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ESA TRACKING STATIONS (ESTRACK) FACILITIES MANUAL (EFM)

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EOP-PC	EUI-TC	HME-HT		SCI-S
EOP-PG	EUI-TL	HME-HP		SCI-SA
EOP-PL	EUI-TM	HME-HM		SCI-SM
EOP-PR	EUI-TP	HME-M		SCI-SD
EOP-PS	EUI-TS	HME-MA		SCI-SO
EOP-PT	EUI-TT	HME-MP		SCI-P
EOP-PW	EUI-W	HME-ME		SCI-PB
EOP-PY		HME-MC		SCI-PD
EOP-G		HME-MF		SCI-PE
EOP-GC		HME-MS		SCI-PJ
EOP-GM		HME-MH		SCI-PL
EOP-GS		HME-E		SCI-PN
EOP-GF		HME-I		SCI-PP
EOP-GU		HME-CO		SCI-PR
EOP-GQ		HME-CL		SCI-PT
EOP-GP		HME-UC		SCI-PW
EOP-GR				
D/TEC	D/OPS			
TEC-E	OPS-O	OPS-ONN all	OPS-GS all	TIA-R
TEC-EC	OPS-OP	OPS-ONF all	OPS-GSY all	
TEC-ED	OPS-OA	OPS-ONV all	OPS-GSA all	
TEC-EE	OPS-OE	OPS-ONS	OPS-GSS all	
TEC-EP	OPS-ON	OPS-ONK	OPS-EC all	
TEC-ET	OPS-OT	OPS-GIB all		
TEC-M	OPS-OW	OPS-GIM all		
TEC-MC	OPS-H	SOM:		
TEC-MM	OPS-HO	OPS-OPR		
TEC-MP	OPS-HI	OPS-OPV		
TEC-MX	OPS-HA	OPS-OPB		
TEC-MY	OPS-HE	OPS-OPM		
TEC-MZ	OPS-HS	OPS-OPC		
TEC-NT	OPS-HC	OPS-OPU		
TEC-OS	OPS-HM	OPS-OPS		
TEC-Q	OPS-G	OPS-OAH		
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TEC-QM	OPS-GD	OPS-OAG		
TEC-QP	OPS-GS	OPS-OAX		
TEC-QQ	OPS-GF	OPS-OAI		
TEC-QR	OPS-GN	OPS-OAL		
TEC-S	OPS-GR	OPS-OEG		
TEC-SN	OPS-E	OPS-OEA		
TEC-SP	OPS-ES	OPS-OEC		
TEC-SQ	OPS-EM	OPS-OEW		
TEC-SR	OPS-ET	OPS-OES		
TEC-ST	OPS-EC	OPS-OEV		

TEC-SW	OPS-ER	OPS-OEE		
TEC-SY	OPS-EH			
TEC-TC	OPS-EV			
	OPS-CQ			
	OPS-PM			

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CHANGE LOG

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This document is a complete re-write of the previous Network Facilities Manual, that was split in two documents: 1. ESA Tracking Stations (ESTRACK) Facilities Manual (EFM) and 2. Operations Control Center (OCC) Facilities Manual (OFM)	1	0	17/07/2006
The whole document has been re-structured, reviewed and updated in order to document the latest upgrades applied to ESTRACK as well as the decommissioning of TS-1 and the inauguration of SMA-1	1	1	2008-07-31

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1 INTRODUCTION

This ESA Tracking Stations (ESTRACK) Facilities Manual (EFM), previously known as "Network Facilities Manual (NFM)", describes characteristics of the ESA ground station Infrastructure under the responsibility of the Directorate of Operations and Infrastructure. The description of the Station's capabilities and performance characteristics shall allow potential future missions to assess the suitability of the ESTRACK Infrastructure for their needs.

2 SCOPE

This document does not cover ESA Programs dedicated ground station Infrastructures, i.e. the ARIANE-5 network of downrange stations located at Kourou (Frensh Guiana), Natal (Brasil), Ascension Island, Libreville (Gabon), Malindi (Kenya), or the Earth Observation Payload Data Reception Stations located at Maspalomas (Canary Islands), Matera (Italy), or the ARTEMIS data relay satellite feeder link station used for ENVISAT located at ESRIN (Italy).

3 DEFINITIONS AND ABBREVIATIONS

The following terminology for the notions "station", "site" and "terminal" is adopted in this document. The notion "station" usually refers to a terminal and its associated site infrastructure. The notion "site" describes a plot of land, its legal embedding, and its associated technical infrastructure to support a terminal. The notion "terminal" denotes the antenna and all associated signal processing equipment.

4 RELATED DOCUMENTS

[OFM]	Operations Control Centre (OCC) Facilities Manual (OFM), Issue 1, Revision 0, to be issued
[Comms&Principles]	European Cooperation for Space Standardisation (ECSS), Space Engineering, Communications – Part 1: Principles and requirements, ECSS-E-50 Part 1A, 20 October 2003
[RF&Mod]	European Cooperation for Space Standardisation (ECSS), Space Engineering, Radio frequency and modulation, ECSS-E-50-05A, 24 January 2003
[TM-Coding]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, TM Synchronization and Channel Coding, CCSDS 131.0-B-1, Blue Book, Issue 1, September 2003

[TM-Link]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, TM Space Data Link Protocol, CCSDS 132.0-B-1, Blue Book, Issue 1, September 2003
[TM-Packet]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, Space Packet Protocol, CCSDS 133.0-B-1, Blue Book, Issue 1, September 2003
[TC-Coding]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, TC Synchronization and Channel Coding, CCSDS 231.0-B-1, Blue Book, Issue 1, September 2003
[TC-Coding Corr.]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, Technical Corrigendum 1 to CCSDS 231.0-B-1, CCSDS 231.0-B-1 Cor. 1, Issued September 2003, Blue Book, Issue 1, June 2006
[TC-Link]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, TC Space Data Link Protocol, CCSDS 232.0-B-1, Blue Book, Issue 1, September 2003
[TC-Packet]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, Communications Operation Procedure-1, CCSDS 232.1-B-1, Blue Book, Issue 1, September 2003
[Rg&Dp]	European Cooperation for Space Standardisation (ECSS), Space Engineering, Ranging and Doppler Tracking, ECSS-E-50-02A, 24 November 2005
[SLE-RAF]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, Space Link Extension – Return All Frames Service Specification, CCSDS 911.1-B-2, Blue Book, Issue 2, November 2004
[SLE-RCF]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, Space Link Extension – Return Channel Frames Service Specification, CCSDS 911.2-B-1, Blue Book, Issue 1, November 2004
[SLE-OCF]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, Space Link Extension – Return Operational Control Field Service Specification, CCSDS 911.5-B-1, Blue Book, Issue 1, November 2004
[SLE-CLTU]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, Space Link Extension – Forward CLTU

	Service Specification, CCSDS 912.2-B-2, Blue Book, Issue 1, November 2004
[SLE-FSP]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, Space Link Extension – Forward Space Packet Service Specification, CCSDS 912.3-B-1, Blue Book, Issue 1, November 2004
[ODM]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, Orbit Data Messages, CCSDS 502.0-B-1, Blue Book, September 2004
[Time]	Consultative Committee for Space Data Systems, Recommendation for Space Data System Standards, Time Code Formats, CCSDS 301.0-B-3, Blue Book, January 2002

5 ESTRACK NETWORK INTRODUCTION

5.1 Global Coverage

ESTRACK is designed to provide global Space link connectivity coverage for a wide range of space missions:

- The Deep Space missions (DS)
- The Near-Earth missions (NE), e.g. Geostationary Transfer Orbits (GTO), Medium Earth Orbits (MEO), Geostationary Orbits (GEO), Highly Excentric Orbits, Lunar Orbits, Lagrangian Orbits
- The Low Earth Orbit (LEO) missions

The definition of Deep Space missions is derived from ITU for orbits that are more than 2 Million Kilometers away from the Earth.

The number of missions to be supported by the European Space Agency, often referred to as the “ESA Mission Model”, is highly variable with time and requires a continuous adaptation of the corresponding set of ground segments including the terminals. The development of the technology both in the Space and the Ground segments has recently resulted in the migration to higher frequency bands (from S-band to the X, Ku and Ka-bands), to more sophisticated modulation and coding schemes and to very high data transfer rates.

This from the ESA viewpoint resulted, in the creation of three nested Networks of ground stations, see Figure 1:

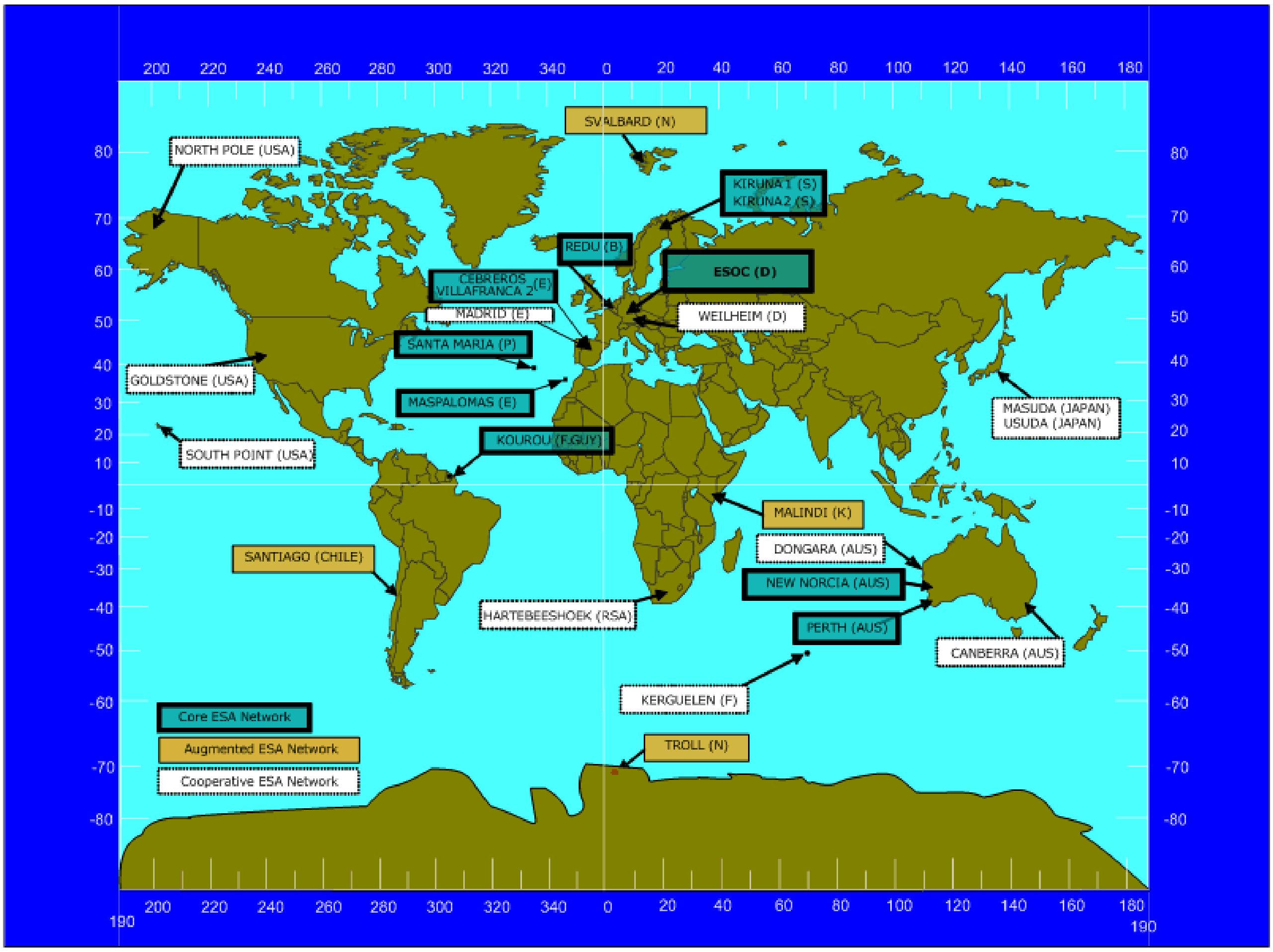

Figure 1: ESA Tracking Stations (ESTRACK) Network

5.2 The ESTRACK Core Network

The ESTRACK Core Network, see Figure 1, consists of 8 stations that host 13 terminals, i.e. at Cebreros (Spain), terminal CEB-1; Kiruna (Sweden), terminals KIR-1 and KIR-2; Kourou (French Guiana), terminal KRU-1; Maspalomas (Spain), terminal MSP-1; New Norcia (Western Australia), terminal NNO-1; Perth (Western Australia), terminal PER-1; Redu (Belgium), terminals RED-1, RED-2, RED-3; and Villafranca (Spain), terminals TS-1, VIL-1, VIL-2. These terminals are continuously maintained, upgraded or put into a safe state in relation to the evolution of the ESA Mission Model.

5.3 The ESTRACK Augmented Network

This ESTRACK Augmented Network, see Figure 1, consists of the ESTRACK Core Network station augmented at present (2006) by three additional non-ESA stations: Malindi (Kenya), terminal MAL-1; Santiago (Chile), terminals AGO-7m, AGO-9m, AGO-12m; Svalbard (Norway), terminals SG-2, SG-3; and the future Troll (Norway) station. The terminals at these station are rented for a long duration in support of extensive routine operations or for regular LEOP supports.

5.4 The ESTRACK Cooperative Network

The ESTRACK Cooperative Network stations, see Figure 1, for a subset, consists of the ESA Augmented Network, to which Networks of other Space Organizations have been added (CNES, DLR, NASA/DSN, NASA/GSFC, JAXA, CNSA, RFSA, SSC/USN and KSAT) after contractual negotiation and technical validation. This global Network gives the possibility for a mission to have access to a very wide number of terminals, mainly during a short duration LEOP or other critical mission phases. It permits an efficient utilization of the available ESA resources without necessarily having to support a very high number of expensive new terminal procurements.

5.5 Adherence to International Regulations and Standards

The ESTRACK antennas operate in the ITU frequency bands allocated to the space science services (Space Operation, Space Research, Earth Exploration-Satellite Services), and to the Fixed-Satellite Service in the case of Artemis support at Redu.

In accordance with the ITU radio regulations and with the agreements between ESA and the station host countries, the ESTRACK terminals respect the requirements on minimum elevation angle and maximum power spectral density radiated towards the Earth surface as well as any site specific constraints included in these agreements.

Individual frequency licenses are obtained for any missions to be supported by ESTRACK. Station operations must be in line with the obtained licenses.

The ESTRACK stations are designed in accordance with the European Cooperation for Space Standardisation (ECSS) standards and are compatible in the majority of cases with the international Consultative Committee for Space Data Systems (CCSDS) recommendations in order to ensure interoperability between space agencies. This applies to the Radio Frequency domain with Modulation and Channel Coding, [RF&Mod, TM-Coding], the Packet Telemetry and Telecommand domain [TM-Link, TM-Packet, TC-Link, TC-Packet, Time], as well as the ground communications domain [SLE-RAF, SLE-RCF, SLE-OCF, SLE-CLTU, SLE-FSP] and radiometric measurement of Ranging and Doppler Tracking, [Rg&Dp] and orbit data delivery [ODM].

Deviation from international standards may be supported on special request.

5.6 Performance Characteristics

Table 1 lists the individual terminal performance characteristics for the ESTRACK terminals in the Core and Augmented Network. All sites and terminals are described in detail in the specific chapters. For mission Spacelink analysis it is recommended to use the performance characteristics figures as indicative only and to consult the ESTRACK point of contact given in 5.16 for detailed design questions.

Explanations for the individual table entry attributes:

1. Revision number of the Performance Characteristics table. Separation of ESTRACK Core Network Terminals and ESTRACK Augmented Network Terminals.

2. Revision date of the Performance Characteristics table. ESTRACK terminal name in the convention of site name, hyphen, terminal number on the site. Frequency bands supported in the convention (Uplink-bands / Downlink-bands).
3. TERMINAL, the basic radio frequency and mechanical performance characteristics follow in rows 4-17. Terminal acronym is given in the convention site acronym, hyphen, terminal number on the site.
4. Longitude is the geographical longitude in [degrees (deg), minutes (‘), seconds (“) rounded to max 4 digits decimal] in the Geodetic Reference System 1980 (GRS80), which is a refinement of the World Geodetic System 1984 (WGS84) ellipsoidal coordinate system. Please note that for antennas with tilting capability the exact location is dependent on the tilt direction, it is provided here for Tilt-West. On request the location can also be provided for Tilt-East, and in the cartesian International Terrestrial Reference Frame (ITRF) 2000, reference epoch 1997.0 coordinate system for high precision orbit determination.
5. Latitude is the geographical latitude in [degrees (deg), minutes (‘), seconds (“) rounded to max 4 digits decimal] in the GRS80 ellipsoidal coordinate system.
6. Altitude is the geographical altitude in [m] in the GRS80 ellipsoidal coordinate system. Please note the altitude can be negative as the Earth surface geoid can be below the theoretical ellipsoid.
7. Antenna Diameter in [m] defines the mechanical dish aperture.
8. S-band Beamwidth in [deg] is the angle between the half-power (3dB) points of the main lobe, when referenced to the peak effective radiated or received power of the main lobe. As this figure is frequency dependent it is given for the Receive and Transmit band.
9. X-band Beamwidth in [deg] is the angle between the half-power (3dB) points of the main lobe, when referenced to the peak effective radiated or received power of the main lobe. As this figure is frequency dependent it is given for the Receive and Transmit band.
10. Ka-band Beamwidth in [deg] is the angle between the half-power (3dB) points of the main lobe, when referenced to the peak effective radiated or received power of the main lobe. As this figure is frequency dependent it is given for the Receive and Transmit band.
11. Antenna Speed is the maximum speed in [deg/s] of the Azimuth and Elevation axis.
12. Azimuth Range is the maximum azimuth axis range in [deg]
13. Elevation Range is the maximum elevation axis range in [deg]
14. Search / Acquisition Aid specifies if the antenna is equipped with a system to acquire a spacecraft in case of contingency. This system can be a search facility, or a specific acquisition aid antenna.
15. Tilt Facility specifies the capability to avoid the keyhole singularity in an Elevation over Azimuth mount antenna by tilting the entire rotating part of the antenna, typically in East and West direction. The tilting affects the horizon mask of the antenna.
16. Tracking Mode specifies if the antenna is equipped in addition to program track with an auto track facility and for which downlink band. Autotrack uses the downlink signal from the satellite and a feedback control loop to point the antenna.
17. Angular Data Accuracy (autotrack + pointing error) is the maximum combined accuracy of the autotracked signal and the resulting mechanical pointing accuracy.
18. FUNCTIONALITIES, the basic functionalities follow in rows 19-28.
19. TM/TC Standards specifies the Telemetry (TM) and Telecommand (TC) standards that are supported.

20. TM/TC Redundancy specifies if the terminal is equipped with redundant TM and TC signal processing chains.
21. Comms Redundancy specifies if the terminal is equipped with a redundant and diversely routed communication system towards the control centre.
22. Ranging names the Ranging measurement equipment installed, the footnote specifies IFMS based ESA Code Ranging with ranging tones up to 1.5 MHz, Cortex based ESA Code Ranging with ranging tones up to 500 kHz, and Enertec based ESA Tone Ranging with ranging tones up to 200 kHz.
23. Doppler states if a Doppler measurement equipment is installed.
24. Meteo states if a Meteorological measurement equipment is installed.
25. Autotrack Antenna Angles states if an antenna Azimuth and Elevation measurement equipment is installed.
26. Delta-DOR states if a Delta Differential One-way Range measurement equipment is installed.
27. Radio Science states if a Radio Science measurement equipment is installed.
28. Frequency & Timing states the source used for the frequency generation.
29. UPLINK, the uplink performance characteristics follow in rows 30-40.
30. S-band TX band in [MHz] states the S-band Transmit frequency range supported.
31. S-band Polarisation specifies the S-band uplink polarisation supported.
32. S-band EIRP specifies the S-band uplink Effectively Isotropically Radiated Power (EIRP) in [dBm].
33. X-band TX band in [MHz] states the X-band Transmit frequency range supported.
34. X-band Polarisation specifies the X-band uplink polarisation supported.
35. X-band EIRP specifies the X-band uplink Effectively Isotropically Radiated Power (EIRP) in [dBm].
36. Ka-band TX band in [MHz] states the Ka-band Transmit frequency range supported.
37. Ka-band Polarisation specifies the Ka-band uplink polarisation supported.
38. Ka-band EIRP specifies the Ka-band uplink Effectively Isotropically Radiated Power (EIRP) in [dBm].
39. Modulation Schemes names the uplink modulation equipment installed, the footnote specifies for the IFMS Uplink Modulator: PM on subcarrier or carrier, BPSK, QPSK, OQPSK, UQPSK, GMSK, TC Modulation (On sinusoidal subcarrier: PCM/PSK/PM); for the Cortex Uplink Modulator (IFM): PM or FM on subcarrier or carrier, BPSK, QPSK, OQPSK, AQPSK. TC Modulation (on sinusoidal subcarrier: PCM/PSK/PM); and for the Enertec Uplink Modulator: PCM/PSK/PM, BPSK, QPSK, Spread Spectrum and PM/FM.
40. Subcarrier Frequency states the available uplink subcarrier frequencies.
41. DOWNLINK, the downlink performance characteristics follow in rows 42-58.
42. L-band RX band in [MHz] states the L-band Receive frequency range supported.
43. L-band Polarisation specifies the L-band downlink polarisation supported.
44. L-band G/T specifies the L-band downlink Figure of Merit (Gain / System Noise Temperatur) in [dB/K].
45. S-band RX band in [MHz] states the S-band Receive frequency range supported.
46. S-band Polarisation specifies the S-band downlink polarisation supported.
47. S-band G/T specifies the S-band downlink Figure of Merit (Gain / System Noise Temperatur) in [dB/K].

48. X-band RX band in [MHz] states the X-band Receive frequency range supported.
49. X-band Polarisation specifies the X-band downlink polarisation supported.
50. X-band G/T specifies the X-band downlink Figure of Merit (Gain / System Noise Temperatur) in [dB/K].
51. Ka-band RX band in [MHz] states the Ka-band Receive frequency range supported.
52. Ka-band Polarisation specifies the Ka-band downlink polarisation supported.
53. Ka-band G/T specifies the Ka-band downlink Figure of Merit (Gain / System Noise Temperatur) in [dB/K].
54. Modulation Schemes names the downlink demodulation equipment installed, the footnote specifies for the IFMS Downlink Demodulator (RCD): PCM/PSK/PM using NRZ-L, NRZ-M, Date Rates: 10 sps to 1.2 Msps, PCM/PSK/PM using SP-L, Date Rates: 10sps to 600ksps; (SCD): BPSK -Data Rates: up to 8.192 Msps (High Speed), 2.048 Msps (Light Speed), QPSK& OQPSK- Data Rates: up to 16.384 Msps (High Speed), 4.096 Msps (Light Speed) UQPSK-Data Rates: up to 4.096 Msps (High & (Light Speed); for the Cortex Downlink Demodulator (IFR) with Subcarrier: PCM/BPSK/PM or FM, PCM/PM/PM or FM using NRZ-L/M/S, BP-L/M/S, DBP-M/S, or R-NRZ: Data rate: up to 256 kbps; (IFR) Direct Carrier: BPSK, QPSK, D-QPSK, OQPSK, D-OKPSK, AQPSK using NRZ-L/M/S, SP-L/M/S, DBP-M/S, or R-NRZ: Data rate: 10-40 Mbps; for the Enertec Downlink Demodulator: PCM/PSK/PM, BPSK, QPSK, Spread Spectrum and PM/FM.
55. Carrier Freq. Search Range specifies the downlink carrier frequency search range in [MHz] around the nominal carrier frequency.
56. Subcarrier Frequency specifies the subcarrier frequency range supported.
57. Data Rates specifies the demodulation equipment dependant maximum data rates supported.
58. Data Coding Scheme specifies the telemetry channel decoding schemes supported.
59. INTERFACES, the interfaces to the control center follow in rows 60-65.
60. TM/TC Connectivity specifies the communication and application protocols used for telemetry and telecommand data transfers between the terminal and the control center.
61. Rng/Dop Connectivity specifies the communication and equipment dependant application protocols used for Ranging and Doppler data transfers between the terminal and the control center.
62. Meteo Connectivity specifies the communication and equipment dependant application protocols used for Meteorological data transfers between the terminal and the control center.
63. Angles Connectivity specifies the communication and monitoring and control equipment dependant application protocols used for Azimuth and Elevation angles data transfers between the terminal and the control center.
64. Pointing Format specifies the pointing format supported for antenna pointing purposes, i.e. Spacecraft Trajectory Data Message (STDM) or Two Line Elements (TLE) formats.
65. Tracking Interface (ESOC) specifies the ESOC type of interface used to process the Radiometric Data provided, i.e. Flight Dynamics System (FDS) or External Partner Organisation Server (EPOS).

The footnotes describe the equipment dependant uplink modulation, downlink demodulation and radiometric measurements schemes.

1	Rev. 2.4	ESTRACK Core Networks Terminals													ESTRACK Augmented Networks Terminals		
2	18-Sep-2008	CEBREROS-1 (X / X Ka)	KIRUNA-1 (S / S X)	KIRUNA-2 (S / S X)	KOUROU-1 (S X / S X)	MASPALOMAS-1 (S X / S X)	NEW NORCIA-1 (S X / S X)	PERTH-1 (S X / S X)	REDU-1 (S / S)	REDU-2 (Ka / Ka)	REDU-3 (S / S)	SANTAMARIA-1 (. / S X)	VILSPA-1 (S / S)	VILSPA-2 (S / S)	SANTIAGO (./SX) , (S/S) , (S/L)	MALINDI-1 (S / S X)	SVALBARD-3 (S / S X)
3	TERMINAL	CEB-1	KIR-1	KIR-2	KRU-1	MSP-1	NNO-1	PER-1	RED-1	RED-2	RED-3	SMA-1	VIL-1	VIL-2	AGO-1	MAL-1	SG-3
4	Longitude	04 deg 22' 03.18" W	20 deg 57' 51.57" E	20 deg 58' 00.77" E	52 deg 48' 16.79" W	15 deg 38' 01.68" W	116 deg 11' 29.40" E	115 deg 53' 06.58" E	5 deg 08' 43.24" E	5 deg 08' 42.64" E	5 deg 08' 48.00" E	25 deg 08' 08.60" W	3 deg 57' 05.70" W	3 deg 57' 09.36" W	70 deg 40' W	40 deg 11' 40.24" E	15 deg 24' 28.03" E
5	Latitude	40 deg 27' 09.68" N	67 deg 51' 25.66" N	67 deg 51' 30.34" N	5 deg 15' 05.18" N	27 deg 45' 46.40" N	31 deg 02' 53.61" S	31 deg 48' 09.08" S	50 deg 00' 01.64" N	50 deg 00' 07.41" N	50 deg 00' 05.29" N	36 deg 59' 50.10" N	40 deg 26' 33.23" N	40 deg 26' 44.14" N	33 deg 08' S	2 deg 59' 44.00" S	78 deg 13' 47.18" N
6	Altitude [m]	794.095	402.1724	400.6815	-14.6709	205.1177	252.2558	22.1631	386.6835	385.519	372	275	655.151	664.7997	723	-12.7551	501.2934
7	Antenna Diameter [m]	35	15	13	15	15	35	15	15	13.5	2.4	5.5	15	15	12 / 9 / 7 m	10	13
8	S-band Beamwidth [deg]	N/A	Rx: 0.60 Tx: 0.65	Rx: 0.65 Tx: 0.70	Rx: 0.60 Tx: 0.65	Rx: 0.60 Tx: 0.65	Rx: 0.28 Tx: 0.30	Rx: 0.60 Tx: 0.65	Rx: 0.60 Tx: 0.65	N/A	Rx: 3.8 Tx: 4.1	Rx: 1.7 Tx: N/A	Rx: 0.60 Tx: 0.65	Rx: 0.60 Tx: 0.65	Rx: 0.75 / 1.0 / na Tx: na / 1.1 / tbc	Rx: 0.93 Tx: 1.02	Rx: 0.63 Tx: 0.68
9	X-band Beamwidth [deg]	Rx: 0.064 Tx: 0.074	Rx: 0.16	Rx: 0.19	Rx: 0.16 Tx: 0.18	Rx: 0.16	Rx: 0.064 Tx: 0.074	Rx: 0.16	N/A	N/A	N/A	Rx: 0.5 Tx: N/A	N/A	N/A	Rx: 0.2 (12 m)	Rx: 0.26	Rx: 0.19
10	Ka-band Beamwidth [deg]	Rx: 0.017	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Rx: 0.05 Tx: 0.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	Antenna Speed [deg/s]	Az: 1.0 deg/s El: 1.0 deg/s	Az: 15.0 deg/s El: 5.0 deg/s	Az: 12.0 deg/s El: 7.5 deg/s	Az: 15 deg/s El: 5 deg/s	Az: 15 deg/s El: 5 deg/s	Az: 0.4 deg/s El: 0.4 deg/s	Az: 15 deg/s El: 5 deg/s	Az: 5 deg/s El: 5 deg/s	0.5 deg/s	5.0 deg/s	Az: 5 deg/s El: 5 deg/s	Az: 3 deg/s El: 3 deg/s	Az: 15 deg/s El: 5 deg/s	X/Y: 4 deg/s	Az: 21.0 deg/s El: 7.0 deg/s	Az: 15 deg/s El: 10 deg/s
12	Azimuth Range [deg]	0 - 540	0 to 720	+/- 400	0 to 720	0 to 720	0 to 480	0 to 720	0 to 720	0-360	0 to 360	No limitations due to X/Y mount	0 to 720	0 to 720	X/Y Mount	+/- 420	+/- 540
12	Elevation Range [deg]	0 to 90	-1 to 181	-3 to 182	-1 to 181	-1 to 181	0 to 90	-1 to 181	-1 to 181	0-90	3.35 to 176	0 to 90	0 to 90	-1 to 181	X/Y Mount	- 4 to 90	-5 to +183
14	Search / Acquisition Aid	NO	Search	Datron search	Search / Acq aid (X)	Search / Acq aid (X)	Perth Steering	Search / Acq aid (X)	Search	Search	NO	NO	Search	Search / Acq aid (X)	3 STDM sets	NO	Search
15	Tilt Facility	NO	EAST / WEST	EAST / WEST	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	Rotating Tilt Axis
16	Tracking Mode	Program	Auto (S) / Program	Auto (S X) / Program	Auto (S X) / Program	Auto (S X) / Program	Program / Slave	Auto (S X) / Program	Auto (S) / Program	Auto (Ka) / Program	Program	Auto (S) / Program	Auto (S) / Program	Auto (S) / Program	Auto (S) / Program / Slave	Auto (L S X) / Program	Auto / Program
17	Angular Data Accuracy (autotrack+pointing error)	N/A	80 mdeg	100 mdeg	80 mdeg	80 mdeg	N/A	80 mdeg	80 mdeg	tbc	N/A	150 mdeg	80 mdeg	80 mdeg	tbc	200 mdeg	80 mdeg
18	FUNCTIONALITIES																
19	TM/TC Standards	PCM, CCSDS	PCM, CCSDS	PCM, CCSDS	PCM, CCSDS	PCM, CCSDS	PCM, CCSDS	PCM, CCSDS	PCM, CCSDS	PCM, CCSDS	PCM, CCSDS	PCM/FSK	PCM, CCSDS	PCM, CCSDS	PCM, CCSDS	PCM, CCSDS	PCM, CCSDS
20	TM/TC Redundancy	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES
21	Comms Redundancy	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	NO	NO
22	Ranging	IFMS compliant	IFMS & CORTEX compliant	IFMS & CORTEX compliant	IFMS compliant	IFMS & CORTEX compliant	IFMS compliant	IFMS & CORTEX compliant	IFMS compliant	ENERTEC Compliant	NO	N/A	IFMS compliant	IFMS compliant	YES	IFMS compliant	CORTEX compliant
23	Doppler	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	N/A	YES	YES	YES	YES	YES
24	Meteo	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	N/A	YES	YES	NO	NO	YES
25	Autotrack Antenna Angles	NO	YES	YES	YES	YES	NO	YES	YES	YES	NO	N/A	YES	YES	YES	YES	YES
26	Delta-DOR	YES	NO	NO	NO	NO	YES	NO	NO	NO	NO	N/A	NO	NO	NO	NO	NO
27	Radio-Science	YES	NO	NO	NO	NO	YES	NO	NO	NO	NO	N/A	NO	NO	NO	NO	NO
28	Frequency & Timing	MASER	CESIUM	CESIUM	MASER	CESIUM	MASER	CESIUM / RUBIDIUM	CESIUM	Tbc	Oven heated crystal oscillator and GPS	Crystal	CESIUM	CESIUM	Tbc	Crystal	Tbc
29	UPLINK																
30	S-band TX band [MHz]	N/A	2025-2120	2025-2120	2025-2120	2025-2120	2025-2120	2025-2120	2025-2120	N/A	2025-2110	N/A	2025-2120	2025-2120	2025-2120	2025-2120	2025-2120
31	S-band Polarization	N/A	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	N/A	RHC	N/A	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC
32	S-band EIRP [dBm]	N/A	101	99	111.2 (SHPA) 104.7 (SLPA)	102.1 (SLPA)	127 (SHPA) 117 (SLPA)	102 (S-SSA) 108 (SHPA)	102.5 (S-SSA)	N/A	42	N/A	102.9 (S-SSA)	101 (S-SSA) 109 (S-HPA)	115 (9 meter) 90 (7 meter)	98.7 minimum.	98
33	X-band TX band [MHz]	7145 - 7235	N/A	N/A	7145-7235	7145-7235	7145 - 7235	7145-7235	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
34	X-band Polarization	RHC, LHC	N/A	N/A	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	X-band EIRP [dBm]	138 (XHPA), 128 (XLPA), 122 (XSSA)	N/A	N/A	112.8	112.8	137 (XHPA) 127 (XLPA)	112.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	Ka-band TX band (MHz)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Ka-band 28500-30000	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37	Ka-band Polarization	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Y	N/A	N/A	N/A	N/A	N/A	N/A	N/A
38	Ka-band EIRP [dBm]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	84.5 dBW	N/A	N/A	N/A	N/A	N/A	N/A	N/A
39	Modulation Schemes	IFMS compliant	IFMS & CORTEX compliant	IFMS & CORTEX compliant	IFMS compliant	IFMS & CORTEX compliant	IFMS compliant	IFMS & CORTEX compliant	IFMS compliant	ENERTEC compliant	ENERTEC compliant	N/A	IFMS compliant	IFMS compliant	CORTEX compliant	CORTEX compliant	CORTEX compliant
40	Subcarrier Freq. [kHz]	8 or 16 kHz	8 or 16 kHz	8 or 16 kHz	8 or 16 kHz	8 or 16 kHz	8 or 16 kHz	8 or 16 kHz	8 or 16 kHz	N/A	PSK=50kHz FSK=100kHz	N/A	8 or 16 kHz	8 or 16 kHz	8 or 16 kHz	8 or 16 kHz	100 Hz to 100 kHz
41	DOWNLINK																
42	L-band RX band [MHz]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1690 - 1710	N/A	N/A
43	L-band Polarization	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RHC	N/A	N/A
44	L-band G/T [dB/K]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	17.25 (7 meter)	N/A	N/A
45	S-band RX band (MHz)	N/A	2200-2300	2200-2300	2200-2300	2200-2300	2200-2300	2200-2300	2200-2300	N/A	2200-2300	2200-2300	2200-2300	2200-2300	2200 - 2300	2200-2300	2200-2300
46	S-band Polarization	N/A	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	N/A	RHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC
47	S-band G/T [dB/K]	N/A	27.7 (at 5 deg El.)	21.4 (at 5 deg El.)	29.1	29.2	37.5	27.5	29.6	N/A	8.6	16.0	28.9	28.23	27.1 (12 meter) 21.8 (9 meter)	21.3 (5 deg El)	23
48	X-band RX band [MHz]	8400 - 8500	8025-8500	7600-8500	8025-8500	8025-8500	8400 - 8500	8025-8500	N/A	N/A	N/A	8025-8400	N/A	N/A	N/A	8025-8500	7500-8500
49	X-band Polarization	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	RHC, LHC	N/A	N/A	N/A	RHC, LHC	N/A	N/A	N/A	RHC	RHC, LHC
50	X-band G/T [dB/K]	50.8 (at 10 deg El.)	36.9 (at 5 deg El.)	35.6. (at 5 deg El.)	41	37.5	50.1	37.5	N/A	N/A	N/A	30 (spec)	N/A	N/A	40.0 (12 meter)	31.8	32
51	Ka-band RX band [MHz]	31800 - 32300	N/A	N/A	N/A	N/A	N/A	N/A	N/A	18100 - 20200	N/A	N/A	N/A	N/A	N/A	N/A	N/A
52	Ka-band Polarization	RHC, LHC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Y	N/A	N/A	N/A	N/A	N/A	N/A	N/A
53	Ka-band G/T [dB/K]	55.8 (at 10 deg El.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
54	Modulation Schemes	IFMS compliant	IFMS & CORTEX compliant	IFMS & CORTEX compliant	IFMS compliant	IFMS & CORTEX compliant	IFMS compliant	IFMS & CORTEX compliant	IFMS compliant	ENERTEC compliant	ENERTEC compliant	PCM/FM, BPSK	IFMS compliant	IFMS compliant	tbc	CORTEX compliant	CORTEX compliant
55	Carrier Freq Search Range	+/- 1.5 MHz	+/- 1.5 MHz	+/- 1.5 MHz	+/- 1.5 MHz	+/- 1.5 MHz	+/- 1.5 MHz	+/- 1.5 MHz	+/- 1.5 MHz	tbc	+/- 300 KHz	+/- 0.5 MHz	+/- 1.5 MHz	+/- 1.5 MHz	tbc	+/- 0.5 MHz	+/- 0.5 MHz
56	Subcarrier Frequency	2 kHz to 1.2 MHz	1.2 kHz to 2 MHz	1.2 kHz to 2 MHz	2 kHz to 1.2 MHz	1.2 kHz to 2 MHz	2 kHz to 1.2 MHz	1.2 kHz to 2 MHz	2 kHz to 1.2 MHz	1.2 kHz to 1.5 MHz	PSK up to 1MHz	N/A	2 kHz to 1.2 MHz	2 kHz to 1.2 MHz	1 kHz to 2 MHz	1.2 kHz to 2 MHz	Up to 1.2 MHz
57	Data Rates	IFMS compliant: - 1.2 Mbps (RCD) - 8 Mbps (SCD HS)	IFMS compliant: - 1.2 Mbps (RCD) - 8 Mbps (SCD HS) Cortex compliant: - 256 Kbps (subcarrier) - 40 Mbps (Direct PCM) X-band: Up to 100 Mbps	IFMS compliant: - 1.2 Mbps (RCD) - 8 Mbps (SCD HS) Cortex compliant: - 256 Kbps (subcarrier) - 40 Mbps (Direct PCM) X-band: Up to 100 Mbps	IFMS compliant: - 1.2 Mbps (RCD) - 2 Mbps (SCD LS)	IFMS compliant: - 1.2 Mbps (RCD) - 2 Mbps (SCD LS) Cortex compliant: 256 Kbps (subcarrier) 40 Mbps (Direct PCM)	IFMS compliant: - 1.2 Mbps (RCD) - 2 Mbps (SCD LS)	IFMS compliant: - 1.2 Mbps (RCD) - 2 Mbps (SCD LS)	IFMS compliant: - 1.2 Mbps (RCD) - 2 Mbps (SCD LS)	up to 200 Mbps	Enertec compliant: 250 Kbps (subcarrier) 1 Mbps (Direct PCM)	Ariane-5 compliant: 1Mbps, 500kbps, 250kbps, 125kbps, 62,5kbps, 31,25kbps,	IFMS compliant: - 1.2 Mbps (RCD) - 8 Mbps (SCD HS)	IFMS compliant: - 1.2 Mbps (RCD) - 8 Mbps (SCD HS)	Up to 2 Mbps	Cortex compliant: 256 Kbps (subcarrier) 40 Mbps (Direct PCM)	S- Band Cortex: 256 Kbps (subcarrier) 10 Mbps (Direct PCM) X-band up to 300Mbps
58	Data Coding Scheme	R-S, Convolutional and Concatenated	R-S, Convolutional and Concatenated	R-S, Convolutional and Concatenated	R-S, Convolutional and Concatenated	R-S, Convolutional and Concatenated	R-S, Convolutional and Concatenated	R-S, Convolutional and Concatenated	R-S, Convolutional and Concatenated	tbc	R-S, Convolutional and Concatenated	R-S and Convolutional	R-S, Convolutional and Concatenated	R-S, Convolutional and Concatenated	R-S, Convolutional and Concatenated	R-S, Convolutional and Concatenated	R-S, Convolutional and Concatenated
59	INTERFACES																
60	TM/TC Connectivity	TCP/IP SLE (TMTCS)	TCP/IP SLE (CORTEX) EIPD (TMP/TCE)	TCP/IP SLE (CORTEX) EIPD (TMP/TCE)	TCP/IP SLE (TMTCS)	TCP/IP / X25 SLE (CORTEX) EIPD (TMP/TCE)	TCP/IP SLE (TMTCS)	TCP/IP SLE (TMTCS)	TCP/IP SLE (TMTCS)	TCP/IP	TCP/IP	HDLC	TCP/IP SLE (TMTCS)	TCP/IP SLE (TMTCS)	TCP/IP SLE (CORTEX) EIPD (TMP/TCE)	TCP/IP SLE (CORTEX)	TCP/IP SLE (CORTEX)
61	Rng/Dop Connectivity	FTP (IFMS)	FTP (IFMS / CORTEX)	FTP (IFMS / CORTEX)	FTP (IFMS)	FTP (IFMS / CORTEX)	FTP (IFMS)	FTP (IFMS / CORTEX)	FTP (IFMS)	TCP-IP	N/A	N/A	FTP (IFMS)	FTP (IFMS)	SDID/X25 via RG Protocol Conv.	IP via CSMC	TCP-IP / FTP UTDF
62	Meteo Connectivity	FTP (IFMS)	FTP (IFMS)	FTP (IFMS)	FTP (IFMS)	FTP (IFMS)	FTP (IFMS)	FTP (IFMS)	FTP (IFMS)	TCP-IP	N/A	N/A	FTP (IFMS)	FTP (IFMS)	N/A	NA	TCP-IP / FTP UTDF
63	Angles Connectivity	N/A	IP Via CSMC	IP Via CSMC	IP via STC	IP via STC	N/A	IP via STC	IP via STC	TCP-IP	N/A	N/A	IP via STC	IP via STC	N/A	IP via CSMC	TCP-IP / FTP UTDF
64	Pointing Format	STDM	STDM	STDM	STDM	STDM	STDM	STDM	STDM	STDM	TLE	DO, TLE	STDM	STDM	STDM	STDM	TLE
65	Tracking Interface (ESOC)	FDS	FDS	FDS	FDS	FDS	FDS	FDS	FDS	NO	NO	NO	FDS	FDS	EPOS	FDS	EPOS

Notes: IFMS Modulation Scheme & Data rate:
RCD: PCM/PSK/PM using NRZ-L, NRZ-M, Date Rates: 10 sps to 1.2 Msps, PCM/PSK/PM using SP-L, Date Rates: 10sps to 600ksps
SCD: BPSK -Data Rates: up to 8.192 Msps (High Speed), 2.048 Msps (Light Speed), QPSK& OQPSK- Data Rates: up to 16.384 Msps (High Speed), 4.096 Msps (Light Speed) UQPSK-Data Rates: up to 4.096 Msps (High & Light Speed)
ULM (PM on subcarrier or carrier, BPSK, QPSK, OQPSK, UQPSK, GMSK), TC Modulation (On sinusoidal subcarrier: PCM/PSK/PM)

IFMS Ranging with ESA code
Tone up to 1.5 MHz

CORTEX Modulation Scheme & Data rate:
IFR with Subcarrier: PCM/BPSK/PM or FM, PCM/PM/PM or FM using NRZ-L/M/S, BP-L/M/S, DBP-M/S, or R-NRZ: Data rate: up to 256 kbps
IFR Direct Carrier: BPSK, QPSK, D-QPSK, OQPSK, D-OKPSK, AQPSK using NRZ-L/M/S, SP-L/M/S, DBP-M/S, or R-NRZ: Data rate: 10-40 Mbps
IFM: PM or FM on subcarrier or carrier, BPSK, QPSK, OQPSK, AQPSK. TC Modulation (on sinusoidal subcarrier: PCM/PSK/PM)

Cortex Ranging with ESA code
Tone up to 500 kHz

ENERTEC Modulation Scheme:
Uplink & Downlink: PCM/PSK/PM, BPSK, QPSK, Spread Spectrum and PM/FM (ENERTEC 3801-20)

Enertec Ranging with ESA tone
Tone up to 200 kHz

Table 1: ESTRACK Performance Characteristics

5.7 Operations Concept

The Resource Allocation (which mission uses which antenna at which time) control is centralized at the ESOC Scheduling Office.
All antennas are permanently operated remotely from the ESOC Ground Facilities Control Centre (GFCC) on a 24 hours, 7 days a week basis. A more detailed description of the GFCC can be found in the OCC Facilities Manual [OFM].
The station Maintenance and Operations (M&O) staff, operate the antennas locally during critical LEOP and Planetary Insertion activities.

5.8 Maintenance and Integration Concept

The station M&O teams perform regular preventive and corrective maintenance. The manufacturer performs regular inspections of major antenna subsystems, e.g. mechanics and RF, typically once per year, regular Performance Retests once every 3 years.
Overall configuration control of the ESTRACK Installations is handled through the ESTRACK Configuration Control Board (ECCB). Upgrade integrations are performed according to an ESOC internal Ground Station Subsystem Integration Standard (GSSIS). All maintenance activities and upgrades are centrally coordinated from ESOC, site visits require a confirmed Station Intervention form sheet.

5.9 Station Preparation and Configuration Concept

Station Preparation and Configuration starts after the definition of station and facilities implementation requirements.
Where the terminals are not readily compatible with the mission requirements, upgrades are performed. These upgrades are handled like small projects with their own project life cycle (requirement definition, development, implementation, validation).
Based on the Space to Ground Interface Control Document (ICD) of a spacecraft a Radio Frequency Compatibility Test (RFCT) is derived. It is typically conducted in the ESOC Reference Station with a representative electrical model of the satellite RF subsystem. The adherence to applicable Spacelink standards and the compatibility between the satellite and ESTRACK is established on a “type approval” basis.
The individual station configurations are derived from the RFCT results. Shortly before launch a terminal System Performance Test (SPT) is conducted to verify the performance assumed in spacelink budget calculations for the particular frequency band the spacecraft is to be operated. In parallel the operations personnel are trained during Mission Readiness Tests (MRTs).

5.10 Interfacing to cooperating Control Centres

The interface for Telemetry and Telecommand to cooperating Control Centres is based on the Spacelink Extension Service [SLE-RAF, SLE-RCF, SLE-OCF, SLE-CLTU, SLE-FSP], for Orbit Determination and Orbit data on Orbit Data Messages [ODM]. These elements are typically

provided by the ESOC Flight Dynamics service. The communication interface for access to all ESTRACK stations is via OPSNET typically at ESOC.
Customized interface options can be arranged. Legacy interfaces are available.

5.11 Interfacing to cooperating Stations

The interface to cooperating stations in the ESTRACK Augmented Network is also based on SLE for Telemetry and Telecommand and on [CCSDS-ODM] for flight dynamics data.
Customized interface options can be arranged. Legacy interfaces are available.

5.12 Communications

All data and voice communication services used for spacecraft operations are rendered by the ESA Operational Network (OPSNET). It is comprised of a Wide Area Network (WAN) of international private leased circuits (IPLCs) and international subscriber digital network (ISDN) on-demand circuits; and Local Area Networks (LAN) in the stations and the operations control center.
Administrative data communication, e.g. email and database access, is provided by the ESA Administrative Network (ESACOM) or via Internet service providers.
Administrative telephone and fax service uses commercially available services.

5.13 Quality Assurance

All services are handled in line with the directorate’s ISO-9001 based Quality Management System.

5.14 GPS Tracking and Data Analysis Facility

A Global Positioning System (GPS) Tracking and Data Analysis Facility (GPS-TDAF) is currently in operation. It comprises a control centre located at the ESOC Navigation Facility and nine worldwide distributed remote stations. The GPS-TDAF is designed to achieve high accuracy orbit and clock determination for Global Navigation Satellite Systems (GNSS) and user satellites and to perform error analysis for spacecraft missions. Since July 1992 the system has contributed to the official combined products of the International GPS Service, now International GNSS Service (IGS). Products and receiver data are made available via file transfer protocol (ftp) and real time streams. A block diagram of the system is given in

Figure 2. The Navigation Facility in the ESOC Control Centre provides an operational environment for the data handling and processing. Several projects such as the Ground Support Network for the Metop GPS Receiver for Atmospheric Sounding (GRAS GSN) or real time GPS products are developed and supported by the Navigation Facility. The hardware is based on a Sun Solaris network and each of the remote stations includes a GPS receiver with geodetic quality and a PC which provides communications support and remote operation capabilities. Communications for remote operations and data retrieval is via Internet or ESA dedicated lines. The remote stations are located at the Cebreros, Kiruna, Kourou, Malindi, Maspalomas, New Norcia, Perth, Redu and Villafranca ESTRACK ground stations and at the Meteo France site in Tahiti. Equipment

redundancy is provided at the stations. Each remote receiver tracking at 1 Hz produces a 3 kbps stream that is transferred to ESOC in real time. The data is checked, reformatted, stored and forwarded to external sites at Goddard Space Flight Center, Washington (CCDIS) and IGN Paris among others. More information is available from http://nng.esoc.esa.de.
Picture to be updated accordingly reflecting SMA ?

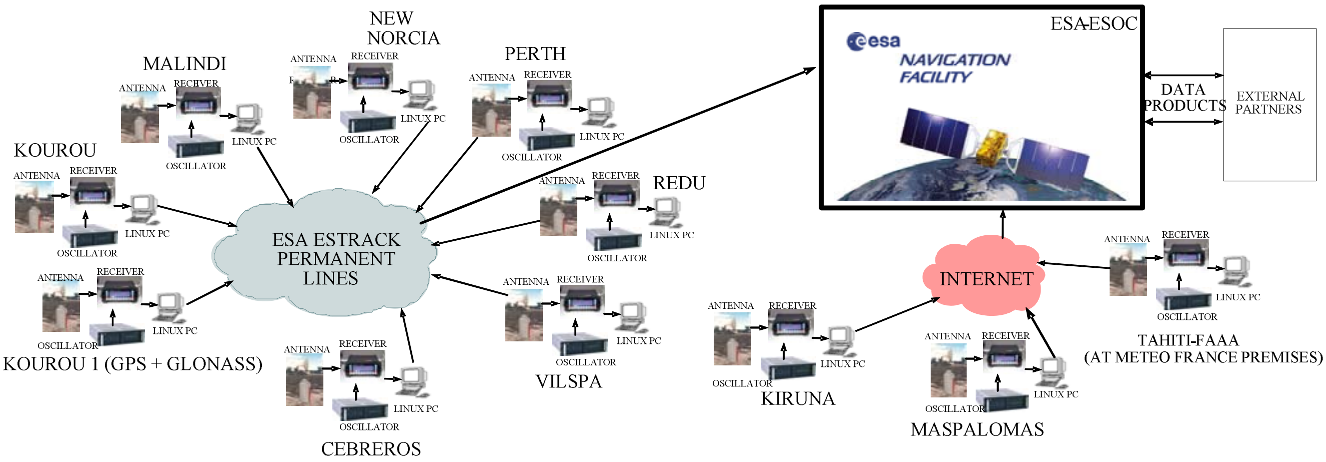

Figure 2: GPS Tracking and Data Analysis Facility (GPS-TDAF)

5.15 *Galileo Experimental Sensor Stations*

The Galileo System Test Bed V2 (GSTB-V2) is a prototype of the future Galileo navigation system including a complete space and ground system. The space segment consists of two satellites called Giove-A and Giove-B built by different manufacturers. The ground segment consists of tracking stations and two Ground Satellite Centres (GSC) and a common Ground Mission Segment. The navigation signal-in-space produced by the satellites is received by 13 Galileo Experimental Sensor Station (GESS) and used for mission validation purposes.
Some of these Galileo Experimental Sensor Stations are deployed on the ESTRACK sites at Kiruna, Kourou, New Norcia and Malindi.
The GESS stations are comprised of an experimental antenna and Galileo Receiver, a PC for data collection with monitoring and control, a Rubidium atomic clock as reference frequency, and a communication system. The Galileo Receiver includes a GPS receiver and a bi-standard Galileo/GPS receiver.
The collected data is transmitted to the ESOC Navigation Facility, from where it is further distributed into the GSTB-V2 Ground Mission Segment.

