Aeolus shall be able to perform continuous operations (i.e. measurements or internal calibration).

OPS-5 It shall be possible to command small angular offsets to the ideal Yaw Steering to produce a relative velocity of the satellite with respect to the ground along the line-of-sight. Relative velocities between 0 and ±150 m/s shall be commandable. The error in a-posteriori knowledge of this relative velocity shall be less than 1 m/s.

OPS-6 It shall be possible to change the angluar offset without leaving the Nominal Operation Mode.

5.1.2.2 End-to-End Calibration Mode

OPS-7 Aeolus shall have the capability to operate in a mode where the instrument line-of-sight is pointing near Nadir.
Aeolus shall be able to perform fully calibrated measurements meeting the measurement requirements MNT-10 to MNT-25 except requirement MNT-16 (altitude resolution, which can be increased to allow unchanged sample clock frequency). However, the measured HLOS winds are in this case the appareant winds resulting from the projected satellite velocity on the line-of-sight.

OPS-8 It shall be possible to command small angular offsets to produce a relative velocity of the satellite with respect to the sub-satellite air mass or ground. Relative velocities between 0 and ± 150 m/s shall be commandable. The error in a-posteriori knowledge of this relative velocity shall be less than 1 m/s, assuming stationary air in the sub-satellite column.

OPS-9 It shall be possible to change the angluar offset without leaving the End-to-End Calibration Mode.

OPS-10 Aeolus shall be able to operate at least 30 min continuously in the End-to-End calibration mode.

OPS-11 Aeolus shall be capable to transit from nominal operation mode to the End-to-End Calibration Mode or back in less than 15 min.

5.1.2.3 Orbit Control Mode

OPS-12 The Orbit Control Mode shall be used to perform orbit maintenance manoevres. The manoevres include any necessary corrections for injection dispersion. Lost nominal operations shall be considered as unavailability in the sense of requirement GSR-11.

OPS-13 Orbit maintenance shall be commanded by ground.

OPS-14 Illumination of the solar array shall be maintained during the Orbit Control Mode.

5.1.3 End of Life Phase

OPS-15 At end of life, Aeolus shall either allow controlled de-orbiting to avoid that harmful debris could reach populated areas, or it shall be designed such that no harmful debris will be generated when entering the atmosphere, as specified in the European Space Debris Safety and Mitigation Standard (Draft) [SD-20].

OPS-16 The end of life requirement shall be met in nominal and one-failure situations.

OPS-17 The end of life requirement shall be met without the use of mechanical gyroscopes.

5.1.4 Safe Mode

OPS-18 The safe mode shall either be initiated automatically on-board in the case of detection of a failure which affects satellite safety, or by ground command.

OPS-19 Aeolus shall be able to survive in a Safe Mode for at least 8 days without the need for ground intervention, provided there is no further failure.

OPS-20 Aeolus shall be recoverable from Safe Mode within 30 days.

OPS-21 The capability to enter Safe Mode autonomously shall be present during all mission phases and modes, and it shall be possible to deactivate / activate this capability by ground command.

OPS-22 The Safe Mode shall maintain a safe attitude within the constraints allowing a continuous supply of power and maintaining a stable thermal environment compatible with the satellite and essential loads.

OPS-23 The Safe Mode shall ensure a two-way communication link with the ground station when coverage is available for at least housekeeping telemetry data and commanding (i.e. providing suitable link margins with omni directional coverage).

OPS-24 The Safe Mode shall be sustained without reference to any mechanical gyroscope.

OPS-25 No nominal operation shall require inhibition of Safe Mode, nor a forced entry to Safe Mode.

5.2 Commandability

OPS-26 The satellite design shall take into account the operational design requirements as defined in the Operations Interface Requirements Document [AD-2].

OPS-27 During nominal operation including incidence of a single failure, there shall be no requirement for the control centre to send telecommands more often than once every 5 days.

OPS-28 Nominal operations shall consist of the repeated execution of a deterministic ‘Nominal Operations Sequence’ which repeats with the orbit repeat cycle.

OPS-29 The Nominal Operations Sequence shall not include orbit maintenance.

OPS-30 The Nominal Operations Sequence shall include all necessary on-board control for wind measurement, for any required periodic calibration, for on-board data storage and for data downlink.

OPS-31 Situations in which the control centre is expected to react shall be unambiguously recognisable in the available telemetry by means of a downlinked identifier.

OPS-32 Execution of hazardous functions shall be implemented by means of two independent telecommands.
Note: Hazardous functions are those which when executed at the incorrect time could cause mission degradation or damage to equipment, facilities or personnel.
This requirement is in addition to any derived from launch site safety requirements.

5.3 Observability

OPS-33 Throughout the mission the Ground Segment shall be provided on request with all data, with a minimum of on-board processing, required for the execution and analysis of all foreseen operations for the spacecraft sub-systems and instrument.

OPS-34 The on-board storage as well as the command and control downlink shall be consistent with storage and downlinking of all outputs generated on-board and required for spacecraft monitoring and control purposes for a duration of 120 hours.

OPS-35 All timing information used for on-board functions like time tagging of telecommands and running of application software and for telemetry and measurement data time stamping shall be synchronised with a single on-board system clock.

OPS-36 The downlinked data stream shall contain all ancillary telemetry data that are required for the on-ground data processing.

5.4 Space Ground Interface Compatibility Requirements

OPS-37 Aeolus shall be compatible with the Ground Segment as specified in the Aeolus Space/Ground Interface Control Document [AD-1].

OPS-38 Aeolus shall be compatible with the LEOP networks compatible with the selected launchers.

OPS-39 Aeolus shall be supported using the Kiruna Station only for nominal command and control.

OPS-40 The design of Aeolus shall allow reception of data at least once per orbit using the nominal ground stations, which are Svalbard, Gatineau and Prince Albert (as defined in COM-26 and Annex B). The use of Svalbard shall be maximised in this case.

The design of Aeolus shall allow the reception of data using any additional X-band station with characteristics as described in COM-26. It shall be possible to dump at least a full orbit worth of data within 2 minutes. A maximum of three stations per orbit (including the nominal station) shall be assumed.

The satellite shall also be compatible with downlinking all measurement data to one station only. In such a case all data shall be stored onboard during blind orbits and subsequently downlinked in visibility of Svalbard. In this case there is no requirement on the delay of this transmission, however, all data generated by the satellite shall be downlinked without data losses.

OPS-41 The packet service definition shall implement the functionality required in the Aeolus Operations Interface Requirements Document [AD-2].

5.5 Fault Detection and Recovery

OPS-42 Aeolus shall automatically detect any fault, failure and error, which makes it deviate from its nominal configuration and operating mode. This includes hardware and software failures.

OPS-43 Aeolus shall detect single faults, failures and errors. Where such events affect only instrument, but not platform, operation, the instrument may be switched to a non-operational state. Where such events affect platform operations the instrument may be switched to non-operational state, but the platform shall be reconfigured to continue its commanded mode. Switch down of the instrument to non-operational states should not occur for inessential reasons.
In exceptional cases it shall be permissible for the satellite to enter safe mode as a result of a single anomaly event. All such cases shall be identified by the contractor and approved by the agency.

6 Design Requirements

6.1 General Satellite Requirements

GSR-1 **Environment:**
Aeolus shall be designed:

- to operate in the space environment as specified in ECSS E-10-04 [SD-2], and
- to survive the environment and handling during assembly, integration and testing, transport and the launch.

GSR-2 **Mass:**
Aeolus shall be compatible with a launch on Dnepr and Vega with a fuel margin of 20%.
Aeolus shall also be compatible with a launch on Rockot in October 2007, with a fuel margin of 10 %.
The following performance of Rockot applies: Maximum spacecraft mass at separation from Rockot in a circular orbit, altitude 400 km, inclination 97 degrees: 1252 kg.

GSR-3 **Volume:**
The integrated satellite in the launch configuration shall be compatible with the following launchers: Rockot, Dnepr and Vega as defined by the reference documents [RD-5 to RD-7]

GSR-4 **Launcher Compatibility:**
Aeolus shall be compatible with at least two launchers. Aeolus shall be able to withstand the environment generated by the selected launchers without degradation of mission products.

GSR-5 Aelous shall be analysed, designed and tested according to guidelines established for the selected launchers.

GSR-6 Aeolus shall be designed to cope with rapid depressurization during the ascent.

GSR-7 Aeolus shall be able to sustain sun illumination from any direction for at least 30 s duration without any degradation of performance.
Note: after launch or in case of a major failure, the satellite could enter an unusual attitude where direct sun irradiation enters sensitive parts, like the receiver telescope of ALADIN.

6.1.1 Lifetime, Reliability and Availability

GSR-8 **In-orbit Lifetime:**
Aeolus shall be designed for a duration in-orbit of:

- LEOP: 7 days,
- Commissioning phase: 3 months, and
- Operational phase at least 36 months.

GSR-9 **Total Lifetime:**
Aeolus shall be designed for a total lifetime of:

- up to 7 years on-ground activities in controlled conditions including at least half of this time in storage, and
- the in-orbit lifetime as specified above.

GSR-10 **Reliability** is defined as the probability that the satellite will carry out its specified mission for the specified total lifetime, including the controlled de-orbit or burn-up at the end of life.
Aeolus shall be designed to provide a reliability of higher than 0.85 over the total lifetime.

GSR-11 **Availability** is defined as the probability that the space segment and the link to the ground segment provides the required data to the ground segment.
Aeolus shall be designed to provide an availability during the operation phase of higher than 0.95.
Note: All sources of non-availability shall be considered. Examples are planned and unplanned orbit maintenance, the effects of non-responses to on-board events for 5 days at a time, atmospheric effects and single event upsets due to cosmic ray effects.

GSR-12 **Time Allocation for in-orbit calibration:**
The time required for Aeolus internal calibration and characterisation measurements shall not exceed 6% of the total time of operation. This time is not counted as unavailability.

GSR-13 **Single-point failures** are defined as any failure, which causes the service to be permanently discontinued without possibility of recovery. This can be a hardware failure or an irrecoverable software error.
Single-point failures are not permitted except where specifically agreed by ESA.

GSR-14 **Single Failure Tolerance** (Definitions in ECSS-Q-40 [SD-3]):
The satellite shall be able to sustain a single failure or operator error without critical or catastrophic consequences, and any combination of two failures or operator errors without catastrophic consequences.

6.1.2 Ground Handling Capabilities

6.1.2.1 Ground Testing

GSR-15 The complete satellite shall be able to operate and be testable in at least one orientation under 1g. This specifically includes fully representative thermal testing. It is not required to perform deployment tests on the integrated satellite.

GSR-16 The satellite design and its launch site GSE shall provide the capability for pre-launch operational checkout, functional performance checkout and launch readiness verification of the integrated launch configuration including the instrument. The checkout capability at the launch site, shall be provided without disassembly of the integrated launch configuration.

GSR-17 The satellite and its launch site GSE shall for all launch site operations comply with the launch site facilities and the launch vehicle interfaces specified in the Aeolus Satellite to Launcher Interfaces Documents [AD-4] and [AD-5].

6.1.2.2 Contamination and Cleanliness

GSR-18 The satellite design shall be compatible with the contamination environment encountered during AIT, pre-launch, launch and all mission phases.

GSR-19 The satellite and its GSE shall be designed to minimise the areas of settling and accumulation of molecular and particulate contamination. If elimination is not possible, such areas shall be designed for easy access for cleaning.

GSR-20 The satellite shall be visibly clean at all times during integration and testing and at the time of the integration with the launcher.
Visible clean is defined in ESA PSS-01-201 [SD-4], 300 ppm obscuration factor, as a minimum.

GSR-21 Ground covers shall be provided to protect the ingress of contamination into apertures except when such apertures are specifically required to be open.

GSR-22 If required, provisions for purging of sensitive subsystems (e.g. receiver optics, laser heads) shall be implemented in the satellite.

GSR-23 The maximum expected contamination levels shall be compatible with the instrument allowable contamination budget.

6.1.2.3 Modularity

GSR-24 The satellite shall be constructed in modules, which allow parallel manufacturing and test on each module. These modules shall be at least:

- the ALADIN instrument including laser, telescope and baffle,
- the satellite bus,
- the solar array.

GSR-25 Mechanical and electrical integration of modules shall together require no more than two shifts of AIT activity for the mating of any flight items.

GSR-26 Mechanical and electrical disassembly and re-integration shall be possible in no more than two shifts of AIT activity.

GSR-27 The satellite shall be transportable to the launch site in a fully integrated configuration.

6.1.2.4 Maintainability

GSR-28 It shall be possible to mate and de-mate all electrical connectors of the instrument, when the instrument is standing alone, without further disassembly. A permissible exception is the interface between the detector and its front-end electronics.

GSR-29 It shall be possible to remove and replace any electrical box from the instrument after disassembly of only the instrument core from the remote electrical panel. A permissible exception is the detector front-end electronics.

GSR-30 It shall be possible to mate and de-mate all electrical connectors on the satellite bus, whether the bus is standing alone or integrated to the instrument, after the removal of no more than two access panels. These access panels shall not themselves have electrical units mounted on them.

GSR-31 It shall be possible to remove and replace any electrical box from the satellite bus after disassembly of a single panel from the bus. This panel may have electrical units mounted to it.

GSR-32 It shall be possible to access any PROM containing flight software without removing the corresponding electronics box from the satellite.

GSR-33 Pyro safe/arm and fill/drain connections shall be accessible on the skin of the satellite when the satellite is in a fully integrated configuration.

GSR-34 Pyro installation and replacement shall be possible when the satellite is in an otherwise fully integrated configuration.

6.1.3 Safety Requirements

GSR-35 All elements of the system shall be designed to minimise hazards to personnel and property.

GSR-36 The safety requirements of the launcher authority as well as the requirements in force for facilities to be used in the execution of the AIV programme shall be fully complied with.

GSR-37 Design choices likely to create safety concerns shall be identified and submitted to the Agency for approval.

6.2 Mechanical Requirements

6.2.1 General Mechanical Requirements

STR-1 The following failure modes, for the satellite and all equipment at all level of integration, shall be prevented:

- Permanent deformation, yield,
- Rupture,
- Instability, buckling,
- Gapping, of bolted joints, of storage devices,
- Degradation of bonded joints,
- Vibration induced mounting interface slip,
- Loss of alignment of equipment and payloads subject to alignment stability requirements,
- Distortion violating any specified envelope,
- Distortion causing functional failure or short circuit.

STR-2 Wherever practical a fail-safe design based on redundant structural elements shall be used.
A design implementation is considered fail-safe if the failure of one structural element in the load path does not affect the stiffness of the structure significantly and does not cause the remaining structural elements to fail under the new load distribution.

STR-3 In cases where a fail-safe design cannot be implemented, the load path shall be verified to be safe-life. The corresponding structural elements shall be tracked as potential fracture critical items (PFCIs).
The following items are PFCIs: Pressurised systems, Rotating machinery, Fasteners in safe-life design implementations, Items fabricated using welding, forging or casting used at limit stress levels above 25% of the ultimate tensile strength.

STR-4 Non-metallic flight structural items (e.g. composites, glass, bonded joints) shall be proof-tested at 1.25 x limit load as a minimum.

STR-5 Rotating machinery shall be spin tested at 1.1 x maximum operating speed as a minimum.

STR-6 Pressurised systems shall be tested at a proof pressure in accordance with the Design Safety Factors Table (Table 6.2-1).

STR-7 Fasteners shall be verified similarly to other structural items.

STR-8 Titanium alloy fasteners and fasteners smaller than M5 are not allowed for safe-life design implementations.

STR-9 Fasteners shall be procured and tested according to approved aerospace standards. After proof-testing or non-destructive inspection, they shall be marked and stored separately.

STR-10 The spacecraft, spacecraft structure and equipment shall be able to withstand the worst case expected combination of the required loads and associated environments encountered during ground and in-orbit operational phases. These include manufacturing, assembly, testing, transport, launch and in-orbit operations. All mechanical elements shall demonstrate positive margins of safety. In addition, the factors of safety defined in the table below shall be applied to derive the margins of safety.

These factors do not include other load multipliers specified by the launcher design authority (e.g. development factor, uncertainty factor, acceptance factor, qualification factor, test factor), which apply in addition to the design safety factors.
The margin of safety shall be calculated as follows:

$$MS = \frac{allowable\_load}{applied\_load \cdot safety\_factors} - 1 \ .$$

Table 6.2-1: DESIGN SAFETY FACTORS TABLE

COMPONENTS/LOAD TYPE	**Minimum Factors of Safety**		
NON-PRESSURE LOAD CASES [a]:	**Proof [b]**	**Yield**	**Ultimate**
General Structure, Metallic	-	1.1	1.5
Non-Metallic Structures	1.20	-	1.5
Mechanisms and Mechanisms Components	-	1.4	2.0
PRESSURE LOAD CASES [a]:			
Pressure Vessels	1.25	-	1.5
Pressurised components:			
• Lines and Fittings			
- Smaller than 38 mm diameter	2.0	-	4.0
- 38 mm diameter or greater	1.5	-	2.0
• Valves, Filters, Regulators, Other Pressurised Components	1.5	-	2.5
Potentially Explosive Containers	1.5	-	2.5

Notes:

[a] (1) For combined loads where L(P) is the load due to maximum expected operating pressure and L(M) is the non-pressure limit load, the factored, ultimate load case shall be : 1.5 L(M) + 1.5 L(P)

[a] (2) For load cases involving thermal and/or moisture desorption loads, the thermal/moisture desorption stress at the applicable temperature shall be factored by 1.5 to determine the equivalent ultimate thermal/ moisture desorption load and this shall be added to 1.5 times the non-pressure load and/or the pressure load.