5.16 Contact

For all ESTRACK Service requests please contact:

Directorate of Operations and Infrastructure (D/OPS)
Mission Operations Department (OPS-O)
Head of Ground Facilities Operations Division (H/OPS-ON)
Robert-Bosch-Str. 5
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Tel +49-6151-90-0
Fax +49-6151-90-3190

6 ESTRACK CORE NETWORK STATIONS

6.1 Cebreros (CEB) Station

Figure 3 shows the Cebreros Aerial View.

Figure 3: Cebreros Aerial View

6.1.1 GENERAL INFORMATION

The Cebreros site is made available to ESA, based on an international agreement between ESA and the Government of Spain.

6.1.1.1 Location

The Cebreros site is located near the village of Cebreros, province of Avila, Spain, about 85 km west of Madrid, on km 8 on the road AV-562, see Figure 4.

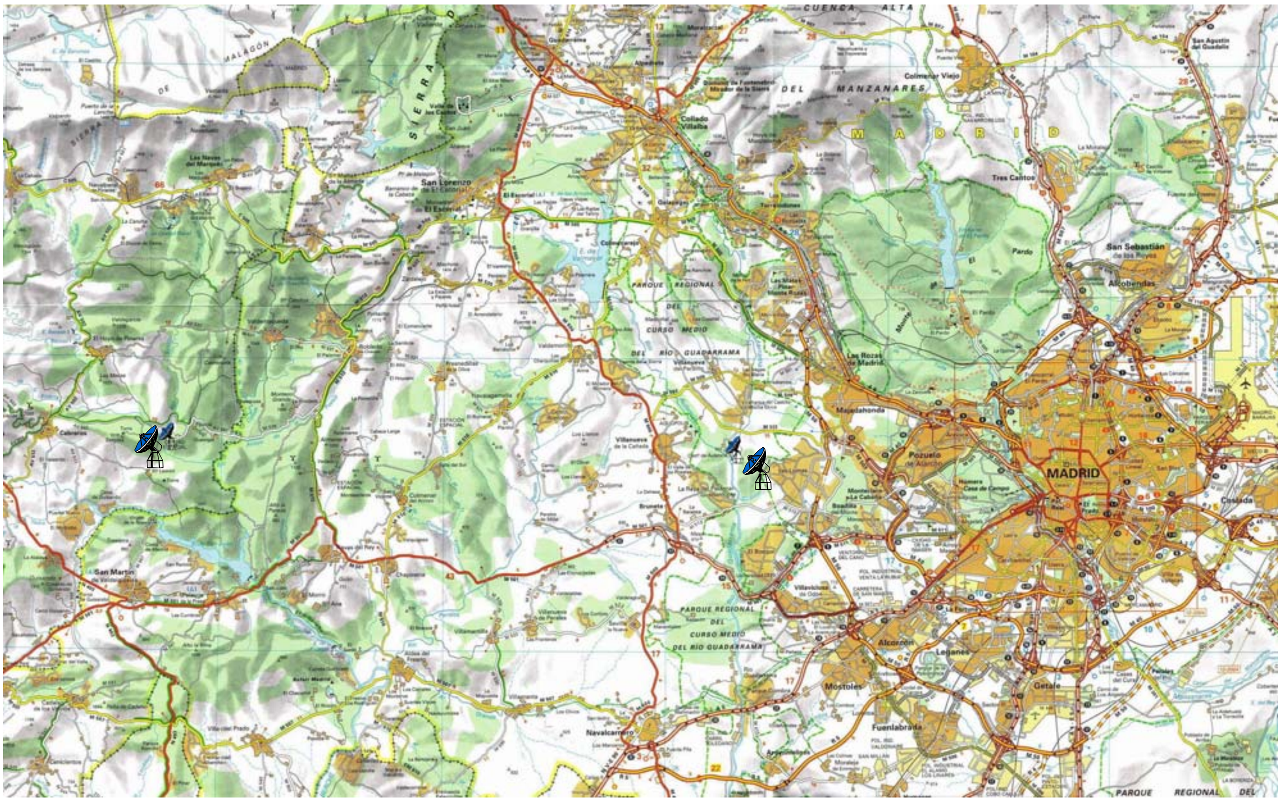

Figure 4: Cebreros Area Map

The site was formerly the “Cebreros” Deep Space Station 62 of the National Aeronautics and Space Administration (NASA).

6.1.1.2 Access

Site visits require a confirmed Station Intervention form sheet.
The Cebreros site is accessible only by road, it is not served by public transport.
Following the northern road, Cebreros station is approximately 93 Km from Barajas Airport.
At the Airport exit, take the A10 in the direction “M40 Norte, A1 Burgos, A6” for approximately 7 Km. Exit at junction 3 direction “M40 Zaragoza, R2” to join the M40 motorway ring. Continue on the ring for 18 km in direction of A6. Exit the M40 at Junction 46 (Km 48) and Join the A6 in the direction of “A Loruña”. Continue the A6 for approximately 7 Km until junction 18 to join the M505 in direction of Las Rozas, El Escorial. Continue the M505 motorway heading west in direction of El Escorial during 27 Km. Arriving in the first round-about, take on the left the M600 heading south in direction of “Valdemorillo / Avila” to avoid El Escorial. After 600 m in the second roundabout, turn on the right to join again the M505 in direction of Avila. Continue the M505 for a approximately 8 Km until you reach the “Puerto de la Cruz Verde” and continue straight to take the M512 in direction of “Robledo de Chavala”. Follow the M512 for 10 Km to pass Robledo and continue for 3,5 Km until the intersection with the M539 (Cebreros). At the intersection, turn right on the M539 in direction of Cebreros. After 6 Km you enter in the province

of Avila and the M539 change to AV562. Continue for 4 Km until the ESA sign is shown (Km 10). Turn left to follow the sign and continue for 1,1 Km to the Station entrance.
Accommodation can be arranged through the station manager.

6.1.1.3 Entry Requirements

The entry requirements to Spain are as for the European Union. Spain is in addition part of the EU "Schengen" Agreement.

6.1.1.4 Climate

Outside temperature may differ from –10° C in winter to + 40° C in summer.
A summary of the weather characteristics for Cebreros area is given below:

Warmest month:	July/August
Average daily maximum temperature for July/August:	34 °C
Maximum recorded temperature in July/August:	37 °C
Lowest recorded temperature in July/August:	19 °C
Coldest month:	February
Average daily minimum temperature for February:	-5.5 °C
Maximum recorded temperature in February:	tbd °C
Minimum recorded temperature in February:	-7 °C
Average annual rainfall:	476 mm

6.1.1.5 Management

The ESA on-site representative is the Cebreros TT&C and Site Manager.
The Maintenance and Operations (M&O) of the site is provided by Ingenieria y Servicios Aerospaciales S.A (INSA).

6.1.1.6 Local Contact

The local ESA contact point for Cebreros is:

ESA Cebreros TT&C and Site Manager
Mr Lionel Hernandez
email: Lionel.Hernandez@esa.int
Tel +34-91 89638-45
Fax +34-91 89638-13

The Postal address of the station (mail, letters) is:

European Space Agency (ESA)/Agencia Europea del Espacio
Cebreros Satellite Tracking Station
P.O. Box - Apartado 32 A
E- 05260 Cebreros (Avíla)
Spain

The Delivery address of the station is:

European Space Agency (ESA)/Agencia Europea del Espacio
Cebreros Satellite Tracking Station
Road/Carretera AV-562 , Km 10
E-05260 CEBREROS (Avila)
Spain

6.1.1.7 Logistics

Address for packages transported via airfreight

European Space Agency (ESA)/Agencia Europea del Espacio
Cebreros Satellite Tracking Station
c/o Agente de Aduanas / Customs Agent VALTAIR S.L
Terminal de Carga - Oficina 161
Madrid-Barajas Airport
E-28043 Madrid,
Spain

Custom Clearance Agent:

VALTAIR S.L.
Customs Agent Code Núm. 23.820
Postal Address:
Alcarria, 5-7 Oficina 6,
E-28820 Coslada, Madrid, España
Tel.: +34.91.669.03.02
Fax: +34.91.669.66.01
Person of Contact:
Mr. Julio Puerro / Mrs. Conchita Franco

6.1.2 STATION SERVICES

Figure 5 shows the site plan of Cebreros.

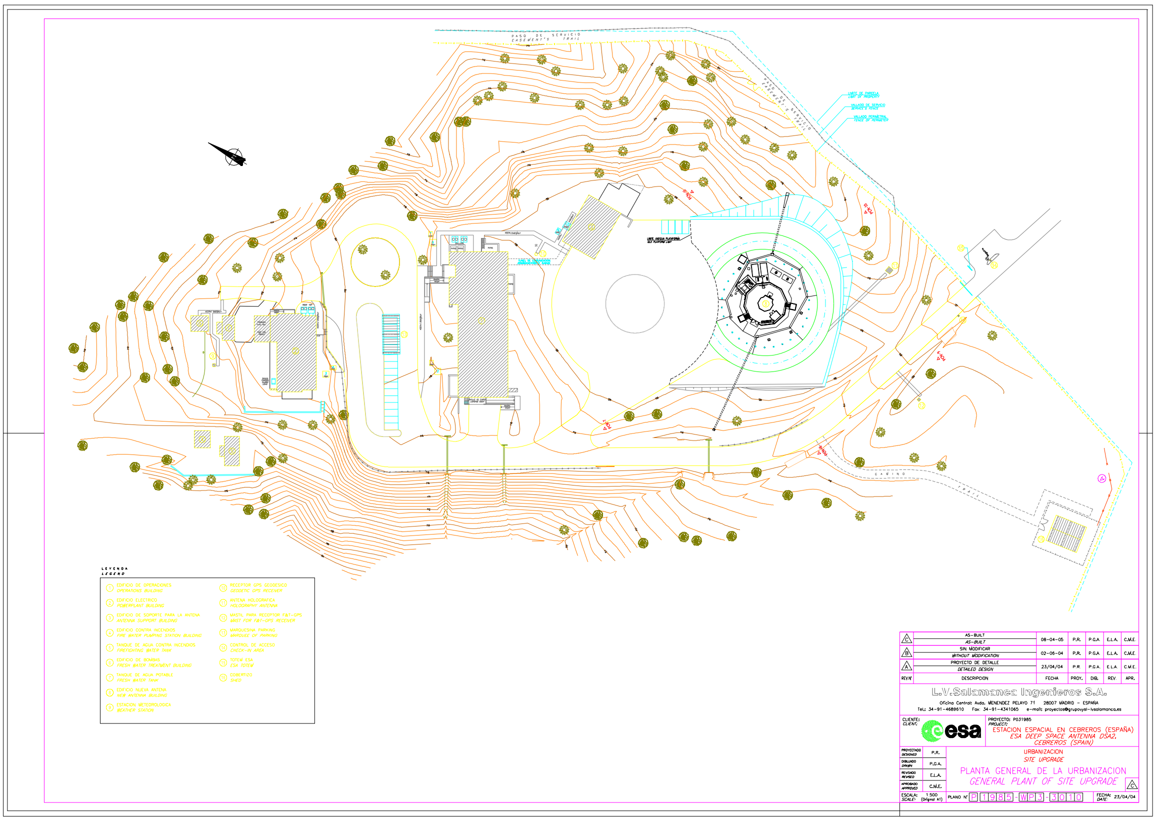

Figure 5: Cebreros Site Plan

6.1.2.1 *Security*

The site is fenced and guarded 24/7. An access control and surveillance system is installed.

6.1.2.2 *Power*

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, and a no-break dirty (NB-dirty) and a no-break clean (NB-clean) power supply using Static Converters and Batteries. Via low voltage switches the electricity (3x 400V, 50 Hz) is distributed to the consumer groups.
Public power into the power plant is rendered by two diversely routed 15 kV medium voltage line and two transformers of 1000 kVA.
Two Diesel Generators supply each 500 kVA within 15 seconds after public power failure. Two Static Converters supply each 80 kVA. The Battery capacity allows for a maximum bridging time of 6 minutes.

6.1.2.3 Air Conditioning

The station air conditioning system supplies air to the main building equipment rooms at a temperature of 24° C + 10%, with a controlled humidity of 50% - 70% Relative Humidity.

6.1.2.4 Communications

The Cebreros station is connected via the ESA Operations Network (OPSNET) in a triangular setup (Cebreros, Villafranca, ESOC) using 2 Mbps international private leased circuits (IPLCs). The connectivity into the Cebreros site is diversely routed through a fibre optic link and a microwave link.
All non-operational and Internet traffic is routed via the ESA Administrative Network (ESACOM).

6.1.3 CEBREROS-1 (CEB-1) TERMINAL

Figure 6 shows shows the Cebreros-1 (CEB-1) antenna, which provides X-band transmit, as well as X- and Ka-band receive capability (X/XKa).

Figure 6: Cebreros-1 (CEB-1) Antenna

6.1.3.1 Services and Performance

The Cebreros-1 (CEB-1) terminal provides the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Meteo, Delta-DOR)
- Radio Science

Table 2 details the Cebreros-1 (CEB-1) Performance Characteristics. For the definition of individual characteristics see 5.6.

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	CEBREROS-1 (X / X Ka)	42	L-band RX band [MHz]	N/A
3	TERMINAL	CEB-1	43	L-band Polarization	N/A
4	Longitude	04 deg 22' 03.18" W	44	L-band G/T [dB/K]	N/A
5	Latitude	40 deg 27' 09.68" N	45	S-band RX band (MHz)	N/A
6	Altitude [m]	794.095	46	S-band Polarization	N/A
7	Antenna Diameter [m]	35	47	S-band G/T [dB/K]	N/A
8	S-band Beamwidth [deg]	N/A	48	X-band RX band [MHz]	8400 - 8500
9	X-band Beamwidth [deg]	Rx: 0.064 Tx: 0.074	49	X-band Polarization	RHC, LHC
10	Ka-band Beamwidth [deg]	Rx: 0.017	50	X-band G/T [dB/K]	50.8 (at 10 deg El.)
11	Antenna Speed [deg/s]	Az: 1.0 deg/s El: 1.0 deg/s	51	Ka-band RX band [MHz]	31800 - 32300
12	Azimuth Range [deg]	0 - 540	52	Ka-band Polarization	RHC, LHC
12	Elevation Range [deg]	0 to 90	53	Ka-band G/T [dB/K]	55.8 (at 10 deg El.)
14	Search / Acquisition Aid	NO	54	Modulation Schemes	IFMS compliant
15	Tilt Facility	NO	55	Carrier Freq Search Range	+/- 1.5 MHz
16	Tracking Mode	Program	56	Subcarrier Frequency	2 kHz to 1.2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	N/A	57	Data Rates	IFMS compliant: - 1.2 Mbps (RCD) - 8 Mbps (SCD HS)
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP SLE (TMTCS)
21	Comms Redundancy	YES	61	Rng/Dop Connectivity	FTP (IFMS)
22	Ranging	IFMS compliant	62	Meteo Connectivity	FTP (IFMS)
23	Doppler	YES	63	Angles Connectivity	N/A
24	Meteo	YES	64	Pointing Format	STDM
25	Autotrack Antenna Angles	NO	65	Tracking Interface (ESOC)	FDS
26	Delta-DOR	YES			
27	Radio-Science	YES			
28	Frequency & Timing	MASER			
29	UPLINK				
30	S-band TX band [MHz]	N/A			
31	S-band Polarization	N/A			
32	S-band EIRP [dBm]	N/A			
33	X-band TX band [MHz]	7145 - 7235			
34	X-band Polarization	RHC, LHC			
35	X-band EIRP [dBm]	138 (XHPA), 128 (XLPA), 122 (XSSA)			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	IFMS compliant			
40	Subcarrier Freq. [kHz]	8 or 16 kHz			

Table 2: Cebreros-1 (CEB-1) Performance Characteristics

6.1.3.2 Antenna Horizon

Figure 7 shows the Cebreros-1 (CEB-1) Antenna Horizon Mask.

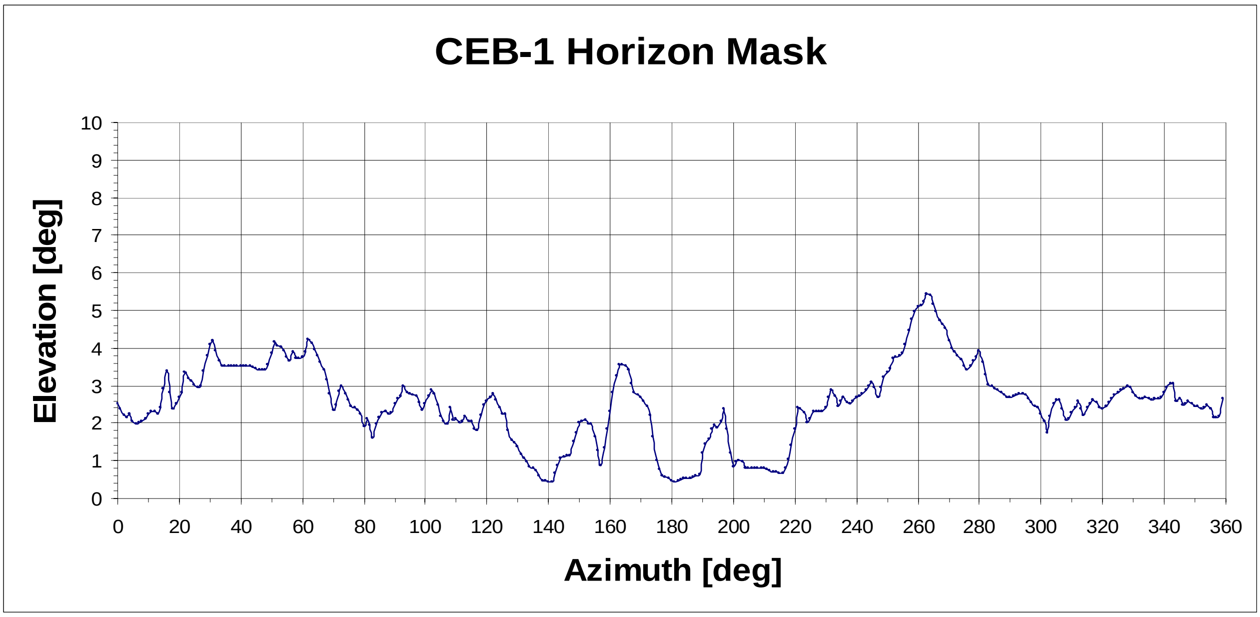

Figure 7: Cebreros-1 (CEB-1) Antenna Horizon Mask

6.1.3.3 Functional Description

Figure 8 shows the Cebreros-1 (CEB-1) Block Diagram, which is used for the functional description.

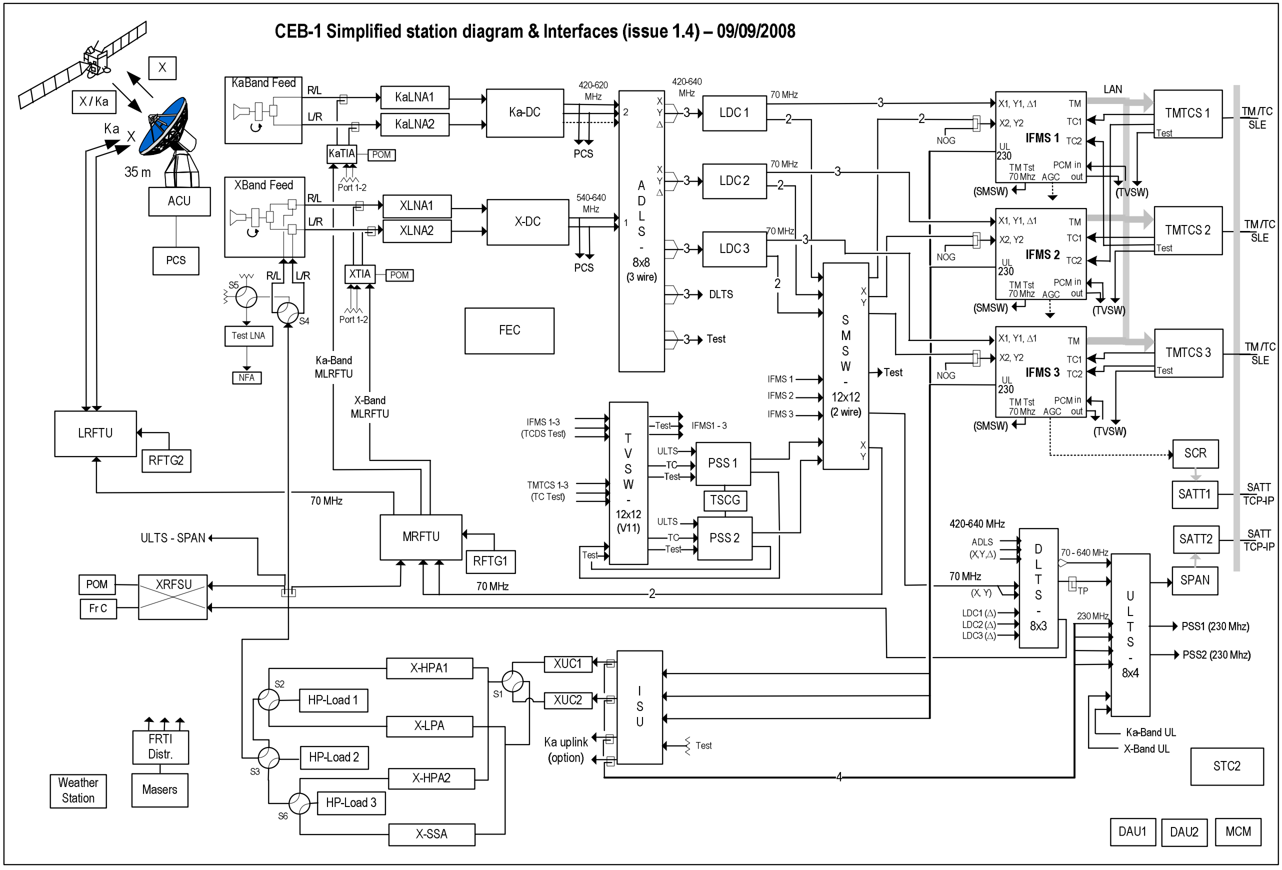

Figure 8: Cebreros-1 (CEB-1) Block Diagram

6.1.3.3.1 Antenna

The X-band transmit and X- and Ka-band receive (X/XKa) Cassegrain Beam Wave Guide antenna is fitted with a shaped 35m parabolic main reflector and a shaped hyperbolic subreflector in an elevation over azimuth mount. Auto-tracking of X- and Ka-band signals is not possible. An S- and X-band probe with reflective converter allows for signal delay calibration. An air-conditioning system outside the antenna tower provides cooling of the antenna tower.
The antenna pointing is performed by the Antenna Control Unit (ACU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation positions to the ACU.
The incoming electromagnetic wave is conveyed via the reflector, subreflector and beam waveguide system to a frequency sensitive dichroic mirror, that splits the X-Band and the Ka-Band

signals, to the respective feeds, which together with their polarizer matches the free space field electromagnetic configuration to the waveguide modes.

The coexisting X-band receive and transmit signals for each polarisation are separated by Diplexer filters. The receive waveguide branches (X-band and Ka-band receive) are fed to cryogenically cooled Low Noise Amplifiers (LNAs), which amplify the Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC) signals, which subsequently can be phase adjusted by Phase Shifters.

The X-band signals [8400-8500 MHz] are down-converted to L-band [620-420 MHz]. The Ka-band signals [31,800-32,300 MHz] are down-converted to L-band [640-540 MHz]. The downlink signals are then transferred for telemetry processing.

The uplink signal coming from telecommand processing at 230 MHz is delivered to X-band transmission. It is routed to the X-band Up-Converter (XUC) for conversion to [7145 - 7235 MHZ] and via a switch to the X-band High Power Amplifier (XHPA) or X-band Low Power Amplifier (XLPA).

A transmit waveguide assembly routes the RF signal to the X-band feed. The transmitted polarisation is selected with the polarization switch, which routes the RF signal to the uplink arm of one of the two Diplexers, one for each polarisation. To avoid radiating the RF power to the antenna, the RF signal can also be routed via a set of switches to one of the two high power dummy loads.

The X-Band Feed (including polarizer) matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from one of the two Diplexers. The Beam Wave Guide (BWG) system conveys the high power RF flux from the X-Band feed to the antenna sub-reflector and main reflector where it is forwarded to free space.

6.1.3.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions.

For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Spacecraft Trajectory Data Messages (STDM's) or State Vectors in the Front End Controller (FEC).

6.1.3.3.3 Telemetry

The downlink L-band signals are fed via the Antenna Downlink Switch (ADLS) into tuneable L-band down-converters for conversion to 70 MHz intermediate frequency (IF) and further signal routing through the 70 MHz switch (SMSW).

The 70 MHz signals are combined and demodulated in the Intermediate Frequency Modem System (IFMS), which provides remnant and suppressed carrier demodulation. Doppler predictions coming from Spacecraft Trajectory Data Messages (STDM) information improve the signal acquisition process. The Telemetry Channel Decoding System (TCDS) hosted inside the IFMS performs frame synchronisation, time tagging, Viterbi and Reed-Solomon decoding. The output data is transferred to the Telemetry and Telecommand System (TMTCS) for data structure processing according to Space Link Extension (SLE), which ultimately delivers the telemetry data via OPSNET to the Spacecraft Control Systems.

All three telemetry chains are redundant and the various switches allow flexible signal routing.

6.1.3.3.4 Telecommand

The Telemetry and Telecommand System (TMTCS) receives SLE conformant Telecommand data via OPSNET from the Spacecraft Control Systems. It provides telecommand data and clock to the Intermediate Frequency Modem System (IFMS) Uplink Modulator (ULM), which provides the Phase Shift Key (PSK) modulation of the telecommand bit stream onto a sub-carrier, which is then used to phase modulate the uplink carrier at 230 MHz. Via the Antenna Uplink Switch (AULS) the uplink signal is routed to the X- band antenna uplink.
The telecommand chains are redundant and the various switches allow flexible signal routing.

6.1.3.3.5 Radiometric

The radiometric measurements comprise Doppler, Ranging, Meteorological, Delta Differential One-way Range (Delta-DOR) and Radio Science measurements.
The station design is such that any of the three downlink chains can be used for Telemetry reception and for radiometric measurement including Delta-DOR and Radio Science Investigation (RSI).
The Intermediate Frequency Modem System (IFMS) Ranging and Telemetry Demodulators deliver integrated Doppler measurements of the received carrier phase, known as Doppler-1 and Doppler-2.
The IFMS Uplink Modulator generates the ranging tone, which is Phase-Shift-Key (PSK) modulated by a sequence of codes. This ranging tone is phase modulated on the uplink carrier and can be transmitted simultaneously with the telecommand subcarrier. The IFMS Ranging Demodulator pre-steers the expected downlink carrier in case of coherent transponding of the spacecraft based on Spacecraft Trajectory Data Messages (STDMs), demodulates the received tone and compares the received codes with codes replica to derive the two-way propagation delay.
The IFMS meteorological unit gathers outside air temperature, pressure, humidity, wind force and direction information.
All radiometric measurement data are delivered through OPSNET to Flight Dynamics for processing.
For (Delta-DOR) the IFMS records spectra for further processing in a correlator to derive the phase of the received satellite electromagnetic wave with respect to the same reception at a another location on earth. Angular calibration of the signal is achieved by measuring known radio sources, e.g. quasars, before and after the satellite measurement. Due to the amount of data collected, the DDOR samples are stored in the External Storage Units (ESU). Two redundant ESU are available, allowing DDOR to be performed from any two of the three redundant downlink chains.
For Radio Science Investigations the IFMS records spectra and doppler measurements of the received X- and Ka-band downlinks. In addition dual frequency ranging can be performed, i.e. one uplink X-band signal containing the ranging code is coherently transponded on-board to an X-band and Ka-band downlink signal, which are received simultaneously by two IFMS Ranging Demodulators, which both use the same codes replica. The frequency dependent downlink propagation delay can be measured in this way.
All Radio Science measurements are delivered through OPSNET to the Science Community for processing.

6.1.3.3.6 Monitoring and Control

The monitoring and control (M&C) system allows full local and remote control over the terminal. It is based on a hierarchy of M&C systems: the Station Computer (STC), the Front End Controller (FEC), the Monitoring and Control Module (MCM) and Local Man Machine Interfaces (MMI) on the various devices.

The Station Computer (STC) is composed of a local server, a local workstation and a remote workstation housed in the ESTRACK Control Centre (ECC). Mission specific terminal configurations are normally affected through pre-validated macro-procedures, also individual equipment configurations are possible. The STC interacts through a set of subsystem controllers, either in separate units or implemented in complex devices (e.g. IFMS/TMTCS), with all the terminal equipment. Remote spectrum visualisation is supported.

The Front End Controller (FEC) is the subsystem controller for all the antenna front end devices and responsible for antenna steering.

The Monitoring and Control Module (MCM) is the subsystem controller for all simple back end devices, e.g. switches.

In case of failure of the monitoring and control system, the terminal can be locally operated from the individual equipment Local Man Machine Interfaces.

6.1.3.3.7 Frequency and Timing

The frequency reference generation is based on a Hydrogen Maser with very high long term frequency stability. The frequency distribution system coherently derives 5, 10 and 100 MHz signals and amplifies them for distribution to the devices.

The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 5 MHz, 1 kHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

6.1.3.3.8 Test and Calibration

The objective of the test and calibration function is to validate the telemetry and telecommand functions, and to calibrate the Ranging and Doppler function before the operational satellite pass.

The telemetry function is tested with simulated spacecraft telemetry, which is generated in the Portable Satellite Simulator (PSS), frequency converted to the appropriate downlink frequency and injected into the antenna via a test antenna, so called Telemetry Test Long Loop (TTLL) configuration. The telemetry is then delivered in a Data Flow Test (DFT) to the spacecraft control system for verification.

The telecommand function is tested by demodulating and decoding of the 230 MHz uplink signal and comparing it to known telecommand formats. Based on the telecommand received in the PSS the simulated telemetry generation can be altered. The test telecommands originate from the spacecraft control system.

The ranging and doppler function is calibrated by conducting a ranging and doppler measurement in an antenna loopback configuration, in which the uplink frequency is transponded to the downlink frequency. The emulated transponding involves reception of the uplink frequency by the test antenna and conversion to the downlink frequency in the Reflective Converter (RFLC) with

subsequent transmission via the test antenna back into the main antenna. This calibration measures the station internal signal delay and any frequency offset.
For phase calibration of the tracking channels, a remote controllable calibration tower is available.
Test tools for integration and performance validation activities are not described.

6.1.4 ADDITIONAL FACILITIES

6.1.4.1 GPS-TDAF

A Global Positioning System (GPS) dual-frequency receiver system with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

6.1.5 PLANNED DEVELOPMENTS

It is planned to upgrade the CEB-1 terminal with Ka-band transmit and Ka-band autotrack capability for support of the Bepi-Colombo mission.

6.2 Kiruna (KIR) Station

Figure 9 shows the Kiruna Aerial View.

Figure 9: Kiruna Aerial View

6.2.1 GENERAL INFORMATION

The Kiruna site is made available to ESA, based on an international agreement between ESA and the Government of Sweden.

6.2.1.1 Location

The Kiruna site is located in the northern part of Sweden at Salmijaervi, 38 kilometres east of Kiruna in northern Sweden, see Figure 10.

Figure 10: Kiruna Area Map

6.2.1.2 Access

Site visits require a confirmed Station Intervention form sheet.
The ESA satellite tracking station can be reached from Kiruna town after about 35 km. Drive from Kiruna town to Jukkasjärvi, then direction ESRANGE station.
Accommodation can be arranged through the station manager.

6.2.1.3 Entry Requirements

Entry requirements for citizens of the fifteen European Union countries (EU/EEA), as well as citizens of the Iceland, Norway, Switzerland and Liechtenstein only need a valid passport or ID card clearly stating their nationality to enter Sweden.

6.2.1.4 Climate

A summary of the weather characteristics for the Kiruna area is given below:

Warmest month:	July
Average daily max. temperature for July:	18.2 °C
Max. recorded temperature in July:	31.3 °C
Lowest recorded temperature in July:	0.4 °C
Coldest month:	February

Max. recorded temperature in February:	6.4 °C
Min. recorded temperature in February:	-41.6 °C
Average annual rainfall:	513 mm

6.2.1.5 Management

The ESA on-site representative is the Kiruna Station Manager.
The Maintenance and Operations (M&O) of the site is provided by Swedish Space Corporation (SSC).

6.2.1.6 Local Contact

The local point of contact for the Kiruna station is:

ESA Kiruna Station Manager
Mr Anders Pääjärvi
e-mail: anders.paajarvi@esa.int.
Tel +46-980-76000
Fax +46-980-17121

6.2.1.7 Logistics

The postal address of the station is:

ESA Satellite Station
P.O. Box 815
SE-98128 Kiruna
Sweden

For courier mail delivery and shipment by road:

ESA Satellite Station
(Box 815)
Esrangevägen (Jukkasjaervi)
SE-98128 Kiruna
Sweden

For air cargo:

ESA Satellite Station
Kiruna, Sweden
c/o SAS Cargo
Kiruna airport, Sweden
Tel +46-980-284860
Fax +46-980-284869

For any shipments please contact:

Mrs Astrid Taavo
Tel +46-980-76000
Fax +46 980-17121
email astrid.taavo@esrange.ssc.se

6.2.2 STATION SERVICES

Figure 11 shows the Kiruna Site Plan.

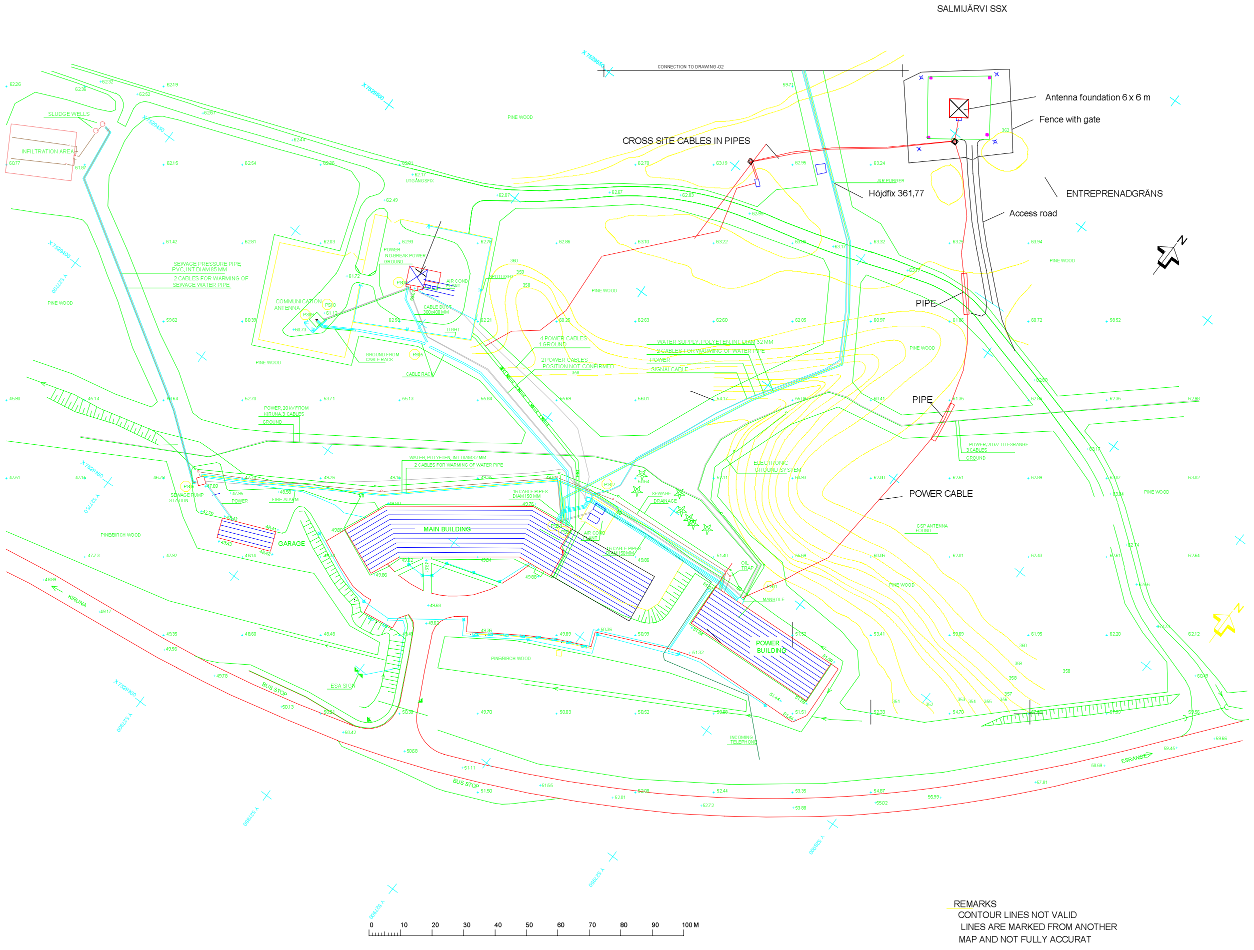

Figure 11: Kiruna Site Plan

6.2.2.1 Security

The site is partly fenced and guarded 24/7. An access control and surveillance system is installed.

6.2.2.2 Power

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, and a no-break (NB) power

supply using Static Converters and Batteries. Via low voltage switches the electricity (3x 400V, 50 Hz) is distributed to the consumer groups.
Public power into the power plant is rendered by one 20 kV medium voltage line and two transformers of 1000 kVA.
Three Diesel Generators supply each 400 kVA, within 15 seconds after public power failure. Four Static Converters supply each 80 kVA. The Battery capacity allows for a maximum bridging time of 6 minutes.

6.2.2.3 Air Conditioning

The station air conditioning system supplies air to the main building equipment rooms at a temperature of 20-22° C + 10%, with a controlled humidity of 50% - 70% relative humidity.

6.2.2.4 Communications

The Kiruna station is connected via the ESA Operations Network (OPSNET) to ESOC using two redundant 2 Mbps international private leased circuits (IPLCs). The connectivity into the Kiruna site is diversely routed through two fibre optic links.
For ERS-2 and ENVISAT payload data distribution a VSAT system is installed and access to the High Speed ESA Earth Observation Network (HiSCEEN) is provided.
All non-operational and Internet traffic is routed via the SSC Administrative Network.

6.2.3 KIRUNA-1 (KIR-1) AND KIRUNA-2 (KIR-2) TERMINALS

Figure 12 shows the Kiruna-1 (KIR-1) and Figure 13 shows the KIR-2 antenna, which both provide S-band transmit, and S- and X-band receive capability (S/SX).

Figure 12: Kiruna-1 (KIR-1) Antenna

Figure 13: Kiruna-2 (KIR-2) Antenna

6.2.3.1 *Services and Performance*

The Kiruna-1 (KIR-1) and Kiruna-2 (KIR-2) terminals provide the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Meteo, Autotrack Angles)

Table 3 details the Kiruna-1 (KIR-1) Performance Characteristics. For the definition of individual characteristics see 5.6.

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	KIRUNA-1 (S / S X)	42	L-band RX band [MHz]	N/A
3	TERMINAL	KIR-1	43	L-band Polarization	N/A
4	Longitude	20 deg 57' 51.57" E	44	L-band G/T [dB/K]	N/A
5	Latitude	67 deg 51' 25.66" N	45	S-band RX band (MHz)	2200-2300
6	Altitude [m]	402.1724	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	15	47	S-band G/T [dB/K]	27.7 (at 5 deg El.)
8	S-band Beamwidth [deg]	Rx: 0.60 Tx: 0.65	48	X-band RX band [MHz]	8025-8500
9	X-band Beamwidth [deg]	Rx: 0.16	49	X-band Polarization	RHC, LHC
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	36.9 (at 5 deg El.)
11	Antenna Speed [deg/s]	Az: 15.0 deg/s El: 5.0 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	0 to 720	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	-1 to 181	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	Search	54	Modulation Schemes	IFMS & CORTEX compliant
15	Tilt Facility	EAST / WEST	55	Carrier Freq Search Range	+/- 1.5 MHz
16	Tracking Mode	Auto (S) / Program	56	Subcarrier Frequency	1.2 kHz to 2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	80 mdeg	57	Data Rates	IFMS compliant: - 1.2 Mbps (RCD) - 8 Mbps (SCD HS) Cortex compliant: - 256 Kbps (subcarrier) - 40 Mbps (Direct PCM) X-band: Up to 100 Mbps
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP SLE (CORTEX) EIPD (TMP/TCE)
21	Comms Redundancy	YES	61	Rng/Dop Connectivity	FTP (IFMS / CORTEX)
22	Ranging	IFMS & CORTEX compliant	62	Meteo Connectivity	FTP (IFMS)
23	Doppler	YES	63	Angles Connectivity	IP Via CSMC
24	Meteo	YES	64	Pointing Format	STDM
25	Autotrack Antenna Angles	YES	65	Tracking Interface (ESOC)	FDS
26	Delta-DOR	NO			
27	Radio-Science	NO			
28	Frequency & Timing	CESIUM			
29	UPLINK				
30	S-band TX band [MHz]	2025-2120			
31	S-band Polarization	RHC, LHC			
32	S-band EIRP [dBm]	101			
33	X-band TX band [MHz]	N/A			
34	X-band Polarization	N/A			
35	X-band EIRP [dBm]	N/A			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	IFMS & CORTEX compliant			
40	Subcarrier Freq. [kHz]	8 or 16 kHz			

Table 3: Kiruna-1 (KIR-1) Performance Characteristics

Table 4 details the Kiruna-2 (KIR-2) Performance Characteristics. For the definition of individual characteristics see 5.6.

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	KIRUNA-2 (S / S X)	42	L-band RX band [MHz]	N/A
3	TERMINAL	KIR-2	43	L-band Polarization	N/A
4	Longitude	20 deg 58' 00.77" E	44	L-band G/T [dB/K]	N/A
5	Latitude	67 deg 51' 30.34" N	45	S-band RX band (MHz)	2200-2300
6	Altitude [m]	400.6815	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	13	47	S-band G/T [dB/K]	21.4 (at 5 deg El.)
8	S-band Beamwidth [deg]	Rx: 0.65 Tx: 0.70	48	X-band RX band [MHz]	7600-8500
9	X-band Beamwidth [deg]	Rx: 0.19	49	X-band Polarization	RHC, LHC
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	35.6. (at 5 deg El.)
11	Antenna Speed [deg/s]	Az: 12.0 deg/s El: 7.5 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	+/- 400	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	-3 to 182	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	Datron search	54	Modulation Schemes	IFMS & CORTEX compliant
15	Tilt Facility	EAST / WEST	55	Carrier Freq Search Range	+/- 1.5 MHz
16	Tracking Mode	Auto (S X) / Program	56	Subcarrier Frequency	1.2 kHz to 2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	100 mdeg	57	Data Rates	IFMS compliant: - 1.2 Mbps (RCD) - 8 Mbps (SCD HS) Cortex compliant: - 256 Kbps (subcarrier) - 40 Mbps (Direct PCM) X-band: Up to 100 Mbps
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP SLE (CORTEX) EIPD (TMP/TCE)
21	Comms Redundancy	YES	61	Rng/Dop Connectivity	FTP (IFMS / CORTEX)
22	Ranging	IFMS & CORTEX compliant	62	Meteo Connectivity	FTP (IFMS)
23	Doppler	YES	63	Angles Connectivity	IP Via CSMC
24	Meteo	YES	64	Pointing Format	STDM
25	Autotrack Antenna Angles	YES	65	Tracking Interface (ESOC)	FDS
26	Delta-DOR	NO			
27	Radio-Science	NO			
28	Frequency & Timing	CESIUM			
29	UPLINK				
30	S-band TX band [MHz]	2025-2120			
31	S-band Polarization	RHC, LHC			
32	S-band EIRP [dBm]	99			
33	X-band TX band [MHz]	N/A			
34	X-band Polarization	N/A			
35	X-band EIRP [dBm]	N/A			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	IFMS & CORTEX compliant			

1	Rev. 2.4		41	DOWNLINK	
40	Subcarrier Freq. [kHz]	8 or 16 kHz			

Table 4: Kiruna-2 (KIR-2) Performance Characteristics

6.2.3.2 *Antennas Horizons*

Figure 14 and Figure 15 show the KIR-1 horizon in West and East Tilt configuration respectively.

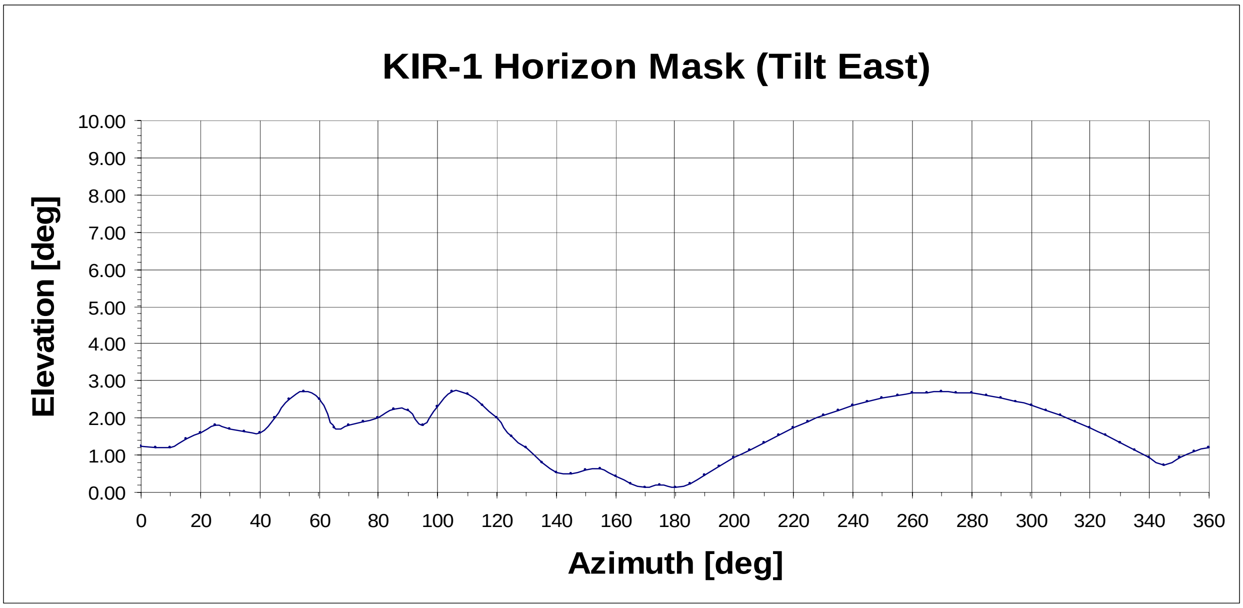

Figure 14: Kiruna-1 (KIR-1) Antenna Horizon Mask, Tilt East

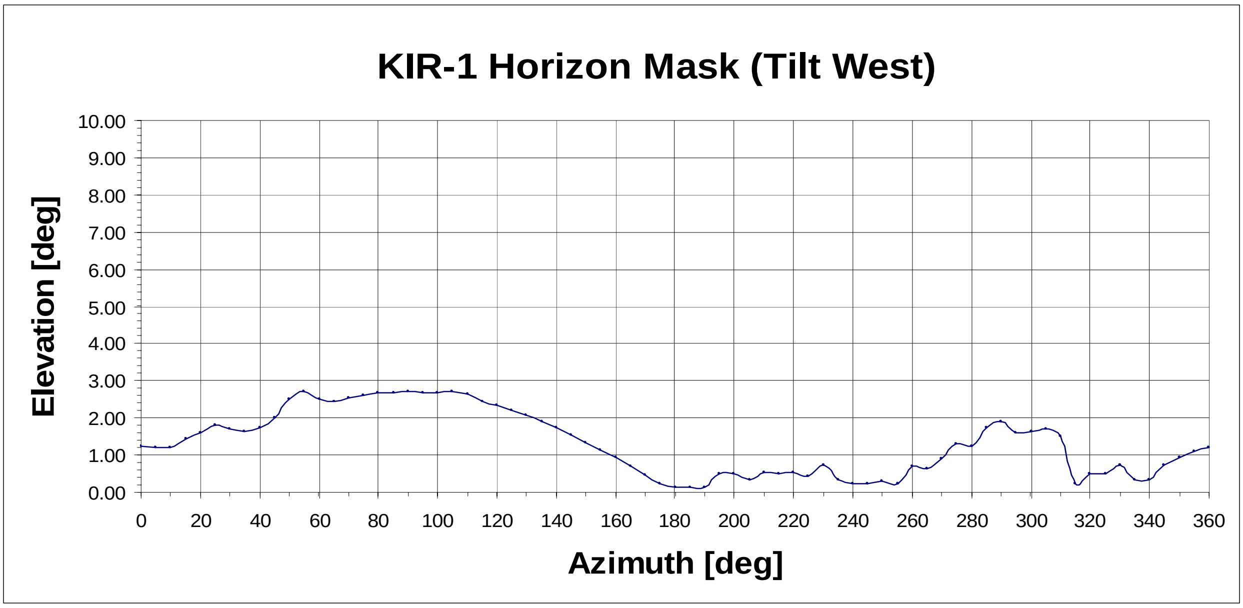

Figure 15: Kiruna-1 (KIR-1) Antenna Horizon Mask, Tilt West

Figure 16 and Figure 17 show the KIR-2 horizon in West and East Tilt configuration respectively.