[a] (3) Where pressure and/or temperature and/or moisture desorption relieve the non-pressure load a Factor of Safety of 1.0 shall be used for the pressure and/or thermal and/or moisture desorption loads. In this case the pressure load shall be based on the minimum operating pressure.

[b] No yielding is allowed at proof load/proof pressure. Protoflight hardware shall not yield during testing.

STR-11 Prior to verification of the structural dynamic model of the satellite by dynamic testing, all dynamic loads derived by analysis, including launch vehicle/satellite coupled dynamic loads, shall be factored by the J_u uncertainty factor, additional to the design safety factors, accounting for inaccurate predictions of structural damping and dynamic coupling:

$$J_u = 1.25 \; .$$

STR-12 The Aeolus Structure Model shall be able to survive 4 times all mechanical qualification tests.

STR-13 The Aeolus Flight Model shall be able to survive 4 times all mechanical acceptance tests plus one launch.

STR-14 **Notching:**
Primary notching, i.e. notching to keep the accelerations of the centre of mass of Aeolus at the design loads, is allowed.

STR-15 Secondary notching, i.e. notching to protect internal equipment, the instrument or notching to achieve accelerations at the centre of mass of Aeolus lower than the design loads, is not allowed.

STR-16 **Flight, acceptance, qualification factors:**
The minimum factors in Table 6.2-2 shall be applied. If larger factors are requested by the launcher user manual or the launcher authority, these larger factors shall be applied.

Table 6.2-2: Load factors for flight, acceptance and qualification testing.

Test	Unit	Flight	Acceptance	Qualification
Sine vibration	g	given by launcher authority	x 1	x 1.25
Acoustic	DBPa	given by launcher authority	+ 0 dB	+ 4 dB
Random (1)	g^2/Hz	given by launcher authority	x 1	x 1.25^2
Shock	g	given by launcher authority	not required	x 1.25

(1) for equipment only

6.2.2 Mechanical Functional Requirements

STR-17 The spacecraft structure shall provide the physical interfaces to all equipment or units.

STR-18 The spacecraft structure shall provide the physical interface to the launch vehicle.

STR-19 The spacecraft structure shall maintain the required alignment during ground and in-orbit operations.

STR-20 The structure shall be protected against corrosion, moisture and stress corrosion.

STR-21 The structural and thermal interfaces shall be designed to allow analysis of the modules and their interaction.

STR-22 The mechanical design shall provide access to connectors. The mechanical design shall allow removal and maintenance of all secondary structures, equipment and the payload.

6.2.3 Mechanical Performance Requirements

STR-23 The lowest frequencies and the effective masses of the spacecraft in launch configuration, hard mounted to the launch vehicle interface shall be in accordance with the applicable Launch Vehicle User's Manual.

STR-24 The structural design shall provide a minimum margin of +15% over the specified frequencies before verification of the spacecraft dynamic properties by test.

STR-25 The satellite shall comply with the dynamic envelope requirements applicable to ground handling, transportation and launch when subject to the worst case combination of limit loads and root-mean-square manufacturing tolerances.

6.3 Mechanisms and Pyrotechnics

6.3.1 Mechanism General Requirements

MEP-1 Flight mechanisms shall provide actuation torques / forces throughout the operational life which exceed at least by a factor of 2 the combined worst-case resistance torques/forces predicted. The following minimum factors shall be applied in the design for the component of resistance:

Resistance		Factor
Friction	F	3 [a]
Hysteresis	Hy	3 [a]
Spring	S	1.2
Inertia	I	1.1
Others	Ha	3 [a]

The required torque/force – worst case – is defined by the equation:

$$T = 2 \cdot (3 \cdot F + 3 \cdot H_y + 1.2 \cdot S + 1.1 \cdot I + 3 \cdot H_a)$$

[a] This coefficient may be reduced to 1.5 the worst-case measured value if data are confirmed by test according to an ESA approved test procedure.

MEP-2 All reliability and redundancy requirements (series 30300 from) of ECSS-E-30-00 Part 2-3 [SD 5] apply.

MEP-3 All tribology requirements (series 32500, 32600, 32700 and 32800) of ECSS-E-30-00 Part 2-3 [SD 5] apply.

MEP-4 All design and sizing requirements (series 33500, 33600 and 33700) of ECSS-E-30-00 Part 2-3 [SD 5] apply.

MEP-5 Life test of the mechanisms shall be as per requirement 36617 of ECSS-E-30-00 Part 2-3 [SD-5].

MEP-6 Life test of the mechanisms shall be successfully completed prior to flight.

MEP-7 All flight mechanisms shall be designed to allow ground verification testing.

MEP-8 All mechanisms shall be able to perform nominally after a storage period of one year at spacecraft level. The mechanisms shall not request any additional tests during or after this period to confirm the performance of the mechanisms. Storage configuration needs not be flight configuration.

6.3.2 Mechanism Functional Requirements

MEP-9 Deployment mechanism shall allow contingency operations to correct deployment anomalies (e.g. possibility to power up redundant winding of deployment motors, reverse operation of motors) by design features, which do not introduce significant additional complexity.

MEP-10 The mechanisms shall provide data to monitor its status.

MEP-11 Mission critical functions shall be monitored by redundant sensors.

MEP-12 It shall be possible to command all mechanism from ground.

6.3.3 Deployables

MEP-13 The only deployable shall be the solar array.

MEP-14 deleted

6.3.4 Pyrotechnics Requirements

MEP-15 Pyrotechnics application and design shall be approved by ESA.

MEP-16 All pyrotechnic devices shall be redundant.

MEP-17 High reliability and safety shall be provided for pyrotechnic devices by the use of approved practices including the screening of all leads and electronics.

MEP-18 All pyrotechnics shall be initiated via a dedicated module which is mechanically segregated, electrically independent and screened, and thermally decoupled from the rest of the unit that houses it to avoid failure propagation within the unit. This module shall incorporate the safety inhibits. The unit initiating thermal knives, if any, shall also incorporate inhibits.

MEP-19 The use of pyrotechnic devices shall be compatible with the cleanliness requirements of the spacecraft.

6.4 Thermal Control Sub-System (TCS)

6.4.1 TCS General Requirements

TCS-1 The thermal design shall take into account the degradation of thermal properties of TCS items during the lifetime of the satellite.

TCS-2 The thermal design shall be flexible enough:

- to accommodate changes in configuration, power dissipation, platform and payload operation, and temperature requirements during the development;
- to allow trimming of the radiator areas to correct the temperature biases predicted after correlation of the thermal mathematical models.

TCS-3 The guaranteed TCS temperature range (to be compared to the TCS design range) shall include uncertainties originated by inaccuracies in the input data and/or in the analysis process as defined in ECSS-E-30 Part 1A [SD-6].

TCS-4 The TCS shall establish a coherent set of minimum and maximum design temperatures, taking into account the unit acceptance temperature limits provided by the system.

TCS-5 The unit qualification temperature limits are equal to the acceptance limits extended at both ends by the qualification margin of at least 10 ºC.

TCS-6 In co-operation with the unit manufacturers, the TCS shall define temperature reference points (TRP), which are representative of the thermal status of the unit.

6.4.2 TCS Functional Requirements

TCS-7 The TCS shall provide the thermal environment (temperatures, temperature gradients and temperature stability) required to ensure the integrity and the proper performance of the satellite during LEOP, the nominal phase of the mission, safe mode and initiation of any end of life maneuver.

TCS-8 The TCS shall comprise sufficient temperature sensors to enable adequate ground temperature monitoring (health check and stability monitoring) and control (ground intervention) during nominal and non-nominal phases.

6.4.3 TCS Design Requirements

TCS-9 The thermal control of the platform and of the payload should be achieved by passive means and with the aid of electrical heaters where necessary.

TCS-10 The TCS shall be designed such that its elements do not prevent accessing other units and equipment, and it shall allow easy integration, inspection and, if necessary, removal of TCS items.

TCS-11 The TCS of the complete satellite shall be able to operate fully and with total representativity in at least one orientation under 1g under vacuum.

6.4.4 TCS Mathematical Modelling

TCS-12 Geometrical and Thermal Mathematical Models (GMM and TMM, respectively) of Platform and Payload shall be detailed enough to demonstrate that the thermal requirements are met over the whole service life.

6.5 Electrical and Power System (EPS)

6.5.1 EPS General Requirements

EPS-1 The power system shall be designed in accordance with chapter 5 of ECSS-E-20 A [SD-7] and PSS-01-604 Issue 1 [SD-8].

EPS-2 The power system shall provide all power required by the spacecraft for the launch ascending phase and all mission modes through the entire duration of the mission under the environmental conditions and shall support test, pre-launch and launch activities.

EPS-3 The power resources shall be dimensioned with adequate margin providing power up to the end of the mission as defined in ECSS E-20A [SD 7], however the margins shall be at least 10% at EOL until Platform Qualification Review, and 5 % thereafter..

6.5.2 EPS Functional Requirements

EPS-4 The power system shall condition, control, store and protect/distribute electrical power on board of the spacecraft.