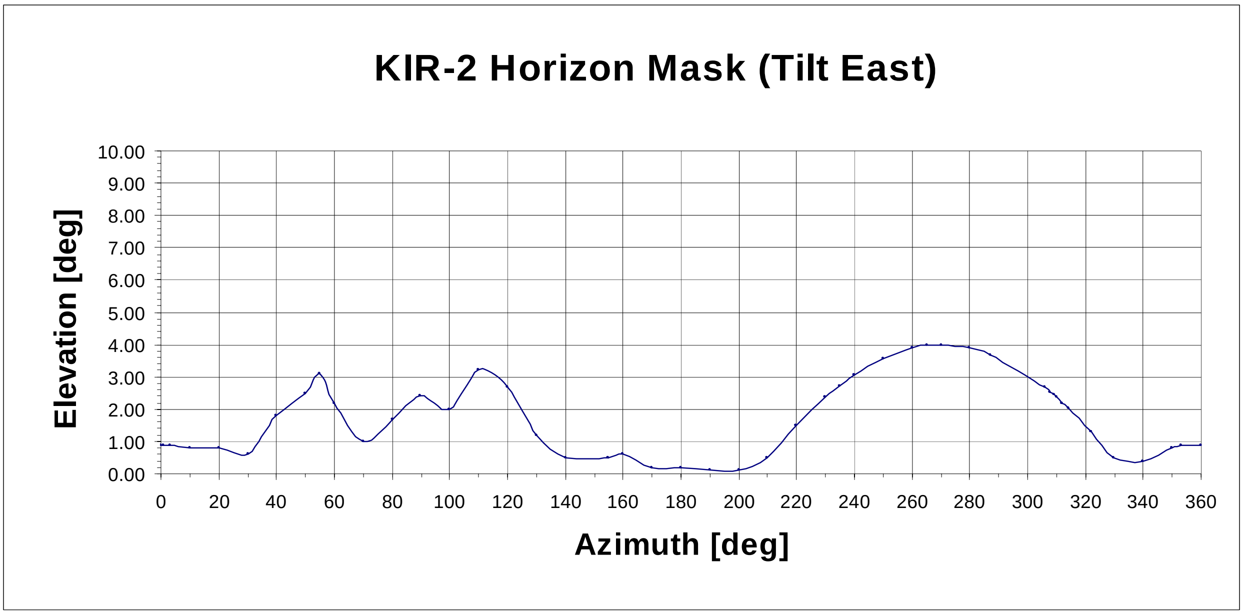

Figure 16: Kiruna-2 (KIR-2) Antenna Horizon Mask, Tilt East

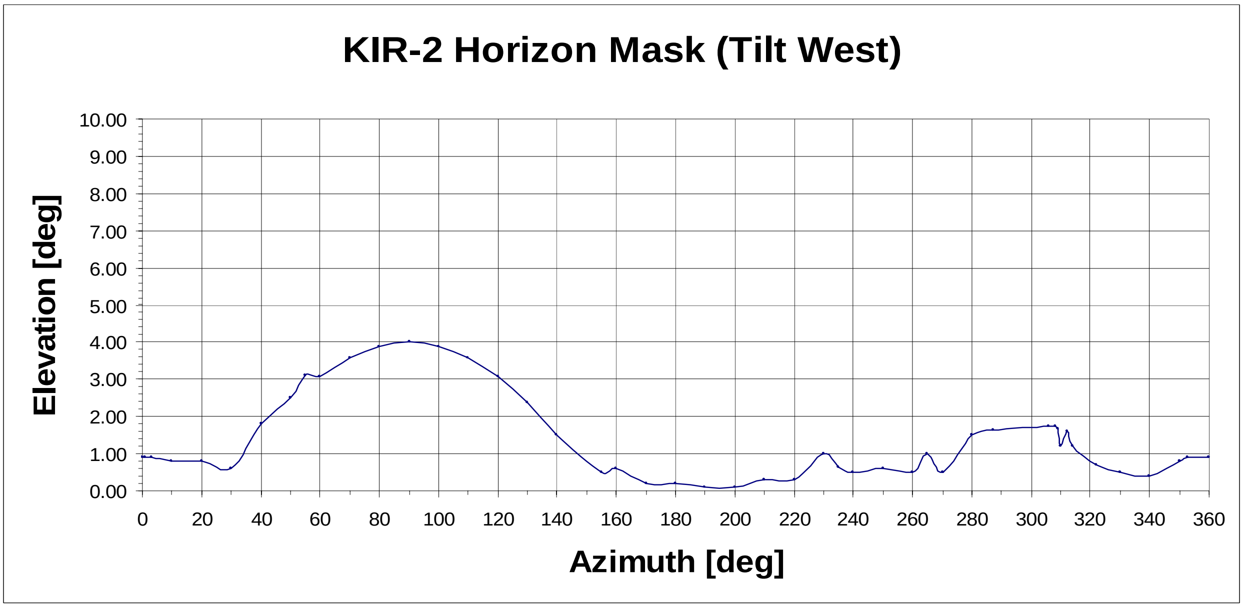

Figure 17: Kiruna-2 (KIR-2) Antenna Horizon Mask, Tilt West

6.2.3.3 Functional Description

Figure 18 shows the combined Kiruna Block Diagram, which is used for the functional description.

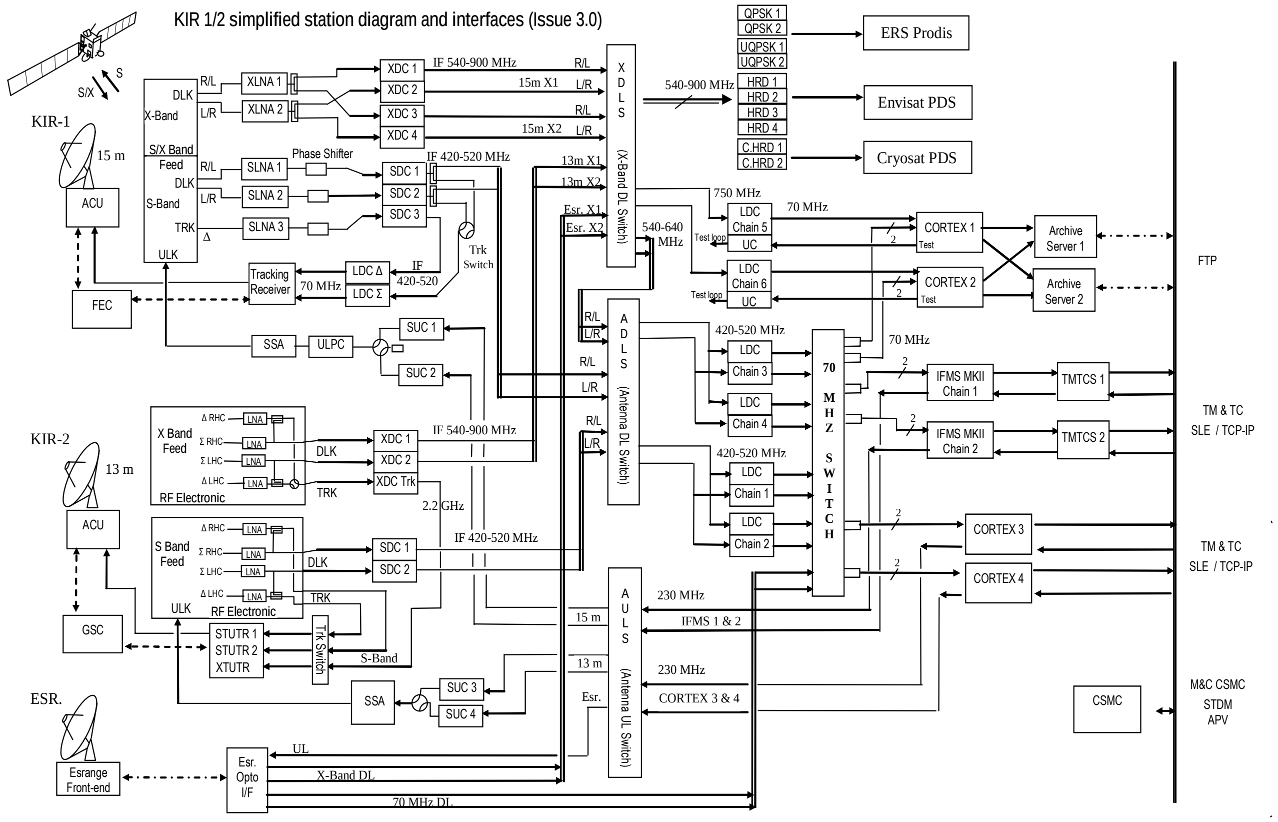

Figure 18: Kiruna (KIR) Block Diagram

6.2.3.3.1 KIR-1 Antenna

The S-band transmit and S- and X-band receive (S/SX) Cassegrain antenna is fitted with a shaped 15m parabolic main reflector and a shaped hyperbolic subreflector in an elevation over azimuth over tilt axis mount. Auto-tracking of the S-band signal is possible by a two-channel monopulse tracking system. An S- and X-band test antenna with reflective converter allows for signal delay calibration. An air-conditioning system outside the antenna tower provides cooling and heating of the antenna tower and the Apex cabin.

The antenna pointing is performed by the Antenna Control Unit (ACU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation positions to the ACU.

The incoming electromagnetic wave is conveyed via the reflector and subreflector into the S/SX feed, which together with its polarizer matches the free space field electromagnetic configuration to the waveguide modes. The combined S/SX feed consists of an S-band corrugated horn with a dielectric rod inside for X-band. The coexisting receive and transmit signals for each polarisation inside the S-band feed are separated by Diplexer filters. The receive waveguide branches are fed to Low Noise Amplifiers (LNAs), which amplify the Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC) signals, which subsequently can be phase adjusted by Phase Shifters. The S-band signals [2200-2300 MHz] are down-converted to L-band [520-420 MHz]. The X-band signals [8025-8400, 8400-8500 MHz] are down-converted to L-band [540-900 MHz] and routed via the X-band Downlink Switch (XDLS) to the High Rate Demodulators. The [8400-8500 MHz] X-band signals are further down-converted to 70 MHz. These S- and X-band downlink signals are then transferred for tracking and telemetry processing.

The uplink signal coming from telecommand processing at 230 MHz is delivered to S-band transmission. It is converted by the S-band up-converter (SUC) to [2025-2120 MHZ] and delivered via a switch to the S-band Solid State Amplifier (SSSA). Fine control of the radiated power is performed by adjustable external attenuators.

A transmit waveguide assembly routes the RF signal to the S-band feed. The transmitted polarisation is selected with the polarization switch, which routes the RF signal to the uplink arm of one of the two Diplexers, one for each polarisation. To avoid radiating the RF power to the antenna, the RF signal can also be routed via a set of switches to a high power dummy load.

The S-band Feed (including polarizer) matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from one of the two Diplexers and conveys the high power RF flux from the S-band feed to the antenna sub-reflector and main reflector, where it is forwarded to free space.

The S-band tracking error signals in both polarisations are derived in waveguide mode couplers. A polarisation selection switch allows routing of one polarisation to the Tracking Low Noise Amplifier (LNA). This Delta-signal is down-converted to L-band [520-420 MHz] (from S-band) via a dedicated third channel in the down-converter. This Delta-signal and the associated Sum-signals are then further down-converted to 70 MHz by a dedicated three channel L-band Tracking down-converter. The Tracking Receiver processes the three signals (Sum-1, Sum-2, Delta) coming from the S-band feed in either Phase Locked Loop mode for remnant carrier modulated signals or Cross Correlation mode for suppressed carrier modulated signals. It derives the error signals for the ACU to point the antenna in autotrack mode.

6.2.3.3.2 KIR-2 Antenna

The S-band transmit and S- and X-band receive (S/SX) Cassegrain antenna is fitted with a shaped 13m parabolic main reflector and a dichroic hyperbolic subreflector with heater (X-band pass through, S-band reflection), in an elevation over azimuth over tilt-axis mount. Auto-tracking of the S- and X-band signals is possible by a single channel monopulse tracking system. An S- and X-band test signal injection with reflective converter (S-band only) allows for signal delay calibration. An air-conditioning system provides cooling and heating to the antenna pedestal and the Apex equipment box.

The antenna pointing is performed by the Digital Electronics Unit (DEU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation readings to the DEU.

The incoming electromagnetic wave is conveyed via the reflector and subreflector into the S-band feed, which together with its polarizer matches the free space electromagnetic field configuration to the waveguide modes. The coexisting receive and transmit signals for each polarization are separated by a diplexer filter. The receive waveguide branches are fed to Low Noise Amplifiers

(LNAs), which amplify the RHC and LHC signals. The S-band signals are down-converted to 70 MHz and routed to the Antenna Downlink Switch (ADLS) and 70 MHz switch (SMSW) and further transferred for telemetry processing.

The X-band feed behind the dichroic subreflector allows X-Band reception. The RHC and LHC signals are down-converted to 750 MHz for high rate demodulation.

The uplink signal coming from the telecommand processing at 230 MHz is delivered to the S-Band up-converter (SUC) and further to the S-Band solid state power amplifier for transmission.

The S-Band feed matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from the diplexer and conveys the high power RF flux from the S-Band feed to the antenna subreflector and Main reflector where it is radiated to free space.

The S-band error tracking signals in both polarisations are derived in waveguide mode couplers and routed to the Tracking Low Noise Amplifiers (LNAs). These delta-signals are added onto the Tracking Sum channels. In S-band the tracking polarisation selection is defined by the DEU. The signals are processed in the Tracking receivers in Cross-correlation mode, which derives the error signals for the DEU to point the antenna in autotrack mode. The X-Band tracking signal is first down-converted to S-Band in order to be processed by the Tracking receiver. In X-Band only autotrack of one selectable polarisation is possible.

6.2.3.3.3 Tracking

The KIR-1 and KIR-2 tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or autotrack mode using the received signal.

For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Spacecraft Trajectory Data Messages (STDM's) or State Vectors in the Front End Controller (FEC). For autotrack the antenna Azimuth and Elevation pointing angles are derived from error signals proportional to the direction of highest electrical field strength received. These pointing angles are made available to the Front End Controller (FEC) for delivery for orbit determination purposes.

6.2.3.3.4 Telemetry

The downlink L-band signals of KIR-1 and KIR-2 are fed via the Antenna Downlink Switch (ADLS) into tuneable L-band down-converters for conversion to 70 MHz intermediate frequency (IF) and further signal routing through the 70 MHz switch (SMSW).

The 70 MHz signals are combined and demodulated in the Intermediate Frequency Modem System (IFMS), which provides remnant and suppressed carrier demodulation. Doppler predictions coming from Spacecraft Trajectory Data Messages (STDM) information improve the signal acquisition process. The Telemetry Channel Decoding System (TCDS) hosted inside the IFMS performs frame synchronisation, time tagging, Viterbi and Reed-Solomon decoding. The output data is transferred to the Telemetry and Telecommand System (TMTCS) for data structure processing according to Space Link Extension (SLE), which ultimately delivers the telemetry data via OPSNET to the Spacecraft Control Systems.

Alternatively the 70 MHz signals are delivered to the Cortex processing equipment, which integrates the above functions in a single unit, and delivers SLE conformant telemetry services.

The telemetry chains are redundant and the various switches allow flexible signal routing.

6.2.3.3.5 Telecommand

The Telemetry and Telecommand System (TMTCS) receives SLE conformant Telecommand data via OPSNET from the Spacecraft Control Systems. It provides telecommand data and clock to the Intermediate Frequency Modem System (IFMS) Uplink Modulator (ULM), which provides the Phase Shift Key (PSK) modulation of the telecommand bit stream onto a sub-carrier, which is then used to phase modulate the uplink carrier at 230 MHz. Via the Antenna Uplink Switch (AULS) the uplink signal is routed to the KIR-1 and KIR-2 S-band uplinks. Alternatively the uplink can be generated from the Cortex processing equipment.

The telecommand chains are redundant and the various switches allow flexible signal routing.

6.2.3.3.6 Radiometric

The KIR-1 and KIR-2 radiometric measurements comprise Doppler, Ranging, Meteorological and autotrack Pointing measurements.

The Intermediate Frequency Modem System (IFMS) Ranging and Telemetry Demodulators deliver integrated Doppler measurements of the received carrier phase, known as Doppler-1 and Doppler-2.

The IFMS Uplink Modulator generates the ranging tone, which is Phase-Shift-Key (PSK) modulated by a sequence of codes. This ranging tone is phase modulated on the uplink carrier and can be transmitted simultaneously with the telecommand subcarrier. The IFMS Ranging Demodulator pre-steers the expected downlink carrier in case of coherent transponding of the spacecraft based on Spacecraft Trajectory Data Messages (STDMs), demodulates the received tone and compares the received codes with codes replica to derive the two-way propagation delay.

The IFMS meteorological unit gathers outside air temperature, pressure and humidity information.

Alternatively the Doppler and Ranging measurements can be provided by the Cortex processing equipment.

The Antenna Control Unit delivers the actually pointed antenna Azimuth and Elevation angles during autotrack of the received carrier signal.

All radiometric measurement data are delivered through OPSNET to Flight Dynamics for processing.

6.2.3.3.7 Monitoring and Control

The monitoring and control (M&C) system allows full local and remote control over the terminal. It is based on a hierarchy of M&C systems: the Central Station Monitoring and Control (CSMC) system, the Front End Controller (FEC) and Local Man Machine Interfaces (MMI) on the various devices.

The Central Station Monitoring and Control (CSMC) system is composed of redundant Acquisition Nodes, a Master Node, and two User Nodes to support remote monitoring and control from a remote workstation housed in the Ground Facilities Control Centre (GFCC). Mission specific terminal configurations are normally affected through pre-validated macro-procedures, which are executed from an automatic schedule, which takes into account the available resources. Also individual equipment configurations are possible.

The Front End Controller (FEC) is the subsystem controller for all the KIR-1 antenna front end devices and responsible for KIR-1 antenna steering. The Ground Station Controller (GSC) is the subsystem controller for all the KIR-2 antenna front end devices and responsible for KIR-2 antenna steering.

In case of failure of the monitoring and control system, the terminal can be locally operated from the individual equipment Local Man Machine Interfaces.

6.2.3.3.8 Frequency and Timing

The frequency reference generation is based on a Caesium Beam Tube with appropriate long term frequency stability. The frequency distribution system coherently derives 5 MHz signals and amplifies them for distribution to the KIR-1 and KIR-2 devices.

The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 1 KHz, 5 MHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

6.2.3.3.9 Test and Calibration

The objective of the test and calibration function is to validate the telemetry and telecommand functions, and to calibrate the Ranging and Doppler function before the operational satellite pass.

The telemetry function is tested with simulated spacecraft telemetry, which is generated in the Portable Satellite Simulator (PSS), frequency converted to the appropriate downlink frequency and injected into the antenna via a test antenna for KIR-1 or at an injection point in the waveguide before the KIR-2 S-LNAs, so called Telemetry Test Long Loop (TTLL) configuration. The telemetry is then delivered in a Data Flow Test (DFT) to the spacecraft control system for verification.

The X-band high rate payload telemetry function is tested with simulated spacecraft telemetry, which is generated in the high rate modulator and frequency converted to the appropriate downlink frequency and injected into the waveguide before the KIR-1 and KIR-2 X-LNAs.

The telecommand function is tested by demodulating and decoding of the 230 MHz uplink signal and comparing it to known telecommand formats. Based on the telecommand received in the PSS the simulated telemetry generation can be altered. The test telecommands originate from the spacecraft control system.

The ranging and doppler function is calibrated by conducting a ranging and doppler measurement in an antenna loopback configuration, in which the uplink frequency is transponded to the downlink frequency. The emulated transponding involves reception of the uplink frequency by the test antenna and conversion to the downlink frequency in the Reflective Converter (RFLC) with subsequent transmission via the test antenna back into the main antenna. This calibration measures the station internal signal delay and any frequency offset.

For phase calibration of the S- and X-band tracking channels, a remote controllable calibration tower is available. An S-band reflective converter allows for loopback tests.

Test tools for integration and performance validation activities are not described.

6.2.4 ADDITIONAL FACILITIES

6.2.4.1 GPS-TDAF

A Global Positioning System (GPS) dual-frequency receiver system with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

6.2.4.2 GESS

A Galileo Experimental Sensor Station with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

6.2.4.3 Esrange Antenna Interface

Esrange Satellite Station is located 8 km from the ESA Satellite Station and provides S-band uplink and S- and X-band downlink capabilities to ESA by means of two 13 m and two 9 m antennas.
The main characteristics of the Esrange antennas are listed in Table 1.

Antenna Name	ES1 (ETX)	ES2 (ESSEX)	ES3 (ESX)	ES4 (ELS)
Size	13 m	13 m	9 m	9 m
TX Band	2025-2120 MHz (S)	2025-2120 MHz (S)	-	-
EIRP	70 dBW	68 dBW	-	-
RX Band	2200-2400 MHz (S) 8025-8400 MHz (X)	2200-2400 MHz (S) 7600-8500 MHz (X)	2200-2300 MHz (S) 8025-8400 MHz (X)	2200-2300 MHz (S) 8025-8400 MHz (X)
Antenna G/T	23 dB/°K (S) 33 dB/°K (X)	24 dB/°K (S) 37 dB/°K (X)	21 dB/°K (S) 31 dB/°K (X)	21 dB/°K (S) 31 dB/°K (X)
Autotrack	S+X	S+X	S+X	S

Table 5 Esrange Antenna Performance Characteristics

The pool of Esrange antennas are prepared to support the ENVISAT, ERS-2, CryoSat-2, Astro-F, GOCE and Aeolus missions. The Esrange antennas are connected to the ESA Satellite Station S- and X-band baseband equipment through a wideband optical interface.

The optical cable between the sites was established in 1995, and contains 12 single mode fibres. The cable is mounted on existing power line poles, approximately 5 meters above the ground.

6.2.5 PLANNED DEVELOPMENTS

None.

6.3 Kourou (KRU) Station

Figure 19 shows the Kourou Aerial View.


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Figure 19: Kourou (KRU) Aerial View

6.3.1 GENERAL INFORMATION

The Kourou site is made available to ESA, based on an international agreement between ESA and the Government of France.

6.3.1.1 Location

The Kourou site, also known as Kourou Diane or Kourou 93, is located on the campus of the Centre Spatiale Guyanais (CSG). CSG is located on the Atlantic coast of French Guiana, South America, 90 km from Cayenne, see Figure 20. The Kourou site is located 27 km away from the town of Kourou.

Figure 20: Kourou (KRU) Area Map

6.3.1.2 *Access*

Site visits require a confirmed Station Intervention form sheet. Visitors have to be announced by the Station M&O Supervisor to CNES/CSG for security clearance.
The international airport serving French Guiana is situated at Rochambeau, 17 km from Cayenne, with regular Air France flights from Paris. Transport between the airport and Kourou is usually by rental car.
Heavy transport is by sea to the port of Dégrad des Cannes.
Accommodation can be arranged through the station manager.

6.3.1.3 Entry Requirements

French Guiana is a French Overseas Department and the legal formalities are the same as for a visit to France.
Vaccinations against yellow fever are mandatory for entrance to French Guiana.
Typhoid/paratyphoid is recommended to be checked with a medical authority before arranging a visit. Malaria tablets are not necessary for visits to the Kourou area.

6.3.1.4 Climate

The climate is tropical with high rainfall between March and June. A summary of the weather characteristics for the Kourou area is given below:

Warmest month:	October
Average daily maximum temperature for October:	31.8° C
Highest recorded temperature in October:	34.6° C
Lowest recorded temperature in October:	19.1° C
Coldest month:	January
Average daily minimum temperature in January:	22.6° C
Highest recorded temperature in January:	31.4° C
Lowest recorded temperature in January:	17.4° C
Average annual rainfall:	3651 mm

6.3.1.5 Management

There is no ESA D/OPS on-site representative at the Kourou site. Official representation vis-à-vis CNES/CSG is performed through the D/LAU ESA Kourou Office.
The Maintenance and Operations (M&O) of the site is provided by Merlin VT.

6.3.1.6 Local Contact

The local point of contact for the Kourou station is:

Kourou M&O Supervisor
Mr. Andy Casswell
email: Andy.Caswell@esa.int
Tel +594-594-33-6498
Fax +594-594-33-6336

6.3.1.7 Logistics

The postal address is:

ESA Station Diane
Boite Postal No. 27
F-97311 Kourou Cedex
Guyane Francaise

The post box is checked every work day.

Delivery Address:

ESA Station Kourou
Attn.: Mr. Andy Casswell
c/o GEODIS Overseas
Aeroport de Rochambeau
Boite Postal No. 805
Zone Industriel de Paraibo
F-97368 Kourou

Guyane Francaise

Customs agent:

GEODIS Overseas
Aeroport de Rochambeau
Boite Postal No. 805
Zone Industriel de Paraibo
F-97368 Kourou
Guyane Francaise

6.3.2 STATION SERVICES

Figure 21 shows the Kourou Site Plan.

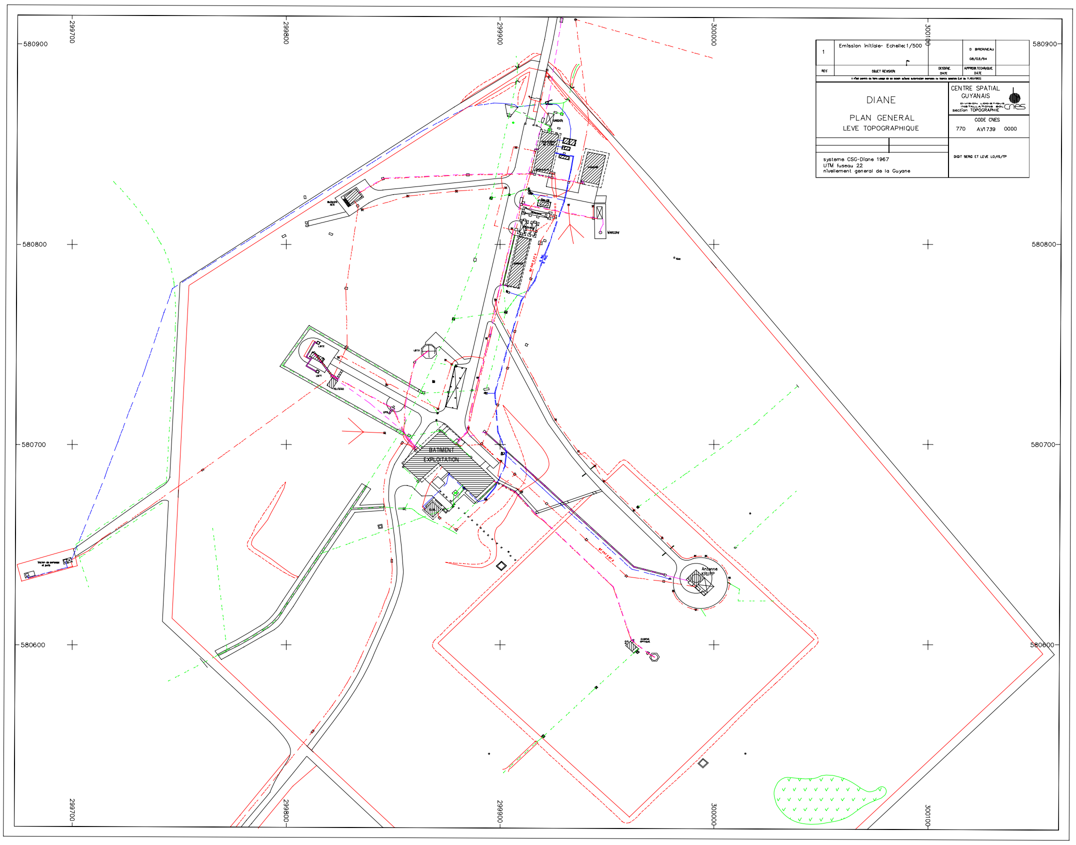

Figure 21: Kourou (KRU) Site Plan

6.3.2.1 Security

The site is fenced and guarded 24/7. An access control and surveillance system is installed.

6.3.2.2 Power

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, and a no-break (NB) power supply using Static Converters and Batteries. Via low voltage switches the electricity (400V, 50 Hz) is distributed to the consumer groups.

Public power into the power plant is rendered by one 20 kV medium voltage line and two transformers of 630 kVA.

Two Diesel Generators supply each 80 kVA within 15 seconds after public power failure. Two Static Converters supply each 80 kVA. The Battery capacity allows for a maximum bridging time of 6 minutes.

6.3.2.3 Air Conditioning

The station air conditioning system supplies air to the main building equipment rooms at a temperature of 24° C + 10%, with a controlled humidity of 50% - 70% relative humidity.

6.3.2.4 Communications

The Kourou station is connected via the OPSNET to ESOC using a 512 kbps VSAT point-to-point link, and a 256 kbps international private leased circuit (IPLC). ISDN on-demand connectivity is also available.

All non-operational and Internet traffic is routed via the ESA Administrative Network (ESACOM). The connectivity into the Kourou site is provided as part of the CNES/CSG communication infrastructure.

6.3.3 KOUROU-1 (KRU-1) TERMINAL

Figure 22 shows the Kourou-1 (KRU-1) terminal, which provides S- and X-band transmit, as well as S- and X-band receive capability (SX/SX).

Figure 22: Kourou-1 (KRU-1) Antenna

6.3.3.1 Services and Performance

The Kourou-1 (KRU-1) terminal provides the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Meteo, Autotrack Angles)
- System Validation Test (SVT) support of satellites during final Checkout
- Listen-In Test (LIT) support of satellites on the Ariane-5 launcher while on the launch pad

Table 6 details the Kourou-1 (KRU-1) Performance Characteristics. For the definition of individual characteristics see 5.6.

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	KOUROU-1 (S X / S X)	42	L-band RX band [MHz]	N/A
3	TERMINAL	KRU-1	43	L-band Polarization	N/A
4	Longitude	52 deg 48' 16.79" W	44	L-band G/T [dB/K]	N/A
5	Latitude	5 deg 15' 05.18" N	45	S-band RX band (MHz)	2200-2300
6	Altitude [m]	-14.6709	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	15	47	S-band G/T [dB/K]	29.1
8	S-band Beamwidth [deg]	Rx: 0.60 Tx: 0.65	48	X-band RX band [MHz]	8025-8500
9	X-band Beamwidth [deg]	Rx: 0.16 Tx: 0.18	49	X-band Polarization	RHC, LHC
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	41
11	Antenna Speed [deg/s]	Az: 15 deg/s El: 5 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	0 to 720	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	-1 to 181	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	Search / Acq aid (X)	54	Modulation Schemes	IFMS compliant
15	Tilt Facility	NO	55	Carrier Freq Search Range	+/- 1.5 MHz
16	Tracking Mode	Auto (S X) / Program	56	Subcarrier Frequency	2 kHz to 1.2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	80 mdeg	57	Data Rates	IFMS compliant: - 1.2 Mbps (RCD) - 2 Mbps (SCD LS)
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP SLE (TMTCS)
21	Comms Redundancy	YES	61	Rng/Dop Connectivity	FTP (IFMS)
22	Ranging	IFMS compliant	62	Meteo Connectivity	FTP (IFMS)
23	Doppler	YES	63	Angles Connectivity	IP via STC
24	Meteo	YES	64	Pointing Format	STDM
25	Autotrack Antenna Angles	YES	65	Tracking Interface (ESOC)	FDS
26	Delta-DOR	NO			
27	Radio-Science	NO			
28	Frequency & Timing	MASER			
29	UPLINK				
30	S-band TX band [MHz]	2025-2120			
31	S-band Polarization	RHC, LHC			
32	S-band EIRP [dBm]	111.2 (SHPA) 104.7 (SLPA)			
33	X-band TX band [MHz]	7145-7235			
34	X-band Polarization	RHC, LHC			
35	X-band EIRP [dBm]	112.8			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	IFMS compliant			
40	Subcarrier Freq. [kHz]	8 or 16 kHz			

Table 6: Kourou-1 (KRU-1) Performance Characteristics

6.3.3.2 Antenna Horizon

Figure 23 shows the Kourou-1 (KRU-1) Antenna Horizon Mask.

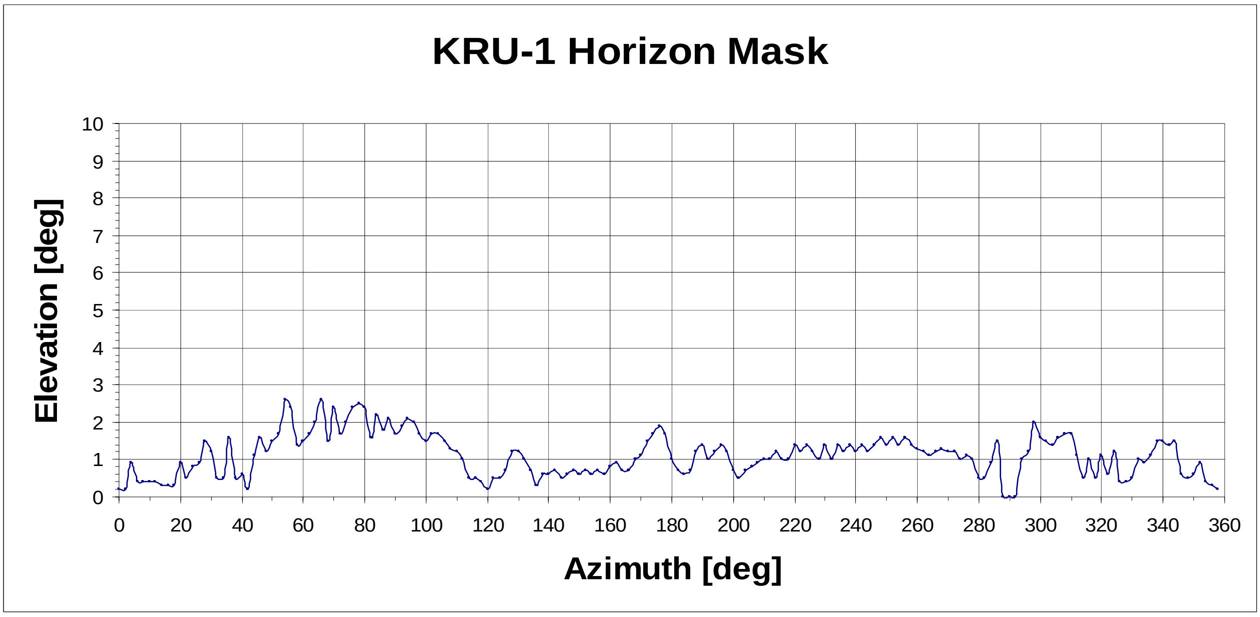

Figure 23: Kourou-1 (KRU-1) Antenna Horizon Mask

6.3.3.3 Functional Description

Figure 24 shows the Kourou-1 (KRU-1) Block Diagram, which is used for the functional description.

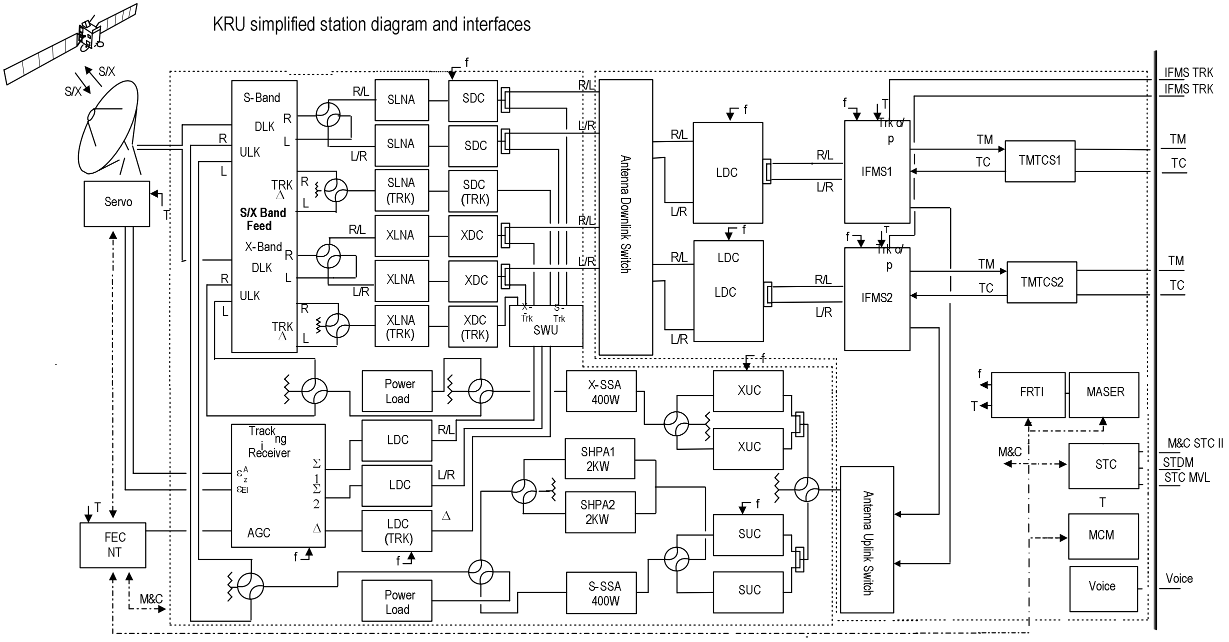

Figure 24: Kourou-1 (KRU-1) Block Diagram

6.3.3.3.1 Antenna

The S- and X-band transmit and S- and X-band receive (SX/SX) Cassegrain antenna is fitted with a shaped 15m parabolic main reflector and a shaped hyperbolic subreflector in an elevation over azimuth mount. Auto-tracking of the S- and X-band signals is possible by a two-channel monopulse tracking systems in each frequency band. An S- and X-band test antenna with reflective converter allows for signal delay calibration. An air-conditioning system outside the antenna tower provides cooling of the antenna tower and the Apex cabin.

The antenna pointing is performed by the Antenna Control Unit (ACU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation positions to the ACU.

The incoming electromagnetic wave is conveyed via the reflector and subreflector into the SX/SX feed, which together with its polarizer matches the free space field electromagnetic configuration to the waveguide modes. The combined SX/SX feed consists of an S-band corrugated horn with a dielectric rod inside for X-band. The coexisting receive and transmit signals for each polarisation inside each feed are separated by Diplexer filters. The receive waveguide branches are fed to Low Noise Amplifiers (LNAs), for X-Band cryogenically cooled Low Noise Amplifiers (LNAs) are used, to amplify the Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC) signals, which subsequently can be phase adjusted by Phase Shifters. The S-band signals [2200-2300 MHz] are down-converted to L-band [520-420 MHz]. The X-band signals [8400-8500 MHz] are down-converted to L-band [640-540 MHz]. The downlink signals are then transferred for tracking and telemetry processing.

The uplink signal coming from telecommand processing at 230 MHz is delivered to S-band or X-band transmission. It is converted by the S-band up-converter (SUC) to [2025-2120 MHZ] and delivered via a switch to the redundant S-band High Power Amplifiers (SHPAs) or the S-band Solid State Amplifier (SSSA); or by the X-band upconverter (XUC) for conversion to [7145-7235 MHZ] and via a switch to the X-band Solid State Amplifier (XSSA). Fine control of the radiated power is performed by adjustable external attenuators.

A transmit waveguide assembly routes the RF signal to the X-band feed or S-band feed. The transmitted polarisation is selected with the polarization switch, which routes the RF signal to the uplink arm of one of the two Diplexers, one for each polarisation and frequency band. To avoid radiating the RF power to the antenna, the RF signal can also be routed via a set of switches to one of the two high power dummy loads

The X-Band Feed or S-band Feed (including polarizer) matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from one of the two Diplexers and conveys the high power RF flux from the X-Band or S-band feed to the antenna sub-reflector and main reflector, where it is forwarded to free space. Concurrent radiation in X-band and S-band is not foreseen.

The S- and X-band tracking error signals in both polarisations are derived in waveguide mode couplers. A polarisation selection switch allows routing of one polarisation to the Tracking Low Noise Amplifier (LNA). This Delta-signal is down-converted to L-band [520-420 MHz] (from S- or X-band) via a dedicated third channel in the down-converter. This Delta-signal and the associated Sum-signals are then further down-converted to 70 MHz by a dedicated three channel L-band Tracking down-converter. The Tracking Receiver processes the three signals (Sum-1, Sum-2, Delta) coming from the S- or X-band feed in either Phase Locked Loop mode for remnant carrier modulated signals or Cross Correlation mode for suppressed carrier modulated signals. It derives the error signals for the ACU to point the antenna in autotrack mode.

6.3.3.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or autotrack mode using the received signal.

For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Spacecraft Trajectory Data Messages (STDM's) or State Vectors in the Front End Controller (FEC). For autotrack the antenna Azimuth and Elevation pointing angles are derived from error signals proportional to the direction of highest electrical field strength received. These pointing angles are made available to the Front End Controller (FEC) for delivery for orbit determination purposes.

6.3.3.3.3 Telemetry

The downlink L-band signals are fed via the Antenna Downlink Switch (ADLS) into tuneable L-band down-converters for conversion to 70 MHz intermediate frequency (IF) and further signal routing through the 70 MHz switch (SMSW).

The 70 MHz signals are combined and demodulated in the Intermediate Frequency Modem System (IFMS), which provides remnant and suppressed carrier demodulation. Doppler predictions

coming from Spacecraft Trajectory Data Messages (STDM) information improve the signal acquisition process. The Telemetry Channel Decoding System (TCDS) hosted inside the IFMS performs frame synchronisation, time tagging, Viterbi and Reed-Solomon decoding. The output data is transferred to the Telemetry and Telecommand System (TMTCS) for data structure processing according to Space Link Extension (SLE), which ultimately delivers the telemetry data via OPSNET to the Spacecraft Control Systems.
The telemetry chains are redundant and the various switches allow flexible signal routing.

6.3.3.3.4 Telecommand

The Telemetry and Telecommand System (TMTCS) receives SLE conformant Telecommand data via OPSNET from the Spacecraft Control Systems. It provides telecommand data and clock to the Intermediate Frequency Modem System (IFMS) Uplink Modulator (ULM), which provides the Phase Shift Key (PSK) modulation of the telecommand bit stream onto a sub-carrier, which is then used to phase modulate the uplink carrier at 230 MHz. Via the Antenna Uplink Switch (AULS) the uplink signal is routed either to the S band or X-band antenna uplink.
The telecommand chains are redundant and the various switches allow flexible signal routing.

6.3.3.3.5 Radiometric

The radiometric measurements comprise Doppler, Ranging, Meteorological and autotrack Pointing measurements.
The Intermediate Frequency Modem System (IFMS) Ranging and Telemetry Demodulators deliver integrated Doppler measurements of the received carrier phase, known as Doppler-1 and Doppler-2.
The IFMS Uplink Modulator generates the ranging tone, which is Phase-Shift-Key (PSK) modulated by a sequence of codes. This ranging tone is phase modulated on the uplink carrier and can be transmitted simultaneously with the telecommand subcarrier. The IFMS Ranging Demodulator pre-steers the expected downlink carrier in case of coherent transponding of the spacecraft based on Spacecraft Trajectory Data Messages (STDMs), demodulates the received tone and compares the received codes with codes replica to derive the two-way propagation delay.
The IFMS meteorological unit gathers outside air temperature, pressure and humidity.
The Antenna Control Unit delivers the actually pointed antenna Azimuth and Elevation angles during autotrack of the received carrier signal.
All radiometric measurement data are delivered through OPSNET to Flight Dynamics for processing.

6.3.3.3.6 Monitoring and Control

The monitoring and control (M&C) system allows full local and remote control over the terminal. It is based on a hierarchy of M&C systems: the Station Computer (STC), the Front End Controller (FEC), the Monitoring and Control Module (MCM) and Local Man Machine Interfaces (MMI) on the various devices.
The Station Computer (STC) is composed of a local server, a local workstation and a remote workstation housed in the ESTRACK Control Centre (ECC). Mission specific terminal configurations are normally affected through pre-validated macro-procedures, also individual equipment configurations are possible. The STC interacts through a set of subsystem controllers,

either in separate units or implemented in complex devices (e.g. IFMS/TMTCS), with all the terminal equipment. Remote spectrum visualisation is supported.

The Front End Controller (FEC) is the subsystem controller for all the antenna front end devices and responsible for antenna steering.

The Monitoring and Control Module (MCM) is the subsystem controller for all simple back end devices, e.g. switches.

In case of failure of the monitoring and control system, the terminal can be locally operated from the individual equipment Local Man Machine Interfaces.

6.3.3.3.7 Frequency and Timing

The frequency reference generation is based on a Hydrogen Maser with very high long term frequency stability. The frequency distribution system coherently derives 5 and 10 MHz signals and amplifies them for distribution to the devices.

The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 5 MHz, 1 kHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

6.3.3.3.8 Test and Calibration

The objective of the test and calibration function is to validate the telemetry and telecommand functions, and to calibrate the Ranging and Doppler function before the operational satellite pass.

The telemetry function is tested with simulated spacecraft telemetry, which is generated in the Portable Satellite Simulator (PSS), frequency converted to the appropriate downlink frequency and injected into the antenna via a test antenna, so called Telemetry Test Long Loop (TTLL) configuration. The telemetry is then delivered in a Data Flow Test (DFT) to the spacecraft control system for verification.

The telecommand function is tested by demodulating and decoding of the 230 MHz uplink signal and comparing it to known telecommand formats. Based on the telecommand received in the PSS the simulated telemetry generation can be altered. The test telecommands originate from the spacecraft control system.

The ranging and doppler function is calibrated by conducting a ranging and doppler measurement in an antenna loopback configuration, in which the uplink frequency is transponded to the downlink frequency. The emulated transponding involves reception of the uplink frequency by the test antenna and conversion to the downlink frequency in the Reflective Converter (RFLC) with subsequent transmission via the test antenna back into the main antenna. This calibration measures the station internal signal delay and any frequency offset.

For phase calibration of the tracking channels, a remote controllable calibration tower is available on top of the Ariane-5 Batiment Assemblage Final (BAF) building, 5km away from the KRU-1 terminal.

Test tools for integration and performance validation activities are not described.

6.3.4 ADDITIONAL FACILITIES

6.3.4.1 GPS-TDAF

A Global Positioning System (GPS) dual-frequency receiver system with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

6.3.4.2 GESS

A Galileo Experimental Sensor Station with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

6.3.4.3 BAF RF Link

For satellites, which undergo final checkout before launch on Ariane-5 in the Batiment Assemblage Final (BAF) building, an RF link capability to KRU-1 for transmission and reception is available. This capability allows to support a System Validation Test (SVT) of the satellite during final checkout.

6.3.4.4 Launch Pad RF Link

For satellites on top of Ariane-5, which are rolled out to the launch pad, an RF link capability to KRU-1 for reception is available. This capability allows to support a Listen-In Test (LIT) of the satellite before lift-off.

6.3.5 PLANNED DEVELOPMENTS

none.

6.4 Maspalomas (MSP) Station

Figure 25 shows the Maspalomas (MSP) Aerial View.

Figure 25: Maspalomas (MSP) Aerial View

6.4.1 GENERAL INFORMATION

The Maspalomas site is owned by Instituto Nacional de Tecnica Aerospacial (INTA).

6.4.1.1 Location

The Maspalomas site is located in the southern part of Gran Canaria, the biggest island of the Canarian archipelago.

6.4.1.2 Access

Site visits require a confirmed Station Intervention form sheet.
The Maspalomas ground station is located 38 km south of the Gran Canaria International Airport and 60 km from the city of Las Palmas de Gran Canaria, see Figure 26. Transport between the airport and the station is by rental car or taxi.

Figure 26: Maspalomas (MSP) Area Map

Take the motorway GC1 south from the airport and stay on it until exit 50 (Pasito Blanco) . The station is signposted (INTA Estacion Espacias de Maspalomas) to the right 1.7 km after of the motorway and is then a further 1.6 km.
Accommodation can be arranged through the station manager.

6.4.1.3 Entry Requirements

Entry requirements for the Canary Island are as for the European Union.

6.4.1.4 Climate

The climate in the south of the island is mild. Wind speed is less than 50 km/h for 97% of the time and occurrences of haze, hail and thunderstorms are negligible. Occasionally dust is blown from the Sahara desert but is only present for short periods. A summary of the weather characteristics for the Maspalomas area is given below:

Warmest month:	August.
Average daily maximum temperature for August:	26.8°C.
Highest temperature recorded in August:	44.2°C.
Lowest temperature recorded in August:	16.0°C.
Coldest month:	January.
Average daily minimum temperature for January:	13.3°C.
Highest temperature recorded in January:	28.6°C.
Lowest temperature recorded in January:	7.0°C.
Average annual rainfall:	170 mm

6.4.1.5 Management

There is no ESA on-site representative at the Maspalomas site. INTA is represented by their Station Director.
Maintenance and Operations (M&O) of the Maspalomas terminal is provided by Ingenieria de Servicios Aeroespaciales Sociedad Anonima (INSA).

6.4.1.6 Local Contact

The local INTA point of contact at the Maspalomas station is:

INTA Estacion Espacial de Maspalomas
Station Director
Mr Pablo Martinez-Darve Martinez
Email: martinezdmp@inta.es
Tel +34-28-727100
Fax +34-28-727124

6.4.1.7 Logistics

The postal and delivery address is:

INTA Estacion Espacial de Maspalomas
Apartado 29
E-35100 Maspalomas
Gran Canaria
Canary Islands, Spain

The Logistics contact persons at the Maspalomas Station are:
Jose Vicente Fernandez or Guillermo Rivero
Tel: +34-928-727-112

Customs Agent:

Agencia de Aduanas "Blas Betancor"
Contact Person: Mr. Chano
Tel: +34-928-463-045 / -119
Fax: +34-928-465-782
E- Mail: blasbetancor@portel.com

6.4.2 STATION SERVICES

Figure 27 shows the Maspalomas (MSP) Site Plan.

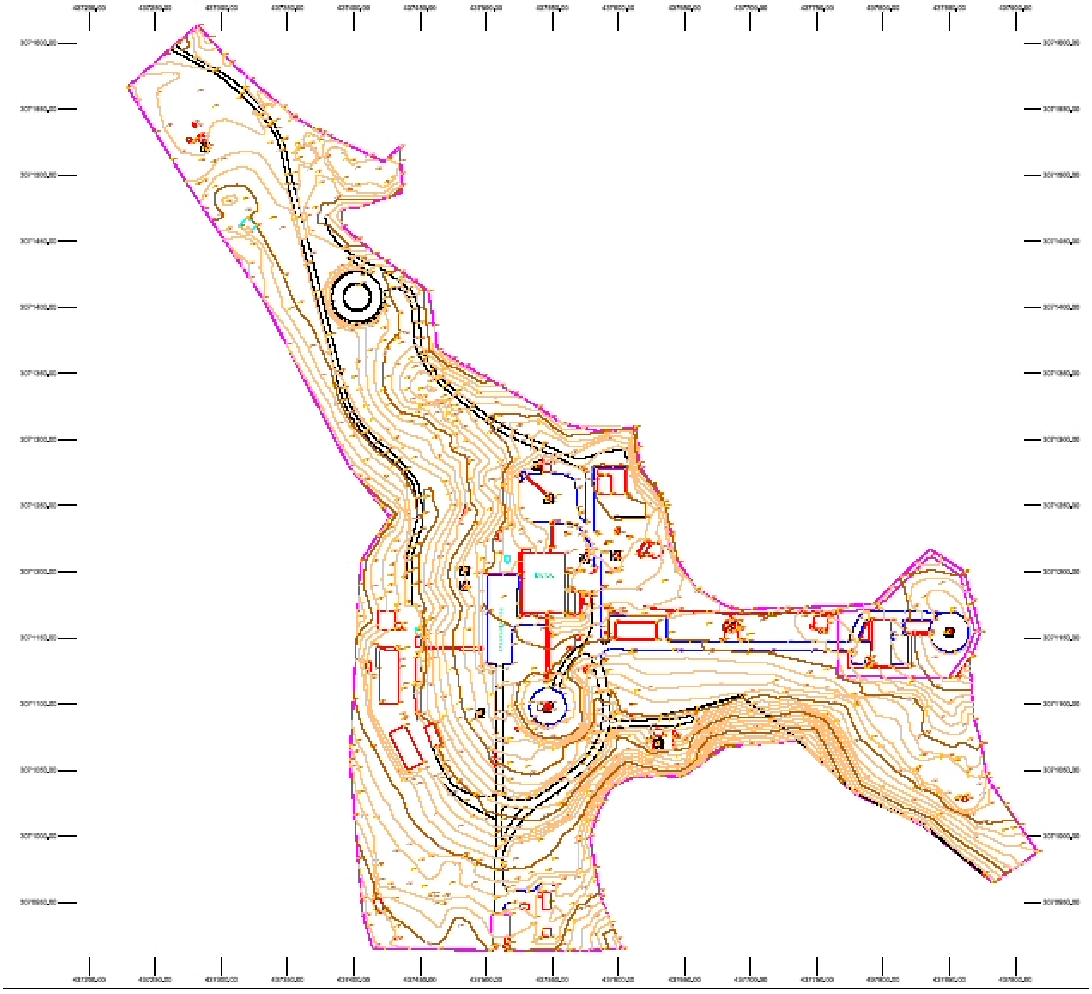

Figure 27: Maspalomas (MSP) Site Plan

6.4.2.1 Security

The site is fenced and guarded 24/7. An access control and surveillance system is installed.

6.4.2.2 Power

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, and a no-break (NB) power supply using Static Converters and Batteries. Via low voltage switches the electricity (3x 400V, 50 Hz) is distributed to the consumer groups.

Public power into the power plant is rendered by a 20 kV medium voltage line and two transformers of 1000 kVA. The public power can be replaced by an “old” Diesel Generator.

Two Diesel Generators supply each 425 kVA and a third Diesel Generator supplies 450 kVA within 15 seconds after public power failure. Three Static Converters supply each 80 kVA. The Battery capacity allows for a minimum bridging time of 6 hours depending on the load.

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, and a no-break (NB) power supply using Static Converters and Batteries. Via low voltage switches the electricity (3 x 400V, 50Hz) is distributed to the consumer groups.

Public power into the power plant is rendered by 20kV medium voltage line and two transformers of 1000 kVA. The public power can be replaced by an 'old 'Diesel Generator. Two Diesel Generators supply each 425 kVA and a third Diesel Generator supplies 450 kVA within 15 seconds after public power failure.

Three Static Converters supply each 80 kVA. The Battery capacity allows for a minimum bridging time of 6 hours depending on the load.

6.4.2.3 Air Conditioning

The station air conditioning system supplies air to the main building equipment rooms at a temperature of 20-22° C + 10%, with a controlled humidity of 50% - 70% relative humidity.

6.4.2.4 Communications

The Maspalomas station is connected via the ESA Operations Network (OPSNET) to ESOC using a 256 kbps international private leased circuits (IPLC) and an ISDN on-demand connectivity up to 384 kbps. The connectivity into the Maspalomas site is diversely routed through a prime and a backup fibre optic link.

All non-operational and Internet traffic is routed via the INTA Administrative Network.

6.4.3 MASPALOMAS-1 (MSP-1) TERMINAL

Figure 28 shows the Maspalomas-1 (MSP-1) antenna, which provides S-and X-band transmit, and S- and X-band receive capability (SX/SX).

Figure 28: Maspalomas-1 (MSP-1) Antenna

6.4.3.1 Services and Performance

The Maspalomas-1 (MSP-1) terminal provides the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Meteo, Autotrack Angles)

Table 7 details the Maspalomas-1 (MSP-1) Performance Characteristics. For the definition of individual characteristics see 1.7

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	MASPALOMAS-1 (S X / S X)	42	L-band RX band [MHz]	N/A
3	TERMINAL	MSP-1	43	L-band Polarization	N/A
4	Longitude	15 deg 38' 01.68" W	44	L-band G/T [dB/K]	N/A
5	Latitude	27 deg 45' 46.40" N	45	S-band RX band (MHz)	2200-2300
6	Altitude [m]	205.1177	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	15	47	S-band G/T [dB/K]	29.2
8	S-band Beamwidth [deg]	Rx: 0.60 Tx: 0.65	48	X-band RX band [MHz]	8025-8500
9	X-band Beamwidth [deg]	Rx: 0.16	49	X-band Polarization	RHC, LHC
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	37.5
11	Antenna Speed [deg/s]	Az: 15 deg/s El: 5 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	0 to 720	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	-1 to 181	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	Search / Acq aid (X)	54	Modulation Schemes	IFMS & CORTEX compliant
15	Tilt Facility	NO	55	Carrier Freq Search Range	+/- 1.5 MHz
16	Tracking Mode	Auto (S X) / Program	56	Subcarrier Frequency	1.2 kHz to 2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	80 mdeg	57	Data Rates	IFMS compliant: - 1.2 Mbps (RCD) - 2 Mbps (SCD LS) Cortex compliant: 256 Kbps (subcarrier) 40 Mbps (Direct PCM)
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP / X25 SLE (CORTEX) EIPD (TMP/TCE)
21	Comms Redundancy	YES	61	Rng/Dop Connectivity	FTP (IFMS / CORTEX)
22	Ranging	IFMS & CORTEX compliant	62	Meteo Connectivity	FTP (IFMS)
23	Doppler	YES	63	Angles Connectivity	IP via STC
24	Meteo	YES	64	Pointing Format	STDM
25	Autotrack Antenna Angles	YES	65	Tracking Interface (ESOC)	FDS
26	Delta-DOR	NO			
27	Radio-Science	NO			
28	Frequency & Timing	CESIUM			
29	UPLINK				
30	S-band TX band [MHz]	2025-2120			
31	S-band Polarization	RHC, LHC			
32	S-band EIRP [dBm]	102.1 (SLPA)			
33	X-band TX band [MHz]	7145-7235			
34	X-band Polarization	RHC, LHC			
35	X-band EIRP [dBm]	112.8			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	IFMS & CORTEX compliant			
40	Subcarrier Freq. [kHz]	8 or 16 kHz			

Table 7: Maspalomas-1 (MSP-1) Performance Characteristics

6.4.3.2 Antenna Horizon

Figure 29 shows the Maspalomas-1 (MSP-1) Antenna Horizon Mask.

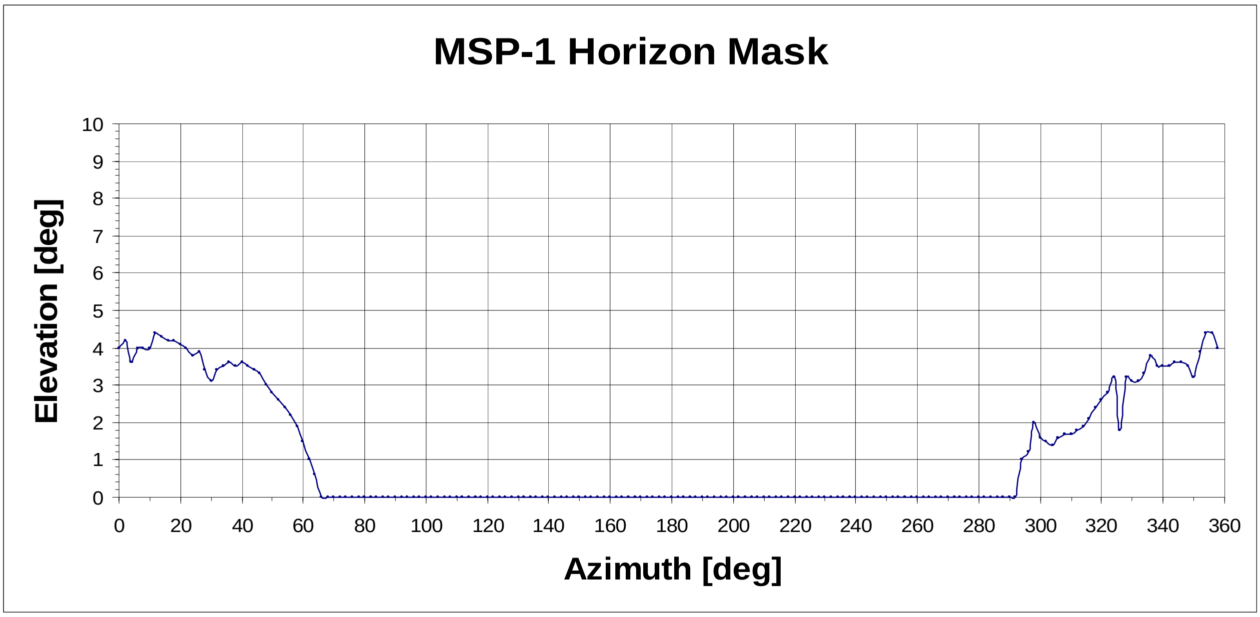

Figure 29: Maspalomas-1 (MSP-1) Antenna Horizon Mask

6.4.3.3 Functional Description

Figure 30 shows the Maspalomas-1 (MSP-1) Block Diagram, which is used for the functional description.

MSP- 1 simplified station diagram and interfaces

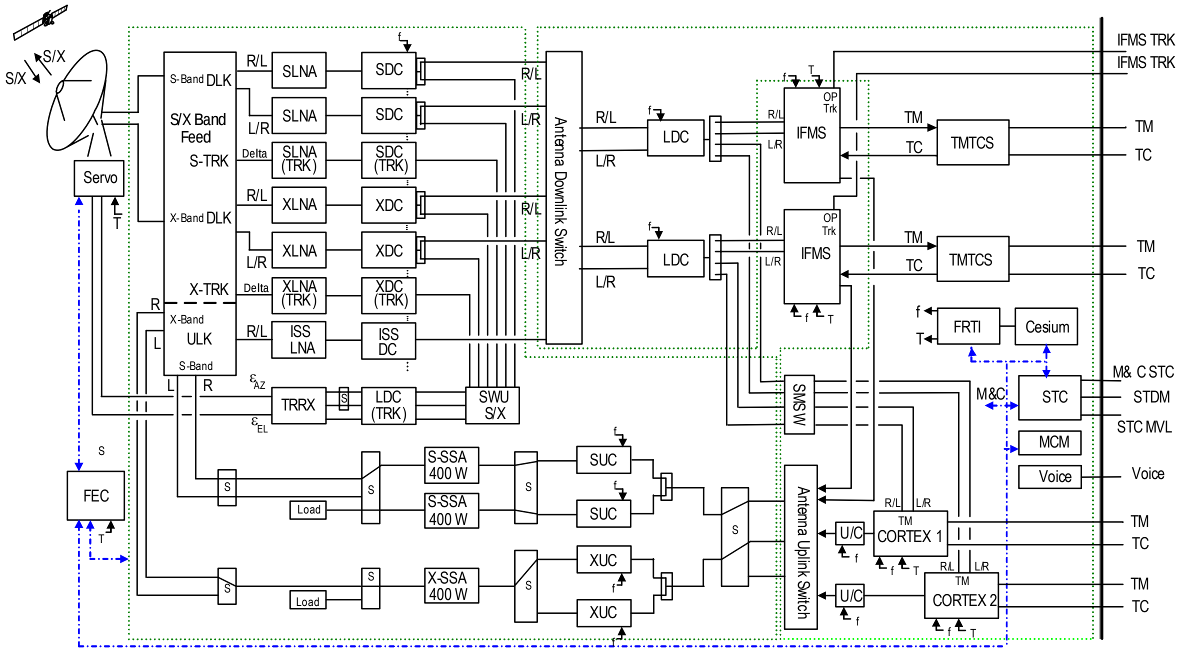

Figure 30: Maspalomas-1 (MSP-1) Block Diagram

6.4.3.3.1 Antenna

The S- and X-band transmit and S- and X-band receive (SX/SX) Cassegrain antenna is fitted with a shaped 15m parabolic main reflector and a shaped hyperbolic sub-reflector in an elevation over azimuth mount. Auto-tracking of the S- and X-band signals is possible by a two-channel monopulse tracking systems in each frequency band. An S- and X-band test antenna with reflective converter allows for signal delay calibration. An air-conditioning system outside the antenna tower provides cooling of the antenna tower and the Apex cabin.

The antenna pointing is performed by the Antenna Control Unit (ACU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation positions to the ACU.

The incoming electromagnetic wave is conveyed via the reflector and sub-reflector into the SX/SX feed, which together with its polarizer matches the free space field electromagnetic configuration to the waveguide modes. The combined SX/SX feed consists of an S-band corrugated horn with a dielectric rod inside for X-band. The coexisting receive and transmit signals for each polarization inside each feed are separated by Diplexer filters. The receive waveguide branches are fed to Low Noise Amplifiers (LNAs), which amplify the Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC) signals, which subsequently can be phase adjusted by Phase Shifters. The S-band signals [2200-2300 MHz] are down-converted to L-band [520-420 MHz]. The X-band signals [8400-8500 MHz] are down-converted to L-band [640-540 MHz]. The downlink signals are then transferred for tracking and telemetry processing.

The uplink signal coming from telecommand processing at 230 MHz is delivered to S-band or X-band transmission. It is converted by the S-band up-converter (SUC) to [2025-2120 MHZ] and delivered via a switch to the redundant S-band Solid State Amplifiers (SSSA); or by the X-band upconverter (XUC) for conversion to [7145-7235 MHZ] and via a switch to the X-band Solid State Amplifier (XSSA). Fine control of the radiated power is performed by adjustable external attenuators.

A transmit waveguide assembly routes the RF signal to the X-band feed or S-band feed. The transmitted polarization is selected with the polarization switch, which routes the RF signal to the uplink arm of one of the two Diplexers, one for each polarization and frequency band. To avoid radiating the RF power to the antenna, the RF signal can also be routed via a set of switches to a high power dummy load.

The MSP-1 antenna also has a reception capability in the S-band transmit band [2025-2120 MHz], which is used for special International Space Station (ISS) and Ariane Transfer Vehicle (ATV) docking validation purposes. It is comprised of a waveguide and switch assembly to feed the signal to an LNA, and frequency conversion equipment.

6.4.3.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or autotrack mode using the received signal.

For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Spacecraft Trajectory Data Messages (STDM's) or State Vectors in the Front End Controller (FEC). For autotrack the antenna Azimuth and Elevation pointing angles are derived from error signals proportional to the direction of highest electrical field strength received. These pointing angles are made available to the Front End Controller (FEC) for delivery for orbit determination purposes.

6.4.3.3.3 Telemetry

The downlink L-band signals are fed via the Antenna Downlink Switch (ADLS) into tuneable L-band down-converters for conversion to 70 MHz intermediate frequency (IF) and further signal routing through the 70 MHz switch (SMSW).
The 70 MHz signals are combined and demodulated in the Intermediate Frequency Modem System (IFMS), which provides remnant and suppressed carrier demodulation. Doppler predictions coming from Spacecraft Trajectory Data Messages (STDM) information improve the signal acquisition process. The Telemetry Channel Decoding System (TCDS) hosted inside the IFMS performs frame synchronisation, time tagging, Viterbi and Reed-Solomon decoding. The output data is transferred to the Telemetry and Telecommand System (TMTCS) for data structure processing according to Space Link Extension (SLE), which ultimately delivers the telemetry data via OPSNET to the Spacecraft Control Systems.
Alternatively the 70 MHz signals are delivered to the Cortex processing equipment, which integrates the above functions in a single unit, and delivers SLE conformant telemetry services.
The telemetry chains (IFMS and Cortex) are redundant and the various switches allow flexible signal routing.

6.4.3.3.4 Telecommand

The Telemetry and Telecommand System (TMTCS) receives SLE conformant Telecommand data via OPSNET from the Spacecraft Control Systems. It provides telecommand data and clock to the Intermediate Frequency Modem System (IFMS) Uplink Modulator (ULM), which provides the Phase Shift Key (PSK) modulation of the telecommand bit stream onto a sub-carrier, which is then used to phase modulate the uplink carrier at 230 MHz. Via the Antenna Uplink Switch (AULS) the uplink signal is routed either to the S- or X-band antenna uplink. Alternatively the uplink can be generated from the Cortex processing equipment.
The telecommand chains are redundant and the various switches allow flexible signal routing.

6.4.3.3.5 Radiometric

The radiometric measurements comprise Doppler, Ranging, Meteorological and autotrack Pointing measurements.
The Intermediate Frequency Modem System (IFMS) Ranging and Telemetry Demodulators deliver integrated Doppler measurements of the received carrier phase, known as Doppler-1 and Doppler-2.
The IFMS Uplink Modulator generates the ranging tone, which is Phase-Shift-Key (PSK) modulated by a sequence of codes. This ranging tone is phase modulated on the uplink carrier and can be transmitted simultaneously with the telecommand subcarrier. The IFMS Ranging Demodulator pre-steers the expected downlink carrier in case of coherent transponding of the spacecraft based on Spacecraft Trajectory Data Messages (STDMs), demodulates the received tone and compares the received codes with codes replica to derive the two-way propagation delay.
The IFMS meteorological unit gathers outside air temperature, pressure and humidity.

Alternatively the Doppler and Ranging measurements can be provided by the Cortex processing equipment.
The Antenna Control Unit delivers the actually pointed antenna Azimuth and Elevation angles during autotrack of the received carrier signal.
All radiometric measurement data are delivered through OPSNET to Flight Dynamics for processing.

6.4.3.3.6 Monitoring and Control

The monitoring and control (M&C) system allows full local and remote control over the terminal. It is based on a hierarchy of M&C systems: the Station Computer (STC), the Front End Controller (FEC), the Monitoring and Control Module (MCM) and Local Man Machine Interfaces (MMI) on the various devices.
The Station Computer (STC) is composed of a local server, a local workstation and a remote workstation housed in the ESTRACK Control Centre (ECC). Mission specific terminal configurations are normally affected through pre-validated macro-procedures, also individual equipment configurations are possible. The STC interacts through a set of subsystem controllers, either in separate units or implemented in complex devices (e.g. IFMS/TMTCS), with all the terminal equipment. Remote spectrum visualisation is supported.
The Front End Controller (FEC) is the subsystem controller for all the antenna front end devices and responsible for antenna steering.
The Monitoring and Control Module (MCM) is the subsystem controller for all simple back end devices, e.g. switches.
In case of failure of the monitoring and control system, the terminal can be locally operated from the individual equipment Local Man Machine Interfaces.

6.4.3.3.7 Frequency and Timing

The frequency reference generation is based on a Caesium Beam Tube with appropriate long term frequency stability. The frequency distribution system coherently derives 5, 10 and 100 MHz signals and amplifies them for distribution to the devices.
The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 5 MHz, 1 kHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

6.4.3.3.8 Test and Calibration

The objective of the test and calibration function is to validate the telemetry and telecommand functions, and to calibrate the Ranging and Doppler function before the operational satellite pass.
The telemetry function is tested with simulated spacecraft telemetry, which is generated in the Portable Satellite Simulator (PSS), frequency converted to the appropriate downlink frequency and injected into the antenna via a test antenna, so called Telemetry Test Long Loop (TTLL) configuration. The telemetry is then delivered in a Data Flow Test (DFT) to the spacecraft control system for verification.
The telecommand function is tested by demodulating and decoding of the 230 MHz uplink signal and comparing it to known telecommand formats. Based on the telecommand received in the PSS

the simulated telemetry generation can be altered. The test telecommands originate from the spacecraft control system.

The ranging and doppler function is calibrated by conducting a ranging and doppler measurement in an antenna loopback configuration, in which the uplink frequency is transponded to the downlink frequency. The emulated transponding involves reception of the uplink frequency by the test antenna and conversion to the downlink frequency in the Reflective Converter (RFLC) with subsequent transmission via the test antenna back into the main antenna. This calibration measures the station internal signal delay and any frequency offset.

For phase calibration of the tracking channels, a remote operable, far field calibration tower for S- & X-Band is available, which is located 22 km north of the station.

Test tools for integration and performance validation activities are not described.

6.4.4 ADDITIONAL FACILITIES

6.4.4.1 GPS – TDAF

A Global Positioning System (GPS) dual-frequency receiver system with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

6.4.5 PLANNED DEVELOPMENTS

The 15 m antenna (MSP-1) can be co-utilized by INTA.

It is planned to integrate an X-Band Acquisition Aid (XAA) antenna.

6.5 New Norcia (NNO) Station

Figure 31 shows the New Norcia (NNO) Arial View.

Figure 31: New Norcia (NNO) Aerial View

6.5.1 GENERAL INFORMATION

The New Norcia site is owned by ESA.

6.5.1.1 Location

The New Norcia site is located 140 kilometres north of Perth in Western Australia, see Figure 32.. It occupies an area of 170 m x 190 m.

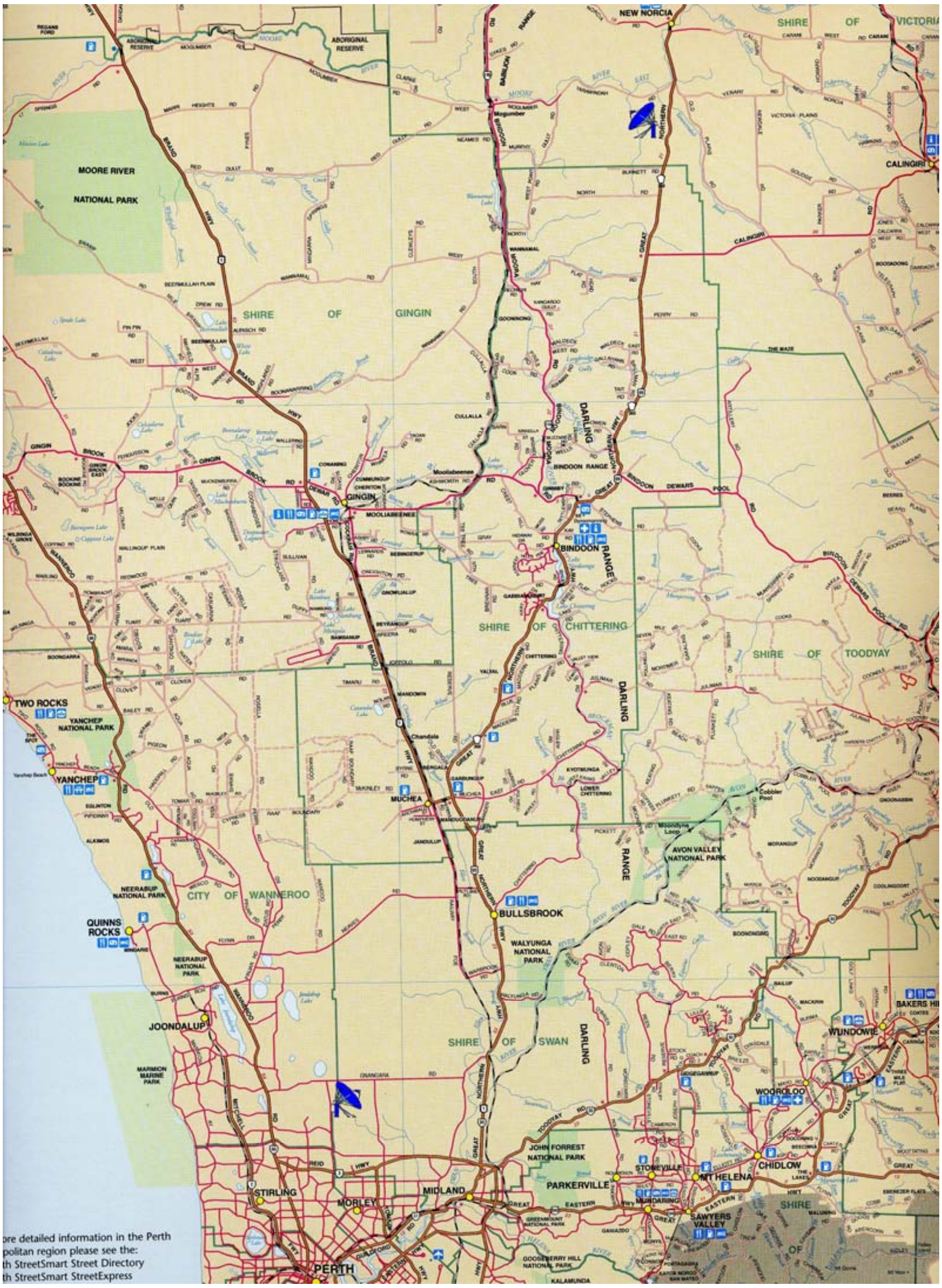

Figure 32: New Norcia (NNO) Area Map

6.5.1.2 Access

Site visits require a confirmed Station Intervention form sheet.
Perth has an international airport. The New Norcia site is located on the Great Northern Highway. The exit to the access road of the site is signposted.
Accommodation can be arranged through the station manager.

6.5.1.3 Entry Requirements

Visitors from overseas require a current passport and an entry visa for Australia.

6.5.1.4 Climate

A summary of the weather characteristics for the New Norcia area is given below:

Warmest month	February
Average maximum daily temperature in February	29.9° C
Highest recorded temperature in February	44.6° C
Lowest recorded temperature in February	8.7° C
Coldest month	July
Average minimum daily temperature for July	9.0° C
Highest recorded temperature in July	24.7° C
Lowest recorded temperature in July	1.2° C
Average annual rainfall	893 mm

6.5.1.5 Management

There is no ESA on-site representative at the New Norcia site.
The Maintenance and Operations (M&O) of the site is provided by Stratos.

6.5.1.6 Local Contact

The local point of contact for the New Norcia station is:

New Norcia Station Manager
Mr. John Holt
email: John.Holt@stratosglobal.com
Tel +61-8-93020-400
Fax +61-8-9321 5526

6.5.1.7 Logistics

Postal delivery is via Xantic at the Perth International Telecommunications Centre. The postal address is:

Xantic BV
Perth International Telecommunications Centre
PO Box 1115
Wangara
W.A. 6065
Australia

Delivery is via Xantic at the Perth International Telecommunications Centre. The delivery address is:

Xantic BV
Perth International Telecommunications Centre
ESA Operations New Norcia
620 Gnangara Road
Wangara
W.A. 6065
Australia

The postal address of the Customs Manager is:

Global Transport Logistics
Attn Mr Peter Thornett
73 North Lake Road
Myaree 6154
Western Australia
Phone +61 8 9333 5000
Fax +61 8 9333 5050
email: peter@globaltransport.com.au

6.5.2 STATION SERVICES

Figure 33 shows the New Norcia (NNO) Site Plan.

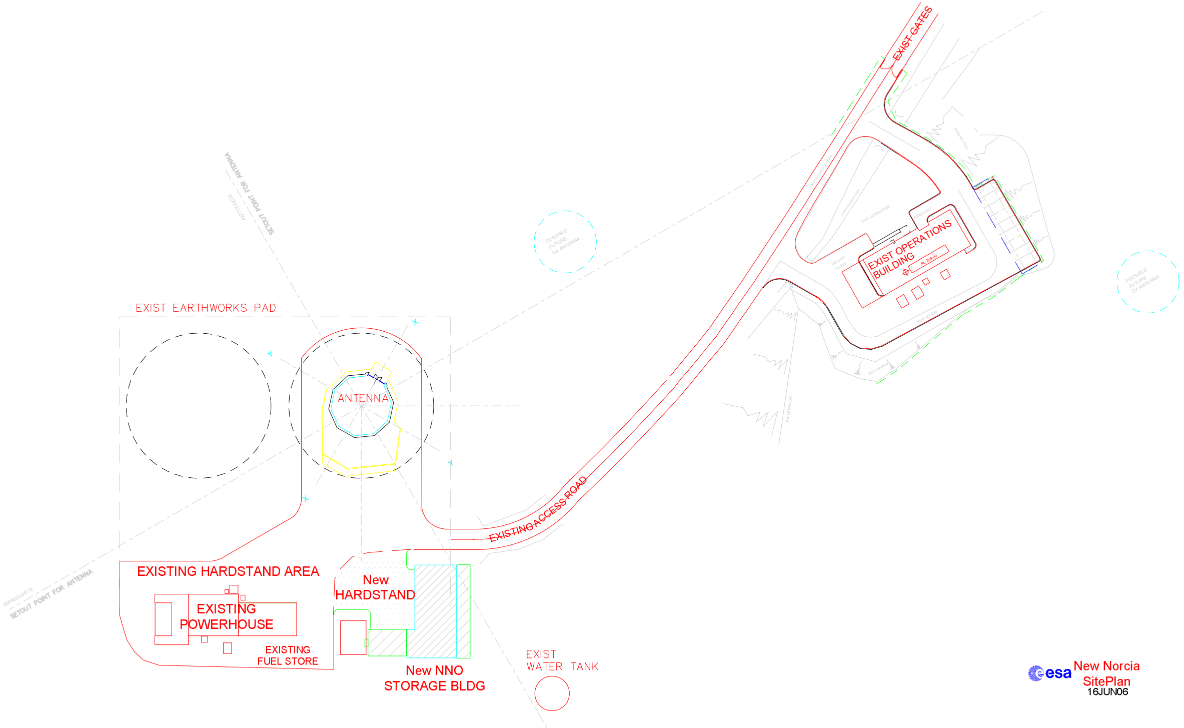

Figure 33: New Norcia (NNO) Site Plan

6.5.2.1 Security

The site is fenced and guarded 24/7. An access control and surveillance system is installed.

6.5.2.2 Power

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, and a no-break (NB) power supply using Static Converters and Batteries. Via low voltage switches the electricity (3x 400V, 50 Hz) is distributed to the consumer groups.

Public power into the power plant is rendered by one 33 kV medium voltage line and two transformers of 500 kVA.

Two Diesel Generators supply each 400 kVA within 1-2 minutes after public power failure. Two Static Converters supply each 300 kVA. The Battery capacity allows for a maximum bridging time of 6 minutes.

6.5.2.3 Air Conditioning

The station air conditioning system supplies air to the main building equipment rooms at a temperature of 24°C + 10%, with a controlled humidity of 50% - 70% relative humidity.

6.5.2.4 Communications

The New Norcia station is connected via the ESA Operations Network (OPSNET) in a triangular setup (New Norcia, Perth, ESOC) using 2 Mbps international private leased circuits (IPLCs). The connectivity into the New Norcia site is diversely routed through two fibre optic links.
All non-operational and Internet traffic is routed via the Xantic Administrative Network.

6.5.3 NEW NORCIA-1 (NNO-1) TERMINAL

Figure 34 shows the New Norcia-1 (NNO-1) antenna, which provides S- and X-band transmit, as well as S- and X-band receive capability (SX/SX).

Figure 34: New Norcia-1 (NNO-1) Antenna

6.5.3.1 Services and Performance

The New Norcia-1 (NNO-1) terminal provides the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Meteo, Delta-DOR)
- Radio Science

Table 8 details the New Norcia-1 (NNO-1) Performance Characteristics. For the definition of individual characteristics see 5.6

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	NEW NORCIA-1 (S X / S X)	42	L-band RX band [MHz]	N/A
3	TERMINAL	NNO-1	43	L-band Polarization	N/A
4	Longitude	116 deg 11' 29.40" E	44	L-band G/T [dB/K]	N/A
5	Latitude	31 deg 02' 53.61" S	45	S-band RX band (MHz)	2200-2300
6	Altitude [m]	252.2558	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	35	47	S-band G/T [dB/K]	37.5
8	S-band Beamwidth [deg]	Rx: 0.28 Tx: 0.30	48	X-band RX band [MHz]	8400 - 8500
9	X-band Beamwidth [deg]	Rx: 0.064 Tx: 0.074	49	X-band Polarization	RHC, LHC
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	50.1
11	Antenna Speed [deg/s]	Az: 0.4 deg/s El: 0.4 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	0 to 480	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	0 to 90	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	Perth Steering	54	Modulation Schemes	IFMS compliant
15	Tilt Facility	NO	55	Carrier Freq Search Range	+/- 1.5 MHz
16	Tracking Mode	Program / Slave	56	Subcarrier Frequency	2 kHz to 1.2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	N/A	57	Data Rates	IFMS compliant: - 1.2 Mbps (RCD) - 2 Mbps (SCD LS)
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP SLE (TMTCS)
21	Comms Redundancy	YES	61	Rng/Dop Connectivity	FTP (IFMS)
22	Ranging	IFMS compliant	62	Meteo Connectivity	FTP (IFMS)
23	Doppler	YES	63	Angles Connectivity	N/A
24	Meteo	YES	64	Pointing Format	STDM
25	Autotrack Antenna Angles	NO	65	Tracking Interface (ESOC)	FDS
26	Delta-DOR	YES			
27	Radio-Science	YES			
28	Frequency & Timing	MASER			
29	UPLINK				
30	S-band TX band [MHz]	2025-2120			
31	S-band Polarization	RHC, LHC			
32	S-band EIRP [dBm]	127 (SHPA) 117 (SLPA)			
33	X-band TX band [MHz]	7145 - 7235			
34	X-band Polarization	RHC, LHC			
35	X-band EIRP [dBm]	137 (XHPA) 127 (XLPA)			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			

39	Modulation Schemes	IFMS compliant			
40	Subcarrier Freq. [kHz]	8 or 16 kHz			

Table 8: New Norcia-1 (NNO-1) Performance Characteristics

6.5.3.2 *Antenna Horizon*

Figure 35 shows the New Norcia-1 (NNO-1) Antenna Horizon Mask.

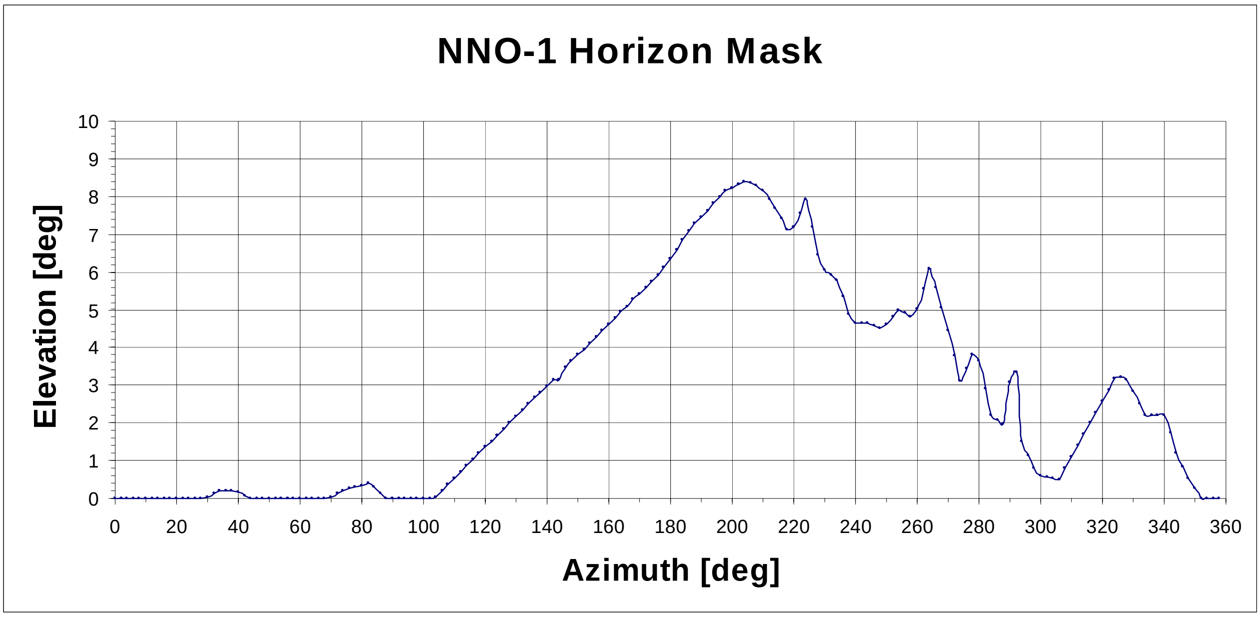

Figure 35: New Norcia-1 (NNO-1) Antenna Horizon Mask

6.5.3.3 *Functional Description*

Figure 36 shows the New Norcia-1 (NNO-1) Block Diagram, which is used for the functional description.

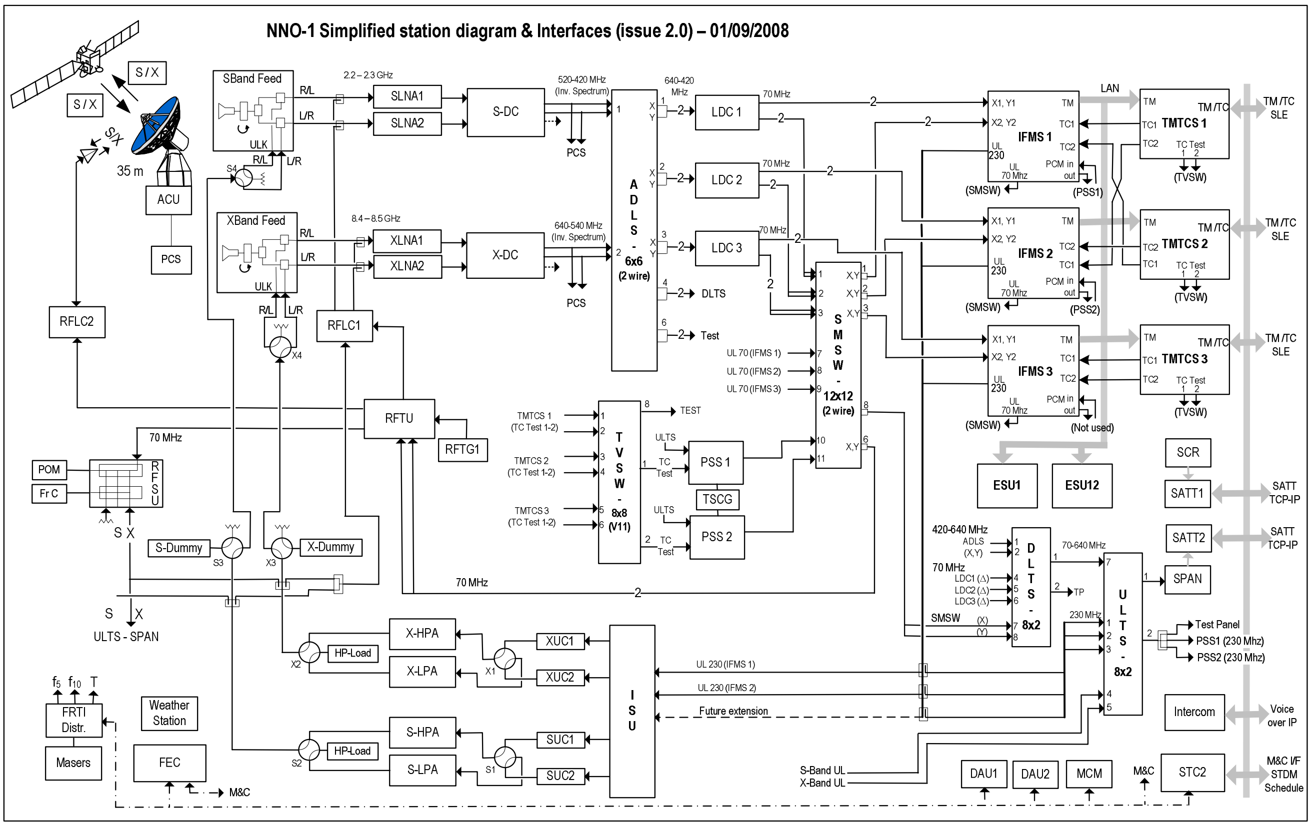

Figure 36: New Norcia-1 (NNO-1) Block Diagram

6.5.3.3.1 Antenna

The S- and X-band transmit and S- and X-band receive (SX/SX) Cassegrain Beam Wave Guide antenna is fitted with a shaped 35m parabolic main reflector and a shaped hyperbolic subreflector in an elevation over azimuth mount. Auto-tracking of S- and X-band signals is not possible. An S- and X-band test antenna with reflective converter allows for signal delay calibration. An air-conditioning system outside the antenna tower provides cooling of the antenna tower.

The antenna pointing is performed by the Antenna Control Unit (ACU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation positions to the ACU.

The incoming electromagnetic wave is conveyed via the reflector, subreflector and beam waveguide system to a frequency sensitive dichroic mirror, that splits the S-Band and the X-Band signals, to the respective feeds, which together with their polarizer matches the free space field electromagnetic configuration to the waveguide modes.

The coexisting receive and transmit signals for each polarisation inside each feed are separated by Diplexer filters. The receive waveguide branches are fed to cryogenically cooled Low Noise Amplifiers (LNAs), which amplify the Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC) signals, which subsequently can be phase adjusted by Phase Shifters.

The S-band signals [2200-2300 MHz] are down-converted to L-band [520-420 MHz]. The X-band signals [8400-8500 MHz] are down-converted to L-band [640-540 MHz]. The downlink signals are then transferred for telemetry processing.

The uplink signal coming from telecommand processing at 230 MHz is delivered to S-band or X-band transmission. It is routed either to the S-band Up-Converter (SUC) for conversion to [2025 - 2120 MHZ] and via a switch to the S-band High Power Amplifier (SHPA) or S-band Low Power Amplifier (SLPA); or to the X-band Up-Converter (XUC) for conversion to [7145 - 7235 MHZ] and via a switch to the X-band High Power Amplifier (XHPA) or X-band Low Power Amplifier (XLPA)

A transmit waveguide assembly routes the RF signal to the X-band feed or S-band. The transmitted polarisation is selected with the polarization switch, which routes the RF signal to the uplink arm of one of the two Diplexers, one for each polarisation and frequency band. To avoid radiating the RF power to the antenna, the RF signal can also be routed via a set of switches to one of the two high power dummy loads.

The X-Band Feed or S-band Feed (including polarizer) matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from one of the two Diplexers. The Beam Wave Guide (BWG) system conveys the high power RF flux from the X-Band and S-Band feeds to the antenna sub-reflector and Main reflector where it is forwarded to free space.

Concurrent radiation in X-band and S-band is possible.

6.5.3.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or slaving the antenna to PER-1 in autotrack mode using the same received signal.

For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Spacecraft Trajectory Data Messages (STDM's) or State Vectors in the Front End Controller (FEC). Autotrack is achieved by slaving the antenna to the PER-1 antenna.

6.5.3.3.3 Telemetry

The downlink L-band signals are fed via the Antenna Downlink Switch (ADLS) into tuneable L-band down-converters for conversion to 70 MHz intermediate frequency (IF) and further signal routing through the 70 MHz switch (SMSW).

The 70 MHz signals are combined and demodulated in the Intermediate Frequency Modem System (IFMS), which provides remnant and suppressed carrier demodulation. Doppler predictions coming from Spacecraft Trajectory Data Messages (STDM) information improve the signal acquisition process. The Telemetry Channel Decoding System (TCDS) hosted inside the IFMS performs frame synchronisation, time tagging, Viterbi and Reed-Solomon decoding. The output data is transferred to the Telemetry and Telecommand System (TMTCS) for data structure processing according to Space Link Extension (SLE), which ultimately delivers the telemetry data via OPSNET to the Spacecraft Control Systems.

All three telemetry chains are redundant and the various switches allow flexible signal routing.

6.5.3.3.4 Telecommand

The Telemetry and Telecommand System (TMTCS) receives SLE conformant Telecommand data via OPSNET from the Spacecraft Control Systems. It provides telecommand data and clock to the Intermediate Frequency Modem System (IFMS) Uplink Modulator (ULM), which provides the Phase Shift Key (PSK) modulation of the telecommand bit stream onto a sub-carrier, which is then used to phase modulate the uplink carrier at 230 MHz. Via the Antenna Uplink Switch (AULS) the uplink signal is routed either to the S band or X-band antenna uplink.

The telecommand chains are redundant and the various switches allow flexible signal routing.

6.5.3.3.5 Radiometric

The radiometric measurements comprise Doppler, Ranging, Meteorological, Delta Differential One-way Range (Delta-DOR) and Radio Science measurements.

The station design is such that any of the three downlink chains can be used for Telemetry reception and for radiometric measurement including Delta-DOR and Radio Science Investigation (RSI).

The Intermediate Frequency Modem System (IFMS) Ranging and Telemetry Demodulators deliver integrated Doppler measurement of the received carrier phase, known as Doppler-1 and Doppler-2.

The IFMS Uplink Modulator generates the ranging tone, which is Phase-Shift-Key (PSK) modulated by a sequence of codes. This ranging tone is phase modulated on the uplink carrier and can be transmitted simultaneously with the telecommand subcarrier. The IFMS Ranging Demodulator pre-steers the expected downlink carrier in case of coherent transponding of the spacecraft based on Spacecraft Trajectory Data Messages (STDMs), demodulates the received tone and compares the received codes with codes replica to derive the two-way propagation delay.

The IFMS meteorological unit gathers outside air temperature, pressure, humidity, wind force and direction information.

All radiometric measurement data are delivered through OPSNET to Flight Dynamics for processing.

For Delta-DOR, the IFMS records spectra for further processing in a correlator to derive the phase of the received satellite electromagnetic wave with respect to the same reception at a another location on earth. Angular calibration of the signal is achieved by measuring known radio sources, e.g. quasars, before and after the satellite measurement. Due to the amount of data collected, the DDOR samples are stored in the External Storage Units (ESU). Two redundant ESU are available, allowing DDOR to be performed from any two of the three redundant downlink chains.

For Radio Science Investigations the IFMS records spectra, doppler and AGC measurements of the received S- and X-band downlinks. In addition dual frequency ranging can be performed, i.e. one uplink X-band signal containing the ranging code is coherently transponded on-board to an X-band and S-band downlink signal, which are received simultaneously by two IFMS Ranging Demodulators, which both use the same codes replica. The frequency dependent downlink propagation delay can be measured in this way.

All Radio Science measurements are delivered through OPSNET to the Science Community for processing.

6.5.3.3.6 Monitoring and Control

The monitoring and control (M&C) system allows full local and remote control over the terminal. It is based on a hierarchy of M&C systems: the Station Computer (STC), the Front End Controller (FEC), the Monitoring and Control Module (MCM) and Local Man Machine Interfaces (MMI) on the various devices.

The Station Computer (STC) is composed of a local server, a local workstation and a remote workstation housed in the Ground Facilities Control Centre (GFCC). Mission specific terminal configurations are normally affected through pre-validated macro-procedures, also individual equipment configurations are possible. The STC interacts through a set of subsystem controllers, either in separate units or implemented in complex devices (e.g. IFMS/TMTCS), with all the terminal equipment. Remote spectrum visualisation is supported.

The Front End Controller (FEC) is the subsystem controller for all the antenna front end devices and responsible for antenna steering.

The Monitoring and Control Module (MCM) is the subsystem controller for all simple back end devices, e.g. switches.

In case of failure of the monitoring and control system, the terminal can be locally operated from the individual equipment Local Man Machine Interfaces.

6.5.3.3.7 Frequency and Timing

The frequency reference generation is based on a Hydrogen Maser with very long term frequency stability. The frequency distribution system coherently derives 5, 10 and 100 MHz signals and amplifies them for distribution to the devices.

The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 5 MHz, 1 kHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

6.5.3.3.8 Test and Calibration

The objective of the test and calibration function is to validate the telemetry and telecommand functions, and to calibrate the Ranging and Doppler function before the operational satellite pass.

The telemetry function is tested with simulated spacecraft telemetry, which is generated in the Portable Satellite Simulator (PSS), frequency converted to the appropriate downlink frequency and injected into the antenna via a test antenna, so called Telemetry Test Long Loop (TTLL) configuration. The telemetry is then delivered in a Data Flow Test (DFT) to the spacecraft control system for verification.

The telecommand function is tested by demodulating and decoding of the 230 MHz uplink signal and comparing it to known telecommand formats. Based on the telecommand received in the PSS the simulated telemetry generation can be altered. The test telecommands originate from the spacecraft control system.

The ranging and doppler function is calibrated by conducting a ranging and doppler measurement in an antenna loopback configuration, in which the uplink frequency is transponded to the downlink frequency. The emulated transponding involves reception of the uplink frequency by the test antenna and conversion to the downlink frequency in the Reflective Converter (RFLC) with

subsequent transmission via the test antenna back into the main antenna. This calibration measures the station internal signal delay and any frequency offset.
For alignment of the antenna mechanical axis, an optical target is available.
Test tools for integration and performance validation activities are not described.

6.5.4 ADDITIONAL FACILITIES

6.5.4.1 GPS-TDAF

A Global Positioning System (GPS) dual-frequency receiver system with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

6.5.4.2 GESS

A Galileo Experimental Sensor Station with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

6.5.5 PLANNED DEVELOPMENTS

It is planned to upgrade the NNO-1 terminal with Ka-band receive capability for support of the Bepi-Colombo mission.

6.6 Perth (PER) Station

Figure 37 shows the Perth (PER) Aerial View.

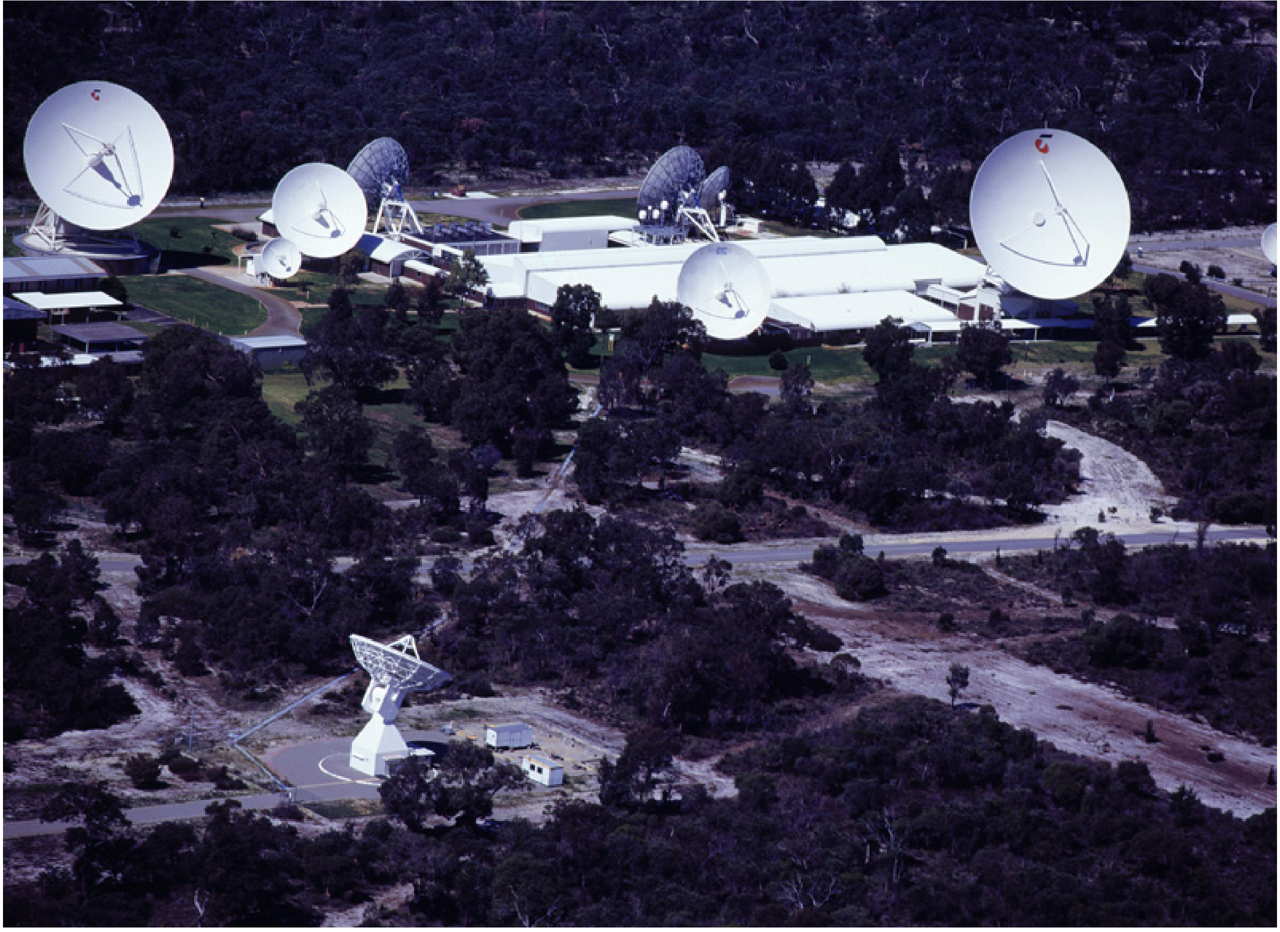

Figure 37: Perth (PER) Aerial View

6.6.1 GENERAL INFORMATION

The Perth site is owned by Telstra.

6.6.1.1 Location

The Perth site, known as the Perth International Telecommunications Centre (PITC), is located 20 km north of the city centre of Perth in Western Australia.