EPS-5 The power system shall autonomously perform mode transition operations of the protection and energy management without support from other spacecraft subsystems.

EPS-6 The power system shall support the connection of external power sources during ground operation.

EPS-7 All automatic H/W and S/W protection features shall be overridable except the hardware-based functions as detailed in paragraph 5.3.b of ECSS-E-20A [SD-7].

EPS-8 The outlets shall be switchable by ground command, with the exception of the outlets supplying the TC reception chain and other essential equipment.

EPS-9 Latching protection devices shall be re-settable.

EPS-10 The power outlets shall be equipped with suitable protection devices preventing failure propagation from any user to the power bus.

EPS-11 The power outlets shall be equipped with suitable protection devices preventing failure propagation from the power bus to any user.

EPS-12 The power system shall be capable to restart automatically after the occurrence of a power interruption as soon as the power for the solar arrays is available again.

6.6 Attitude and Orbit Control System (AOCS)

6.6.1 AOCS General Requirements

AOS-1 The spacecraft shall provide an Attitude and Orbit Control Subsystem (AOCS) that shall be able to:

- provide attitude control around three orthogonal axes during all mission phases,
- correct for worst case launcher injection errors,
- perform orbit corrections to maintain the orbit parameters within the required range during the mission life,
- supply sensor data to allow on-ground attitude and orbit determination,
- protect the payload from sun intrusion into its sensitive field of view for longer than the specified time,

in the case of full fuel tanks as well as in the case of partially filled fuel tanks.

6.6.2 AOCS Functional Requirements

AOS-2 The AOCS shall provide all necessary capabilities and performances to satisfy the attitude and orbit control, and measurement requirements of all mission phases and operational modes.

AOS-3 After separation from the launch vehicle, the AOCS shall:

- damp out the residual angular rates,
- bring the spacecraft into a power safe pointing attitude within a time compatible with the spacecraft internal power,
- maintain the spacecraft in this pointing attitude ready to receive ground commands.

AOS-4 The AOCS shall include all on-board hardware and software to provide an autonomous capability to determine and to maintain the required spacecraft attitude pointing during all the mission phases.

AOS-5 The AOCS shall acquire and maintain a three-axis stabilised Earth pointing control throughout its orbital life (except when in Safe Mode) in the presence of perturbation torques, spacecraft flexible modes or liquid slosh during all mission phases and operational modes.

AOS-6 The AOCS shall protect the payload against sun intrusion and direct impact of atomic oxygen on sensitive surfaces at all times, but in particular during the period between separation and initial attitude acquisition, following AOCS anomaly, Safe Mode transition & steady state operation.

AOS-7 All AOCS functions shall be maintained with full performance after a single failure.

AOS-8 The AOCS shall include an autonomous capability to measure the satellite position with an accuracy sufficient to satisfy all localisation and pointing requirements.

AOS-9 The AOCS shall include an on-board orbit propagator providing a Position on Orbit, which is sufficient to satisfy all localisation and pointing requirements in the event of temporary unavailability of satellite position measurements for up to one orbit.

AOS-10 It shall be possible to synchronise the on-board orbit propagator with orbit measurement information determined on ground.

6.6.3 AOCS Performance Requirements

AOS-11 After separation, the AOCS shall be able to acquire nominal Earth pointing attitude and rates from any initial attitude and, as a minimum, 1.5 times the worst case rates at separation.
Note: the pointing performance at this time may be degraded with respect to Operational Phase requirements, but should be good enough to satisfy the satellite power and thermal safety requirements.

AOS-12 During Commissioning and Operational Phases, following an AOCS anomaly (without transition to Safe Mode) the AOCS shall be able to acquire the nominal Earth pointing attitude and rates from any initial attitude and rates limited only by the physical integrity of the satellite.

AOS-13 In Nominal Operation Mode and End-to-End Calibration Mode, the AOCS performance (absolute pointing error, relative pointing error, pointing stability, rate stability etc.) shall comply with the measurement performance requirements.

AOS-14 The AOCS shall be able to function and meet its performance requirements for any day of launch.

6.6.4 Propulsion System Requirements

AOS-15 The Propulsion Subsystem shall perform nominally for a period including:

- the pre-launch lifetime,
- the satellite storage requirement,
- the mission lifetime.

AOS-16 The characteristics of the thrusters and their accommodation on the satellite shall not cause any adverse effects on either the spacecraft or the payload during the mission.

AOS-17 The AOCS shall provide adequate means for determination of the remaining propellant quantities.

AOS-18 Fuel gauging accuracy shall be such as to maximise fuel usage in the Operational Phase but ensure that sufficient fuel is available:

- to terminate Routine Operations and undertake a controlled re-entry, if this design option is retained,
- in the Operational Phase, to predict the end of the mission with an accuracy of three months.

AOS-19 The design of the thruster control valves shall be such as to avoid a valve-open failure.

AOS-20 For the estimate of the fuel requirements, the following assumptions shall be used:

- six days of thruster attitude control following attitude re-acquisitions,
- two Safe Mode entries, each with ten days steady state operation,
- orbit maintenance as required to fulfil geolocation and repeat cycle requirements, and
- an additional margin of 20 %.

6.6.5 AOCS Commandability and Observability

AOS-21 In all modes, the AOCS shall provide to the ground sufficient housekeeping data to perform:

- failure detection and isolation,
- switch-over to the redundant resources,
- shutdown and isolation of malfunctioning parts.

AOS-22 Without the need for telemetry reprogramming, the AOCS shall provide the ground with sufficient measurement information to permit the spacecraft position and instrument pointing reconstitution with the accuracy required by the mission, system and operational requirements, throughout the relevant mission phases.

AOS-23 In each of the AOCS modes, sufficient data shall be available in telemetry to allow the ground to determine the satellite attitude independently of the on-board estimation process.

AOS-24 All nominal AOCS operations shall be fully automatic and autonomous. Ground intervention shall be limited to support for recovery operations after multiple failures.

AOS-25 AOCS reconfigurations by ground shall not require a “Ground Intervention Mode”. It shall be possible for ground to uplink and store on-board all required reconfiguration commands (H/W change commands, acquisition table, etc.) in advance and then request the software to undertake the reconfiguration by sending a single command without affecting the mission.

AOS-26 The AOCS shall:

- accept immediate or time tagged telecommands to perform attitude and orbit manoeuvres,
- allow reconfiguration and parameter updating upon ground command.

AOS-27 The AOCS shall provide sufficient information to ground to allow diagnosis of on-board failures. This may be by ground command or specific diagnostic telemetry packets.

AOS-28 The AOCS shall permit in-orbit reprogramming of its software.

AOS-29 Adjustments of AOCS control loop parameters by telecommand shall be possible.

AOS-30 In all modes except Safe Mode, it shall be possible to command an attitude bias on the sensor measurements in order to compensate for payload misalignments and AOCS attitude errors.

AOS-31 Any on-board ephemeris table (e.g. earth, sun, stars) shall not require an update from ground more frequently than once every 5 days.

6.6.6 AOCS Safe Mode Requirements

AOS-32 In case of anomalies not resolved by on-board redundancy or back-up actions, the satellite shall provide an autonomous Safe Mode that shall:

- bring the spacecraft into a safe power/thermal/Ground Communication condition which permits satellite survival,
- bring the spacecraft into a stable pointing mode which minimises altitude loss and shall be compatible with an altitude recovery,
- use actuators and measurement sensors different from those used in operational modes (specific or different channels).

AOS-33 The AOCS shall allow to autonomously recover a three-axis stabilised Earth pointing attitude upon Safe Mode exit.

6.7 Data Handling Subsystem (DHS)

6.7.1 DHS General Requirements

DHS-1 The DHS shall support data exchange with other subsystems via dedicated interfaces and/or a standard spacecraft data handling bus.

DHS-2 The DHS shall support data exchange between spacecraft and ground for uplink of telecommands and downlink of telemetry and data.

DHS-3 The DHS shall be autonomous in line with the mission objectives. This shall include an autonomous start-up and initialisation capability upon availability of spacecraft power or upon DHS-reset.

DHS-4 No single failure shall cause unwanted activation of outputs or automatic sequences.

DHS-5 The TC-reception chain shall be hot redundant. This implies that no single failure shall lead to the loss of spacecraft commanding capability.

6.7.2 DHS Functional Requirements

DHS-6 The DHS shall collect, format and store TM data and distribute them to the downlink facility. The telemetry data shall include both measurement and housekeeping data.

DHS-7 Telemetry formatting shall be according to the ESA Packet Telemetry Standard [SD-9] and the ESA Telemetry Channel Coding Standard [SD-10].

DHS-8 The DHS shall be able to process telecommands from ground in accordance with the ESA Packet Telecommand Standard [SD-11] and the ESA Telecommand Decoder Specification [SD-12].

DHS-9 The DHS shall provide the capability of direct commanding essential satellite equipment without software intervention.

DHS-10 The DHS shall include the on-board system/master clock used for stamping all measurement and housekeeping data with an accuracy of at least 1 ms with respect to UTC. Time correlation of measurement data shall allow to meet all measurement performance requirements.