Figure 38: Perth (PER) Area Map

6.6.1.2 Access

Site visits require a confirmed Station Intervention form sheet.

Perth has an international airport. The PITC site is about 25 km north of the airport. The road route to the station is north on the Tonkin Highway, left onto Morley Drive, right on to Alexander Drive and then right to Gnangara Road.

Accommodation can be arranged through the station manager.

6.6.1.3 Entry Requirements

Visitors from overseas require a current passport and an entry visa for Australia.

6.6.1.4 Climate

Perth has temperate with average maximum/minimum temperatures. A summary of the weather characteristics for the Perth area is given below:

Warmest month	February
Average daily maximum temperature for February	29.9° C
Highest recorded temperature in February	44.6° C
Lowest recorded temperature in February	8.7° C
Coldest month	July
Average daily minimum temperature for July	9.0° C
Highest recorded temperature in July	24.7° C
Lowest recorded temperature in July	1.2° C
Average annual rainfall	893mm

6.6.1.5 Management

There is no ESA on-site representative at the Perth site.
The Maintenance and Operations (M&O) of the ESA terminal is provided by Stratos.

6.6.1.6 Local Contact

The local point of contact for the Perth station is:

Perth Station Manager
Mr. John Holt
email: John.Holt@stratosglobal.com
Tel +61-8-93020-400
Fax +61-8-9321 5526

6.6.1.7 Logistics

The postal address is:

Xantic BV
Perth International Telecommunications Centre
PO Box 1115
Wangara
W.A. 6065
Australia

The delivery address is:

Xantic BV
Perth International Telecommunications Centre
ESA Operations Perth
620 Gnangara Road
Wangara
W.A. 6065
Australia

The postal address of the Customs Manager is:

Global Transport Logistics
Attn Mr Peter Thornett
73 North Lake Road
Myaree 6154
Western Australia
Phone +61 8 9333 5000
Fax +61 8 9333 5050
email: peter@globaltransport.com.au

6.6.2 STATION SERVICES

Figure 39 shows the Perth (PER) Site Plan.

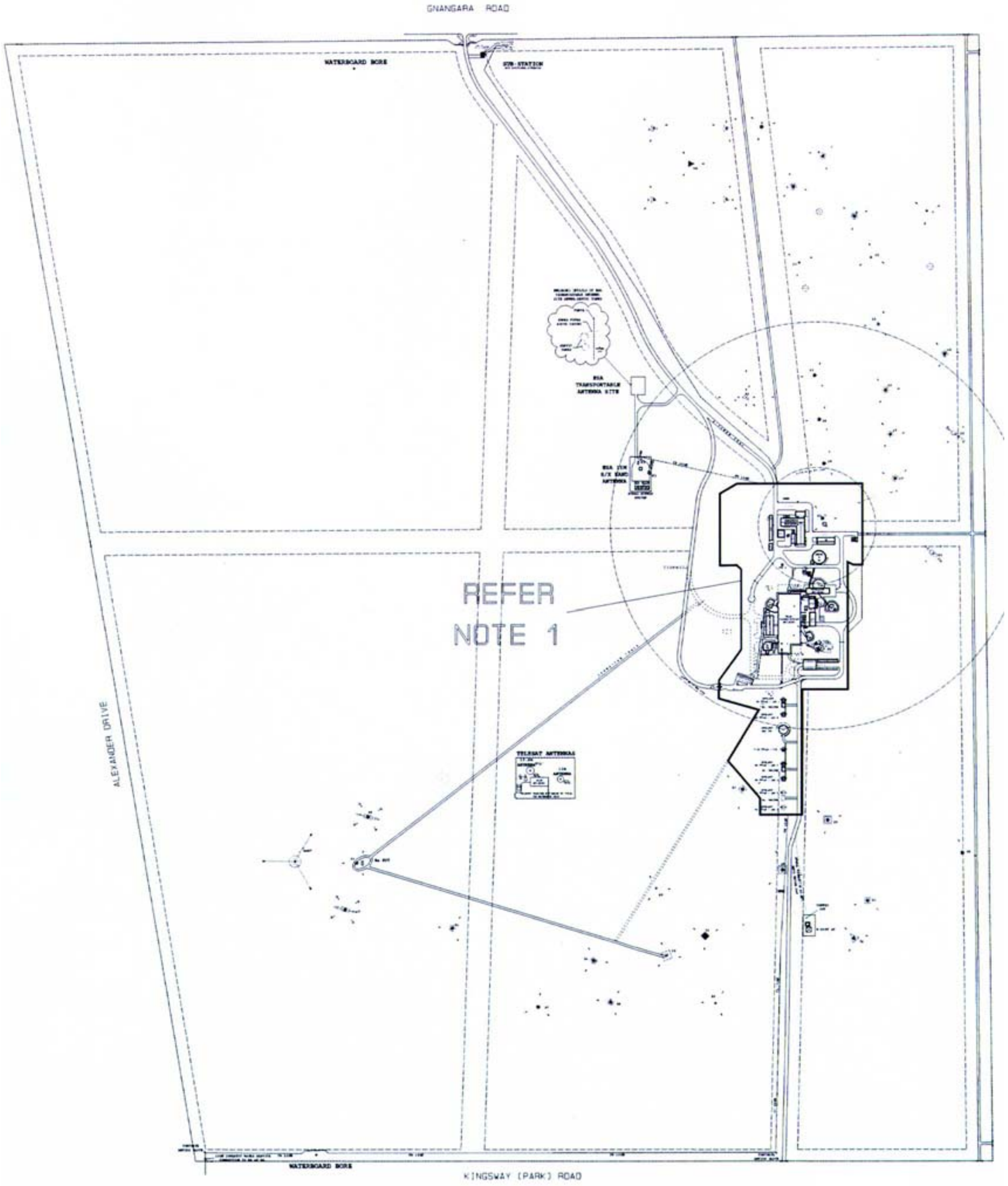

Figure 39: Perth (PER) Site Plan

6.6.2.1 Security

The site is fenced and guarded 24/7. An access control and surveillance system is installed.

6.6.2.2 Power

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, and a no-break (NB) power supply using Static Converters and Batteries. Via low voltage switches the electricity (3x 400V, 50 Hz) is distributed to the consumer groups.
Public power into the power plant is rendered by two diversely routed 20 kV medium voltage line and two transformers of 1000 kVA.
Two Diesel Generators supply each 1000 kVA within 15 seconds after public power failure. Three Static Converters supply each 150 kVA. The Battery capacity allows for a maximum bridging time of 10 minutes.

6.6.2.3 Air Conditioning

The station air conditioning system supplies air to the main building equipment rooms at a temperature of 20°C + 10%, with a controlled humidity of 50% - 70% relative humidity.

6.6.2.4 Communications

The Perth station is connected via the ESA Operations Network (OPSNET) in a triangular setup (New Norcia, Perth, ESOC) using 2 Mbps international private leased circuits (IPLCs). The connectivity into the PITC site is diversely routed through two fibre optic links.
All non-operational and Internet traffic is routed via the Xantic Administrative Network.

6.6.3 PERTH-1 (PER-1) TERMINAL

Figure 40 shows the Perth-1 (PER-1) antenna, which provides S- and X-band transmit, as well as S- and X-band receive capability (SX/SX).

Figure 40: Perth-1 (PER-1) Antenna

6.6.3.1 Services and Performance

The Perth-1 (PER-1) terminal provides the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Meteo, Autotrack Angles)

Table 9 details the Perth-1 (PER-1) Performance Characteristics. For the definition of individual characteristics see 5.6

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	PERTH-1 (S X / S X)	42	L-band RX band [MHz]	N/A
3	TERMINAL	PER-1	43	L-band Polarization	N/A
4	Longitude	115 deg 53' 06.58" E	44	L-band G/T [dB/K]	N/A
5	Latitude	31 deg 48' 09.08" S	45	S-band RX band (MHz)	2200-2300
6	Altitude [m]	22.1631	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	15	47	S-band G/T [dB/K]	27.5
8	S-band Beamwidth [deg]	Rx: 0.60 Tx: 0.65	48	X-band RX band [MHz]	8025-8500
9	X-band Beamwidth [deg]	Rx: 0.16	49	X-band Polarization	RHC, LHC
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	37.5
11	Antenna Speed [deg/s]	Az: 15 deg/s El: 5 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	0 to 720	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	-1 to 181	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	Search / Acq aid (X)	54	Modulation Schemes	IFMS & CORTEX compliant
15	Tilt Facility	NO	55	Carrier Freq Search Range	+/- 1.5 MHz
16	Tracking Mode	Auto (S X) / Program	56	Subcarrier Frequency	1.2 kHz to 2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	80 mdeg	57	Data Rates	IFMS compliant: - 1.2 Mbps (RCD) - 2 Mbps (SCD LS)
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP SLE (TMTCS)
21	Comms Redundancy	YES	61	Rng/Dop Connectivity	FTP (IFMS / CORTEX)
22	Ranging	IFMS & CORTEX compliant	62	Meteo Connectivity	FTP (IFMS)
23	Doppler	YES	63	Angles Connectivity	IP via STC
24	Meteo	YES	64	Pointing Format	STDM
25	Autotrack Antenna Angles	YES	65	Tracking Interface (ESOC)	FDS
26	Delta-DOR	NO			
27	Radio-Science	NO			
28	Frequency & Timing	CESIUM / RUBIDIUM			
29	UPLINK				
30	S-band TX band [MHz]	2025-2120			
31	S-band Polarization	RHC, LHC			
32	S-band EIRP [dBm]	102 (S-SSA), 108 (SHPA)			
33	X-band TX band [MHz]	7145-7235			
34	X-band Polarization	RHC, LHC			
35	X-band EIRP [dBm]	112.8			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	IFMS & CORTEX compliant			

40	Subcarrier Freq. [kHz]	8 or 16 kHz			

Table 9: Perth-1 (PER-1) Performance Characteristics

6.6.3.2 *Antenna Horizon*

Figure 41 shows the Perth-1 (PER-1) Antenna Horizon Mask.

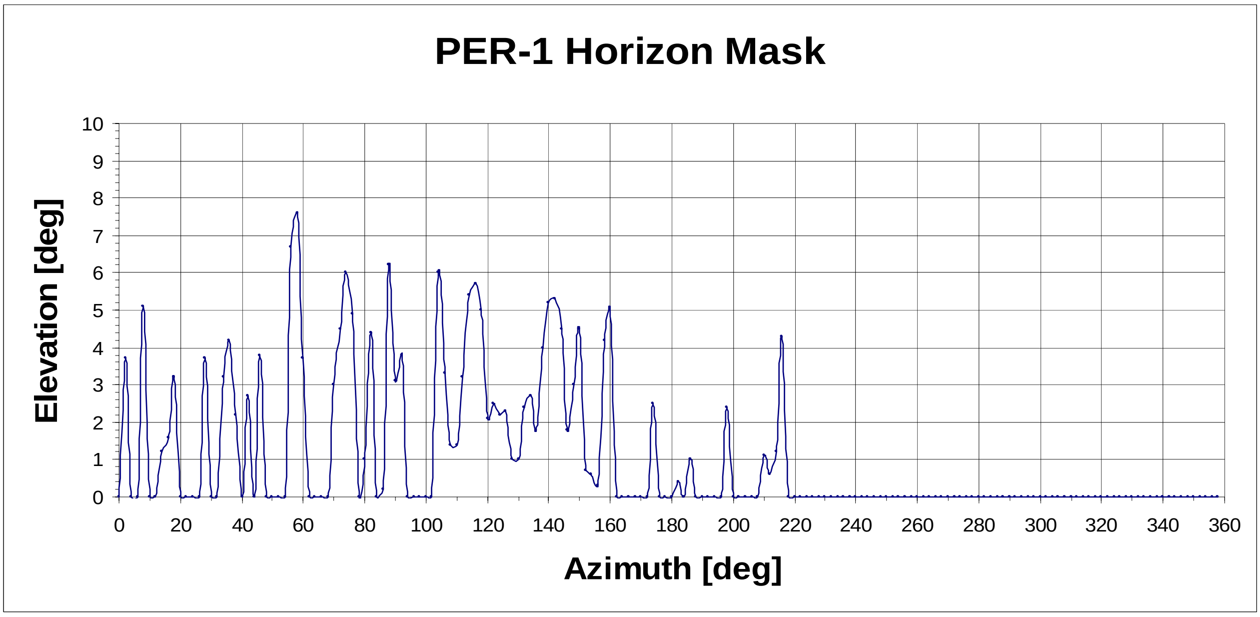

Figure 41: Perth-1 (PER-1) Antenna Horizon Mask

6.6.3.3 *Functional Description*

Figure 42 shows the Perth-1 (PER-1) Block Diagram, which is used for the functional description.

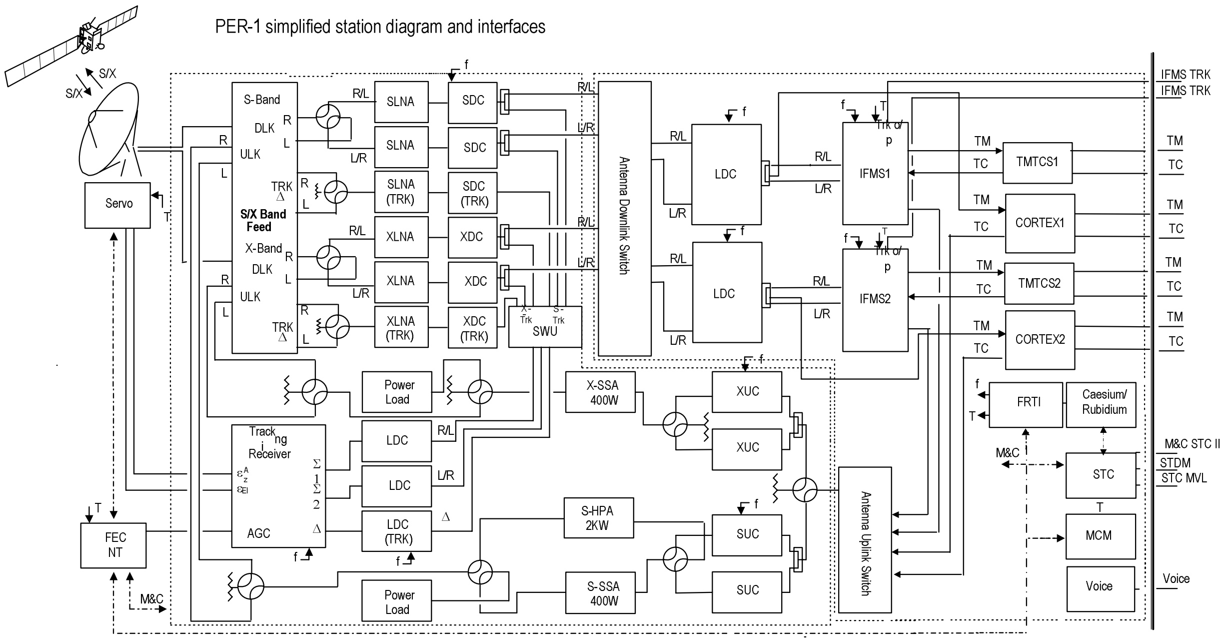

Figure 42: Perth-1 (PER-1) Block Diagram

6.6.3.3.1 Antenna

The S- and X-band transmit and S- and X-band receive (SX/SX) Cassegrain antenna is fitted with a shaped 15m parabolic main reflector and a shaped hyperbolic subreflector in an elevation over azimuth mount. Auto-tracking of the S- and X-band signals is possible by a two-channel monopulse tracking systems in each frequency band. An S- and X-band test antenna with reflective converter allows for signal delay calibration. An air-conditioning system outside the antenna tower provides cooling of the antenna tower and the Apex cabin.

The antenna pointing is performed by the Antenna Control Unit (ACU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation positions to the ACU.

The incoming electromagnetic wave is conveyed via the reflector and subreflector into the SX/SX feed, which together with its polarizer matches the free space field electromagnetic configuration to the waveguide modes. The combined SX/SX feed consists of an S-band corrugated horn with a dielectric rod inside for X-band. The coexisting receive and transmit signals for each polarisation inside each feed are separated by Diplexer filters. The receive waveguide branches are fed to Low Noise Amplifiers (LNAs), which amplify the Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC) signals, which subsequently can be phase adjusted by Phase Shifters. The S-band signals [2200-2300 MHz] are down-converted to L-band [520-420 MHz]. The X-band signals [8400-8500 MHz] are down-converted to L-band [640-540 MHz]. The downlink signals are then transferred for tracking and telemetry processing.

The uplink signal coming from telecommand processing at 230 MHz is delivered to S-band or X-band transmission. It is converted by the S-band up-converter (SUC) to [2025-2120 MHZ] and delivered via a switch to the S-band High Power Amplifiers (SHPA) or the S-band Solid State Amplifier (SSSA); or by the X-band upconverter (XUC) for conversion to [7145-7235 MHZ] and via a switch to the X-band Solid State Amplifier (XSSA). Fine control of the radiated power is performed by adjustable external attenuators.

A transmit waveguide assembly routes the RF signal to the X-band feed or S-band feed. The transmitted polarisation is selected with the polarization switch, which routes the RF signal to the uplink arm of one of the two Diplexers, one for each polarisation and frequency band. To avoid radiating the RF power to the antenna, the RF signal can also be routed via a set of switches to one of the two high power dummy loads.

The X-Band Feed or S-band Feed (including polarizer) matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from one of the two Diplexers and conveys the high power RF flux from the X-Band or S-band feed to the antenna sub-reflector and main reflector, where it is forwarded to free space. Concurrent radiation in X-band and S-band is not foreseen.

The S- and X-band tracking error signals in both polarisations are derived in waveguide mode couplers. A polarisation selection switch allows routing of one polarisation to the Tracking Low Noise Amplifier (LNA). This Delta-signal is down-converted to L-band [520-420 MHz] (from S- or X-band) via a dedicated third channel in the down-converter. This Delta-signal and the associated Sum-signals are then further down-converted to 70 MHz by a dedicated three channel L-band Tracking down-converter. The Tracking Receiver processes the three signals (Sum-1, Sum-2, Delta) coming from the S- or X-band feed in either Phase Locked Loop mode for remnant carrier modulated signals or Cross Correlation mode for suppressed carrier modulated signals. It derives the error signals for the ACU to point the antenna in autotrack mode.

6.6.3.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or autotrack mode using the received signal.

For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Spacecraft Trajectory Data Messages (STDM's) or State Vectors in the Front End Controller (FEC). For autotrack the antenna Azimuth and Elevation pointing angles are derived from error signals proportional to the direction of highest electrical field strength received. These pointing angles are made available to the Front End Controller (FEC) for delivery for orbit determination purposes.

In order to support initial X-band signal aquisition a small X-band aquisition aid antenna with a wide beam is mounted on the side of the main antenna, which allows initial X-band autotrack with subsequent handover of the autotrack to the main antenna.

6.6.3.3.3 Telemetry

The downlink L-band signals are fed via the Antenna Downlink Switch (ADLS) into tuneable L-band down-converters for conversion to 70 MHz intermediate frequency (IF) and further signal routing through the 70 MHz switch (SMSW).

The 70 MHz signals are combined and demodulated in the Intermediate Frequency Modem System (IFMS), which provides remnant and suppressed carrier demodulation. Doppler predictions coming from Spacecraft Trajectory Data Messages (STDM) information improve the signal acquisition process. The Telemetry Channel Decoding System (TCDS) hosted inside the IFMS performs frame synchronisation, time tagging, Viterbi and Reed-Solomon decoding. The output

data is transferred to the Telemetry and Telecommand System (TMTCS) for data structure processing according to Space Link Extension (SLE), which ultimately delivers the telemetry data via OPSNET to the Spacecraft Control Systems.
Alternatively the 70 MHz signals are delivered to the Cortex processing equipment, which integrates the above functions in a single unit, and delivers SLE conformant telemetry services.
The telemetry chains are redundant and the various switches allow flexible signal routing.

6.6.3.3.4 Telecommand

The Telemetry and Telecommand System (TMTCS) receives SLE conformant Telecommand data via OPSNET from the Spacecraft Control Systems. It provides telecommand data and clock to the Intermediate Frequency Modem System (IFMS) Uplink Modulator (ULM), which provides the Phase Shift Key (PSK) modulation of the telecommand bit stream onto a sub-carrier, which is then used to phase modulate the uplink carrier at 230 MHz. Via the Antenna Uplink Switch (AULS) the uplink signal is routed either to the S-band or X-band antenna uplink. Alternatively the uplink can be generated from the Cortex processing equipment.
The telecommand chains are redundant and the various switches allow flexible signal routing.

6.6.3.3.5 Radiometric

The radiometric measurements comprise Doppler, Ranging, Meteorological and autotrack Pointing measurements.
The Intermediate Frequency Modem System (IFMS) Ranging and Telemetry Demodulators deliver integrated Doppler measurements of the received carrier phase, known as Doppler-1 and Doppler-2.
The IFMS Uplink Modulator generates the ranging tone, which is Phase-Shift-Key (PSK) modulated by a sequence of codes. This ranging tone is phase modulated on the uplink carrier and can be transmitted simultaneously with the telecommand subcarrier. The IFMS Ranging Demodulator pre-steers the expected downlink carrier in case of coherent transponding of the spacecraft based on Spacecraft Trajectory Data Messages (STDMs), demodulates the received tone and compares the received codes with codes replica to derive the two-way propagation delay.
The IFMS meteorological unit gathers outside air temperature, pressure and humidity.
Alternatively the Doppler and Ranging measurements can be provided by the Cortex processing equipment.
The Antenna Control Unit delivers the actually pointed antenna Azimuth and Elevation angles during autotrack of the received carrier signal.
All radiometric measurement data are delivered through OPSNET to Flight Dynamics for processing.

6.6.3.3.6 Monitoring and Control

The monitoring and control (M&C) system allows full local and remote control over the terminal.
It is based on a hierarchy of M&C systems: the Station Computer (STC), the Front End Controller (FEC), the Monitoring and Control Module (MCM) and Local Man Machine Interfaces (MMI) on the various devices.
The Station Computer (STC) is composed of a local server, a local workstation and a remote workstation housed in the Ground Facilities Control Centre (GFCC). Mission specific terminal

configurations are normally affected through pre-validated macro-procedures, also individual equipment configurations are possible. The STC interacts through a set of subsystem controllers, either in separate units or implemented in complex devices (e.g. IFMS/TMTCS), with all the terminal equipment. Remote spectrum visualisation is supported.
The Front End Controller (FEC) is the subsystem controller for all the antenna front end devices and responsible for antenna steering.
The Monitoring and Control Module (MCM) is the subsystem controller for all simple back end devices, e.g. switches.
In case of failure of the monitoring and control system, the terminal can be locally operated from the individual equipment Local Man Machine Interfaces.

6.6.3.3.7 Frequency and Timing

The frequency reference generation is based on a Caesium Beam Tube with appropriate long term frequency stability. The frequency distribution system coherently derives 5, 10 and 100 MHz signals and amplifies them for distribution to the devices.
The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 5 MHz, 1 kHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

6.6.3.3.8 Test and Calibration

The objective of the test and calibration function is to validate the telemetry and telecommand functions, and to calibrate the Ranging and Doppler function before the operational satellite pass.
The telemetry function is tested with simulated spacecraft telemetry, which is generated in the Portable Satellite Simulator (PSS), frequency converted to the appropriate downlink frequency and injected into the antenna via a test antenna, so called Telemetry Test Long Loop (TTLL) configuration. The telemetry is then delivered in a Data Flow Test (DFT) to the spacecraft control system for verification.
The telecommand function is tested by demodulating and decoding of the 230 MHz uplink signal and comparing it to known telecommand formats. Based on the telecommand received in the PSS the simulated telemetry generation can be altered. The test telecommands originate from the spacecraft control system.
The ranging and doppler function is calibrated by conducting a ranging and doppler measurement in an antenna loopback configuration, in which the uplink frequency is transponded to the downlink frequency. The emulated transponding involves reception of the uplink frequency by the test antenna and conversion to the downlink frequency in the Reflective Converter (RFLC) with subsequent transmission via the test antenna back into the main antenna. This calibration measures the station internal signal delay and any frequency offset.
For phase calibration of the tracking channels, a remote controllable calibration tower is available.
Test tools for integration and performance validation activities are not described.

6.6.4 ADDITIONAL FACILITIES

6.6.4.1 GPS-TDAF

A Global Positioning System (GPS) dual-frequency receiver system with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

6.6.5 PLANNED DEVELOPMENTS

None.

6.7 Redu (RED) Station

Figure 43 shows the Redu (RED) Aerial View.

Figure 43: Redu (RED) Aerial View

6.7.1 GENERAL INFORMATION

The Redu site is made available to ESA, based on an international agreement between ESA and the Government of Belgium.

6.7.1.1 Location

ESA Redu is located in the Belgian Ardennes just outside the village of Redu, see Figure 44.

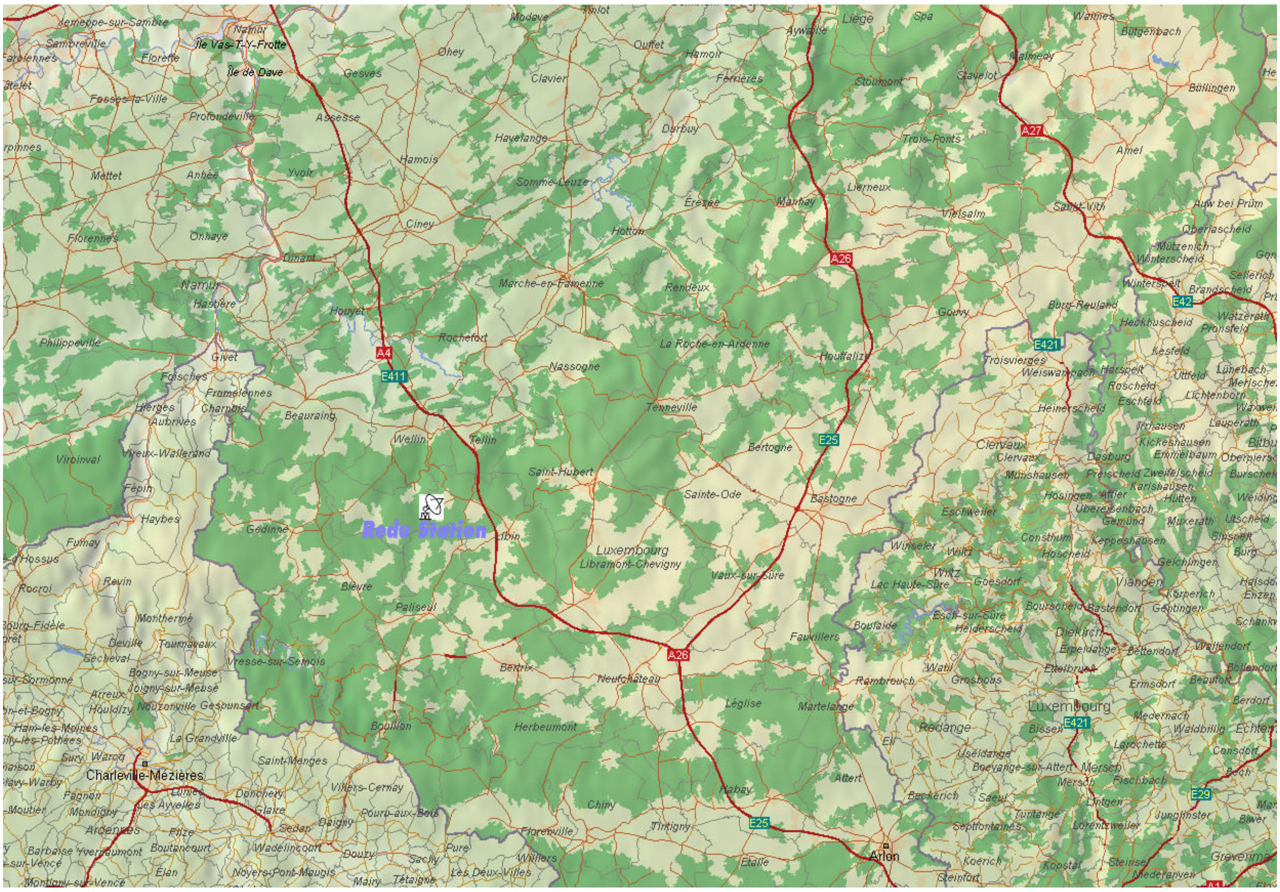

Figure 44: Redu (RED) Area Map

6.7.1.2 Access

Site visits require a confirmed Station Intervention form sheet.
The distance of Redu from Brussels is 115 km, from Luxembourg is 110 km, and from ESOC is 360 km. The nearest towns to Redu are Rochefort (25 km), Libramont (25 km), and Paliseul.
The station can be reached in one of the following ways:
By air: The nearest airports are at Luxembourg (110 km), Charleroi (115 km) and Brussels (125 km). Rental cars are available at all the airports, reservation arrival is recommended.
By car: see Figure 44, drive to and take the highway / auto route E411 (between Brussels and Luxembourg). Leave it at Transinne (exit 24) towards Redu. Continue straight over the crossroads, following the signs to Redu. After approximately 1.5 km the station is signposted to the left. In the centre of the Redu village take the Daverdisse road, then turn left, following the ESA signs.
By train: The nearest railway station is at Libramont, about 25 km away from Redu.
Accommodation can be arranged through the station manager.

6.7.1.3 Entry Requirements

Entry requirements for Belgium are as for the European Union.

6.7.1.4 Climate

In the hills of the Ardennes there is considerable precipitation with heavy falls of snow in winter. Fog is common except in summer. Wind speeds, usually, are not greater than 100 km/h. A summary of the weather characteristics for the Redu area is given below:

Warmest month:	July
Average daily maximum temperature for July:	20.0 °C
Highest recorded temperature in July:	37.0 °C
Lowest recorded temperature in July:	2.0°C
Coldest month:	January
Average daily minimum temperature for January:	-3.0 °C
Highest recorded temperature in January:	13.0 °C
Lowest recorded temperature in January:	-24.0 °C
Average annual rainfall:	1040 mm

6.7.1.5 Management

The ESA on-site representative is the Redu Station Director.
The Maintenance and Operations (M&O) of the site is provided by Redu Satellite Services (RSS).

6.7.1.6 Local Contact

The local point of contact for the Redu station is:

ESA - European Space Agency - Redu Station
Mr. Benoit Demelenne
Head of Redu TT&C and Spacecraft Operations Unit
E-Mail benoit.demelenne@esa.int
Tel +32 61 229514
Fax +32 61 229515

6.7.1.7 Logistics

The postal address of the station is:

ESA - European Space Agency / Agence Spatiale European
Redu Station / Station de Redu
B-6890 Redu, Belgium

The customs agent and logistics contact is:

ESA - European Space Agency - Redu Station
Mr. Benoit Demelenne
Head of Redu TT&C and Spacecraft Operations Unit
E-Mail benoit.demelenne@esa.int
Tel +32 61 229514
Fax +32 61 229515

6.7.2 STATION SERVICES

Figure 45 shows the Redu (RED) Site Plan.

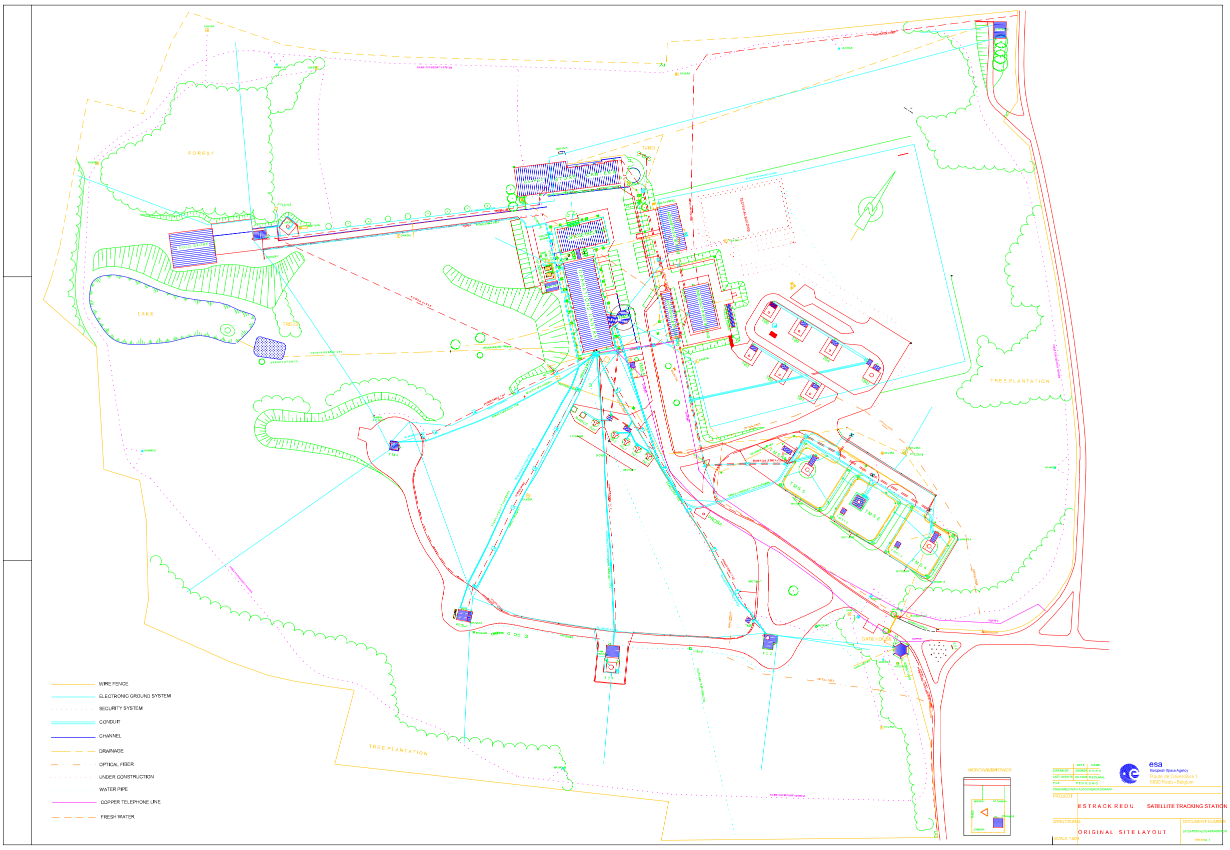

Figure 45: Redu (RED) Site Plan

6.7.2.1 Security

The site is fenced and guarded 24/7. An access control and surveillance system is installed.

6.7.2.2 Power

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, and a no-break (NB) power supply using Static Converters and Batteries. Via low voltage switches the electricity (3x 400V, 50 Hz) is distributed to the consumer groups.

Public power into the power plant is rendered by two diversely routed 15 kV medium voltage lines and two transformers of 1 MVA each.

Three Diesel Generator (500 kVA each) take over the site supply within 15 sec to 1 min after a public power failure. Two Static Converters supply up to 160 kVA for no-break general consumers. The battery capacity allows for a maximum bridging time of more than 16 minutes with a nominal load for those general no-break users. Furthermore, the RED-1 antenna servo is connected to a dedicated no-break system, which allows continuous following of spacecraft during small power outages.

6.7.2.3 Air Conditioning

The station air conditioning system supplies air to the main building equipment rooms at a temperature of 20-22°C + 10%, with a controlled humidity of 50% - 70% relative humidity.

6.7.2.4 Communications

The Redu station is connected via the ESA Operations Network (OPSNET) by a 2 Mbps international private leased circuit (IPLC) and ISDN on-demand connectivity. The connectivity into the Redu site is routed through a fibre optic link.

All non-operational and Internet traffic is routed via the ESA Administrative Network (ESACOM).

6.7.3 REDU-1 (RED-1) TERMINAL

Figure 46 shows the Redu-1 (RED-1) antenna, which provides S-band transmit, and S-band receive capability (S/S).

Figure 46: Redu-1 (RED-1) Antenna

6.7.3.1 Services and Performance

The Redu-1 (RED-1) terminal provides the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Meteo, Autotrack Angles)

Table 10 details the Redu-1 (RED-1) Performance Characteristics. For the definition of individual characteristics see 5.6

1	Rev. 2.4	
2	18-Sep-2008	REDU-1 (S / S)
3	TERMINAL	RED-1
4	Longitude	5 deg 08' 43.24" E
5	Latitude	50 deg 00' 01.64" N
6	Altitude [m]	386.6835
7	Antenna Diameter [m]	15
8	S-band Beamwidth [deg]	Rx: 0.60 Tx: 0.65
9	X-band Beamwidth [deg]	N/A
10	Ka-band Beamwidth [deg]	N/A
11	Antenna Speed [deg/s]	Az: 5 deg/s El: 5 deg/s
12	Azimuth Range [deg]	0 to 720
12	Elevation Range [deg]	-1 to 181
14	Search / Acquisition Aid	Search
15	Tilt Facility	NO
16	Tracking Mode	Auto (S) / Program
17	Angular Data Accuracy (autotrack+pointing error)	80 mdeg
18	FUNCTIONALITIES	
19	TM/TC Standards	PCM, CCSDS
20	TM/TC Redundancy	YES
21	Comms Redundancy	YES
22	Ranging	IFMS compliant
23	Doppler	YES
24	Meteo	YES
25	Autotrack Antenna Angles	YES
26	Delta-DOR	NO
27	Radio-Science	NO
28	Frequency & Timing	CESIUM
29	UPLINK	
30	S-band TX band [MHz]	2025-2120
31	S-band Polarization	RHC, LHC
32	S-band EIRP [dBm]	102.5 (S-SSA)
33	X-band TX band [MHz]	N/A
34	X-band Polarization	N/A
35	X-band EIRP [dBm]	N/A
36	Ka-band TX band (MHz)	N/A
37	Ka-band Polarization	N/A
38	Ka-band EIRP [dBm]	N/A
39	Modulation Schemes	IFMS compliant
40	Subcarrier Freq. [kHz]	8 or 16 kHz
41	DOWNLINK	
42	L-band RX band [MHz]	N/A
43	L-band Polarization	N/A
44	L-band G/T [dB/K]	N/A
45	S-band RX band (MHz)	2200-2300
46	S-band Polarization	RHC, LHC
47	S-band G/T [dB/K]	29.6
48	X-band RX band [MHz]	N/A
49	X-band Polarization	N/A
50	X-band G/T [dB/K]	N/A
51	Ka-band RX band [MHz]	N/A
52	Ka-band Polarization	N/A
53	Ka-band G/T [dB/K]	N/A
54	Modulation Schemes	IFMS compliant
55	Carrier Freq Search Range	+/- 1.5 MHz
56	Subcarrier Frequency	2 kHz to 1.2 MHz
57	Data Rates	IFMS compliant: - 1.2 Mbps (RCD) - 2 Mbps (SCD LS)
58	Data Coding Scheme	R-S, Convolutional and Concatenated
59	INTERFACES	
60	TM/TC Connectivity	TCP/IP SLE (TMTCS)
61	Rng/Dop Connectivity	FTP (IFMS)
62	Meteo Connectivity	FTP (IFMS)
63	Angles Connectivity	IP via STC
64	Pointing Format	STDM
65	Tracking Interface (ESOC)	FDS

Table 10: Redu-1 (RED-1) Performance Characteristics

6.7.3.2 *Antenna Horizon*

Figure 47 shows the Redu-1 (RED-1) Antenna Horizon Mask.

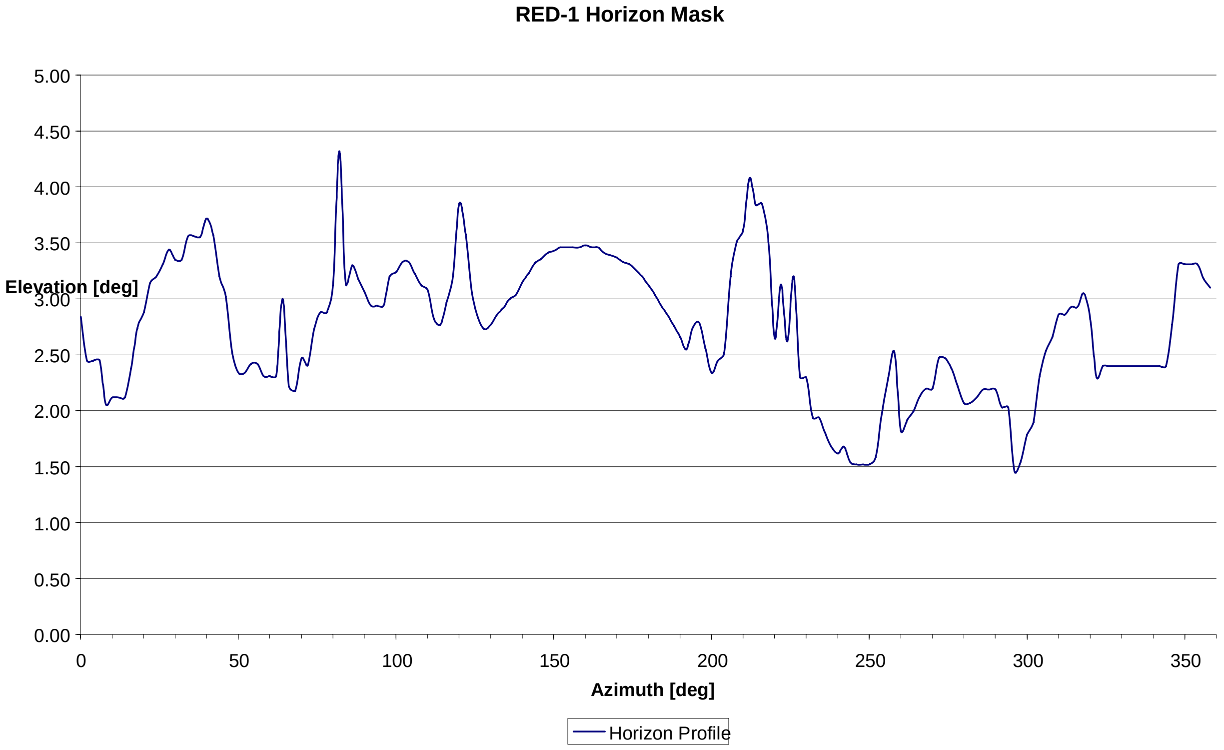

Figure 47: Redu-1 (RED-1) Antenna Horizon Mask

6.7.3.3 *Functional Description*

Figure 48 shows the Redu-1 (RED-1) Block Diagram, which is used for the functional description.

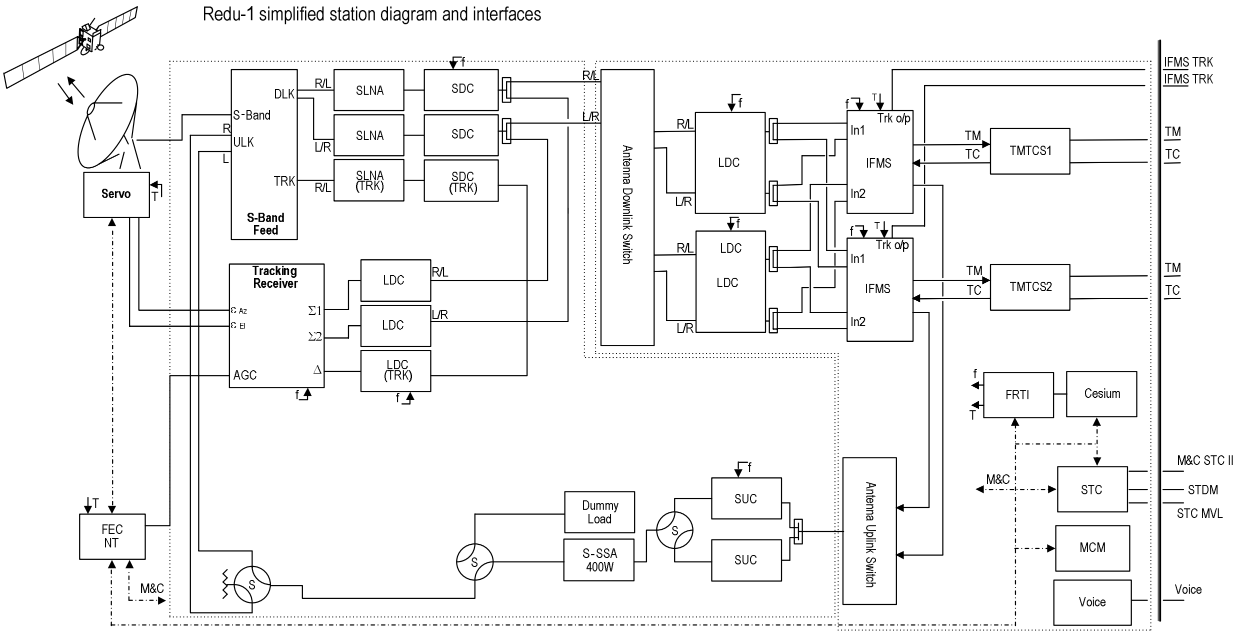

Figure 48: Redu-1 (RED-1) Block Diagram

6.7.3.3.1 *Antenna*

The S-band transmit and S-band receive (S/S) Cassegrain antenna is fitted with a shaped 15m parabolic main reflector and a shaped hyperbolic subreflector in an elevation over azimuth mount. Auto-tracking of the S-band signal is possible by a two-channel monopulse tracking system. An S-band test antenna with reflective converter allows for signal delay calibration. An air-conditioning system outside the antenna tower provides cooling of the antenna tower and the Apex cabin.

The antenna pointing is performed by the Antenna Control Unit (ACU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation positions to the ACU.

The incoming electromagnetic wave is conveyed via the reflector and subreflector into the S/S feed, which together with its polarizer matches the free space field electromagnetic configuration to the waveguide modes. The coexisting receive and transmit signals for each polarisation inside the S-band feed are separated by Diplexer filters. The receive waveguide branches are fed to Low Noise Amplifiers (LNAs), which amplify the Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC) signals, which subsequently can be phase adjusted by Phase Shifters. The S-band signals [2200-2300 MHz] are down-converted to L-band [520-420 MHz]. The S-band downlink signals are then transferred for tracking and telemetry processing.

The uplink signal coming from telecommand processing at 230 MHz is delivered to S-band transmission. It is converted by the S-band up-converter (SUC) to [2025-2120 MHZ] and delivered via a switch to the S-band Solid State Amplifier (SSSA). Fine control of the radiated power is performed by adjustable external attenuators.

A transmit waveguide assembly routes the RF signal to the S-band feed. The transmitted polarisation is selected with the polarization switch, which routes the RF signal to the uplink arm of one of the two Diplexers, one for each polarisation. To avoid radiating the RF power to the antenna, the RF signal can also be routed via a set of switches to a high power dummy load.

The S-band Feed (including polarizer) matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from one of the two Diplexers and conveys the high power RF flux from the S-band feed to the antenna sub-reflector and main reflector, where it is forwarded to free space.

The S-band tracking error signals in both polarisations are derived in waveguide mode couplers. A polarisation selection switch allows routing of one polarisation to the Tracking Low Noise Amplifier (LNA). This Delta-signal is down-converted to L-band [520-420 MHz] (from S-band) via a dedicated third channel in the down-converter. This Delta-signal and the associated Sum-signals are then further down-converted to 70 MHz by a dedicated three channel L-band Tracking down-converter. The Tracking Receiver processes the three signals (Sum-1, Sum-2, Delta) coming from the S-band feed in either Phase Locked Loop mode for remnant carrier modulated signals or Cross Correlation mode for suppressed carrier modulated signals. It derives the error signals for the ACU to point the antenna in autotrack mode.

6.7.3.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or autotrack mode using the received signal.

For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Spacecraft Trajectory Data Messages (STDM's) or State Vectors in the Front End Controller (FEC). For autotrack the antenna Azimuth and Elevation pointing angles are derived from error signals proportional to the direction of highest electrical field strength received. These pointing angles are made available to the Front End Controller (FEC) for delivery for orbit determination purposes.

6.7.3.3.3 Telemetry

The downlink L-band signals are fed via the Antenna Downlink Switch (ADLS) into tuneable L-band down-converters for conversion to 70 MHz intermediate frequency (IF) and further signal routing through the 70 MHz switch (SMSW).

The 70 MHz signals are combined and demodulated in the Intermediate Frequency Modem System (IFMS), which provides remnant and suppressed carrier demodulation. Doppler predictions coming from Spacecraft Trajectory Data Messages (STDM) information improve the signal acquisition process. The Telemetry Channel Decoding System (TCDS) hosted inside the IFMS performs frame synchronisation, time tagging, Viterbi and Reed-Solomon decoding. The output data is transferred to the Telemetry and Telecommand System (TMTCS) for data structure processing according to Space Link Extension (SLE), which ultimately delivers the telemetry data via OPSNET to the Spacecraft Control Systems.

The telemetry chains are redundant and the various switches allow flexible signal routing.

6.7.3.3.4 Telecommand

The Telemetry and Telecommand System (TMTCS) receives SLE conformant Telecommand data via OPSNET from the Spacecraft Control Systems. It provides telecommand data and clock to the Intermediate Frequency Modem System (IFMS) Uplink Modulator (ULM), which provides the

Phase Shift Key (PSK) modulation of the telecommand bit stream onto a sub-carrier, which is then used to phase modulate the uplink carrier at 230 MHz. Via the Antenna Uplink Switch (AULS) the uplink signal is routed to the S band antenna uplink.
The telecommand chains are redundant and the various switches allow flexible signal routing.

6.7.3.3.5 Radiometric

The radiometric measurements comprise Doppler, Ranging, Meteorological and autotrack Pointing measurements.
The Intermediate Frequency Modem System (IFMS) Ranging and Telemetry Demodulators deliver integrated Doppler measurements of the received carrier phase, known as Doppler-1 and Doppler-2.
The IFMS Uplink Modulator generates the ranging tone, which is Phase-Shift-Key (PSK) modulated by a sequence of codes. This ranging tone is phase modulated on the uplink carrier and can be transmitted simultaneously with the telecommand subcarrier. The IFMS Ranging Demodulator pre-steers the expected downlink carrier in case of coherent transponding of the spacecraft based on Spacecraft Trajectory Data Messages (STDMs), demodulates the received tone and compares the received codes with codes replica to derive the two-way propagation delay.
The IFMS meteorological unit gathers outside air temperature, pressure and humidity.
The Antenna Control Unit delivers the actually pointed antenna Azimuth and Elevation angles during autotrack of the received carrier signal.
All radiometric measurement data are delivered through OPSNET to Flight Dynamics for processing.

6.7.3.3.6 Monitoring and Control

The monitoring and control (M&C) system allows full local and remote control over the terminal. It is based on a hierarchy of M&C systems: the Station Computer (STC), the Front End Controller (FEC), the Monitoring and Control Module (MCM) and Local Man Machine Interfaces (MMI) on the various devices.
The Station Computer (STC) is composed of a local server, a local workstation and a remote workstation housed in the Ground Facilities Control Centre (GFCC). Mission specific terminal configurations are normally affected through pre-validated macro-procedures, also individual equipment configurations are possible. The STC interacts through a set of subsystem controllers, either in separate units or implemented in complex devices (e.g. IFMS/TMTCS), with all the terminal equipment. Remote spectrum visualisation is supported.
The Front End Controller (FEC) is the subsystem controller for all the antenna front end devices and responsible for antenna steering.
The Monitoring and Control Module (MCM) is the subsystem controller for all simple back end devices, e.g. switches.
In case of failure of the monitoring and control system, the terminal can be locally operated from the individual equipment Local Man Machine Interfaces.

6.7.3.3.7 Frequency and Timing

The frequency reference generation is based on a Caesium Beam Tube with appropriate long term frequency stability. The frequency distribution system coherently derives 5, 10 and 100 MHz signals and amplifies them for distribution to the devices.