DHS-11 The DHS shall support the onboard Failure Detection, Isolation and Recovery (FDIR) functions.

DHS-12 The DHS shall provide data storage capacity for the storage of all payload and spacecraft data. The sizing of this data storage shall be in line with mission needs, including provisions for anomalies on board and on ground.

DHS-13 The data storage shall be based on a modular solid-state mass memory. It shall be possible to extend the memory size without impact on interfaces and functionality.

DHS-14 The DHS shall include the necessary means for error detection and correction of the information, while stored.

DHS-15 Margins for the DHS shall be at least 25% for data storage. For telemetry and telecommand channels a margin of at least 25 % shall be maintained until Critical Design Review.

6.7.3 DHS Design Requirements

DHS-16 The DHS shall support Failure Detection, Isolation and Recovery (FDIR) of its own proper functioning.

DHS-17 The DHS-FDIR shall ensure the safety of the spacecraft and the minimisation of mission-interruptions without the need for ground intervention.

DHS-18 The DHS-FDIR shall include functions to detect software malfunctions, using e.g. watchdog timers to detect SW lockout situations at SW functional level and at the level of HW/SW interfaces.

DHS-19 Measures shall be taken to minimise the loss or corruption of stored payload and platform data upon the occurrence of DHS and SW anomalies as well as SEUs in the data storage.

DHS-20 The DHS shall support the satellite Safe Mode. In this mode, spacecraft telemetry shall be available which allows ground to assess the spacecraft status and define recovery actions. This may be a subset of the nominal telemetry acquired via independent acquisition and formatting stages.

DHS-21 An end-to-end test capability shall be implemented which allows to verify the correct function of the DHS under ground control.
Note: One example of a possible implementation is the addressing of a free RTU-output by ground-TC, which is configured such that verification telemetry is generated at each step of the command execution chain (TC verification, data handling bus, execution of the command at RTU output level).

6.8 Communication Subsystem (COM)

6.8.1 COM General Requirements

COM-1 The Communication Subsystem shall provide all Tracking, Telemetry and Command services to ensure satellite command and control as well as satellite range and range rate measurements. This function shall be available during all mission phases, including pre-launch and launch.

COM-2 The Communication Subsystem shall also provide the capability to transmit the measurement data, both stored and real-time, to the Ground Stations (Payload Data transmission). This function shall be available during pre-launch and the nominal mission phase, and without any mutual impact or interference with the TT&C function.

COM-3 The RF links shall be designed keeping the following margins:
Link margin shall be > 3 dB for the nominal case,
Link margin shall be > 1 dB for the RSS worst case,
Link margin shall be > 0 dB for the mean 3-Sigma case.

COM-4 The power flux density at the Earth's surface shall not exceed the values specified in the ESA RF and Modulation Reference Document during all in-orbit phases except launch [SD-13].

COM-5 The spurious emissions induced by the RF-transmitters shall be below the limits specified in the ESA RF and Modulation Reference Document [SD-13].

COM-6 The Communication Subsystem shall be compliant with the requirements on RF-emissions imposed by the launcher [AD-4 and AD-5].

COM-7 It shall be possible to switch ON/OFF the RF transmitter by ground command.

6.8.2 Requirements for the Tracking, Telemetry and Command Function (TT&C)

COM-8 The TT&C function shall receive a telemetry data stream from the DHS and transmit these data to ground.

COM-9 The TT&C function shall receive and process the uplink telecommand signal from ground for subsequent transmission to the DHS.

COM-10 The TT&C function shall support range and range rate measurements in accordance with the ESA Ranging Standard [SD-14].

COM-11 The RF link shall be established in S-Band in line with the ESA RF and Modulation Reference Document [SD-13].

COM-12 The following operational modes shall be supported without performance degradation:
Uplink: carrier only, telecommand, ranging, simultaneous telecommand and ranging
Downlink: telemetry, ranging, simultaneous telemetry and ranging.

COM-13 Operation shall be possible in coherent and non-coherent mode. The mode shall be selectable by ground-command.

COM-14 The TT&C function shall support telecommand and telemetry data rates in line with the system requirements.

COM-15 Omni directional up- and downlink coverage from and to ground shall be provided for all mission phases after launch and for any spacecraft attitude. Telemetry shall be available at any spacecraft attitude, without a need to actively switch on board antennas. In order to avoid interferences between the nominal and the backup link the nominal (Nadir-pointing) and the backup (Zenith-pointing) antenna shall be of opposite polarization. Coverage shall be ensured for nominal operations, end-to-end calibration mode and Safe Mode.

COM-16 The on-board antenna polarisation shall be the same for the uplink and the downlink and it can be either RHCP or LHCP. This assumes that the ground station is transmitting the TC in the same polarization as the received TM.

COM-17 Nominal and redundant receivers shall always be ON.

COM-18 The following quality requirements are applicable for the TC-link:
BER on physical channel: $<10^{-5}$,
probability of frame-rejection: $<10^{-5}$,
probability of undetected frame-error: $<10^{-19}$.

COM-19 The TM-link shall have a probability of frame loss below 10^{-7} .

COM-20 The following characteristics shall be assumed for the nominal S-Band ground station (Kiruna):
G/T: 27 dBK
EIRP: 63.7 dBW

6.8.3 Requirements for the Payload Data Transmission Function (PDT)

COM-21 The PDT function shall receive the measurement data stream from the DHS and transmit these data to ground.

COM-22 It shall be possible to switch the PDT function into off-mode or carrier-only mode by ground command.

COM-23 The supported data rates, as well as carrier-frequency, polarisation, modulation and coding, shall be compliant with the specified ground stations.

COM-24 The probability of transfer frame loss shall be $< 10^{-8}$.

COM-25 The Tx-antenna shall have sufficient coverage to ensure complete transmission of the payload data in line with the mission requirements to the ground stations under worst-case operational conditions (e.g. Tx EIRP, Rx G/T, G/S elevation) with a margin of 30 %.

COM-26 The following characteristics shall be assumed for all PDT reception stations:

X-Band
Circular Polarization
Technical Degradation: 1.0 dB
Demodulation Implementation Losses: 2.5 dB
Pointing Loss: 0.2 dB
G/T degradation: 0.6 dB

The characteristics for the nominal ground stations are summarized in Annex B.

For additional X-band ground stations, the following characteristics shall be assumed:
G/T: 21.0 dB/K
Minimum elevation angle: 5 degrees
Axial Ratio: 1.5 dB

6.9 On Board Software

6.9.1 On Board Software General Requirements

SWR-1 The Aeolus software shall implement functions and services, which are necessary to fulfil the mission objectives under the specific operational conditions.

SWR-2 The Aeolus software shall ensure

- a high level of autonomy both under nominal and non-nominal spacecraft conditions,
- the support of all spacecraft operational modes, including ground-testing, pre-launch, launch and nominal operations,
- a robustness against malfunctions at software and Data Handling hardware level and at the level of the other spacecraft subsystems.

SWR-3 The Aeolus software shall implement the necessary functions and services in accordance with the operational principles detailed in the Aeolus Operations Interface Requirements Document [AD-2].

SWR-4 The Aeolus software shall implement a subset of the standard PUS-services. Non-implemented services shall not be present as code.

SWR-5 Non Standard service definitions may be used if agreed as part of the Software Requirements Baseline (D-SW3)

6.9.2 On Board Software Functional Requirements

SWR-6 The Aeolus software shall be able to schedule on board processes (tasks) both cyclically at a pre-defined task-activation frequency, and event-driven (asynchronously).

SWR-7 The Aeolus software shall maintain an Onboard Elapsed Time (OBT).

SWR-8 It shall be possible to synchronise other spacecraft subsystems.

SWR-9 It shall be possible to time-stamp events of operational significance for reporting in the spacecraft telemetry.

SWR-10 The Aeolus software shall be able to process telecommands sent by ground.

SWR-11 The Aeolus software shall distribute telecommands to their target application (external subsystems, data handling subsystem, software).

SWR-12 The Aeolus software shall support the on-board mission time line as specified in [AD-2]. There shall be sufficient storage for the time line to support the orbit repeat cycle plus a margin of 20 %.

SWR-13 The execution accuracy for time-tagged telecommands shall be better than 125 ms.

SWR-14 The Aeolus software shall allow spacing of time-tagged telecommands as close as 125 ms.

SWR-15 The Aeolus software shall acquire spacecraft data and format these data for telemetry transmission to ground.

SWR-16 The sampling rates of periodic telemetry shall be sufficiently high to avoid data loss due to under sampling.

SWR-17 It shall be possible to determine the acquisition time or the time of the occurrence of an event using timing information in the telemetry.

SWR-18 It shall be possible to request Diagnostic Reports as well as to define, modify, and remove definitions of Diagnostic Reports.
Note: Diagnostic Reports will be used to support the download of additional parameters or existing parameters more frequently than downlinked in nominal telemetry.

SWR-19 The software shall provide the necessary functions for the management and handling of the data handling bus.

SWR-20 The software shall support software modification and inspection during flight. The design of Aeolus software shall allow the controlled generation and uplink of small memory areas as patches without requiring all on-board software to be modified. It shall be possible to patch all on-board software, which executes from RAM.

SWR-21 It shall be possible for ground to request a checksum of specified areas of the memory.

SWR-22 A software configuration, capable to fulfil the operational requirements, shall be automatically entered upon switch-on or reset of the onboard computer. There shall be no need for ground intervention, but ground shall have a means to override, or to re-start the switch-on process.

SWR-23 The Aeolus software shall support the storage of payload and spacecraft data (all telemetry packets) on board during periods of missing ground communication for later reporting during ground visibility periods, under ground control.

SWR-24 The simultaneous reporting of both stored data and real-time data shall be possible.

SWR-25 The Aeolus software shall be able to simultaneously report stored data and store new data.

SWR-26 It shall be possible to clear the onboard data storage by ground command.

SWR-27 It shall be possible to selectively clear only those areas of the data storage, which were already reported to ground.

SWR-28 The clearing of the stored payload data shall require at least two independent telecommands.

SWR-29 The software shall provide closed loop control functions according to system-needs. Examples are AOCS and Battery/Power Management.

SWR-30 The software shall have a NOP command.

SWR-31 There shall be no redundant code in the flight software (“dead code”).

SWR-32 The flight software shall not contain any code needed only for on-ground testing.

6.9.3 On Board Software Design Requirements

SWR-33 The Aeolus software shall be written in a single high-level language to be approved by the Agency.

SWR-34 The Aeolus software shall be layered. At least two layers shall be provided:
- a Service Layer which provides interfaces to all on-board hardware, and
- an Applications Layer which implements on-board functions such as AOCS control loops or handling of time lines.

The Service Layer shall be verified prior to and independently from the Applications Layer.
A simplified AIT Applications Layer shall be developed and delivered early to support AIT.
The Flight Applications Layer shall include on a subset all functionality of the AIT Applications Layer.

SWR-35 The Aeolus software shall be modular, minimising the interdependency between software modules in order to allow independent development, testing, and modification of software modules.

SWR-36 The Aeolus software shall be designed with a specific margin philosophy in place.
Note: the requirements below give margins for key metrics at launch time. During the software development process the margins should be higher in order to ensure the minimum margins at launch time.

SWR-37 The Aeolus software shall maintain a 25% margin on CPU-load for an agreed set of reference scenarios.

SWR-38 The Aeolus software shall have a 25% margin on memory usage on all memory (volatile and non-volatile).

SWR-39 The Aeolus software shall have a 25% margin on bus utilisation for an agreed set of reference scenarios.

SWR-40 Fixed areas of the onboard memory shall be dedicated to: a.) code, b.) constant data, c.) variable data.

SWR-41 Software execution shall be deterministic. Under all load conditions permitted by the Flight Operation Manual the software shall complete its functions within the required time. This means that there shall be no schedule overruns leading to uncompleted tasks.

6.10 Electromagnetic Compatibility

EMC-1 Electromagnetic compatibility shall be achieved in accordance with chapter 6 of ECSS-E-20 A [SD-7], except where modified here.

EMC-2 The satellite shall not be susceptible to self generated electromagnetic interference and shall ensure non hazardous operation in ground testing and in the launch environment.

EMC-3 The satellite electromagnetic emission and susceptibility shall comply with the launcher requirements.

EMC-4 The electromagnetic compatibility design shall guarantee a minimum safety margin of 6 dB on system level generally and 20 dB for pyrotechnic circuits.

EMC-5 The differential charging potential of the spacecraft external surfaces shall not exceed voltage levels high enough to affect the performance of sensitive equipment.

EMC-6 The spacecraft shall operate with nominal performance when exposed to electrostatic discharges with the following characteristics:

- Conducted electrostatic discharge (current injected into the structure):
  - C1. magnitude / energy > 10 kV / 10mJ
  - C2. rise time (10 % - 90 %) < 10 nsec
  - C3. duration (half amplitude) 100 nsec
  - C4. repetition rate 10 Hz
  - C5. duration > 3 min
- Radiated electrostatic discharge (at 30 cm distance):
  - R1. magnitude > 10 kV
  - R2. energy 10 mJ
  - R3. repetition rate 10 Hz
  - R4. duration > 3 min

EMC-7 The electrical architecture shall be based on a suitable grounding / isolation philosophy applying the distributed single point grounding concept for power and signal lines. Differential receivers and transmitters should be used for data transmission lines. The performance of the differential transmission lines shall not be affected by common mode noise.

EMC-8 ESD shall be verified by testing on any EQM or EM equipments, otherwise by heritage on flight units or analysis/review on Protoflight Units.

7 Assembly, Integration and Testing (AIT)

7.1 Ground Support Equipment (GSE)

AIT-1 GSE shall be designed for the execution of assembly, integration, verification, transportation, launch support and maintenance of satellite items and spares.

AIT-2 GSE shall consist of all ground support equipment required from development until acceptance of flight items and spares and for the launch phase and shall include as a minimum MGSE, EGSE, OGSE and FGSE.
The MGSE shall include all mechanical ground equipment necessary for transportation, ground handling, testing and storing of the satellite.
The EGSE shall include all electrical ground equipment necessary for unit and subsystem development and testing, satellite integration testing, satellite environmental testing and launch operations.
The OGSE shall include all optical ground equipment necessary for unit, and subsystem development and testing, satellite integration testing, satellite environmental testing and launch operations.
The FGSE shall include all ground equipment necessary for propellant loading/unloading, pressurisation and satellite purging (if required).

AIT-3 The GSE shall comply with requirements and safety standard imposed by the facility in which it has to operate.

AIT-4 Satellite design features and appropriate GSE shall ensure eye safety of all test personnel during all phases of AIT.

AIT-5 The GSE hardware and software developed for testing at unit, assembly, instrument and subsystem level shall be designed to allow maximum re-use at higher level tests.

AIT-6 The GSE system shall be based on commercially available and supported hardware and software.

AIT-7 No GSE fault shall propagate through the interface with flight or other hardware.

AIT-8 The GSE shall provide the capability for all functional interfaces to be verified before connection to flight hardware.

AIT-9 EGSE shall be able to process all data, both measurement data and housekeeping telemetry, in real time.

AIT-10 The GSE design shall allow fast operations for servicing, inspections, confidence testing, fault detection and calibration and shall include features for fast and easy disconnect, removal and replacement of its components.

AIT-11 The GSE shall support ESOC System Validation Tests (SVT).

AIT-12 The GSE shall support the utilisation of the Satellite Reference Data Base.

AIT-13 An RF suitcase for ground segment verification tests shall be part of the GSE.

AIT-14 MGSE shall be proof tested to 2 times the maximum expected load.

AIT-15 GSE shall support to record and analyse the satellite bus traffic.

7.2 Software Development and Verification Environment (SDVE)

AIT-16 The SDVE shall support on-board software development and testing prior to integration with the flight hardware and shall support flight software maintenance.

AIT-17 The SDVE shall support module, functional and validation test of the flight software.

AIT-18 The SDVE shall include breadboards or representative units of the on-board computer.

AIT-19 The SDVE shall include software simulation of the satellite environment in which the software operates (e.g. AOCS, data bus, TM/TC-interfaces, etc.) to present a flight-representative environment.

AIT-20 The SDVE shall include and support tests of AOCS dynamic models.

AIT-21 The SDVE shall be transportable.

8 On-ground Payload Data Processing

8.1 Data Product Definitions

The raw, base band data stream will be as received at the ground stations. The data transmission will comprise sequential recorder dumps and include both observational data and housekeeping telemetry. It will consist of source packets transmitted as Virtual Channel Data Units (VCDU), which may be corrupted, incomplete, out of sequence or duplicate. Upon reception by the processing facility all data segments need to be validated, time ordered and duplications deleted.

PRC-1 The **level 0** product shall consist of a time ordered, validated sequence of packets of instrument data and house keeping data as transmitted by the satellite. Invalid or suspect packets shall be marked as such.

PRC-2 The **level 1a** product shall contain re-constructed, unprocessed instrument measurement data and housekeeping information. All housekeeping data shall be fully processed, including conversion into physical units and co-location with the measurements by means of time stamps.

PRC-3 The **level 1b** product shall be fully geo-located Aeolus atmospheric scene data, with all engineering calibrations applied. Furthermore, estimated spacecraft induced Doppler shifts and HLOS wind profiles derived for aerosol- and molecular channels and corresponding error estimates shall be included. Annotation data shall include all processed calibration data as well as quality parameters, instrument settings and ground processing parameters as relevant for the full interpretation of the product.
The level 1b product data shall meet the performance requirements of section 4 of this document.

8.2 Ground Processor Requirements

PRC-4 The processor shall have interfaces as indicated in Fig. 8-1.

PRC-5 The processor shall be able to produce level 0, level 1a and level 1b products from one orbits raw data within 5 minutes after reception of data at the processor.