The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 5 MHz, 1 kHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

6.7.3.3.8 Test and Calibration

The objective of the test and calibration function is to validate the telemetry and telecommand functions, and to calibrate the Ranging and Doppler function before the operational satellite pass.

The telemetry function is tested with simulated spacecraft telemetry, which is generated in the Portable Satellite Simulator (PSS), frequency converted to the appropriate downlink frequency and injected into the antenna via a test antenna, so called Telemetry Test Long Loop (TTLL) configuration. The telemetry is then delivered in a Data Flow Test (DFT) to the spacecraft control system for verification.

The telecommand function is tested by demodulating and decoding of the 230 MHz uplink signal and comparing it to known telecommand formats. Based on the telecommand received in the PSS the simulated telemetry generation can be altered. The test telecommands originate from the spacecraft control system.

The ranging and doppler function is calibrated by conducting a ranging and doppler measurement in an antenna loopback configuration, in which the uplink frequency is transponded to the downlink frequency. The emulated transponding involves reception of the uplink frequency by the test antenna and conversion to the downlink frequency in the Reflective Converter (RFLC) with subsequent transmission via the test antenna back into the main antenna. This calibration measures the station internal signal delay and any frequency offset.

For phase calibration of the tracking channels, a remote controllable calibration tower is available.

Test tools for integration and performance validation activities are not described.

6.7.4 REDU-2 (RED-2) TERMINAL

6.7.4.1 Antenna

Figure 49: Redu-2 (RED-2) Antenna

The Redu-2 (RED-2) terminal, due to its heritage previously called TMS-1M, is a 13.5m Ka-band full motion antenna. It is part of the ESA Earth Terminal (EET) facility, which simultaneously supports Artemis Data Relay and Ranging functions.

6.7.4.2 Services and Performance

The Redu-2 (RED-2) terminal provides the following services:

- Four simultaneous data relay return feeder link channels at 20 GHz converted to 750 or 70 MHz
- Data relay test loop by means of a synthesised Test Loop Translator (TLT) in order to verify transmit and receive function of any single transmit and receive channel
- Receive and a transmit port (20 and 30 GHZ) respectively interfacing to the Remote Ranging Terminal (RRT)
- Receive the satellite pilot and provide it to the EET

Table 11 details the Redu-2 (RED-2) Performance Characteristics. For the definition of individual characteristics see 5.6

1	Rev. 2.4	
2	18-Sep-2008	REDU-2 (Ka / Ka)
3	TERMINAL	RED-2
4	Longitude	5 deg 08' 42.64" E
5	Latitude	50 deg 00' 07.41" N
6	Altitude [m]	385.519
7	Antenna Diameter [m]	13.5
8	S-band Beamwidth [deg]	N/A
9	X-band Beamwidth [deg]	N/A
10	Ka-band Beamwidth [deg]	Rx: 0.05 Tx: 0.08
11	Antenna Speed [deg/s]	0.5 deg/s
12	Azimuth Range [deg]	0-360
12	Elevation Range [deg]	0-90
14	Search / Acquisition Aid	Search
15	Tilt Facility	NO
16	Tracking Mode	Auto (Ka) / Program
17	Angular Data Accuracy (autotrack+pointing error)	tbc
18	FUNCTIONALITIES	
19	TM/TC Standards	PCM, CCSDS
20	TM/TC Redundancy	YES
21	Comms Redundancy	YES
22	Ranging	ENERTEC Compliant
23	Doppler	YES
24	Meteo	YES
25	Autotrack Antenna Angles	YES
26	Delta-DOR	NO
27	Radio-Science	NO
28	Frequency & Timing	from RED-1
29	UPLINK	
30	S-band TX band [MHz]	N/A
31	S-band Polarization	N/A
32	S-band EIRP [dBm]	N/A
33	X-band TX band [MHz]	N/A
34	X-band Polarization	N/A
35	X-band EIRP [dBm]	N/A
36	Ka-band TX band (MHz)	Ka-band 28500-30000
37	Ka-band Polarization	Y
38	Ka-band EIRP [dBm]	84.5 dBW
39	Modulation Schemes	ENERTEC compliant
40	Subcarrier Freq. [kHz]	N/A
41	DOWNLINK	
42	L-band RX band [MHz]	N/A
43	L-band Polarization	N/A
44	L-band G/T [dB/K]	N/A
45	S-band RX band (MHz)	N/A
46	S-band Polarization	N/A
47	S-band G/T [dB/K]	N/A
48	X-band RX band [MHz]	N/A
49	X-band Polarization	N/A
50	X-band G/T [dB/K]	N/A
51	Ka-band RX band [MHz]	18100 - 20200
52	Ka-band Polarization	Y
53	Ka-band G/T [dB/K]	42.5
54	Modulation Schemes	ENERTEC compliant
55	Carrier Freq Search Range	tbc
56	Subcarrier Frequency	1.2 kHz to 1.5 MHz
57	Data Rates	up to 200 Mbps
58	Data Coding Scheme	tbc
59	INTERFACES	
60	TM/TC Connectivity	TCP/IP
61	Rng/Dop Connectivity	TCP-IP
62	Meteo Connectivity	TCP-IP
63	Angles Connectivity	TCP-IP
64	Pointing Format	STDM
65	Tracking Interface (ESOC)	NO

Table 11: Redu-2 (RED-2) Performance Characteristics

6.7.4.3 Antenna Horizon

The antenna is permanently pointed to the ARTEMIS Data Relay Satellite, therefore no horizon profile is provided here.

6.7.4.4 Functional Description

Figure 50 shows the Redu-2 (RED-2) Block Diagram, which is used for the functional description.

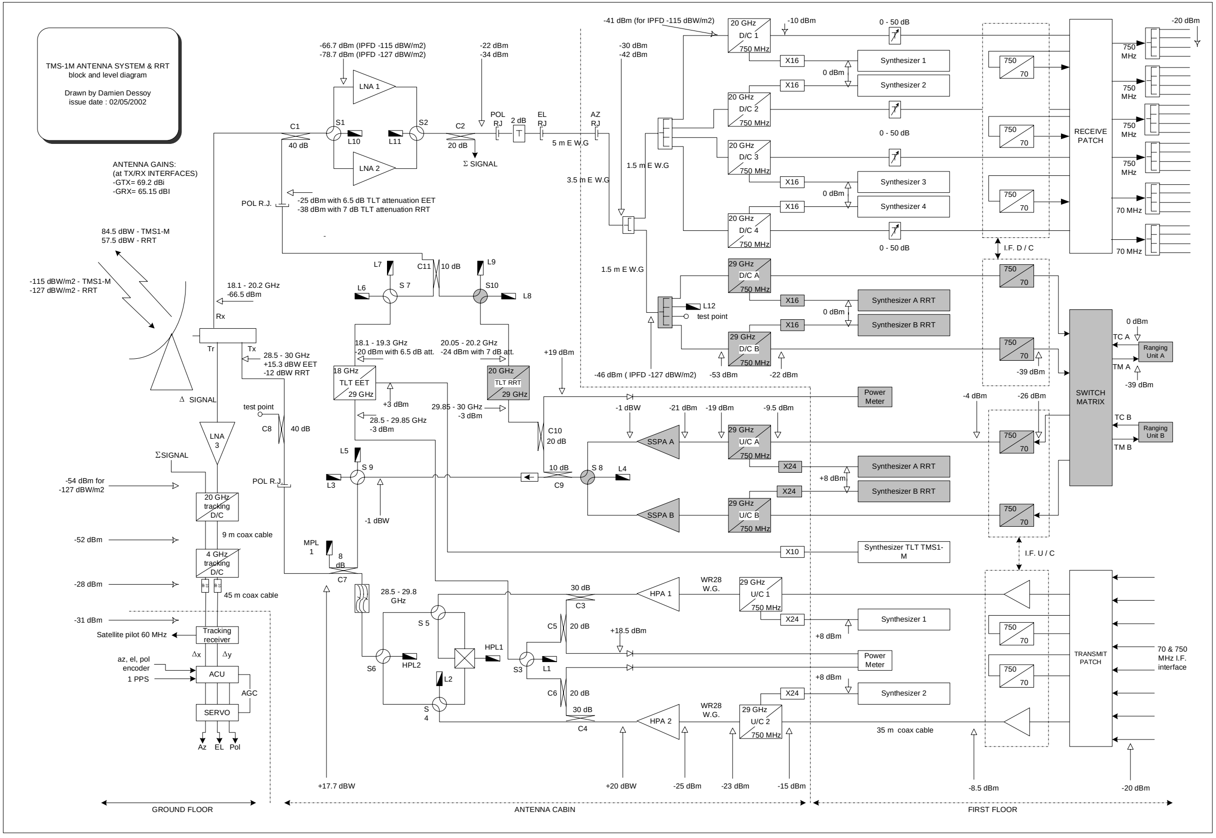

Figure 50: Redu-2 (RED-2) Block Diagram

6.7.4.4.1 Antenna

REDU-2 is a Cassegrain 13.5-metre antenna that is adjustable from 0-360 degrees in azimuth, 0-90 degrees in elevation and 50 degrees in polarisation. The feed includes the feed horn, the mono-pulse tracking coupler, a two ports OMT and a circular to rectangular transition for transmit. A polarizer is included to match the polarization plane to the satellite signals. Both transmission and reception have been designed to work in vertical polarization only.

The feed horn is designed to provide optimum reflector illumination efficiency and match of the fundamental mode across both transmit and receive frequency bands whilst also supporting the higher tracking modes required for the mono-pulse capability.

The antenna is also equipped with a mono-pulse tracking coupler. The TE21V and TE21H modes are coupled using a mode selective multi-hole circular wave guide coupler. Outputs of diametrically opposing coupled rectangular wave guides are combined in hybrid tees to produce the error signals X and Y. These signals are then combined in quadrature in a wave guide 3 dB coupler to produce a single tracking error signal.

The OMT is a 4-ports type (a planar four ports junction with symmetrically positioned coupling apertures between the circular wave guide and the surrounding individual rectangular wave guide). The two diametrically opposing ports are connected to corrugated transmit reject filters and then combined in a hybrid tee. Additional filtering is also provided by an external transmit reject filter at the tee output port (Rx port).

The EET and RRT have 4 and 2 receive chains respectively, with a common part (from feed RX port up to the divider located behind the LNA’s) and an individual part starting after the azimuth rotary joint, down to the IF output.

The common 20 GHz section is composed of the following elements (starting from the feed RX port):

- A waveguide coupler to inject into the receive chain the Test Loop Translator (TLT) output (either for EET or Remote Ranging Terminal, RRT)
- Two waveguide switches to select Low Noise Amplifier 1 (LNA1) or LNA2
- Two LNA’s with 1.5dB noise figure
- A waveguide coupler to pick-up a sample of the received pilot signal in order to provide the sum signal to the auto-track subsystem
- Three rotary joints that allow the azimuth, elevation and polarisation movements of the rigid waveguide path to connect with the 2-way divider located in the first floor

The first 4-way divider distributes the signal to the four EET down-converters. The 750 MHz IF D/C outputs are then delivered to the IF patch sub-system that has the following functions:

- Adjust the IF level by means of the 750 MHz variable attenuators.
- Split the signal at 750 MHz if more than one device must be fed, by means of four 4 way dividers.
- Convert the 750 MHz IF signal to 70 MHz via 3 dedicated IF D/C, if the base band equipment requires 70 MHz IF.
- Split the signal at 70 MHz if more than one device must be fed by means of two 4-way dividers. The IF receive patch is manually configurable.

The second divider distributes the signal to the RRT down-converters and also a SHF monitoring point. The 750 MHz IF output is then down converted to 70 MHz, which is connected to the ranging units through a switch matrix. The ranging units can also operate as telemetry receiver and ARTEMIS telemetry carrier can be treated on both chains at the same time. The switch matrix is remotely configurable.

As for the receive subsystem, EET and RRT transmit systems share a common part up to the TX port of the feed.

The EET transmit subsystem has two complete chains that can feed the antenna TX port simultaneously. The base band signals are connected to the transmit patch at either 750 MHz or 70

MHz depending on the used unit. If needed, the signal is up-converted to 750 MHz before reaching the up-converter input (two 70/750 MHz IF converters are integrated in the transmit patch). Each HPA is a 100 W TWT amplifier. The associated U/C provides a PIN attenuator for EIRP adjustments over a range of at least 20 dB by step of less than 1 dB. Power sensors are connected to each HPA output to measure transmitted EIRP.
Following the HPA, a switch network has been installed to allow the different operational configuration (HPA 1 and/or HPA 2 transmitting on load or on air). This network is installed in the antenna cabin and connected to the feed via rigid wave guide and rotary joint (polarization).
The RRT sub-system has two complete transmit chains that translate the 70 MHz base band signal to 30 GHz. A single switch allows the selection of the chain to be used while the other is sent to load. A power sensor is connected to the output of this switch, via a coupler, to measure the transmitted EIRP. Another switch determines whether the selected chain is sent on load or to antenna.
The power amplifiers are of SSPA type and provide a nominal –1dBW output power. The associated U/C provides a PIN attenuator for EIRP adjustments over a range of at least 20 dB by step of less than 1 dB. A coupler is used to combine EET and RRT sub-systems.

6.7.4.4.2 Tracking

The tracking of the satellite is possible by pointing the antenna in program track mode or autotrack mode. The tracking subsystem is a monopulse type. The tracking chain is part of TMS-1M antenna system and is composed of the following items:

- A mode generator and combining network
- A low noise amplifier for the error signal
- Two dual channel tracking down converters
- A dual channel tracking receiver
- The antenna control unit
- The Azimuth and Elevation antenna servos

The auto track system can be configured for a beacon in the 20.0-20.2 GHz, in steps of 1 kHz. An anti side band circuit avoids to track an undesired signal.

6.7.4.4.3 Telemetry

The REDU-2 receive chains allow to simultaneously acquire ARTEMIS Data Relay signals (EET) and ARTEMIS Ka-band telemetry with the RRT system sub-system. The EET base band sub-system consists of:

- ESBT modem for S-band data relay return link;
- SILEX demodulator for optical data relay return link;
- SM modem for Micro Vibration Monitor and Mission Telemetry reception (experimental);
- K demodulator for K-band (23-26 GHz) data relay return link.

Being not in the scope of this document, the data relay base band equipments are only given as information and are not be further detailed. The telemetry and ranging terminal is an ENERTEC TT&C 3801-10. The 70 MHz IF signal is transposed to a frequency at which it can be sampled and processed by a DSP TMS320C40 module. Acquisition and anti-side band are performed by digital

spectral analysis and phase demodulation by a second-order digital phase lock loop. Acquisition can run with Doppler variations of +/- 350 kHz, with speed up to 1 kHz/s.
The main functions of the telemetry chain are:

- PSK demodulation
- Bit synchronisation
- Frame synchronisation
- Time tagging
- Parameters local decommutation for quick look purpose
- Transmission of data towards AMCF (ARTEMIS Mission Control Facility) and DPTL (Data Relay Payload Test Laboratory), both located in the Redu station.

These processing are implemented on two DSP modules on the telemetry board, with the PM demodulation module: one-DSP module for PSK demodulation and one-DSP module for bit synchronisation and frame synchronisation. The PSK sub-carrier is demodulated by a Costas digital loop. Bit synchronisation includes bit rate recovery by a digital phase-locked loop and bit decision after a matched filter. The frame synchronisation restores raw telemetry data and formats it for further processing. It is set up for an efficient strategy that optimises the use of Reed-Solomon decoder. The function can be by-passed for throughput applications. Data are time tagged. The transmission of data is performed the main CPU. Note that all units (EET and RRT) have redundancy.

6.7.4.4.4 Telecommand

The REDU-2 transmit capacity is only used for data relay applications. The base band TX sub-system consists of:

- ESBT modem for S-band data relay fowrd link;
- SILEX modulator for SILEX demodulator test via the TLT;
- SM modem for optical data relay forward link;
- K modulator for K-band (23-26 GHz) data relay forward link and K demodulator test via the TLT.

As for receive capacity description, the data relay base band equipments are only given as information and are not be further detailed.

6.7.4.4.5 Radiometric

The radiometric measurements are performed by the RRT sub-system and comprise Ranging, Doppler, Meteorological and antenna Pointing measurements. The ENERTEC unit performs ranging measurement and is connected to the meteorological unit. Ranging tones transmission is done by the 70 MHz PM/FM modulator. The carrier modulation is direct PM or FM. On downlink, the IF carrier is PM modulated by the ranging tones. The main functions of the ranging chain are:

- Generation of tones with selection of standard and frequencies;
- Automatic ambiguity resolution (ESA standard)
- Accurate phase or delay measurement;
- Time tagging;
- Statistical pre-processing;

- Transmission of results towards the AOCC (ARTEMIS Operations Control Centre) in Fucino, via the RRT M&C.

Standards for ranging in the equipment are ESA tone standard (TTC-A-04), the ESA code standard (ESA PSS-04-104) and the INTELSAT standard. The meteorological unit gathers outside air temperature, pressure and humidity. The RRT M&C application can interrogate the ACU to receive the actual antenna azimuth, elevation and polarisation angles. All units have redundancy.

6.7.4.4.6 Monitoring and Control

The REDU-2 monitoring and control (M&C) system is split in three sub-system:

- TMS-1M M&C, which monitors and controls the common and data relay components of the antenna
- RRT M&C, which controls RRT elements
- EET M&C (EETC), which controls data relay base band equipments, and REDU-2 TX and RX chains via TMS-1M M&C

REDU-2 design implies a shared use of some hardware for the two main missions, i.e. EET and RRT. There are also some equipments to be shared, i.e. antenna (ACU) and LNA's.

All equipment designated to functionally belong to TMS-1M (TLT, U/C, D/C, synthesisers, etc) are monitored and controlled from the TMS-1M M&C application. That also includes shared equipments such as ACU and LNA's.

Moreover, the equipments exclusively belonging to RRT are exclusively monitored and controlled from the RRT M&C application. The shared equipments (ACU and LNA's) can only be monitored. So, any request regarding antenna pointing modification are done using voice ilne between AOCC site (Fucino) and Redu. All other RRT equipments can be controlled and monitored locally or remotely from Fucino.

The EETC monitors and controls directly the EET base band equipments (modems). The monitoring and control of the equipement belonging to TMS-1M is automatically performed through requests to TMS-1M M&C application.

6.7.4.4.7 Frequency and Timing

The Frequency & Time Distribution (F&T D) sub-system accepts external 10 MHz frequency reference and the 1 kHz IRIG-B time reference and distribute them to TX, RX, tracking, calibration and base band equipments. A GPS receiver provides the input references. This function is obtained by means of a configuration with the following modules:

- A dual power supply of which outputs are linked to ensure uninterrupted supply distribution;
- One alarms module
- Passive signal splitter which delivers the input 10 MHz frequency signal to the frequency distribution amplifier modules
- A number of frequency distribution amplifier modules that provide at least 25 outputs of 10 MHz reference
- One time distribution amplifier module that accepts the 1 kHz IRIG-B time signal and provides at least 3 outputs of 1 KHz IRIG-B (main and backup ranging units, NTS).
- One Network Time Server

- Also the ACU accepts one external PPS signal, which gives the precise time reference at which the satellite position is obtained.

6.7.4.4.8 Test and Calibration

The EET sub-system is equipped with a Test Loop Translator (TLT), based on a single conversion chain. This unit is used to verify the transmit and/or receive functionality of any transmit and receive channel. This type of verification can be performed on demand and before each data relay link.

6.7.5 REDU-3 (RED-3) TERMINAL

Figure 51 shows the Redu-3 (RED-3) antenna, which provides S-band transmit, and S-band receive capability (S/S). Due to its usage for the Proba-1 mission also called Proba-1 terminal.

Figure 51: Redu-3 (RED-3) Antenna

6.7.5.1 Services and Performance

The Redu-3 (RED-3) terminal provides the following services:

- Tracking
- Telemetry
- Telecommand

Table 12 details the Redu-3 (RED-3) Performance Characteristics. For the definition of individual characteristics see 5.6

1	Rev. 2.4	
2	18-Sep-2008	REDU-3 (S / S)
3	TERMINAL	RED-3
4	Longitude	5 deg 08' 48.00" E
5	Latitude	50 deg 00' 05.29" N
6	Altitude [m]	372
7	Antenna Diameter [m]	2.4
8	S-band Beamwidth [deg]	Rx: 3.8 Tx: 4.1
9	X-band Beamwidth [deg]	N/A
10	Ka-band Beamwidth [deg]	N/A
11	Antenna Speed [deg/s]	5.0 deg/s
12	Azimuth Range [deg]	0 to 360
12	Elevation Range [deg]	3.35 to 176
14	Search / Acquisition Aid	NO
15	Tilt Facility	NO
16	Tracking Mode	Program
17	Angular Data Accuracy (autotrack+pointing error)	N/A
18	FUNCTIONALITIES	
19	TM/TC Standards	PCM, CCSDS
20	TM/TC Redundancy	NO
21	Comms Redundancy	NO
22	Ranging	NO
23	Doppler	NO
24	Meteo	NO
25	Autotrack Antenna Angles	NO
26	Delta-DOR	NO
27	Radio-Science	NO
28	Frequency & Timing	Oven heated crystal oscillator and GPS
29	UPLINK	
30	S-band TX band [MHz]	2025-2110
31	S-band Polarization	RHC
32	S-band EIRP [dBm]	42
33	X-band TX band [MHz]	N/A
34	X-band Polarization	N/A
35	X-band EIRP [dBm]	N/A
36	Ka-band TX band (MHz)	N/A
37	Ka-band Polarization	N/A
38	Ka-band EIRP [dBm]	N/A
39	Modulation Schemes	ENERTEC compliant
40	Subcarrier Freq. [kHz]	PSK=50kHz FSK=100kHz
41	DOWNLINK	
42	L-band RX band [MHz]	N/A
43	L-band Polarization	N/A
44	L-band G/T [dB/K]	N/A
45	S-band RX band (MHz)	2200-2300
46	S-band Polarization	RHC
47	S-band G/T [dB/K]	8.6
48	X-band RX band [MHz]	N/A
49	X-band Polarization	N/A
50	X-band G/T [dB/K]	N/A
51	Ka-band RX band [MHz]	N/A
52	Ka-band Polarization	N/A
53	Ka-band G/T [dB/K]	N/A
54	Modulation Schemes	ENERTEC compliant
55	Carrier Freq Search Range	+/- 300 KHz
56	Subcarrier Frequency	PSK up to 1MHz
57	Data Rates	Enertec compliant: 250 Kbps (subcarrier) 1 Mbps (Direct PCM)
58	Data Coding Scheme	R-S, Convolutional and Concatenated
59	INTERFACES	
60	TM/TC Connectivity	TCP/IP
61	Rng/Dop Connectivity	N/A
62	Meteo Connectivity	N/A
63	Angles Connectivity	N/A
64	Pointing Format	TLE
65	Tracking Interface (ESOC)	NO

Table 12: Redu-3 (RED-3) Performance Characteristics

6.7.5.2 *Antenna Horizon*

Figure 52 shows the Redu-3 (RED-3) Antenna Horizon Mask.

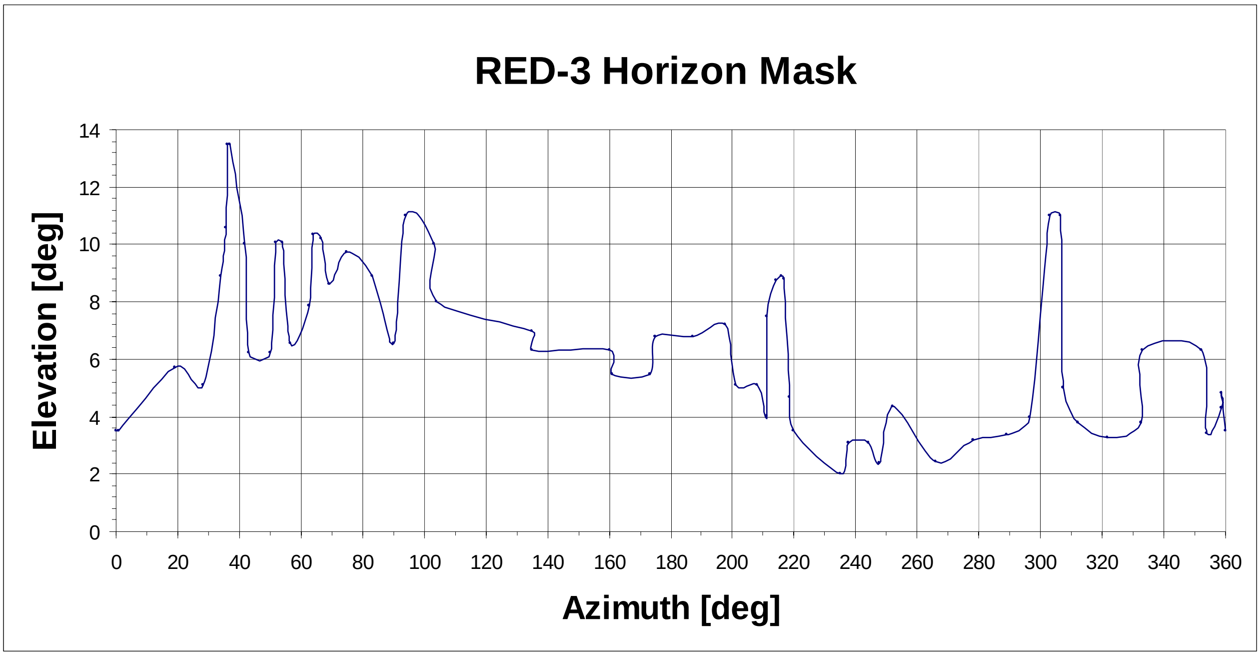

Figure 52: Redu-3 (RED-3) Antenna Horizon Mask

6.7.5.3 *Functional Description*

Figure 53 shows the Redu-3 (RED-3) Block Diagram, which is used for the functional description.

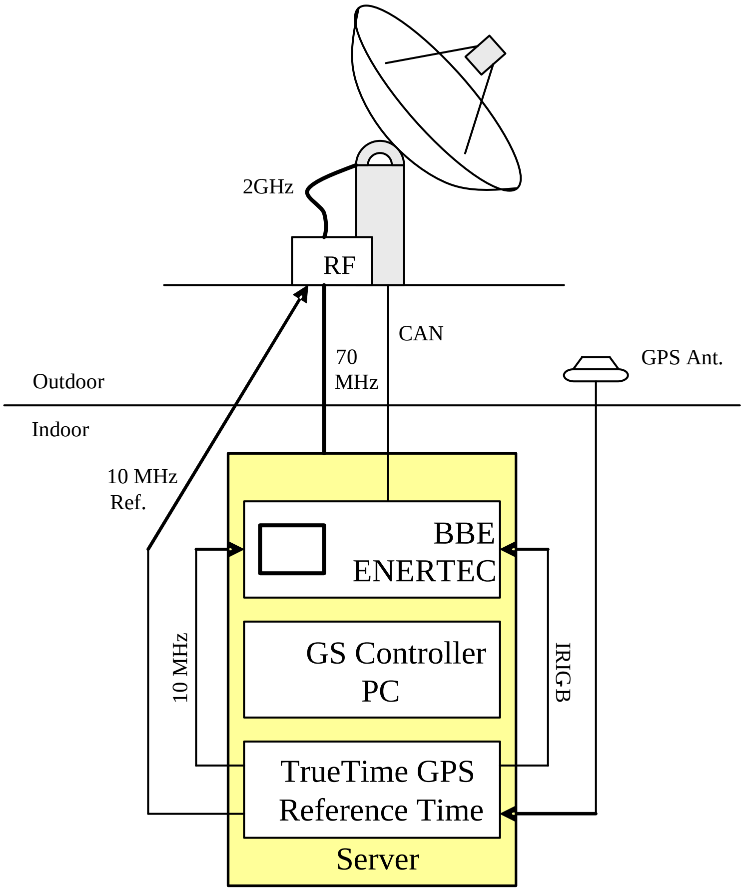

Figure 53: Redu-3 (RED-3) Block Diagram

6.7.5.3.1 Antenna

The S-band transmit and S-band receive (S/S) prime focus antenna is fitted with a 2.4m parabolic main reflector in an elevation over azimuth mount. Auto-tracking of the S-band signal is not possible.

The antenna pointing is performed by the Antenna Control Unit called Ground Station Controller PC (GSC) via a CAN bus to the antenna azimuth and elevation axis controllers. The antenna motion is achieved via stepping motors and gearboxes. The antenna position is derived by the GSC from the number of motor steps executed returned by the axis controllers.

The incoming electromagnetic wave is conveyed via the reflector directly into the S/S feed cross-dipole antenna. The coexisting receive and transmit signals for each polarisation inside the S-band feed are separated by Diplexer filters. The receive coax branches are fed to Low Noise Amplifier (LNA), which amplifies the Right-Hand-Circular (RHC) signal. The S-band signals [2200-2290 MHz] are down-converted to 70 MHz Intermediate Frequency. The S-band downlink signal is then transferred for telemetry processing.

The uplink signal coming from telecommand processing at 70 MHz is delivered to S-band transmission. It is converted by the S-band up-converter (SUC) to [2025-2110 MHZ] and delivered to the S-band Solid State Amplifier (SSSA).

A transmit coax assembly routes the RF signal to the S-band feed. The transmitted polarisation is selected by routing the RF signal to the uplink arm of the Diplexers for Right Hand Circular polarisation.
The S-band Feed (including polarizer) matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from the Diplexer and conveys the high power RF flux from the S-band feed to the antenna main reflector, where it is forwarded to free space.

6.7.5.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions.
For program track the antenna Azimuth and Elevation pointing angles are derived from orbital predictions or State Vectors in the Ground Station Controller (GSC).

6.7.5.3.3 Telemetry

The 70 MHz signal is demodulated in the Enertec 3801-20 baseband equipment, which performs remnant carrier demodulation, frame synchronisation, time tagging, Viterbi and Reed-Solomon decoding, as well as Telemetry data structure processing.
The telemetry chain is non-redundant. The baseband equipment can also be interfaced to RED-1 for backup purposes.

6.7.5.3.4 Telecommand

The Enertec 3801-20 baseband equipment receives Telecommand data from the directly connected and collocated Spacecraft Control System. It provides the Phase Shift Key (PSK) modulation of the telecommand bit stream onto a sub-carrier, which is then used to phase modulate the uplink carrier at 70 MHz. The uplink signal is routed to the S band antenna uplink.
The telecommand chain is non-redundant. The baseband equipment can also be interfaced to RED-1 for backup purposes.

6.7.5.3.5 Radiometric

Radiometric measurements are not performed.

6.7.5.3.6 Monitoring and Control

The monitoring and control (M&C) system allows full local control over the terminal. It is based on the Ground Station Controller (GSC).

6.7.5.3.7 Frequency and Timing

The frequency reference generation is based on an oven heated crystal oscillator. The frequency distribution system coherently derives a 10 MHz signal and amplifies it for distribution to the devices.
The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year

via IRIG-B 5 MHz, 1 kHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

6.7.5.3.8 Test and Calibration

No specific test and calibration is performed.
Test tools for integration and performance validation activities are not described.

6.7.6 ADDITIONAL FACILITIES

6.7.6.1 GPS-TDAF

A Global Positioning System (GPS) dual-frequency receiver system with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

6.7.6.2 Fibre Optic connectivity

There is a fully redundant STM-1 fibre optic connectivity between the site and Brussels.
Each cable is terminated on separate STM-1's, in a separate buildings.

6.7.6.3 In Orbit Test (IOT)

The In Orbit Test (IOT) facilities consist of the following systems:

6.7.6.3.1 Test and Measuring System

The Test and Measuring System (TMS) consists of three subsystems: TMS-4, TMS-5 and TMS-6. Antenna and Front-End Equipment provide a 750 MHz interface and share the same set of Receivers, Test equipment, Computer hardware and Software Tools, which provide Test capabilities to specific frequency bands.

6.7.6.3.2 TMS-4

TMS-4 measures the performance of geostationary satellites in the 12 to 14 GHz band, with the support of the 9 m antenna, which can transmit in dual linear polarisation and in two frequency bands (12.96 to 14.30 GHz and 13.96 to 14.30 GHz); in addition, it is able to receive the 12.46 to 12.79 GHz range, also in dual linear polarisation. TMS-4 is remotely controlled from the Test Measuring Room (TMR).

6.7.6.3.3 TMS-5

The 9 m antenna can transmit in dual circular polarisation on six selectable channels with 80 MHz bandwidth, spread over the 17.3 to 18.1 GHz band; in addition it can receive in dual circular polarisation in the 11.7 to 12.5 GHz band.

6.7.6.3.4 TMS-6

The TMS-6 test and measuring antenna complements TMS-4 & 5, it has two receive chains operating in the 27 to 29 GHz range, and four transmit chains operating in the 18.8 to 19.8 GHz band.

6.7.6.3.5 TMS-L1, TMS-L2 and TMS-L3

Three transportable stations TMS-L1, TMS-L2 and TMS-L3 allow to carry out spot beam measurements. They can be sited at different locations. Each station is equipped with its own Payload Test Laboratory (PTL) and relevant Front End Equipment, i.e. TMS-S, an S-band Front End with a 1.8 m antenna, and TMS-Ka, a Ka-band Front End with a 1.8 m antenna, both capable to simulate the payload of a low orbiting spacecraft.

6.7.6.3.6 TMS-S

An S-band front end with a 1.8m antenna is capable of simulating the payload of a low orbiting spacecraft.

6.7.6.3.7 TMS-Ka

A Ka-band front end with a 1.8m antenna is capable of simulating the payload a low orbiting spacecraft.

6.7.6.3.8 Payload Test Laboratory

The Payload Test Laboratory (PTL) provides the interface to the IOT and Earth Station Verification and Assistance (ESVA) facilities and is the location where IOT and ESVA operations are carried out. The room is mainly equipped with computer consoles.

6.7.6.4 Pastel

The PASTEL Mission Control System (PCMS) provides the necessary scheduling, monitoring and control facilities for the PASTEL Terminal on the CNES SPOT 4 satellite, (which form part of the SILEX experiment). This system provides an optical communications link between SPOT 4 and the ESA ARTEMIS satellites (by means of the Communications Monitor (CM), which allows to exchange files between CNES SPOT 4 CMP and PMCS, included scheduling and booking of the optical payload and the ARTEMIS feeder link). The Mission Planning system is used for scheduling and reservation of PASTEL for transmission of the SPOT 4 images via ARTEMIS and other scientific experiments. The Monitoring and Control system is used to monitor the PASTEL Terminal and to generate the required command messages for controlling the terminal.

6.7.6.5 Eutelsat

These facitities are to provide telecommand, telemetry and ranging for the EUTELSAT fleet in Ku-band and emergency support in S-band.

6.7.6.5.1 Ku-band (TB1, TB2, TB3, TB4, TB5, TB6) Terminals

Six terminals TB1 – TB6, each consisting of a 3.8m, limited motion antenna, a shelter and associated front-end equipment. All front-end equipment is controlled via a front-end interface processor (FIP), which interfaces to the Eutelsat M&C system.

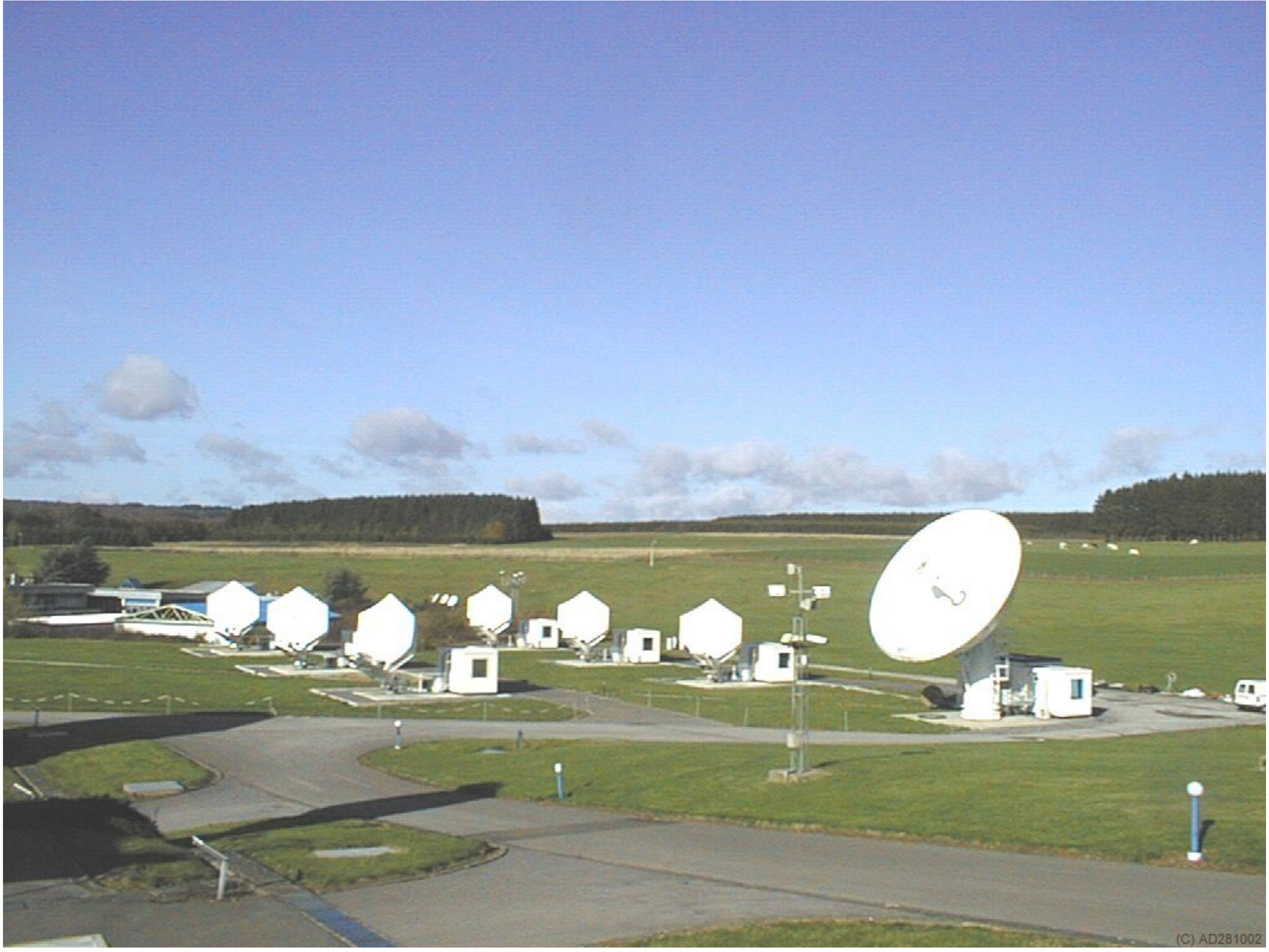

Figure 54: Redu Eutelsat 3.8m and 9m TT&C antennas

6.7.6.5.2 S-band (TBU) Terminal

The S-band terminal comprises of a 9m, limited motion antenna, which is fitted with mono-pulse tracking. All fully redundant front-end equipment is installed in a front-end shelter. All front-end equipment is controlled via a front-end interface processor (FIP), which interfaces to the Eutelsat M&C system.

6.7.6.6 G2SAT Terminal

The G2SAT terminal provides Tracking, Telemetry and Command (TTC) services for the company G2SAT located in Sydney, Australia.

Figure 55: Redu G2SAT 9m C-Band antenna

It is a 9m C-band antenna equipped with Cortex baseband equipment.

6.7.6.7 Newskies

The emergency and back-up Alternate Satellite Operations Centre (ASOC) and Alternate Payload Operations Centre (APOC) for NewSkies satellites are hosted in the Redu Station. Due to its reachability within 4 hours by car from the prime control centre located at The Hague, Netherlands, these facilities are kept in “hot-standby” to allow control centre personnel to take over satellite operations in case of need.

6.7.6.7.1 Alternative Satellite Operations Centre (ASOC)

The Alternative Satellite Operations Centre (ASOC) will be used for processing of Telecommand, Ranging and Telemetry data between the NSS satellites and ground stations located in the following places / countries: The Hague, London, USA, Australia and Israel.

6.7.6.7.2 Alternative Payload Operations Centre (APOC)

The Alternative Payload Operations Centre (APOC) will be used for Monitoring and Control of the various payloads from the NSS satellites. The APOC will receives data from the following places / countries: The Hague, London, USA, Australia and Israel.

6.7.7 PLANNED DEVELOPMENTS

None.

6.8 Santa Maria of Azores (SMA) Station

Figure 56 shows the Santa Maria of Azores Aerial View.

Figure 56: Santa Maria of Azores Aerial View

6.8.1 GENERAL INFORMATION

The Santa Maria of Azores site is made available to ESA based on an international agreement between ESA and the Government of Portugal.

6.8.1.1 Location

The island of Santa Maria is located in the south-eastern part of the Azores, Portugal. The Santa Maria of Azores site is situated in the northern part of the island, 6 km northwards from the village of Vila do Porto. The location is noted as Monte das Flores on local maps.

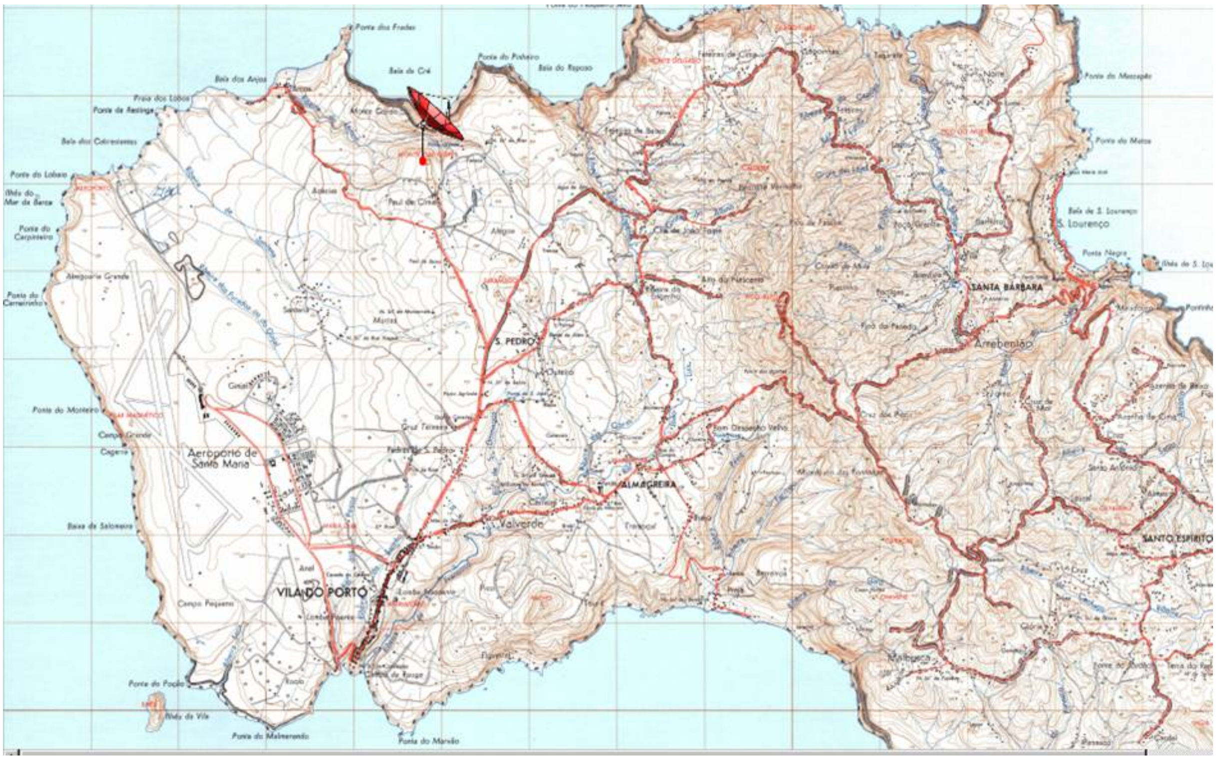

Figure 57: Santa Maria of Azores Area Map

6.8.1.2 *Access*

Site visits require a confirmed Station Intervention form sheet. Accommodation can be arranged through the M&O-Team Supervisor. Main entrance gate is controlled by Securitas Systemas remotely. Keys for the powerplant and shelter entrance have to be picked up at the police station. The Santa Maria of Azores site is accessible only by road, it is not served by public transport.
At the airport exit, take the third exit at the forthcoming roundabout in direction to “Hotel”. Continue along the street for approximately 900 m and turn in direction of “Santana Anjos” on the forthcoming junction. Follow the road for 3 km until the next intersection and pass the intersection going straight ahead for around 400m. An ESA sign indicates the way the station. Take finally the left exit of the forthcoming junction and follow the street for 500 m to the Santa Maria of Azores Tracking Station entrance.

6.8.1.3 *Entry Requirements*

Citizens of the European Union, Switzerland, Andorra, Liechtenstein and Malta require an identity card in order to gain entry into Portugal. Visitors from countries requiring a visa, the maximum length of stay in Portugal are 90 days.
Portugal is in addition part of the EU “Schengen” Agreement.

6.8.1.4 *Climate*

The climate on the island can be compared with the climate near the Mediterranean Sea. The winters are rainy and very windy, the summers are humid and sunny, but seldom very hot.
A summary of the weather characteristics for the Santa Maria of Azores Island is given below:

Warmest month:	August
Average daily maximum temperature for August:	22.2° C
Maximum recorded temperature in August:	28.5° C
Lowest recorded temperature in August:	14.6° C
Coldest month:	February
Average daily minimum temperature in February:	14.0° C
Maximum recorded temperature in February	20.4° C
Lowest recorded temperature in January	4.8° C
Average annual rainfall	775 mm

6.8.1.5 *Management*

There is no ESA on-site representative at the Santa Maria of Azores site.
The Maintenance and Operations (M&O) of the site is provided by EDISOFT S.A. The M&O-Team members travel to the station on a regular basis to perform all necessary maintenance and operations activities.
Daily operations are performed by EDISOFT S.A. in X-band. The reception of Earth Observation data belongs to their responsibility.

6.8.1.6 *Local Contact*

The local point of contact for the Santa Maria of Azores station is:

SMA M&O-Team Supervisor
Mr Ricardo Conde
email: ricardo.conde@edisoft.pt
Tel +351-969 373 108
Fax +351-212 945 999

6.8.1.7 Logistics

The Postal address of the station (mail, letters, postal packages, etc) is:

ESA Tracking Ground Station
Ricardo Conde
Apartado 49 / Rua Assomada
Vila do Porto
9580-909
Santa Maria Island / Acores
Portugal

In case of any transports via cargo and airfreight, please contact Mr Ricardo Conde in advance.

6.8.2 STATION SERVICES

Figure 58 shows the Santa Maria of Azores Site Plan.

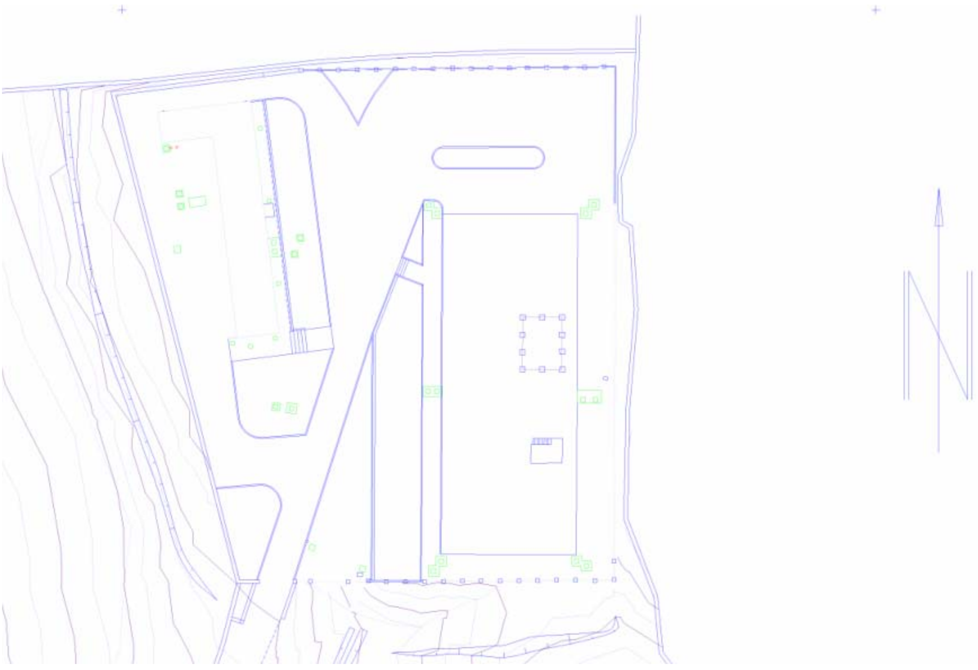

Figure 58: Santa Maria of Azores Site Plan

6.8.2.1 Security

The site is fenced but non-guarded. 24/7 guarding is available only during operational launch campaigns. Remote access control and surveillance system are installed providing 24/7 site security.

6.8.2.2 Power

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, and a no-break dirty (NB-dirty) and a no-break clean (NB-clean) power supply using Static Converters and Batteries. Via low voltage switches the electricity (3x 400V, 50 Hz) is distributed to the consumer groups.
Public power into the power plant is rendered by one 10 kV medium voltage line and two transformers of 100 kVA.
Two Diesel Generators supply each 80 kVA within 45 seconds after public power failure. Two Static Converters supply 20 kVA (clean busbar) each, other two ones supply 10 kVA (dirty busbar) each. The Battery capacity allows for a maximum bridging time of 30 minutes.

6.8.2.3 Air Conditioning

The station air conditioning system supplies air to the three shelters at a temperature of 18-21°C in the equipment shelter and of 21-24°C in the other shelters, with a controlled humidity of 40-70% relative humidity.

6.8.2.4 Communications

The Santa Maria of Azores station features two ISDN lines. The first one is used for the Ariane-5 Telemetry Kit only, the second ISDN line serves non-operational traffic like Internet and telephone. The connectivity into the Santa Maria of Azores site is diversely routed through a 10-screened shielded Twisted Pair cable.
The MiniLINK/2+ multiplexer system is able to multiplex voice and data either over the ISDN network or the Inmarsat terminal to the Système de Centralisation et d`Exploitation des Télémesures (SCET) in Kourou. Connection to the ESA Operations Network (OPSNET) does not exist.

6.8.3 SANTA MARIA OF AZORES-1 (SMA-1) TERMINAL

Figure 59 shows the Santa Maria of Azores-1 (SMA-1) antenna, which provides S- and X-band receive capability (-/SX).

Figure 59: Santa Maria of Azores-1 (SMA-1) Antenna

6.8.3.1 Services and Performance

The Santa Maria of Azores (SMA-1) terminal provides the following services:

- Tracking
- Telemetry

Table 13 details the Maria of Azores (SMA-1) Performance Characteristics. For the definition of individual characteristics see 1.7.