PRC-51 The processor shall be data driven. It shall process data as it arrives. It shall not require scheduling according to ground station passes or spacecraft mode. It shall be able to process one or more observations at a time.

PRC-52 Data arriving whilst the processor is processing existing data shall be stored until that processing is complete.

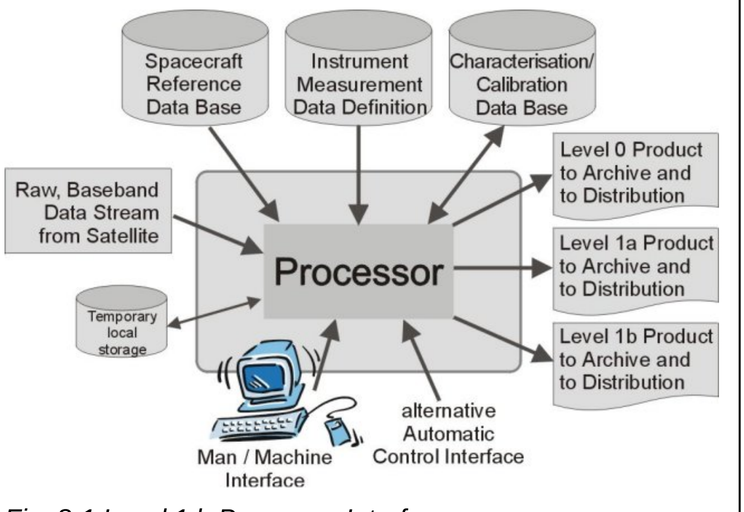


Fig. 8-1 Level 1 b Processor Interfaces

PRC-6 The processor shall be redundant. It is not required, however, to recover from processor unavailability during the processing of one orbits worth of data. Rather the redundant configuration shall be selected and the complete orbit reprocessed.

PRC-7 A man/machine interface shall be provided to allow operational control of the processor. This shall include initialisation and re-initialisation.

PRC-8 An alternative automatic command and control interface shall be provided with similar functionality of the man/machine interface.

PRC-9 It shall be possible to reprocess data of an orbit or less at a time without interfering with the operational flow and timing of regular products.

PRC-10 It shall be possible to modify processing parameters of the data between processing of the data from individual orbits. The processor shall make systematic use of telemetry and telecommand characteristics for command and control telemetry from the Satellite Reference Data Base (SRDB). A copy of this database shall reside in the processor.

PRC-11 The processor shall make systematic use of the Instrument Measurement Data Definition (IMDD) when processing data. A copy of this database shall reside in the processor.

PRC-12 The processor shall make systematic use of the Satellite Characterisation Calibration Data Base (CCDB), which shall initially contain the organised results of all on-ground characterisation activity. A copy of the database shall reside in the processor.

PRC-13 The CCDB shall be updateable in flight as a result of operations experience with the satellite, and of validation campaigns. Such updates shall be possible and convenient through the processor man/machine interface. Any such updates will only be made when the processor is not providing products.

8.3 Data Product Format Specifications

8.3.1 Conventions to be used in the Aeolus Data Products

PRC-14 Digital data used in Aeolus data products shall be stored following the ANSI-C data structure definition, with the addition of **long long** for 64 bit integers. Real numbers shall be stored in the IEEE-754-1985 standard [SD-21].

PRC-15 Data structures in Aeolus data products shall not be stored in fields of less than one byte length, i.e. no bit fields shall be used.

PRC-16 A flag must be a binary information (one bit) stored within **char**, **short**, **long**, or **long long** types. The convention for its value shall be:
FALSE = 0, if there is no error, and
TRUE = 1, if there is an error.

PRC-17 Within the Aeolus ground segment, time shall be used with an accuracy of at least 0.1 ms, expressed as either

Universal Time Coordinated (UTC), represented as a string of 25 significant characters with the following format:

DD-MM-YYYY<blank>hh:mm:ss:tttt
where:

DD day [1 to 31]
MM month [1 to 12]
YYYY year [1950 to 2050]
hh hour [0 to 23]
mm minute [0 to 59]
ss second [0 to 59]
tttt 100 8 microsecond [0000 to 9999] (if not relevant, it may be blanked with spaces)

Modified Julian Day 2000 (MJD 2000), which is the decimal number of the day since 1 Jan 2000, 00:00 hours, and stored as two **long** integers.

PRC-18 All Physical Units shall be expressed in the MKSA system, i.e. meters, kilogram, second, Ampere, etc.

PRC-19 Angular data shall be expressed as Degree.

8.3.2 Data Product Structure

Note: The purpose of this data product structure is to provide compatibility with EnviSat data products. Details of the structure will be agreed with the Contractor in [AD-7].

PRC-20 The Aeolus data products shall follow a generalised structure consisting of:
1 - the Main Product Header (MPH);
2 - a Specific Product Header (SPH) containing information specific to the whole product plus one or more Data Set Descriptors (DSD) which describe individual Data Sets;
3 - one or more Data Sets (DS), each consisting of one or more Data Set Records (DSR). The Data Sets

can be either

- Measurement Data Sets (MDS),
- Annotation Data Sets (ADS), or
- Global Annotation Data Sets (GADS).

PRC-21 Main Product Headers (MPH), Specific Product Headers (SPH) and Data Set Descriptors (DSD) shall be produced in ASCII format using a keyword-value-terminator approach.
Note: The purpose of this method is to create header structures that are self-documenting, understandable and easily readable by the user. The details of these headers will be defined in [AD-7].

PRC-22 Data Sets (DS) which follow the MPH and SPH are in mixed ASCII and binary format.

PRC-23 The Main Product Header (MPH) identifies the product and its main characteristics. It shall be of fixed length and format for all products. It shall contain at least the following major types of information:

- product identification information,
- information regarding data acquisition and processing,
- information on time of data acquisition,
- information on orbit and position,
- information concerning the conversion from on-board time to UTC,
- product confidence data,
- product size information,
- format information.

PRC-24 The Specific Product Header (SPH) shall be included with every product, containing information specific to the particular data product. This information may include relevant processing parameters etc. As a minimum, it shall include an SPH descriptor, and at least one Data Set Descriptor (DSD).

PRC-25 The Data Set Descriptor (DSD) shall be used to describe an attached Data Set or to provide references to external files relevant to the data product (e.g. auxiliary data used in the processing but not included in the product). There must be one DSD per Data Set or per reference to an external file.

PRC-26 The Data Set shall be in mixed-binary format. This may consist of integers, floats, characters (1-byte numbers), or ASCII strings.
The Data Set shall be composed of Data Set Records (DSR). The structure of the DSRs is specified in [AD-7].

Annex A: Reference Atmospheric Model

A1-1 Introduction

The reference atmospheric model is a simplified model of the Earth atmosphere and Earth surface which includes the following features:

Atmospheric temperature and pressure,
Molecular backscatter and extinction,
Clear air aerosol backscatter, extinction and depolarisation,
Typical cloud backscatter and extinction,
Ground and sea reflectance,
Background radiance.

A1-2 Reference Documents

RD-1 ISO 2533 "Standard Atmosphere"

RD-2 R.T.H. Collis and P.B Russell: Lidar Measurements of Particles and Gases by Elastic Backscattering and Differential Absorption, in 'Laser Monitoring of the Atmosphere', E.D.Hinkely (ed.), Springer Verlag 1976

A1-3 Clear air characteristics

Table A1-1 lists the backscatter and extinction properties of the model atmosphere, comprising molecular and aerosol scattering as a function of altitude in the range from 0 to 17 km. Also indicated is the standard air temperature as derived from [RD-1].

As the molecular scattering contribution is easily approximated by analytical expressions given below, these expressions shall be used for performance evaluation. On the other side, the aerosol contributions shall be used as indicated in the table at the fixed altitude levels. Between these levels, the coefficients shall be linearly interpolated.

- **Molecular Scattering**

The backscatter coefficient contribution from the air molecules β_{mol} at a wavelength of 355 nm shall be modeled in the troposphere by an exponentially decreasing function with sample altitude z:

$$\beta_{mol}(z,\lambda) = 8 \cdot 10^{-6} \cdot \exp\left(-\frac{z}{z_{mol}}\right)[m^{-1} \cdot sr^{-1}]$$

where z_{mol} = 8000 m is the scale height[1].

The molecular scattering extinction coefficient α_{mol} is deduced from the molecular backscatter coefficient β_{mol} using the following relation:

$$\alpha_{\text{mol}} = \frac{8 \cdot \pi}{3} \cdot \beta_{mol}$$

The backscatter signal I(ν) is frequency broadened due to the Brownian motion of the air molecules. The frequency spread is described by the Gaussian function

[1] The backscatter coefficient is derived according [RD-2], but neglecting the refractive index correction, which slightly underestimates the actual backscatter coefficient. The exponential approximation to the variation of the particles density is considered accurate enough for the performance assessment.

$$I(\nu) = \sqrt{\frac{1}{\pi}} \cdot \frac{I_0}{\delta\nu} \cdot \exp\left[-\left(\frac{\nu - \nu_0}{\delta\nu}\right)^2\right]$$

where I_0 is the total signal strength,

$\nu = c/\lambda$ is the frequency of the signal,

$\nu_0 = c/\lambda_0$ is the frequency of the unbroadened signal,

and $\delta\nu$ is the half-width at the 1/e points of the Doppler-broadened return which is given as:

$$\delta\nu = 2 \cdot \sqrt{\frac{2 \cdot k \cdot T}{m}} \cdot \frac{\nu_0}{c}$$

where $k = 1.38 \cdot 10^{-23}$ J/K is the Boltzmann-constant,

$m = 4.8 \cdot 10^{-26}$ kg is the average mass of the scattering molecules, and

T is the atmospheric temperature.

Aerosol scattering

The aerosol backscatter model is highly variable. A typical aerosol backscatter profile is defined in Table A1-1, which shall be used for performance predictions. The table indicates the backscatter coefficients β_{aer} at 355 nm wavelength for mid-points of range intervals. For performance simulations, the profile shall be derived by linear interpolation between these points. Above 16 km, the aerosol backscatter becomes negligible small and the molecular backscatter coefficients β_{aer} shall be set to zero.

The aerosols extinction coefficient α_{aer} shall be derived from the aerosols backscatter coefficient β_{aer} using a lidar ratio k = 0.02 sr^{--1} in the relation:

$$\alpha_{aer} = \beta_{aer} / k$$

The backscattering signal from atmospheric aerosols shows a depolarisation ratio ($I_{\perp}/I_{//}$) between 2 % to 6%.

Table A1-1: Backscatter coefficients β and extinction coefficients α for molecular and aerosol scattering in the model atmosphere between the surface and 17 km altitude

altitude [km]	Air temperature [°C]	β_{mol} $\cdot 10^{-6}$ [$m^{-1} \cdot sr^{-1}$]	α_{mol} $\cdot 10^{-6}$ [m^{-1}]	β_{aer} $\cdot 10^{-6}$ [$m^{-1} \cdot sr^{-1}$]	α_{aer} $\cdot 10^{-6}$ [m^{-1}]
0.00	15	8.000	67.021	9.882	494.077
0.50	12	7.515	62.960	7.041	352.033
1.00	9	7.060	59.146	4.200	209.990
1.50	6	6.632	55.562	1.359	67.946
2.00	3	6.230	52.196	0.754	37.695
2.50	0	5.853	49.033	0.149	7.444
3.00	-3	5.498	46.063	0.106	5.294
3.50	-6	5.165	43.272	0.063	3.145
4.00	-9	4.852	40.650	0.050	2.507
4.50	-12	4.558	38.187	0.037	1.869
5.00	-15	4.282	35.874	0.033	1.657
5.50	-18	4.023	33.700	0.029	1.444
6.00	-21	3.779	31.658	0.027	1.332
6.50	-24	3.550	29.740	0.024	1.221
7.00	-27	3.335	27.938	0.024	1.221
7.50	-30	3.133	26.246	0.024	1.221
8.00	-33	2.943	24.656	0.024	1.212
8.50	-36	2.765	23.162	0.024	1.203
9.00	-39	2.597	21.758	0.023	1.128
9.50	-42	2.440	20.440	0.021	1.053
10.00	-45	2.292	19.202	0.020	1.024
10.50	-48	2.153	18.038	0.020	0.994
11.00	-50	2.023	16.945	0.019	0.942
11.50	-50	1.900	15.919	0.018	0.890
12.00	-50	1.785	14.954	0.017	0.869
12.50	-50	1.677	14.048	0.017	0.847
13.00	-50	1.575	13.197	0.017	0.825
13.50	-50	1.480	12.398	0.016	0.803
14.00	-50	1.390	11.646	0.015	0.744
14.50	-50	1.306	10.941	0.014	0.685
15.00	-50	1.227	10.278	0.013	0.673
15.50	-50	1.153	9.655	0.013	0.660
16.00	-50	1.083	9.070	0.007	0.330
16.50	-50	1.017	8.521	0	0
17.00	-50	0.955	8.004	0	0

A1-4 Cloud characteristics

Typical clouds extinction and backscatter coefficients are given in Table A1-2 which shall be considered for the instrument performance simulations. The altitude range column gives typical clouds base and top altitudes.

Table A1-2: Cloud properties in the reference atmospheric model

Cloud type	Altitude range [km]	Backscatter coefficient $[m^{-1} \cdot sr^{-1}]$	Extinction Coefficient $[m^{-1}]$
Stratus	0.2 to 0.7	$5.0 \cdot 10^{-3}$	$9.0 \cdot 10^{-2}$
Sub-visible Cirrus	8.5 to 9.5	$1.4 \cdot 10^{-5}$	$2.0 \cdot 10^{-4}$
Polar Stratospheric Cloud	16 to 17	$3.0 \cdot 10^{-7}$	$6.0 \cdot 10^{-6}$

A1-5 Ground and sea characteristics

The following values for the Earth albedo shall be used to assess sea and ground return signals for instrument calibration purpose, as well as Earth radiance:

Soil:	0.03
Dry Snow:	0.8
Water:	0.14

To determine the dynamic range of the receiver, a dry snow return shall be assumed with clear atmosphere (aerosol backscatter and extinction = 0 m^{-1} sr^{-1} for the full atmosphere).

Ground winds can bias the apparent velocity of the ground return due to the contribution of aerosol scattering in the return signal. A maximal ground wind speed (HLOS) of 20 m/s shall be taken into account.

A1-6 Background Radiance

The outer space sun irradiance E_λ at the wavelength λ = 355 nm where sun light illumination could be relevant to the instrument performance is 1083 $W \cdot m^{-2} \cdot \mu m^{-1}$.

Annex B: Characteristics of the nominal X-Band Stations

B-1 Svalbard

The location of Svalbard is:

N 78° 13' 53.7", E 015° 24' 40.2"

The small antenna shall be used for elevation angles of 5° or more. Its characteristics are:

G/T: 21.0 dB/K

Axial Ratio: 1.5 dB

The large antenna shall be used for elevation angles between the minimum given in Fig. B-1.1 and 5º. Its characteristics are:

G/T: 35 dB/K

Axial Ratio: 1.2 dB

Only one antenna shall be used for a single pass.

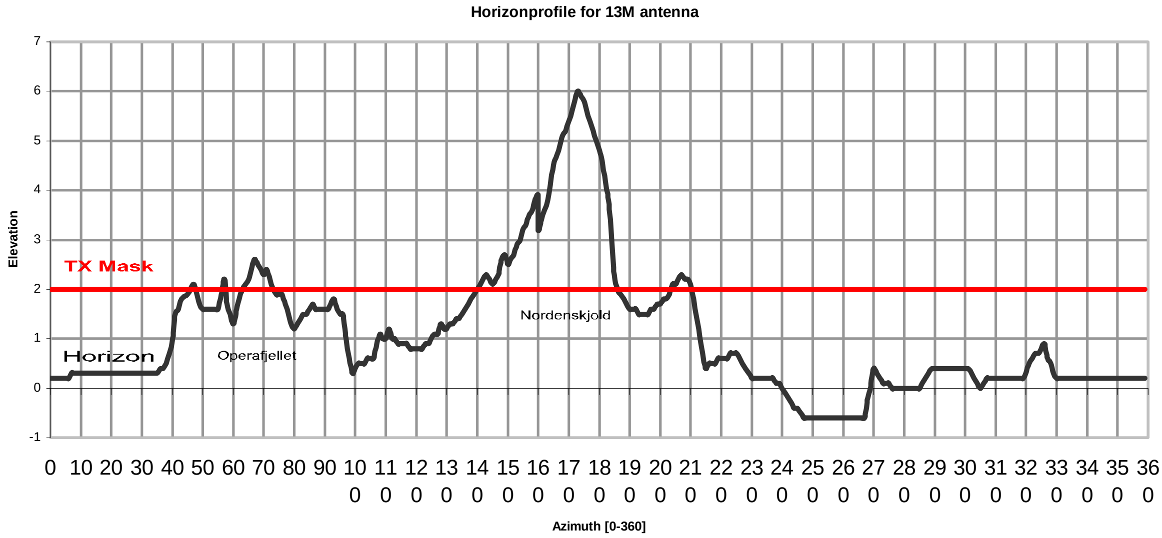


Fig B-1.1: Minimum Elevation Angles at Svalbard

B-2 Gatineau

The location of Gatineau is:

N 45° 34' 52.7", W 075° 48' 22.3"

The station can be used with a maximum elevation of 4º with the following characteristics:

G/T: 35 dB/K

Axial Ratio: 1.2 dB

B-3 Prince Albert

The location of Prince Albert is:

N 53° 12' 45.4", W 105° 56' 0.7"

The station can be used with a maximum elevation of 4º with the following characteristics:

G/T: 35 dB/K

Axial Ratio: 1.2 dB