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	SMA-1 (- / S X)	42	L-band RX band [MHz]	N/A
3	TERMINAL	SMA-1	43	L-band Polarization	N/A
4	Longitude	25 deg 08' 08.60" W	44	L-band G/T [dB/K]	N/A
5	Latitude	36 deg 59' 50.10" N	45	S-band RX band (MHz)	2200-2300
6	Altitude [m]	275	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	5.5	47	S-band G/T [dB/K]	16.0 (TM), 15.5 (Tracking)
8	S-band Beamwidth [deg]	Rx: 1.7 Tx: -	48	X-band RX band [MHz]	8025-8400
9	X-band Beamwidth [deg]	Rx: 0.5 Tx: -	49	X-band Polarization	RHC, LHC
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	30.0 (spec)
11	Antenna Speed [deg/s]	Az: 5 deg/s El: 5 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	No limitations due to X/Y mount	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	0 – 90	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	NO	54	Modulation Schemes	PCM/FM, BPSK
15	Tilt Facility	NO	55	Carrier Freq Search Range	+/- 0.5 MHz
16	Tracking Mode	Auto (only S-band) / Program	56	Subcarrier Frequency	N/A
17	Angular Data Accuracy (autotrack+pointing error)	150 mdeg (spec)	57	Data Rates	31.25 kbps, 62.5 kbps, 125 kbps, 250 kbps, 500 kbps, 1 Mbps
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional
19	TM/TC Standards	PCM/FM, BPSK	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	HDLC
21	Comms Redundancy	YES	61	Rng/Dop Connectivity	N/A
22	Ranging	N/A	62	Meteo Connectivity	N/A
23	Doppler	N/A	63	Angles Connectivity	N/A
24	Meteo	N/A	64	Pointing Format	DO, TLE
25	Autotrack Antenna Angles	YES	65	Tracking Interface (ESOC)	N/A
26	Delta-DOR	NO			
27	Radio-Science	NO			
28	Frequency & Timing	Crystal			
29	UPLINK				
30	S-band TX band [MHz]	N/A			
31	S-band Polarization	N/A			
32	S-band EIRP [dBm]	N/A			
33	X-band TX band [MHz]	N/A			
34	X-band Polarization	N/A			
35	X-band EIRP [dBm]	N/A			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	N/A			
40	Subcarrier Freq. [kHz]	N/A			

Table 13: Santa Maria of Azores (SMA-1) Performance Characteristics

6.8.3.2 Antenna Horizon

Figure 60 shows the Santa Maria of Azores-1 (SMA-1) Antenna Horizon Mask.

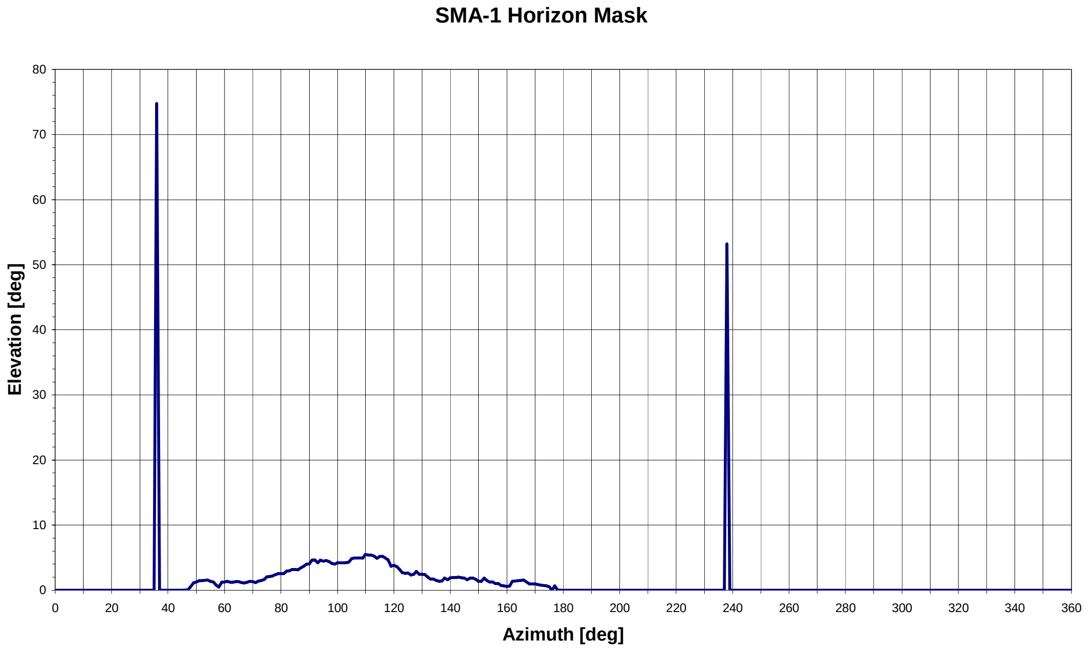

Figure 60: Santa Maria of Azores-1 (SMA-1) Antenna Horizon Mask

6.8.3.3 Functional Description

Figure 61 shows the Santa Maria of Azores-1 (SMA-1) Block Diagram, which is used for the functional description.

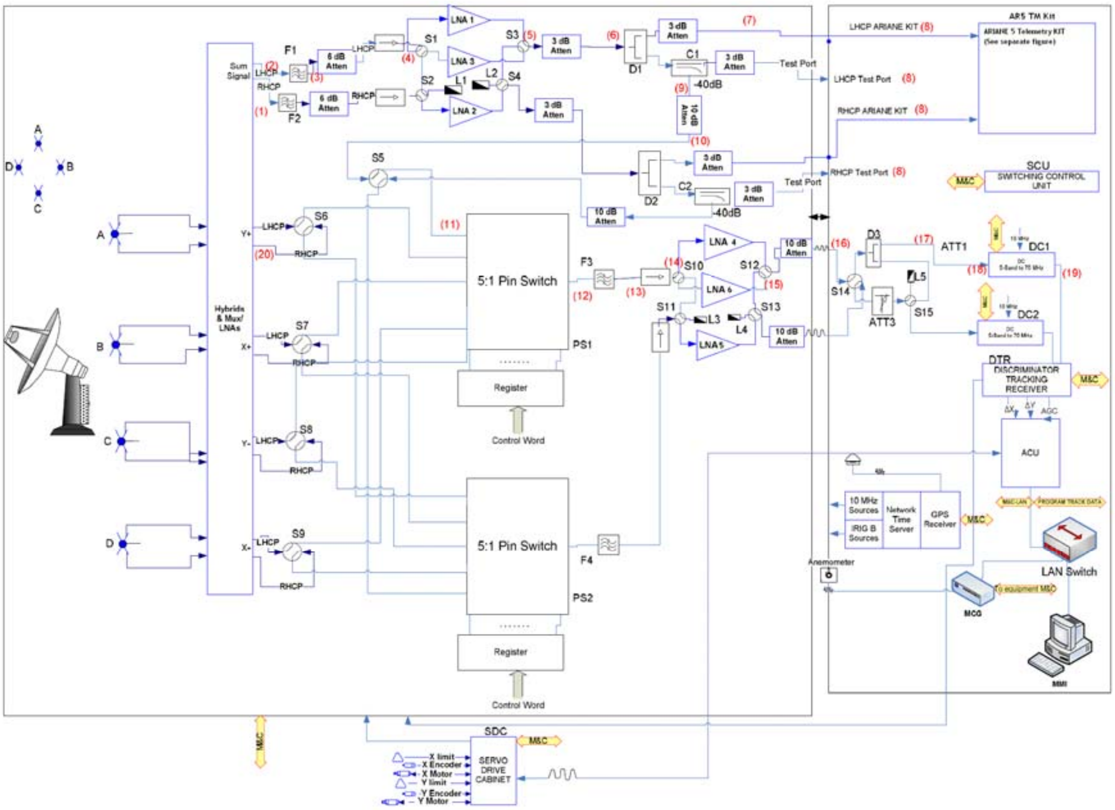

Figure 61: Santa Maria of Azores-1 (SMA-1) Block Diagram

6.8.3.3.1 Antenna

The S- and X-band receive (-/SX) Cassegrain antenna is fitted with a shaped 5.5m parabolic main reflector and a dichroic subreflector in an X/Y mount. The S-Band feed consists of a prime focus mounted array of four dipoles. It is a multi-element array that is combined to produce an independent data channel and an electronic scanned, sequential lobed tracking channel using the dipoles in the outer configuration. The X-band feed, illuminated by a dichroic sub reflector, permits Earth observation satellite data acquisition in program track mode. S- and X-band test antennas located at the calibration tower allow calibration and testing functionality. An additional test dipole is mounted at the edge of the 5.5m antenna allowing the Ariane-5 Telemetry Kit validation.

The antenna pointing is performed by the Antenna Control Unit (ACU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the X and Y positions to the ACU.

The incoming electromagnetic wave is conveyed via the reflector and through the dichroic subreflector into the S - band feed. The feed consists of an assembly of four dipoles and allow auto tracking. Each dipole is connected to a 90° hybrid and 2 Low Noise Amplifiers (LNAs), followed by a 2-connection RF switch for polarisation selection.

The S-band downlink signals [2200-2300 MHz] are combined from the four dipoles and routed directly routed to the Ariane-5 Telemetry Kit, via a 3:2 redundant LNA assembly.

S-band signals coming from the outer dipoles are routed into two 5:1 Pin Switches, one for each signal polarization. The Pin Switches samples the signal and routes the signals to be filtered and amplified carried out by the 3:2 LNA redundant configuration. Finally, the tracking signals are down-converted to 70 MHz.

An Electronic Scan Discriminator & Controller (ESDC) performs amplitude detection of the signals (main signal and signals coming from the outer dipoles) and obtaining the error signals and reference signal power for driving the antenna motors. For each sampled signal by the Pin Switch, an envelop detection is realized by the ESDC. These errors signals will be used in the ACU to point the antenna in auto track mode. The tracking receiver receives two input signals via two different down converters. Auto track capability is feasible either on one single channel or in diversity mode using the stronger signal.

The Ariane-5 Telemetry system consists of an RF distributor, which is responsible for the RF signal distribution to the main and redundant TM chains. Each chain is equipped with a Cortex featuring demodulation, bit reconstruction and decoding as well as TM synchronisation, de-scrambling, Control Visuel Immédiat (CVI) extraction and HDLC packet generation. The Telecom subsystem is based on a single MiniLink multiplexer providing interphone communication with CSG, receiving Désignation d`Objectif (DO) data and transmitting CVI data in HDLC format to the SCET in Kourou over a single 64kbit ISDN line or the Inmarsat terminal. TM can also be stored on the harddisc of the Digital tape Recorders. The playback function of the recorders allows the simulation of a complete launcher support.

6.8.3.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or autotrack mode using the received signal.
For program track the antenna Azimuth and Elevation pointing angles are provided to the ACU by the DO Processor. Input to the DO PC is provided by CNES/CSG in form of state vectors (DO) in real time. The antenna Azimuth and Elevation pointing angles for autotrack capabilities are derived from error signals generated by the off-pointing from the electromagnetic field received.
For testing and maintenance purposes, the ACU can be fed with TLEs and files predicting the pointing angles in the Azimuth/Elevation format.

6.8.3.3.3 Telemetry

The S-band downlink signals are fed to the Ariane-5 Telemetry Kit without frequency down-conversion.

The S-band signals are combined and demodulated in the Cortex Radio Telemetry Receiver / Processeur de Telemesure (RTR/PTM) unit which provides RF acquisition, demodulation, bit reconstruction and Viterbi decoding. The Processeur de Telemesure hosted inside the Cortex performs TM synchronisation, de-scrembling, Reed-Solomon decoding, CVI extraction and HDLC packet generation. The output data is transferred to the MiniLink/2+ multiplexer which ultimately delivers the real-time telemetry data via ISDN line or the Inmarsat terminal to SCET in Kourou. Additionally, telemetry is routed to Digital Tape Recorders to be stored for off-line playback purposes.
The telemetry chains are redundant and the various switches allow flexible signal routing.

6.8.3.3.4 Telecommand

Not applicable.

6.8.3.3.5 Radiometric

Not applicable.

6.8.3.3.6 Monitoring and Control

The monitoring and control (M&C) system allows full local and remote control over the terminal. It is based on a hierarchy of M&C systems: the Station Personal Computer (SPC), the Monitoring and Control Gateway (ACQ) and Local Man Machine Interfaces (MMI) on the various devices. The SPC runs an M&C system based on the Genius application. It is composed of a local server and a local workstation. Mission specific terminal configurations are normally affected through pre-validated macro-commands, also individual equipment configurations are possible. The SPC interacts through a set of subsystem controllers in separate units with all the terminal equipment. In case of failure of the monitoring and control system, the terminal can be locally operated from the individual equipment local Man Machine Interfaces (MMIs).
Remote control of the SPC from the ESTRACK Control Centre (ECC) does not exist.

6.8.3.3.7 Frequency and Timing

The frequency reference generation is based on a Oven Controlled X-tal Oscillator (OCXO) originated from a time and frequency source with appropriate long term frequency stability. The frequency distribution system coherently derives 10 MHz signals and amplifies them for distribution to the devices.
The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 10 MHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

6.8.3.3.8 Test and Calibration

The objective of the test and calibration function is to validate the telemetry functions and antenna performances specific for launcher support.
Telemetry processing functionality is tested by means of playing simulated telemetry from the Digital Tape Recorder. The test signal is generated by a Signal Generator and injected into the antenna via a test dipole, so called Boucle Cornet Mode.
For phase calibration of the tracking channels, a remote controllable calibration tower is available.
Test tools for integration and performance validation activities are not described.

6.8.4 ADDITIONAL FACILITIES

6.8.4.1 Calibration Tower

The calibration tower is located on top of Pico Alto, in a distance of 4310m from the antenna. It comprises transmission antennas for S- and X-band. Two S-band synthesizers allow the simulation of the Ariane-5 signal with an identical I-Q modulated pseudo-random bit stream, and a simultaneous transmission of two frequencies, altering in level. The X-band transmitter has a separate synthesizer offering the selection of the operating frequency and the output power level. The calibration tower units can be controlled from remote by using the wireless link between the shelters and Pico Alto.

6.8.4.2 Diagsat5 unit

This equipment is provided by CNES/CSG and is not integrated in the AR5TM racks. It is housed at the station starting from the Stand-Alone Tests with CSG and needs to be sent back right after the mission support.
The Diagsat5 unit extracts parameters relevant to the Ariane-5 inertial navigation systems from the receiving HDLC CVI frames and elaborates a printable report of the orbital elements.

6.8.4.3 SMA exploitation by Edisoft, S.A.

Edisoft implements a multi-purpose oceanic observation monitoring and surveillance system over the Northern East Atlantic area. The SMA-1 Terminal is used to track Envisat and Radarsat in X-band. Data processing is carried out by Edisoft`s owned baseband equipment housed at the station. The provision of Oil Spill Detection and Vessel Detection and Classification products belong to the exploiters priorities.

6.8.5 PLANNED DEVELOPMENTS

In addition to the ATV supports, it is planned to support Ariane-5 launchers loaded with Galileo satellites as well as Vega and Soyuz launchers with small to medium sized satellite payloads.

6.9 Villafranca (VIL) Station

Figure 56 shows the Villafranca (VIL) Aerial View. The name Villafranca refers to the old tracking station site, which today houses the European Space Astronomy Center (ESAC).

Figure 62: Villafranca (VIL) Aerial View

6.9.1 GENERAL INFORMATION

The Villafranca site is made available to ESA based on an international agreement between ESA and the Government of Spain.

6.9.1.1 Location

The Villafranca site lies in the Guadarrama Valley, 30 kilometres west of Madrid, Spain.

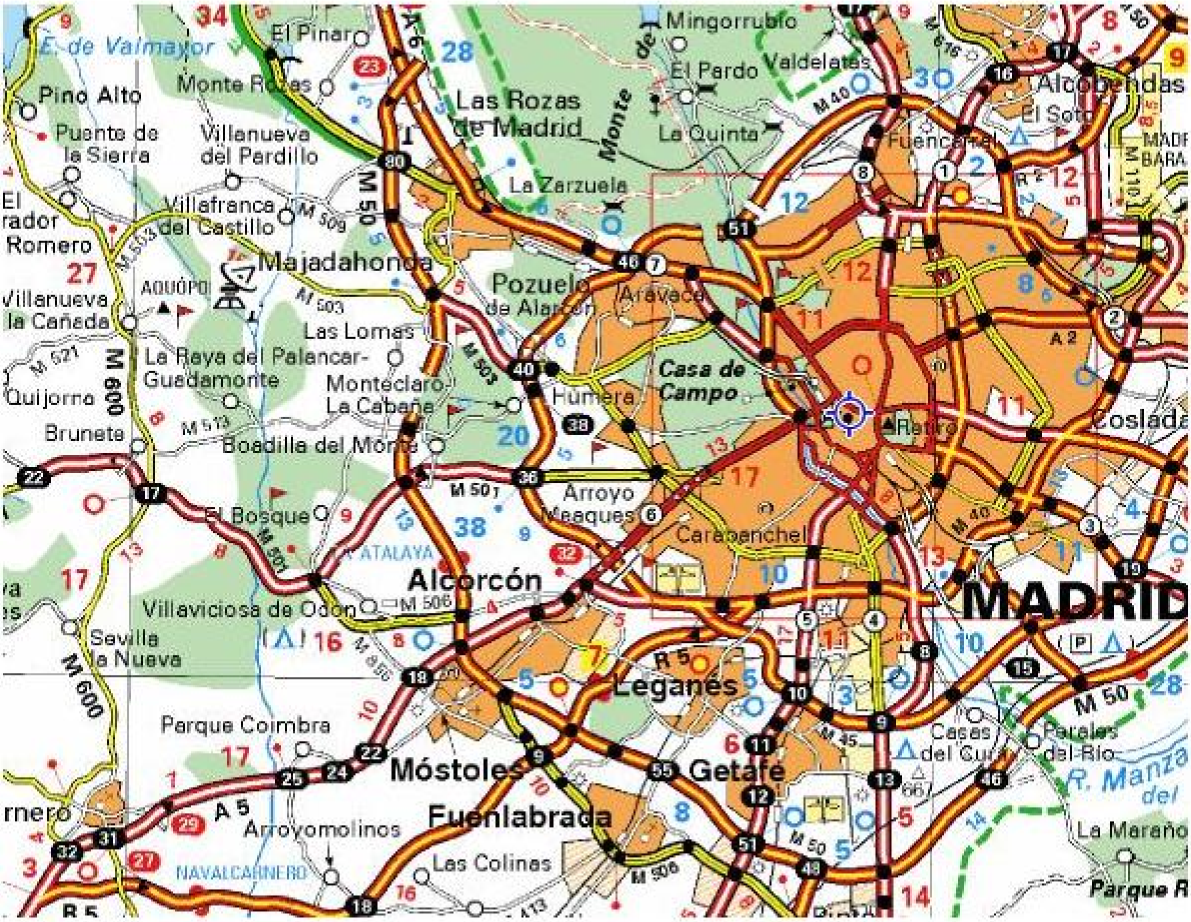

Figure 63: Villafranca (VIL) Area Map

6.9.1.2 *Access*

Site visits require a confirmed Station Intervention form sheet.
Accommodation can be arranged through the station manager.

6.9.1.3 *Entry Requirements*

The entry requirements to Spain are as for the European Union. Spain is in addition part of the EU "Schengen" Agreement.

6.9.1.4 *Climate*

Located in the Guardarrama river valley, the Villafranca station has the climate of central Spain, but due to the proximity of the river the winters can be more humid with low temperatures. A summary of the weather characteristics for the Villafranca area is given below:

Warmest month	July
Average daily maximum temperature for July	30.8° C

Maximum recorded temperature in July	39.1° C
Lowest recorded temperature in July	8.2° C
Coldest month	January
Average daily minimum temperature in January	1.5° C
Maximum recorded temperature in January	18.0° C
Lowest recorded temperature in January	-10.1° C
Average annual rainfall	476 mm

6.9.1.5 Management

The ESA D/OPS on-site representative is the Villafranca TT&C and Site Manager.
The Maintenance and Operations (M&O) of the site is provided by Ingenieria y Servicios Aerospaciales S.A (INSA).

6.9.1.6 Local Contact

The local ESA contact point for Villafranca is:

ESA Villafranca TT&C and Site Manager
Mr Lionel Hernandez
email: Lionel.Hernandez@esa.int
Tel +34-918131-170
Fax +34-918131-164

6.9.1.7 Logistics

The Postal address of the station (mail, letters, postal packages, etc) is:

European Space Astronomy Centre (ESAC)
P.O. Box 78,
E-28691 Villanueva de la Cañada,
Madrid, Spain

The Delivery Address is:

European Space Agency(ESA)
European Space Astronomy Centre (ESAC)
Camino bajo del Castillo, s/n
Urbanizacion Villafranca del Castillo
Villanueva de la Cañada
E-28692 Madrid, Spain

Custom Clearance Agent:

VALTAIR S.L
Customs Agent Code Núm. 23.820
Attn Julio Puerro / Conchita Franco
Alcarria, 5-7 Oficina 6

E-28820 Coslada, Madrid,
España
Tel +34.91.669.03.02
Fax +34.91.669.66.01

6.9.2 STATION SERVICES

Figure 58 shows the Villafranca (VIL) Site Plan.

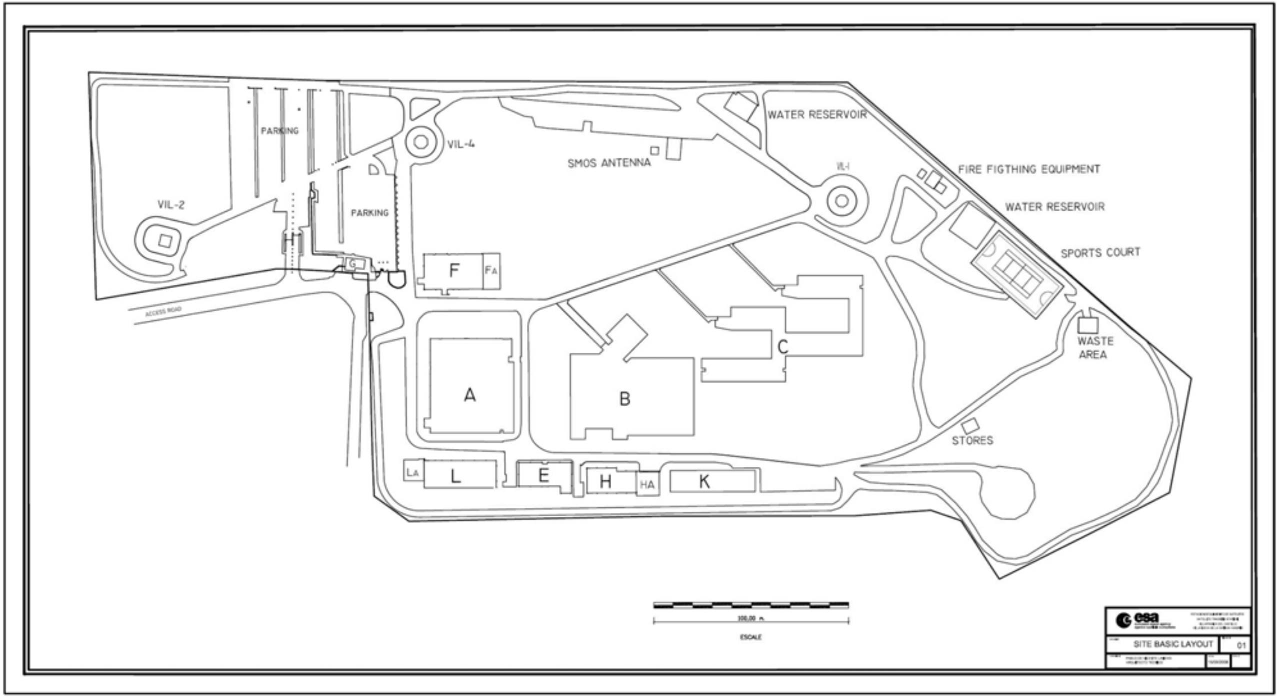

Figure 64: Villafranca (VIL) Site Plan

6.9.2.1 Security

The site is fenced and guarded 24/7. An access control and surveillance system is installed.

6.9.2.2 Power

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, and a no-break (NB) power supply using Static Converters and Batteries. Via low voltage switches the electricity (3x 380V, 50 Hz) is distributed to the consumer groups.
Public power into the power plant is rendered by one 20 kV medium voltage line and three (one spare) transformers of 1000 kVA.
Four Diesel Generators supply each 400 kVA within 15 seconds after public power failure. Five Static Converters supply each 80 kVA. The Battery capacity allows for a maximum bridging time of 6 minutes.

In addition there is a no-break supply of 3x 208V, 60 Hz realised by two Static Converters (2x 30 kVA) and Batteries.

6.9.2.3 Air Conditioning

The station air conditioning system supplies air to the main building equipment rooms at a temperature of 20-22°C + 10%, with a controlled humidity of 50% - 70% relative humidity.

6.9.2.4 Communications

The Villafranca station is connected via the ESA Operations Network (OPSNET) in a triangular setup (Cebreros, Villafranca, ESOC) using 2 Mbps international private leased circuits (IPLCs). The connectivity into the Villafranca site is diversely routed through a fibre optic link and a microwave link.
All non-operational and Internet traffic is routed via the ESA Administrative Network (ESACOM). Other connectivity exists for ESAC Scientific Data Exploitation.

6.9.3 VILLAFRANCA -1 (VIL-1) TERMINAL

Figure 59 shows the Villafranca-1 (VIL-1) antenna, which provides S-band transmit, and S-band receive capability (S/S).

Figure 65: Villafranca-1 (VIL-1) Antenna

6.9.3.1 Services and Performance

The Villafranca-1 (VIL-1) terminal provides the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Meteo, Autotrack Angles)

Table 13 details the Villafranca-1 (VIL-1) Performance Characteristics. For the definition of individual characteristics see 5.6

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	VILSPA-1 (S / S)	42	L-band RX band [MHz]	N/A
3	TERMINAL	VIL-1	43	L-band Polarization	N/A
4	Longitude	3 deg 57' 05.70" W	44	L-band G/T [dB/K]	N/A
5	Latitude	40 deg 26' 33.23" N	45	S-band RX band (MHz)	2200-2300
6	Altitude [m]	655.151	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	15	47	S-band G/T [dB/K]	28.9
8	S-band Beamwidth [deg]	Rx: 0.60 Tx: 0.65	48	X-band RX band [MHz]	N/A
9	X-band Beamwidth [deg]	N/A	49	X-band Polarization	N/A
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	N/A
11	Antenna Speed [deg/s]	Az: 3 deg/s El: 3 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	0 to 720	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	0 to 90	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	Search	54	Modulation Schemes	IFMS compliant
15	Tilt Facility	NO	55	Carrier Freq Search Range	+/- 1.5 MHz
16	Tracking Mode	Auto (S) / Program	56	Subcarrier Frequency	2 kHz to 1.2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	80 mdeg	57	Data Rates	IFMS compliant: - 1.2 Mbps (RCD) - 8 Mbps (SCD HS)
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP SLE (TMTCS)
21	Comms Redundancy	YES	61	Rng/Dop Connectivity	FTP (IFMS)
22	Ranging	IFMS compliant	62	Meteo Connectivity	FTP (IFMS)
23	Doppler	YES	63	Angles Connectivity	IP via STC
24	Meteo	YES	64	Pointing Format	STDM
25	Autotrack Antenna Angles	YES	65	Tracking Interface (ESOC)	FDS
26	Delta-DOR	NO			
27	Radio-Science	NO			
28	Frequency & Timing	CESIUM			
29	UPLINK				
30	S-band TX band [MHz]	2025-2120			
31	S-band Polarization	RHC, LHC			
32	S-band EIRP [dBm]	102.9 (S-SSA)			
33	X-band TX band [MHz]	N/A			
34	X-band Polarization	N/A			
35	X-band EIRP [dBm]	N/A			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	IFMS compliant			
40	Subcarrier Freq. [kHz]	8 or 16 kHz			

Table 14: Villafranca-1 (VIL-1) Performance Characteristics

6.9.3.2 Antenna Horizon

Figure 66 shows the Villafranca-1 (VIL-1) Antenna Horizon Mask.

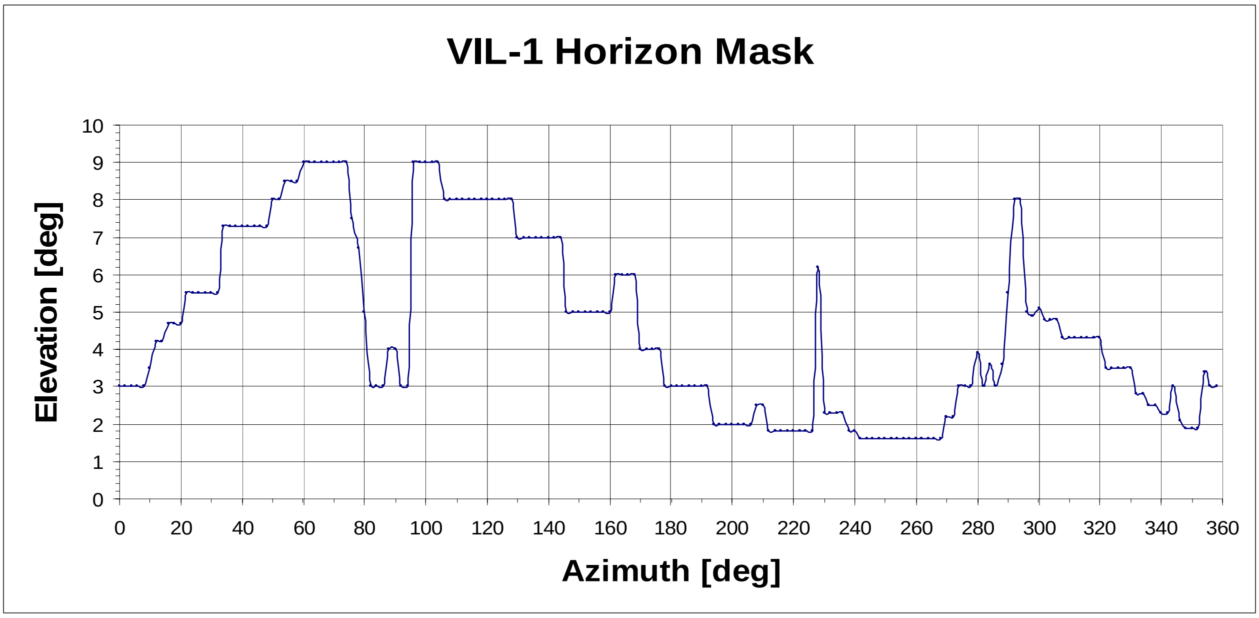

Figure 66: Villafranca-1 (VIL-1) Antenna Horizon Mask

6.9.3.3 Functional Description

Figure 67 shows the Villafranca-1 (VIL-1) Block Diagram, which is used for the functional description.

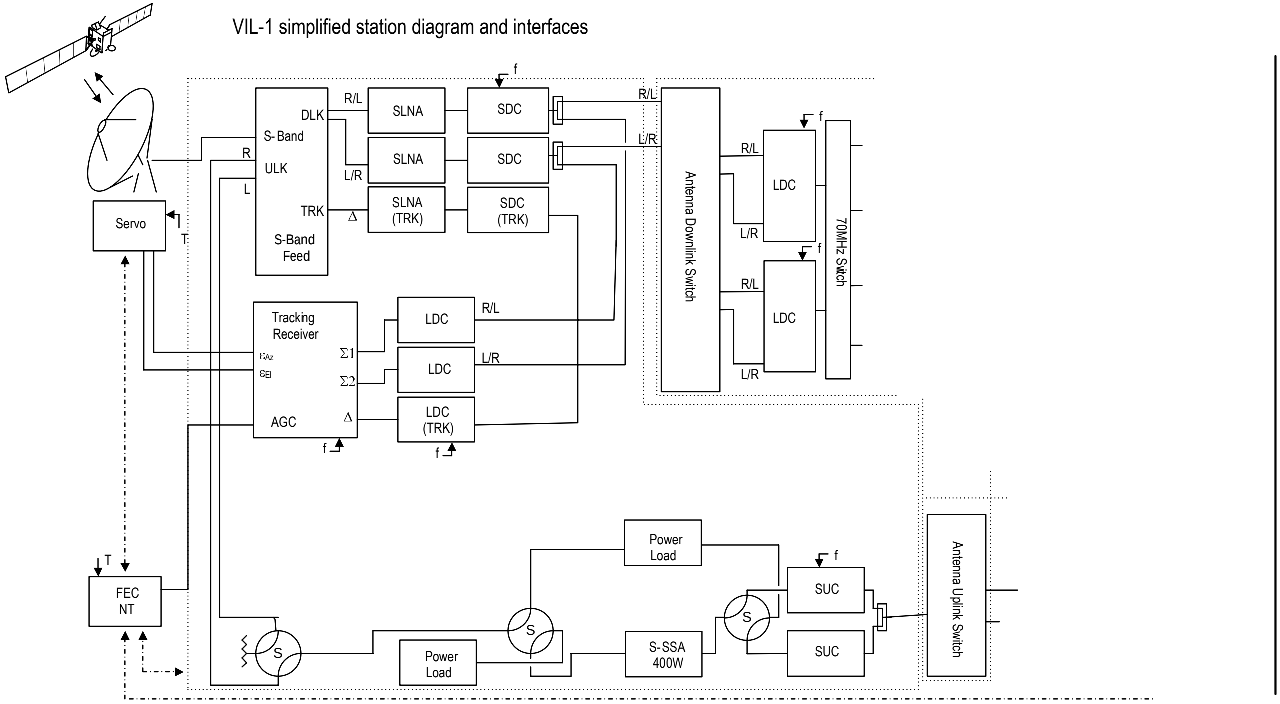

Figure 67: Villafranca-1 (VIL-1) Block Diagram

6.9.3.3.1 Antenna

The S-band transmit and S-band receive (S/S) Cassegrain antenna is fitted with a shaped 15m parabolic main reflector and a shaped hyperbolic subreflector in an elevation over azimuth mount. Auto-tracking of the S-band signal is possible by a two-channel monopulse tracking system. An S-band test antenna with reflective converter allows for signal delay calibration. An air-conditioning system outside the antenna tower provides cooling of the antenna tower and the Antenna Equipment Room (AER) which is located in the Apex cabin.

The antenna pointing is performed by the Antenna Control Unit (ACU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation positions to the ACU.

The incoming electromagnetic wave is conveyed via the main reflector, subreflector and on-axis flat mirror into the S/S feed, which together with its polarizer matches the free space field electromagnetic configuration to the waveguide modes. The coexisting receive and transmit signals for each polarisation inside the S-band feed are separated by Diplexer filters. The receive waveguide branches are fed to Low Noise Amplifiers (LNAs), which amplify the Right-Hand-

Circular (RHC) and Left-Hand-Circular (LHC) signals, which subsequently can be phase adjusted by Phase Shifters. The S-band signals [2200-2300 MHz] are down-converted to L-band [520-420 MHz]. The S-band downlink signals are then transferred for tracking and telemetry processing.
The uplink signal coming from telecommand processing at 230 MHz is delivered to S-band transmission. It is converted by the S-band up-converter (SUC) to [2025-2120 MHZ] and delivered via a switch to the S-band Solid State Amplifier (SSSA). Fine control of the radiated power is performed by adjustable external attenuators.
A transmit waveguide assembly routes the RF signal to the S-band feed. The transmitted polarisation is selected with the polarization switch, which routes the RF signal to the uplink arm of one of the two Diplexers, one for each polarisation. To avoid radiating the RF power to the antenna, the RF signal can also be routed via a set of switches to a high power dummy load.
The S-band Feed (including polarizer) matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from one of the two Diplexers and conveys the high power RF flux from the S-band feed to the antenna sub-reflector and main reflector, where it is forwarded to free space.
The S-band tracking error signals in both polarisations are derived in waveguide mode couplers. A polarisation selection switch allows routing of one polarisation to the Tracking Low Noise Amplifier (LNA). This Delta-signal is down-converted to L-band [520-420 MHz] (from S-band) via a dedicated third channel in the down-converter. This Delta-signal and the associated Sum-signals are then further down-converted to 70 MHz by a dedicated three channel L-band Tracking down-converter. The Tracking Receiver processes the three signals (Sum-1, Sum-2, Delta) coming from the S-band feed in either Phase Locked Loop mode for remnant carrier modulated signals or Cross Correlation mode for suppressed carrier modulated signals. It derives the error signals for the ACU to point the antenna in autotrack mode.

6.9.3.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or autotrack mode using the received signal.
For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Spacecraft Trajectory Data Messages (STDM's) or State Vectors in the Front End Controller (FEC). For autotrack the antenna Azimuth and Elevation pointing angles are derived from error signals proportional to the direction of highest electrical field strength received. These pointing angles are made available to the Front End Controller (FEC) for delivery for orbit determination purposes.

6.9.3.3.3 Telemetry

The telemetry function is not described as it has been removed and combined with VIL-2.

6.9.3.3.4 Telecommand

The telecommand function is not described as it has been removed and combined with VIL-2.

6.9.3.3.5 Radiometric

The radiometric function is not described as it has been removed and combined with VIL-2.

6.9.3.3.6 Monitoring and Control

The monitoring and control function is not described as it has been removed and combined with VIL-2.

6.9.3.3.7 Frequency and Timing

The frequency and timing function is not described as it has been removed and combined with VIL-2.

6.9.3.3.8 Test and Calibration

The test and calibration function is not described as it has been removed and combined with VIL-2.

6.9.4 VILLAFRANCA -2 (VIL-2) TERMINAL

Figure 68 shows the Villafranca-2 (VIL-2) antenna, which provides S-band transmit, and S-band receive capability (S/S).

Figure 68: Villafranca-2 (VIL-2) Antenna

6.9.4.1 Services and Performance

The Villafranca-2 (VIL-2) terminal provides the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Meteo, Autotrack Angles)

Table 15 details the Villafranca-2 (VIL-2) Performance Characteristics. For the definition of individual characteristics see 5.6

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	VILSPA-2 (S / S)	42	L-band RX band [MHz]	N/A
3	TERMINAL	VIL-2	43	L-band Polarization	N/A
4	Longitude	3 deg 57' 09.36" W	44	L-band G/T [dB/K]	N/A
5	Latitude	40 deg 26' 44.14" N	45	S-band RX band (MHz)	2200-2300
6	Altitude [m]	664.7997	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	15	47	S-band G/T [dB/K]	28.23
8	S-band Beamwidth [deg]	Rx: 0.60 Tx: 0.65	48	X-band RX band [MHz]	N/A
9	X-band Beamwidth [deg]	N/A	49	X-band Polarization	N/A
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	N/A
11	Antenna Speed [deg/s]	Az: 15 deg/s El: 5 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	0 to 720	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	-1 to 181	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	Search / Acq aid (X)	54	Modulation Schemes	IFMS compliant
15	Tilt Facility	NO	55	Carrier Freq Search Range	+/- 1.5 MHz
16	Tracking Mode	Auto (S) / Program	56	Subcarrier Frequency	2 kHz to 1.2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	80 mdeg	57	Data Rates	IFMS compliant: - 1.2 Mbps (RCD) - 8 Mbps (SCD HS)
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP SLE (TMTCS)
21	Comms Redundancy	YES	61	Rng/Dop Connectivity	FTP (IFMS)
22	Ranging	IFMS compliant	62	Meteo Connectivity	FTP (IFMS)
23	Doppler	YES	63	Angles Connectivity	IP via STC
24	Meteo	YES	64	Pointing Format	STDM
25	Autotrack Antenna Angles	YES	65	Tracking Interface (ESOC)	FDS
26	Delta-DOR	NO			
27	Radio-Science	NO			
28	Frequency & Timing	CESIUM			
29	UPLINK				
30	S-band TX band [MHz]	2025-2120			
31	S-band Polarization	RHC, LHC			
32	S-band EIRP [dBm]	101 (S-SSA) 109 (S-HPA)			
33	X-band TX band [MHz]	N/A			
34	X-band Polarization	N/A			
35	X-band EIRP [dBm]	N/A			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	IFMS compliant			
40	Subcarrier Freq. [kHz]	8 or 16 kHz			

Table 15: Villafranca-2 (VIL-2) Performance Characteristics

6.9.4.2 Antenna Horizon

Figure 60 shows the Villafranca-2 (VIL-2) Antenna Horizon Mask.

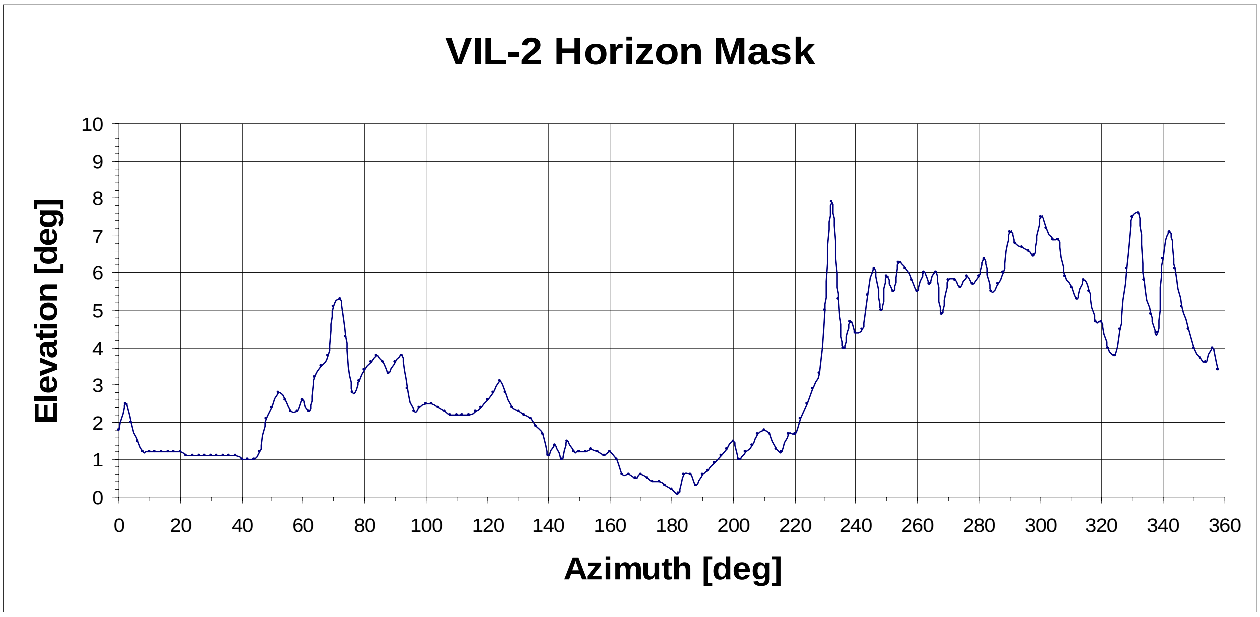

Figure 69: Villafranca-2 (VIL-2) Antenna Horizon Mask

6.9.4.3 Functional Description

Figure 61 shows the Villafranca-2 (VIL-2) Block Diagram, which is used for the functional description.

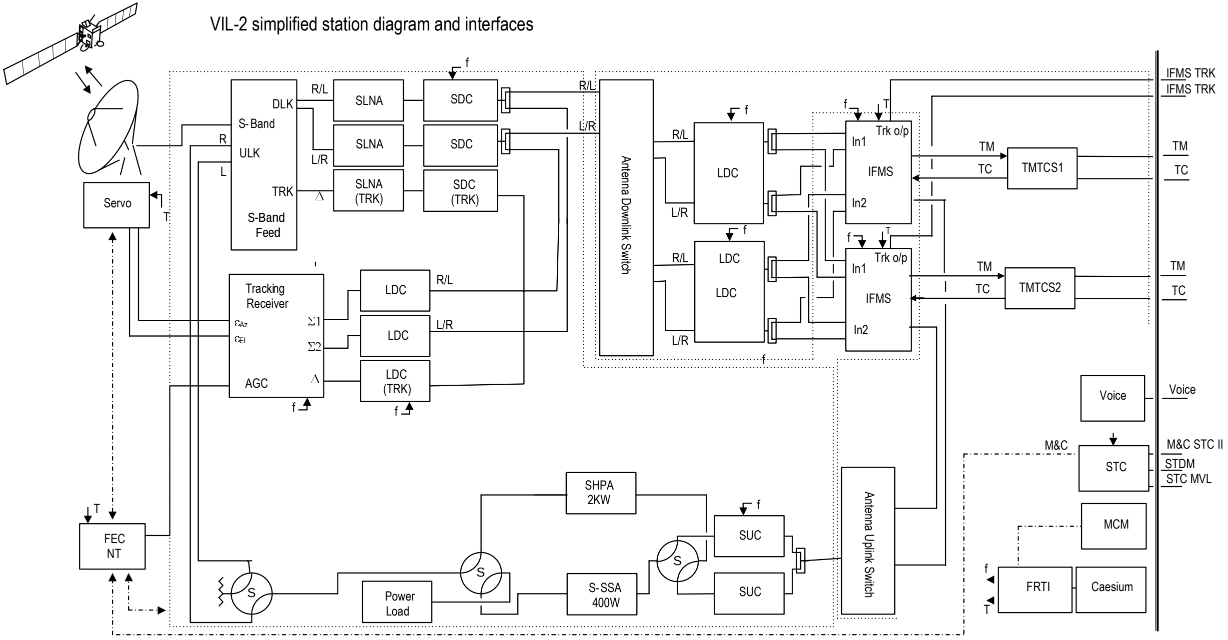

Figure 70: Villafranca-2 (VIL-2) Block Diagram

6.9.4.3.1 Antenna

The S-band transmit and S-band receive (S/S) Cassegrain antenna is fitted with a shaped 15m parabolic main reflector and a shaped hyperbolic subreflector in an elevation over azimuth mount. Auto-tracking of the S-band signal is possible by a two-channel monopulse tracking system. An S-band test antenna with reflective converter allows for signal delay calibration. An air-conditioning system outside the antenna tower provides cooling of the antenna tower and the Apex cabin.

The antenna pointing is performed by the Antenna Control Unit (ACU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation positions to the ACU.

The incoming electromagnetic wave is conveyed via the reflector and subreflector into the S/S feed, which together with its polarizer matches the free space field electromagnetic configuration to the waveguide modes. The coexisting receive and transmit signals for each polarisation inside the S-band feed are separated by Diplexer filters. The receive waveguide branches are fed to Low Noise Amplifiers (LNAs), which amplify the Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC) signals, which subsequently can be phase adjusted by Phase Shifters. The S-band signals [2200-2300 MHz] are down-converted to L-band [520-420 MHz]. The S-band downlink signals are then transferred for tracking and telemetry processing.

The uplink signal coming from telecommand processing at 230 MHz is delivered to S-band transmission. It is converted by the S-band up-converter (SUC) to [2025-2120 MHZ] and delivered via a switch to the S-band Solid State Amplifier (SSSA) or to the High Power Klystron Amplifier (HPA). Fine control of the radiated power is performed by adjustable external attenuators.
A transmit waveguide assembly routes the RF signal to the S-band feed. The transmitted polarisation is selected with the polarization switch, which routes the RF signal to the uplink arm of one of the two Diplexers, one for each polarisation. To avoid radiating the RF power to the antenna, the RF signal can also be routed via a set of switches to a high power dummy load.
The S-band Feed (including polarizer) matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from one of the two Diplexers and conveys the high power RF flux from the S-band feed to the antenna sub-reflector and main reflector, where it is forwarded to free space.
The S-band tracking error signals in both polarisations are derived in waveguide mode couplers. A polarisation selection switch allows routing of one polarisation to the Tracking Low Noise Amplifier (LNA). This Delta-signal is down-converted to L-band [520-420 MHz] (from S-band) via a dedicated third channel in the down-converter. This Delta-signal and the associated Sum-signals are then further down-converted to 70 MHz by a dedicated three channel L-band Tracking down-converter. The Tracking Receiver processes the three signals (Sum-1, Sum-2, Delta) coming from the S-band feed in either Phase Locked Loop mode for remnant carrier modulated signals or Cross Correlation mode for suppressed carrier modulated signals. It derives the error signals for the ACU to point the antenna in autotrack mode.
The VIL-2 antenna also has a reception capability in the S-band transmit band [2025-2120 MHz], which is used for special International Space Station (ISS) and Ariane Transfer Vehicle (ATV) docking validation purposes. It is comprised of a waveguide and switch assembly to feed the signal to an LNA, and frequency conversion equipment.

6.9.4.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or autotrack mode using the received signal.
For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Spacecraft Trajectory Data Messages (STDM's) or State Vectors in the Front End Controller (FEC). For autotrack the antenna Azimuth and Elevation pointing angles are derived from error signals proportional to the direction of highest electrical field strength received. These pointing angles are made available to the Front End Controller (FEC) for delivery for orbit determination purposes.

6.9.4.3.3 Telemetry

The downlink L-band signals are fed via the Antenna Downlink Switch (ADLS) into tuneable L-band down-converters for conversion to 70 MHz intermediate frequency (IF) and further signal routing through the 70 MHz switch (SMSW).
The 70 MHz signals are combined and demodulated in the Intermediate Frequency Modem System (IFMS), which provides remnant and suppressed carrier demodulation. Doppler predictions coming from Spacecraft Trajectory Data Messages (STDM) information improve the signal acquisition process. The Telemetry Channel Decoding System (TCDS) hosted inside the IFMS

performs frame synchronisation, time tagging, Viterbi and Reed-Solomon decoding. The output data is transferred to the Telemetry and Telecommand System (TMTCS) for data structure processing according to Space Link Extension (SLE), which ultimately delivers the telemetry data via OPSNET to the Spacecraft Control Systems.
The telemetry chains are redundant and the various switches allow flexible signal routing.

6.9.4.3.4 Telecommand

The Telemetry and Telecommand System (TMTCS) receives SLE conformant Telecommand data via OPSNET from the Spacecraft Control Systems. It provides telecommand data and clock to the Intermediate Frequency Modem System (IFMS) Uplink Modulator (ULM), which provides the Phase Shift Key (PSK) modulation of the telecommand bit stream onto a sub-carrier, which is then used to phase modulate the uplink carrier at 230 MHz. Via the Antenna Uplink Switch (AULS) the uplink signal is routed to the S band antenna uplink.
The telecommand chains are redundant and the various switches allow flexible signal routing.

6.9.4.3.5 Radiometric

The radiometric measurements comprise Doppler, Ranging, Meteorological and autotrack Pointing measurements.
The Intermediate Frequency Modem System (IFMS) Ranging and Telemetry Demodulators deliver integrated Doppler measurements of the received carrier phase, known as Doppler-1 and Doppler-2.
The IFMS Uplink Modulator generates the ranging tone, which is Phase-Shift-Key (PSK) modulated by a sequence of codes. This ranging tone is phase modulated on the uplink carrier and can be transmitted simultaneously with the telecommand subcarrier. The IFMS Ranging Demodulator pre-steers the expected downlink carrier in case of coherent transponding of the spacecraft based on Spacecraft Trajectory Data Messages (STDMs), demodulates the received tone and compares the received codes with codes replica to derive the two-way propagation delay.
The IFMS meteorological unit gathers outside air temperature, pressure, humidity, wind speed and direction.
The Antenna Control Unit delivers the actually pointed antenna Azimuth and Elevation angles during autotrack of the received carrier signal.
All radiometric measurement data are delivered through OPSNET to Flight Dynamics for processing.

6.9.4.3.6 Monitoring and Control

The monitoring and control (M&C) system allows full local and remote control over the terminal. It is based on a hierarchy of M&C systems: the Station Computer (STC), the Front End Controller (FEC), the Monitoring and Control Module (MCM) and Local Man Machine Interfaces (MMI) on the various devices.
The Station Computer (STC) is composed of a local server, a local workstation and a remote workstation housed in the Ground Facilities Control Centre (GFCC). Mission specific terminal configurations are normally affected through pre-validated macro-procedures, also individual equipment configurations are possible. The STC interacts through a set of subsystem controllers,

either in separate units or implemented in complex devices (e.g. IFMS/TMTCS), with all the terminal equipment.

The Front End Controller (FEC) is the subsystem controller for all the antenna front end devices and responsible for antenna steering.

The Monitoring and Control Module (MCM) is the subsystem controller for all simple back end devices, e.g. switches.

In case of failure of the monitoring and control system, the terminal can be locally operated from the individual equipment Local Man Machine Interfaces.

6.9.4.3.7 Frequency and Timing

The frequency reference generation is based on a Caesium Beam Tube with appropriate long term frequency stability. The frequency distribution system coherently derives 5, 10 and 100 MHz signals and amplifies them for distribution to the devices.

The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 5 MHz, 1 kHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

6.9.4.3.8 Test and Calibration

The objective of the test and calibration function is to validate the telemetry and telecommand functions, and to calibrate the Ranging and Doppler function before the operational satellite pass.

The telemetry function is tested with simulated spacecraft telemetry, which is generated in the Portable Satellite Simulator (PSS), frequency converted to the appropriate downlink frequency and injected into the antenna via a test antenna, so called Telemetry Test Long Loop (TTLL) configuration. The telemetry is then delivered in a Data Flow Test (DFT) to the spacecraft control system for verification.

The telecommand function is tested by demodulating and decoding of the 230 MHz uplink signal and comparing it to known telecommand formats. Based on the telecommand received in the PSS the simulated telemetry generation can be altered. The test telecommands originate from the spacecraft control system.

The ranging and doppler function is calibrated by conducting a ranging and doppler measurement in an antenna loopback configuration, in which the uplink frequency is transponded to the downlink frequency. The emulated transponding involves reception of the uplink frequency by the test antenna and conversion to the downlink frequency in the Reflective Converter (RFLC) with subsequent transmission via the test antenna back into the main antenna. This calibration measures the station internal signal delay and any frequency offset.

For phase calibration of the tracking channels, a remote controllable calibration tower is available.

Test tools for integration and performance validation activities are not described.

6.9.5 ADDITIONAL FACILITIES

6.9.5.1 Calibration Tower

A remote controllable calibration tower is available.

6.9.5.2 GPS-TDAF

A Global Positioning System (GPS) dual-frequency receiver system with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

6.9.5.3 ESAC

The predominant role of Villafranca is today the operation of scientific exploitation centers for ESA Astronomy missions.

6.9.6 PLANNED DEVELOPMENTS

The VIL-1 back-end equipment has been removed. The VIL-1 antenna is left in a safe state and maintained at regular intervals for potential future use.
VIL-2 is used as an ESTRACK backup station during downtime and upgrades of other ESTRACK European longitude stations, and supports EUMETSAT meteorological satellites in S-band for contingency operations.
The Transportable Station TS-1 has been decommissioned and sold.

7 ESTRACK AUGMENTED NETWORK STATIONS

7.1 Malindi (MAL) Station

Figure 71 shows the Malindi (MAL) Aerial View.

Figure 71: Malindi (MAL) Aerial View

7.1.1 GENERAL INFORMATION

The Malindi site is made available to Italy based on an international agreement between the governments of Italy and Kenya. The site is operated by the Italian Space Agency (ASI). The exploitation of the site is carried out by ASI and the Centro Ricerca Aerospaziali (CRA), Centro di Ricerca Progetto San Marco (CRPSM), of the University of Rome. ESA’s usage of the Malindi-1 (MAL-1) terminal and the hosting of the GPS-TDAF system is through CRPSM, while the hosting of the GESS system is through ASI.

7.1.1.1 Location

The Malindi site is located at the base camp of the Luigi Broglio Space Center, see Figure 72, which is a complex of facilities situated in Ungwana Bay, Ngomeni, near Malindi, Kenya. The site is on the coast about 115 km north of Mombasa.

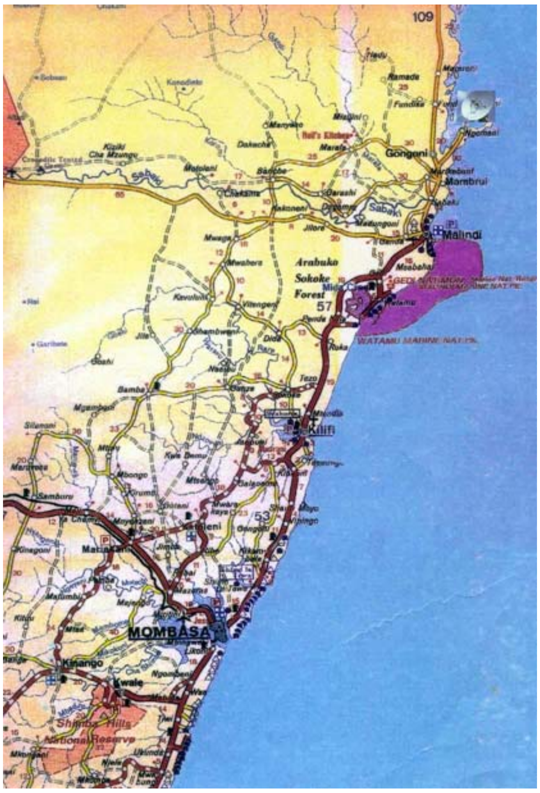

Figure 72: Malindi (MAL) Area Map

7.1.1.2 Access

Site visits require a confirmed Station Intervention form sheet. The access to the site is regulated by ASI. Access has to be requested via a “Malindi Base Camp Access” form sheet.
Access by air is via the airports of Nairobi with onwards flight to Malindi, or via Mombasa. Nairobi is about 500 km north west of Mombasa.
From the city of Malindi proceed North for 20 km on road B8, turn right at the sign “Luigi Broglio Space Center”. Follow the non-asphalted rough road for 11 km.
Accommodation can be arranged through the station manager.

7.1.1.3 Entry Requirements

A visa can be issued at the point of entry in Kenya.
The following vaccinations, although not mandatory, are recommended: Yellow fever, Polio, Typhoid. Malaria tablets must be taken. It is recommended to check these requirements with a medical authority before travelling.

7.1.1.4 Climate

The coastal climate at the station is tropical monsoon, modified by the proximity to the Indian Ocean. A summary of the weather characteristics for the Malindi area is given below:

Warmest month:	March
Average daily maximum temperature for March:	32.3° C
Highest recorded temperature in March:	36.2° C
Lowest recorded temperature in March:	21.0° C
Coldest months:	July/August
Average daily min. temperature in July/August:	21.6° C
Highest recorded temperature in July/August:	32.0° C
Lowest recorded temperature in July/August:	17.2° C
Average annual rainfall:	1060 mm

7.1.1.5 Management

There is no ESA on-site representative at the Malindi site.
The local point of contact for the MAL-1 terminal and GPS-TDAF facility is the CRPSM Station Manager, for GESS the ASI Base Camp Manager.
The Maintenance and Operations (M&O) of the MAL-1 terminal and GPS-TDAF facilities is provided by CRPSM staff, for the GESS by ASI staff.

7.1.1.6 Local Contact

The local point of contact for the Malindi station is:

Luigi Broglio Space Center Telemetry Station
CRPSM Station Manager
Mr Marco Cecchini
Mr Emilio Fioravanti
email: ttcmal@psm.uniroma1.it
Tel +254-42-30959
Fax +254-42-31148

7.1.1.7 Logistics

The postal address is:

Luigi Broglio Space Center Telemetry Station
P.O. Box 203
Malindi
Kenya
East Africa

Normal postal deliveries are made daily to Malindi town, from where they are collected by station staff.

A special procedure is to be followed for import and export to the Malindi site, which is handled by CRPSM in Mombasa and the Italian Embassy in Nairobi.

7.1.2 STATION SERVICES

Figure 73 shows the Malindi (MAL) Site Plan.

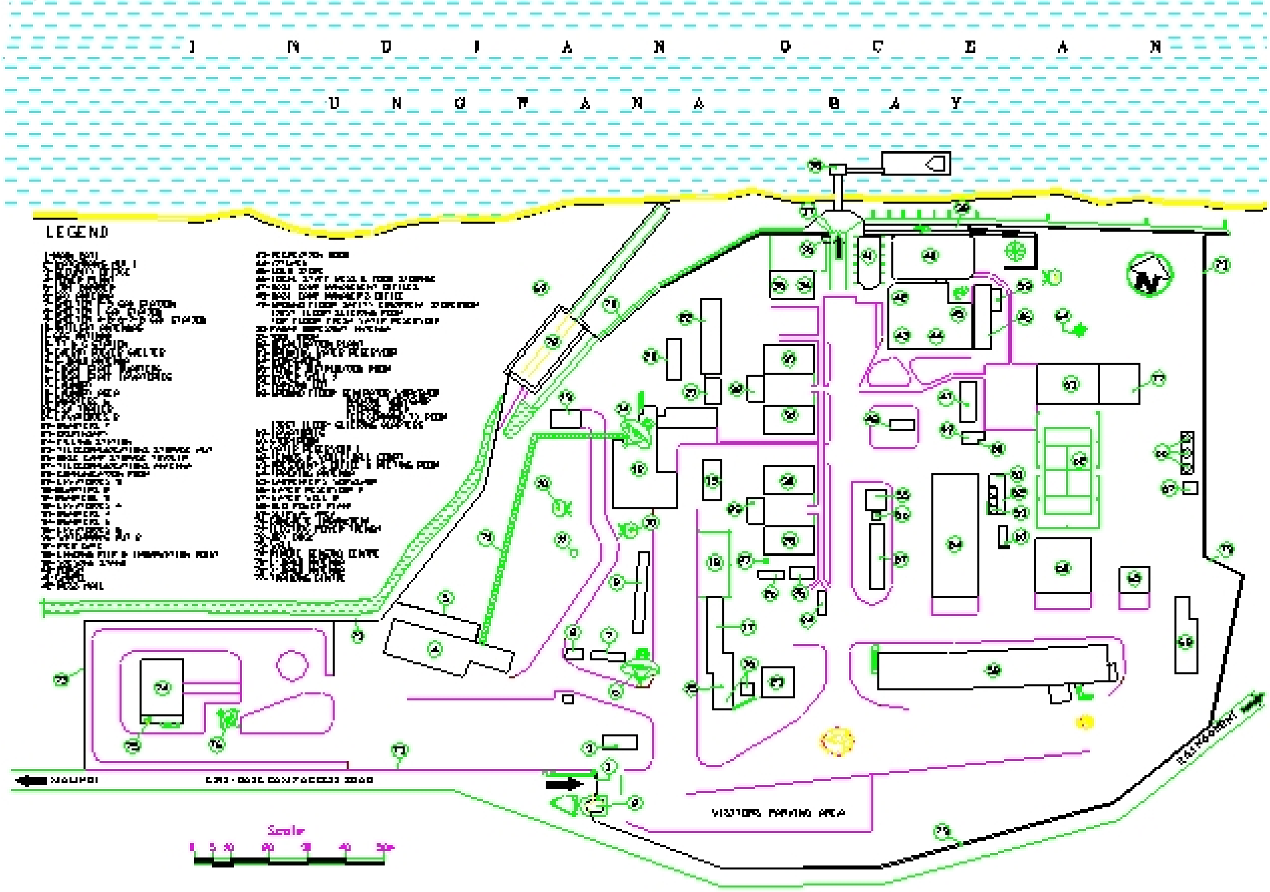

Figure 73: Malindi (MAL) Site Plan

7.1.2.1 Security

The site is fenced and guarded 24/7. An access control and surveillance system is installed.

7.1.2.2 Power

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, and a no-break (NB) power supply using Static Converters and Batteries. Via low voltage switches the electricity (380V, 50 Hz) is distributed to the consumer groups.
There is no public power feed into the power plant.

Three out of six Diesel Generators supply permanently each 235 kVA. Three Static Converters supply each 100 kVA. The Battery capacity allows for a maximum bridging time of 20 minutes.

7.1.2.3 Air Conditioning

The station air conditioning system supplies air to the main building equipment rooms at a temperature of 22°C + 10%, with a controlled humidity of 50% - 65% relative humidity.

7.1.2.4 Communications

The Malindi station is connected via the ESA Operations Network (OPSNET) by a 64 kbps international private leased circuit (IPLC) provided by CRPSM using their VSAT system (Malindi-Fucino) and additional terrestrial communication infrastructure.

7.1.3 MALINDI-1 (MAL-1) TERMINAL

Figure 74 shows the Malindi-1 (MAL-1) antenna, which provides S-band transmit, and L-, S- and X-band receive capability (S/LSX).

Figure 74: Malindi-1 (MAL-1) Antenna

7.1.3.1 Services and Performance

The Malindi-1 (MAL-1) terminal provides the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Autotrack Angles)

Table 16 details the Malindi-1 (MAL-1) Performance Characteristics. For the definition of individual characteristics see 5.6

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	MALINDI-1 (S / S X)	42	L-band RX band [MHz]	N/A
3	TERMINAL	MAL-1	43	L-band Polarization	N/A
4	Longitude	40 deg 11' 40.24" E	44	L-band G/T [dB/K]	N/A
5	Latitude	2 deg 59' 44.00" S	45	S-band RX band (MHz)	2200-2300
6	Altitude [m]	-12.7551	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	10	47	S-band G/T [dB/K]	21.3 (5 deg El)
8	S-band Beamwidth [deg]	Rx: 0.93 Tx: 1.02	48	X-band RX band [MHz]	8025-8500
9	X-band Beamwidth [deg]	Rx: 0.26	49	X-band Polarization	RHC
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	31.8
11	Antenna Speed [deg/s]	Az: 21.0 deg/s El: 7.0 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	+/- 420	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	- 4 to 90	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	NO	54	Modulation Schemes	CORTEX compliant
15	Tilt Facility	NO	55	Carrier Freq Search Range	+/- 0.5 MHz
16	Tracking Mode	Auto (L S X) / Program	56	Subcarrier Frequency	1.2 kHz to 2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	200 mdeg	57	Data Rates	Cortex compliant: 256 Kbps (subcarrier) 40 Mbps (Direct PCM)
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP SLE (CORTEX)
21	Comms Redundancy	NO	61	Rng/Dop Connectivity	IP via CSMC
22	Ranging	IFMS compliant	62	Meteo Connectivity	NA
23	Doppler	YES	63	Angles Connectivity	IP via CSMC
24	Meteo	NO	64	Pointing Format	STDM
25	Autotrack Antenna Angles	YES	65	Tracking Interface (ESOC)	FDS
26	Delta-DOR	NO			
27	Radio-Science	NO			
28	Frequency & Timing	Crystal			
29	UPLINK				
30	S-band TX band [MHz]	2025-2120			
31	S-band Polarization	RHC, LHC			
32	S-band EIRP [dBm]	98.7 minimum.			
33	X-band TX band [MHz]	N/A			
34	X-band Polarization	N/A			
35	X-band EIRP [dBm]	N/A			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	CORTEX compliant			
40	Subcarrier Freq. [kHz]	8 or 16 kHz			

Table 16: Malindi-1 (MAL-1) Performance Characteristics

7.1.3.2 Antenna Horizon

Figure 75 shows the Malindi-1 (MAL-1) Antenna Horizon Mask.

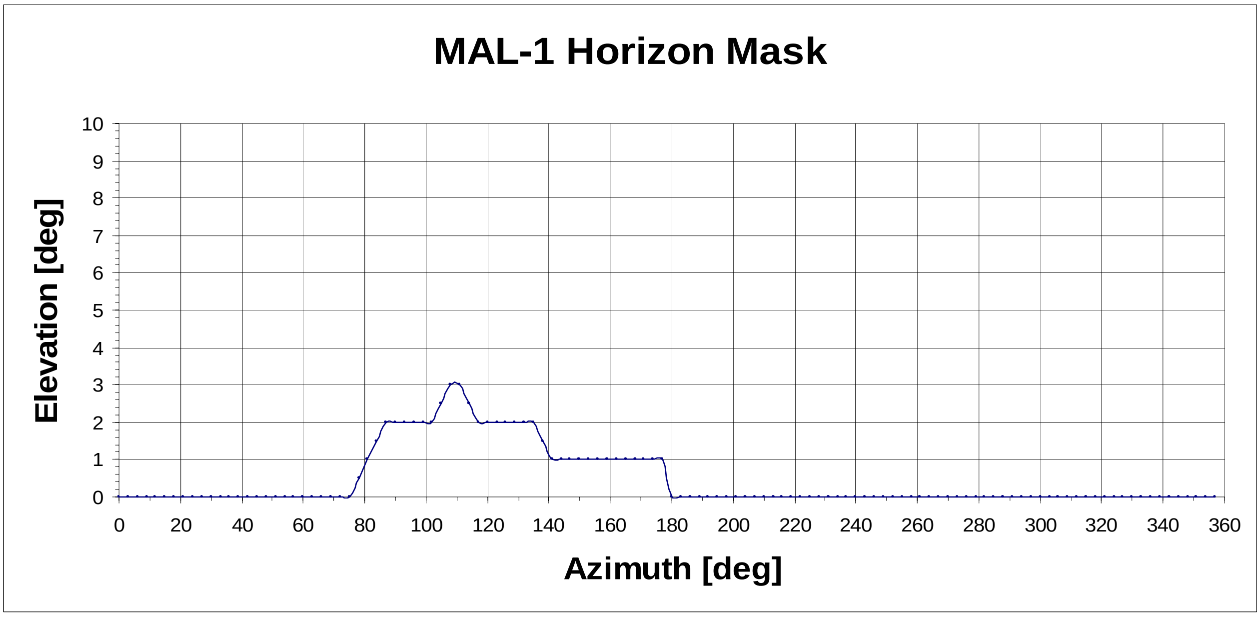

Figure 75: Malindi-1 (MAL-1) Antenna Horizon Mask

7.1.3.3 Functional Description

Figure 76 shows the Malindi-1 (MAL-1) Block Diagram, which is used for the functional description.

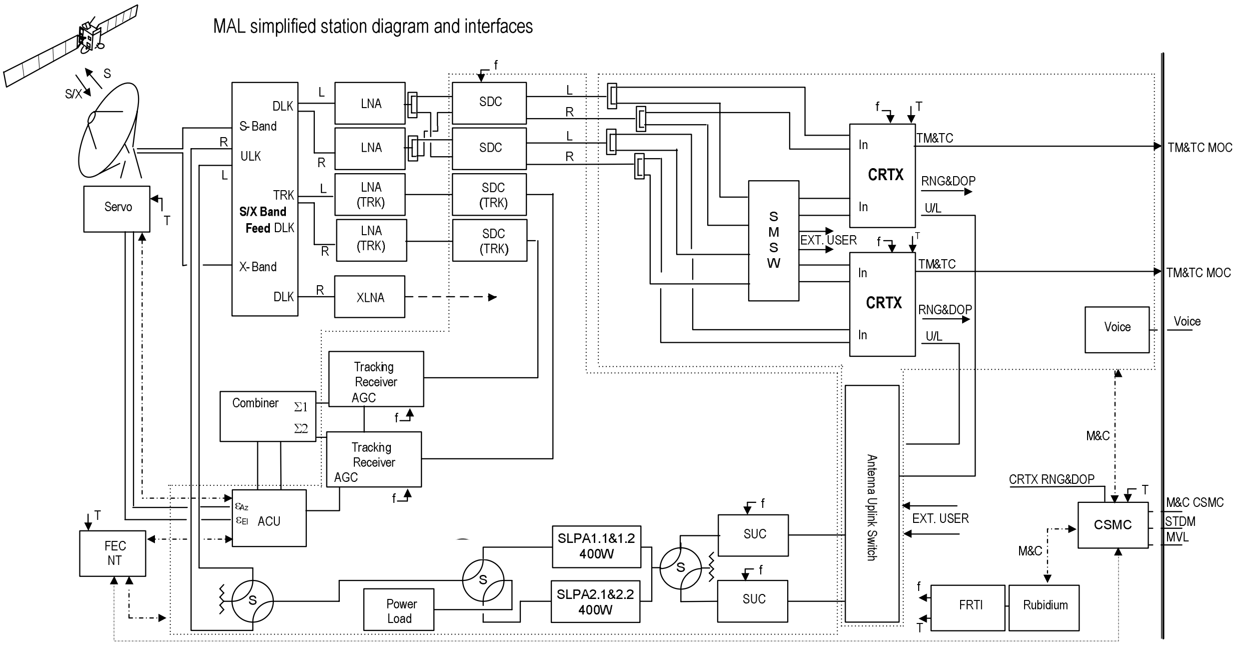

Figure 76: Malindi-1 (MAL-1) Block Diagram

7.1.3.3.1 Antenna

The S-band transmit and L-, S- and X-band receive (S/LSX) Cassegrain antenna is fitted with a 10m parabolic main reflector and a dichroic (X-band pass through, L- and S-band reflection) hyperbolic subreflector in an elevation over azimuth mount. Auto-tracking of the L-, S- and X-band signals is possible by a single-channel monopulse tracking system. An L-, S- and X-band test signal injection with reflective converter allows for signal calibration. An air-conditioning system provides cooling to the antenna building and main equipment room.

The antenna pointing is performed by the Antenna Control Unit (ACU), which affects both axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation positions to the ACU.

The incoming electromagnetic wave is conveyed via the reflector and subreflector into the S/LS feed, which together with its polarizer matches the free space field electromagnetic configuration to the waveguide modes. The coexisting receive and transmit signals for each polarisation are separated by a Triplexer filter. The receive waveguide branches are terminated by Low Noise Amplifiers (LNAs), which amplify the Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC) signals.

The -/X feed behind the dichroic subreflector allows X-band reception, which is down-converted to 720 MHz for high rate demodulation. The X-band signals are processed for Earth Observation Missions.

The S-band signals [2200-2300 MHz] are down-converted to 70 MHz and routed through a 70 MHz switch (SMSW). The S-band downlink signals are then transferred for telemetry processing.

The uplink signal coming from telecommand processing at 230 MHz is delivered to S-band transmission. It is converted by the S-band up-converter (SUC) to [2025-2120 MHZ] and delivered via a switch to the S-band Travelling Wave Tube Amplifiers (STWTAs).
A transmit waveguide assembly routes the RF signal to the S-band feed. The transmitted polarisation is selected with the polarization switch, which routes the RF signal to the uplink arm of the Triplexer making part of the S-band feed. To avoid radiating the power to the antenna, the RF signal can also be routed via a set of switches to a high power dummy load.
The S-band Feed (including polarizer) matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from the Triplexer and conveys the high power RF flux from the S-band feed to the antenna sub-reflector and Main reflector where it is forwarded to free space.
The S-band tracking error signals in both polarisations are derived in mode couplers and routed to the Tracking Low Noise Amplifiers (LNAs). These Delta-signals are modulated onto the Tracking Sum channels. In S-band the tracking polarisation selection is defined by the ACU. The signals are down-converted and processed in the Tracking Receiver in Cross Correlation mode, which derives the error signals for the ACU to point the antenna in autotrack mode. In L-band the tracking polarisation has to be selected manually. In X-band only autotrack of a right-hand circular polarised signal is possible.

7.1.3.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or autotrack mode using the received signal.
For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Spacecraft Trajectory Data Messages (STDM's) or State Vectors in the Front End Controller (FEC). For autotrack the antenna Azimuth and Elevation pointing angles are derived from error signals proportional to the direction of highest electrical field strength received. These pointing angles are made available to the Front End Controller (FEC) for delivery for orbit determination purposes.

7.1.3.3.3 Telemetry

The 70 MHz signals are delivered to the Cortex processing equipment, which integrates the diversity combination, demodulation, decoding and data structure processing functions in a single unit, and delivers SLE conformant telemetry services.
The telemetry chains are redundant and the various switches allow flexible signal routing.

7.1.3.3.4 Telecommand

The Cortex processing equipment receives SLE conformant Telecommand data via OPSNET from the Spacecraft Control Systems, and provides a phase modulated 70 MHz uplink carrier.

7.1.3.3.5 Radiometric

The radiometric measurements comprise Doppler, Ranging, and autotrack Pointing measurements. The Cortex processing equipment’s Intermediate Frequency Receiver delivers integrated Doppler measurements of the received carrier phase.

The Cortex processing equipment's generates the ranging tone, which is phase modulated by a code. This ranging tone is phase modulated on the uplink carrier together with the telecommand subcarrier in the RAU module. The same module demodulates the received tone and compares the received code with a code replica to derive the range. ESA tone ranging is also available.
The Antenna Control Unit delivers the actually pointed antenna Azimuth and Elevation angles during autotrack of the received carrier signal.
All radiometric measurement data are delivered through OPSNET to Flight Dynamics for processing.

7.1.3.3.6 Monitoring and Control

The monitoring and control (M&C) system allows full local and remote control over the terminal. It is based on a hierarchy of M&C systems: the Central Station Monitoring and Control (CSMC) system, the Front End Controller (FEC) and Local Man Machine Interfaces (MMI) on the various devices.
The Central Station Monitoring and Control (CSMC) system is composed of a Main Acquisition and Server Node, and a node to support remote monitoring and control from a remote workstation housed in the Ground Facilities Control Centre (GFCC) and in CRPSM, Rome. Mission specific terminal configurations are normally affected through pre-validated macro-procedures, also individual equipment configurations are possible.
The Front End Controller (FEC) is the subsystem controller for all the antenna front end devices and responsible for antenna steering.
In case of failure of the monitoring and control system, the terminal can be locally operated from the individual equipment Local Man Machine Interfaces.

7.1.3.3.7 Frequency and Timing

The frequency reference generation is based on a crystal oscillator with appropriate long term frequency stability. The frequency distribution system coherently derives 5, 10 and 100 MHz signals and amplifies them for distribution to the devices.
The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 5 MHz, 1 kHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

7.1.3.3.8 Test and Calibration

The objective of the test and calibration function is to validate the telemetry and telecommand functions, and to calibrate the Ranging and Doppler function before the operational satellite pass.
The telemetry function is tested with simulated spacecraft telemetry, which is generated in the Portable Satellite Simulator (PSS), frequency converted to the appropriate downlink frequency and injected into the antenna via a test antenna, so called Telemetry Test Long Loop (TTLL) configuration. The telemetry is then delivered in a Data Flow Test (DFT) to the spacecraft control system for verification.
The telecommand function is tested by demodulating and decoding of the 230 MHz uplink signal and comparing it to known telecommand formats. Based on the telecommand received in the PSS

the simulated telemetry generation can be altered. The test telecommands originate from the spacecraft control system.

The ranging and doppler function is calibrated by conducting a ranging and doppler measurement in an antenna loopback configuration, in which the uplink frequency is transponded to the downlink frequency. The emulated transponding involves reception of the uplink frequency by the test antenna and conversion to the downlink frequency in the Reflective Converter (RFLC) with subsequent transmission via the test antenna back into the main antenna. This calibration measures the station internal signal delay and any frequency offset.

For phase calibration of the tracking channels, a manually operable calibration tower is available.

Test tools for integration and performance validation activities are not described.

7.1.4 ADDITIONAL FACILITIES

7.1.4.1 GPS-TDAF

A Global Positioning System (GPS) dual-frequency receiver system with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

7.1.4.2 GESS

A Galileo Experimental Sensor Station with geodetic accuracy is installed on the site, which delivers continuous measurements to the ESOC Navigation Facility.

7.1.4.3 Planned Developments

It is foreseen to migrate the Malindi Station into a commercial tracking services station operated by the Italian Space Agency (ASI).

7.2 Santiago (AGO) Station

Figure 77 shows the Santiago (AGO) Arial View.

Figure 77: Santiago (AGO) Aerial View

7.2.1 GENERAL INFORMATION

The Santiago site is owned by the University of Chile, Centro de Estudios Espaciales (CEE).

7.2.1.1 Location

The Santiago site lies 38 kilometres North of Santiago, Chile, see Figure 78. It is located on the foothills of the Andes and occupies an area of 1,000 m x 1,000m, or 100 hectares.

Figure 78: Santiago (AGO) Area Map

7.2.1.2 Access

Site visits require a confirmed Station Intervention form sheet.
From Santiago International Airport follow the Highway Santiago-Los Andes direction North. Around 60 km near Colina exit the Highway at Peldehue. Then follow the sign to 'Centro de Estudios Espaciales '.
Accommodation can be arranged through the station manager.

7.2.1.3 Entry Requirements

Citizens of the United States, Canada, the European Union, and Australia need only a valid passport to enter Chile. Visitors from New Zealand must apply for a tourist visa. Most visitors are unaware that Chile charges a steep reciprocity fee for citizens of some countries when they arrive at the Santiago airport before passing through Customs. The U.S. recently upped the fee for Chileans seeking a U.S. tourist visa to $100, so now Chile has responded by charging visitors from the U.S. $100. Visitors from Australia pay $34 and visitors from Canada pay $55. New Zealanders do not pay a fee, nor do visitors from the U.K. The entrance fee must be paid in cash and in U.S. dollars only. The one-time charge is good for the life of your passport; if you are issued a new passport and return to Chile, you will be charged again. Before entering Chile, you'll need to fill out a tourist card that allows visitors to stay for 90 days. You'll need to present this tourist card to Customs when leaving the country, so don't lose it. Also, many hotels waive Chile's 19% sales tax applied to rooms when the guest shows this card and pays with U.S. dollars.

7.2.1.4 Climate

A summary of the weather characteristics for the Santiago area based on the location of the Santiago International Airport is given below:

Warmest month	February
Average daily maximum temperature for February	29.3° C
Highest recorded temperature in February	° C
Lowest recorded temperature in February	° C
Coldest month	July
Average daily minimum temperature for July	3.3° C
Highest recorded temperature in July	° C
Lowest recorded temperature in July	° C
Average annual rainfall	358mm

Winds typically range from 5 to 12 knots. Maximum recorded wind speed is 70 knots. The 07:30 hours local time yearly average relative humidity is 84%, and the 14:30 hours figure is 49%.

7.2.1.5 Management

There is no ESA on-site representative at the Santiago site. The local point of contact for the ESA facilities is the CEE Station Manager.
The Maintenance and Operations (M&O) of the ESA facilities is provided by CEE staff.

7.2.1.6 Local Contact

The local point of contact for the Santiago station is:

CEE Station Manager
Mr Martin Arluciaga
email: marluciaga@cec.uchile.cl
Tel +56 2 672 1816
Fax +56 2 844 1003

7.2.1.7 Logistics

The postal address is:

Centro de Estudios Espaciales (CEE)
Universidad de Chile
Arturo Prat 1171
Casilla 411-3
Santiago
Chile

Custom Clearance is handled by CEE at above address.

7.2.2 STATION SERVICES

Figure 79 shows the Santiago (AGO) Site Plan.

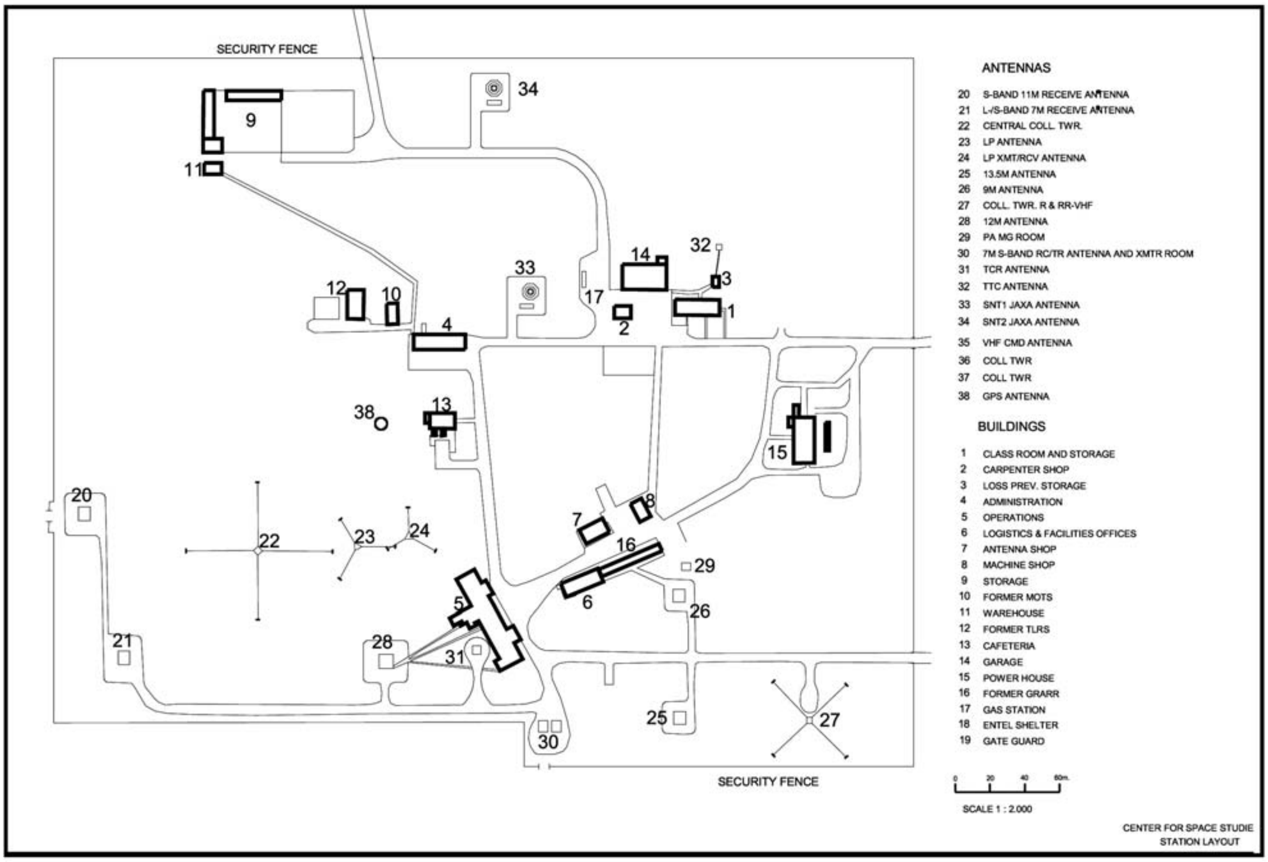

Figure 79: Santiago (AGO) Site Plan

7.2.2.1 Security

The site is fenced and guarded 24/7. An access control and surveillance system is installed.

7.2.2.2 Power

The power plant is designed to furnish a reliable electricity supply to all power consumers. It provides a short-break (SB) power supply using Diesel Generators, there is no central no-break power supply. Via low voltage switches the electricity (3x 208V, 60 Hz) is distributed to the consumer groups.

Public power into the power plant is rendered from a substation, providing 3x 380V, 50 Hz, 600 kVA. A Rotary Converter transforms this into 480 V, 60 Hz, 400 kVA, which is transformed to 4,160 V by two 700 kVA step-up transformers for distribution over the site. Substations located near the facility buildings step-down this voltage to 3x 208 V.

Five Diesel Generators supply 1x 250 kVA, 2x 350 kVA and 2x 500 kVA, 480 V, 60 Hz, the distribution is as described above.

7.2.2.3 Air Conditioning

The station air conditioning system supplies air to the main buildings equipment rooms at a temperature of 21°C + 10%, with a controlled humidity of 50% - 60% relative humidity.

7.2.2.4 Communications

The Santiago station is connected via the ESA Operations Network (OPSNET) by a 128 kbps ISDN on-demand connectivity. The ISDN connectivity into the Santiago site is routed via a microwave link, other connectivity (international private leased circuits) is routed through a fibre optic link.

7.2.3 SANTIAGO (AGO) TERMINALS

Figure 80, Figure 81, Figure 82 shows the Santiago 7m, 9m and 12m (AGO-7m, AGO-9m, AGO-12m) antennas, which provides L- and S-band transmit, and L-, S- and X-band receive capability (LS/LSX).

Figure 80: Santiago 7m (AGO-7m) Antenna

Figure 81: Santiago 9m (AGO-9m) Antenna

Figure 82: Santiago 12m (AGO-12m) Antenna

7.2.3.1 Services and Performance

Together the Santiago (AGO-7m,-9m,-12m) terminals provide the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Autotrack Angles)

Table 17 details the Santiago (AGO-7m,-9m,-12m) combined Performance Characteristics. For the definition of individual characteristics see 5.6.

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	SANTIAGO (./SX) , (S/S) , (S/L)	42	L-band RX band [MHz]	1690 - 1710
3	TERMINAL	AGO-1	43	L-band Polarization	RHC
4	Longitude	70 deg 40' W	44	L-band G/T [dB/K]	17.25 (7 meter)
5	Latitude	33 deg 08' S	45	S-band RX band (MHz)	2200 - 2300
6	Altitude [m]	723	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	12 / 9 / 7 m	47	S-band G/T [dB/K]	27.1 (12 meter) 21.8 (9 meter)
8	S-band Beamwidth [deg]	Rx: 0.75 / 1.0 / na Tx: na / 1.1 / tbc	48	X-band RX band [MHz]	N/A
9	X-band Beamwidth [deg]	Rx: 0.2 (12 m)	49	X-band Polarization	N/A
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	40.0 (12 meter)
11	Antenna Speed [deg/s]	X/Y: 4 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	X/Y Mount	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	X/Y Mount	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	3 STDM sets	54	Modulation Schemes	tbc
15	Tilt Facility	NO	55	Carrier Freq Search Range	tbc
16	Tracking Mode	Auto (S) / Program / Slave	56	Subcarrier Frequency	1 kHz to 2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	tbc	57	Data Rates	Up to 2 Mbps
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP SLE (CORTEX) EIPD (TMP/TCE)
21	Comms Redundancy	YES	61	Rng/Dop Connectivity	SDID/X25 via RG Protocol Conv.
22	Ranging	YES	62	Meteo Connectivity	N/A
23	Doppler	YES	63	Angles Connectivity	N/A
24	Meteo	NO	64	Pointing Format	STDM
25	Autotrack Antenna Angles	YES	65	Tracking Interface (ESOC)	EPOS
26	Delta-DOR	NO			
27	Radio-Science	NO			
28	Frequency & Timing	Tbc			
29	UPLINK				
30	S-band TX band [MHz]	2025-2120			
31	S-band Polarization	RHC, LHC			
32	S-band EIRP [dBm]	115 (9 meter) 90 (7 meter)			
33	X-band TX band [MHz]	N/A			
34	X-band Polarization	N/A			
35	X-band EIRP [dBm]	N/A			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	CORTEX compliant			
40	Subcarrier Freq. [kHz]	8 or 16 kHz			

Table 17: Santiago-7m,-9m,-12m (AGO-7m,-9m,-12m) Performance Characteristics

7.2.3.2 Antennas Horizons

Figure 83 shows the Santiago-7m (AGO-7m) S/L Antenna Horizon Mask.

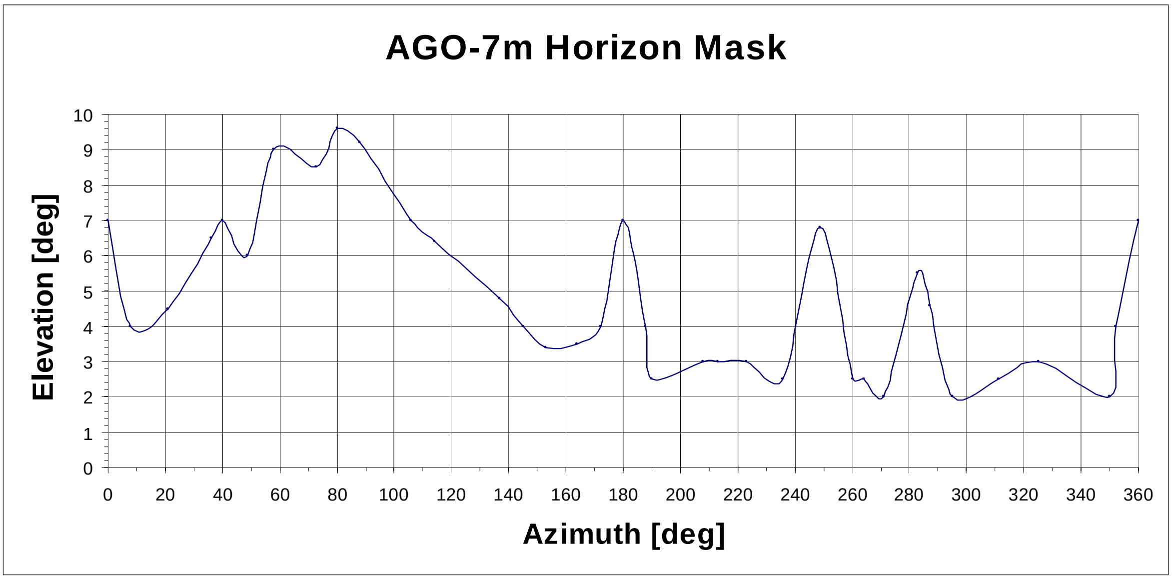

Figure 83: Santiago-7m (AGO-7m) Antenna Horizon Mask

Figure 84 shows the Santiago-9m (AGO-9m) S/S Antenna Horizon Mask.

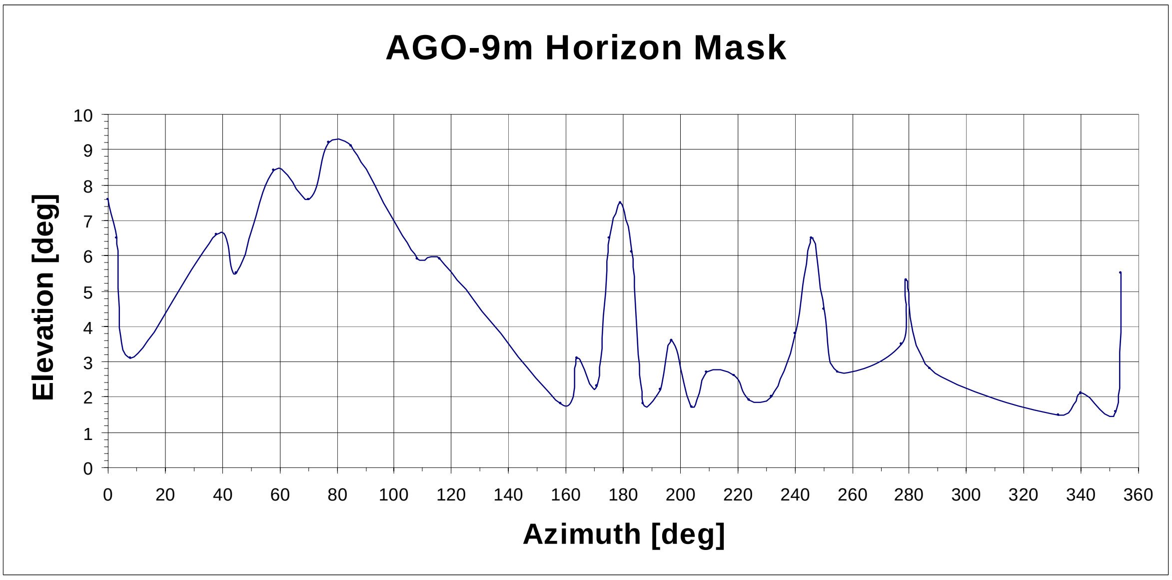

Figure 84: Santiago-9m (AGO-9m) Antenna Horizon Mask

Figure 85 shows the Santiago-7m (AGO-7m) -/SX Antenna Horizon Mask.

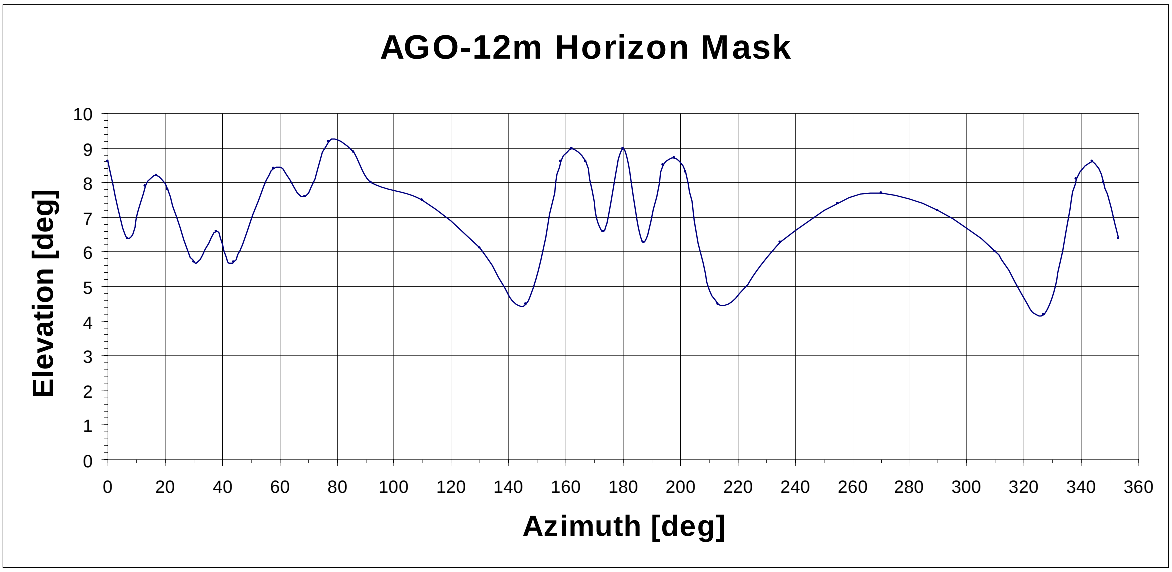

Figure 85: Santiago-12m (AGO-12m) Antenna Horizon Mask

7.2.3.3 *Functional Description*

Figure 86 shows the Santiago (AGO) Block Diagram, which is used for the functional description

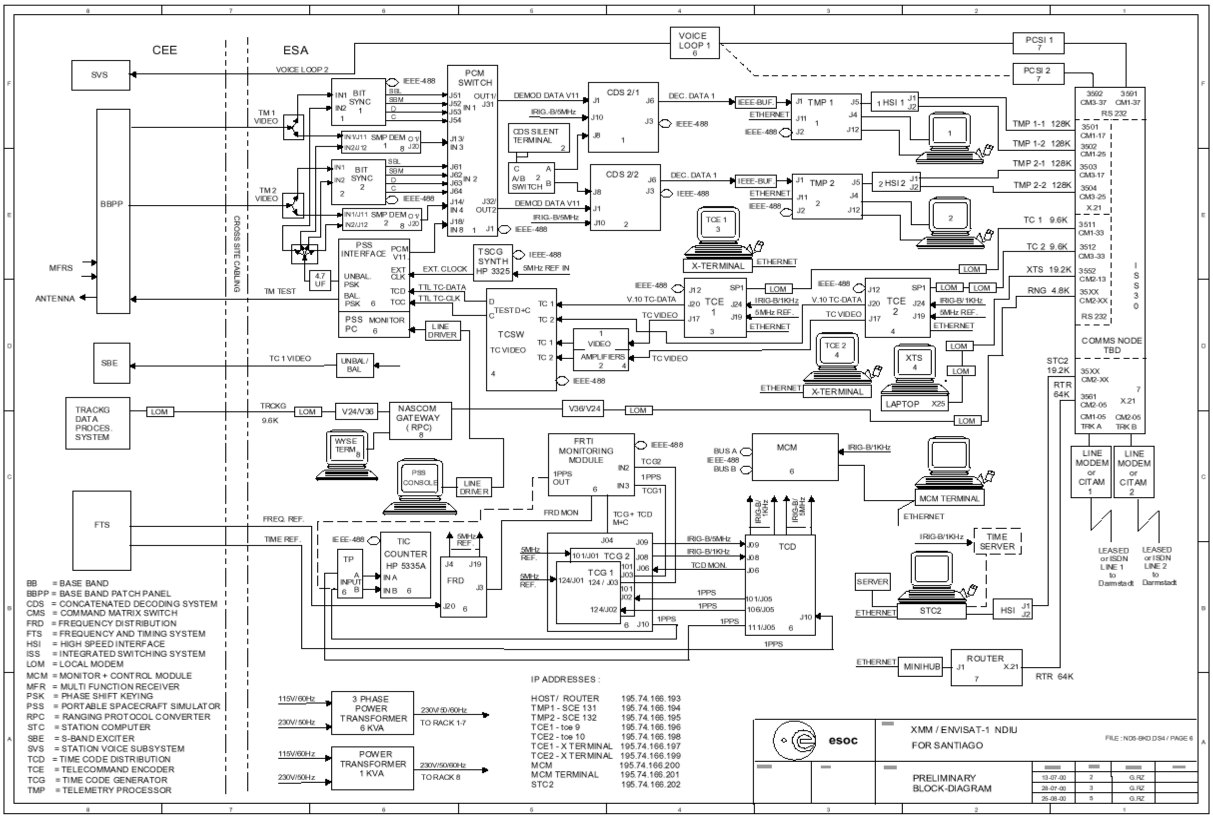

Figure 86: Santiago (AGO) Block Diagram

7.2.3.3.1 Antenna

The Santiago Station is using mainly tree antennas for Up- and Downlink services.

The Santiago-7m antenna is a parabolic shaped antenna for S-and L-band. It receives signals in L-band [1690-1710 MHz] only, while it transmits in S-band from [2025-2120 MHZ]. The receive waveguide in L-band branches is terminated by a single Low Noise Amplifier (LNA), which amplifies the Right-Hand-Circular (RHC) signal only. The received L-band signals are down converted to 70 MHz and forwarded via Multi-coupler to the Multi Function Receivers in the back-end. The Uplink wave guide is connected to a Klystron Amplifier. The antenna has Program and Slave tracking modes only.

The Santiago-9m antenna is a parabolic shaped antenna for S-band. It receives signals in the range [2200-2300 MHz], while it transmits from [2025-2120 MHZ]. The receive waveguide branches are terminated by Low Noise Amplifiers (LNAs), which amplify the Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC). The received signals are down converted to 70 MHz and forwarded via Multi-coupler to the Multi Function Receivers in the back-end. The Uplink wave guide is connected to a Klystron Amplifier. The antenna has autotrack capability. Program and slave tracking modes are available too.

The Santiago-12m antenna is a parabolic shaped receive only antenna for S- and X-band. It receives signals in the in S-band from [2200-2300 MHz] while in X-band from [8000-8600 MHz].

The S-band receive waveguide branches are terminated by Low Noise Amplifiers (LNAs), which amplify the Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC). The X-band receive waveguide is terminated by a single LNA which amplifies the Right-Hand-Circular (RHC) signal only. The received signals are down converted to 70 MHz and forwarded via Multi-coupler to the Multi Function Receivers in the back-end. The antenna has Autotrack capability. Program and slave tracking modes are available too.

7.2.3.3.2 Tracking

The tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or autotrack mode using the received signal.
For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Spacecraft Trajectory Data Messages (STDM's) which were transferred by ESOC Flight Dynamics to the dedicated EPOS server. AGO staff translates the STDM files into a format applicable for the Tracking Computer which controls 7m, 9m and 12m antenna movement. For autotrack the antenna Azimuth and Elevation pointing angles are derived from error signals indicating the direction of highest electrical field strength received. These pointing angles derived on the received signal are made available to the Tracking Computer for delivery of orbit determination.

7.2.3.3.3 Telemetry

The downlink S-band signals are down converted to intermediate frequency (IF) of 70 MHz fed via the Downlink Multicoupler into the Multi Function Receivers (MFR).
The 70 MHz signals are combined inside MFR, then demodulated in a PSK Demodulator/Bitsynchronizer which provides remnant and suppressed carrier demodulation. The Concatenated Decoding System (CDS) performs frame synchronisation, time tagging, Viterbi and Reed-Solomon decoding. The output data is transferred to the Telemetry Processor (TMP) for data structure processing according to CCSDS, which ultimately delivers the telemetry data via OPSNET to the Spacecraft Control Systems. The telemetry chains are redundant.

7.2.3.3.4 Telecommand

The Telecommand Encoder System (TCE) receives CCSDS conformant Telecommand data via OPSNET from the Spacecraft Control Systems. It provides telecommand data and clock to the Telecommand Encoder (TCE). An Internal Video Modem inside the TCE provides the Phase Shift Key (PSK) modulation of the telecommand bit stream onto a sub-carrier, which is then used to phase modulate the S-band uplink carrier in the Dual Exciter located in the antenna. Via an Uplink Patch Panel the uplink signal is routed to the S-band antenna uplink on the 9m or 7m antenna.

7.2.3.3.5 Radiometric

The radiometric measurements comprise Doppler, Ranging, and autotrack Pointing measurements. The S-band Ranging Equipment (SRE) delivers integrated Doppler measurements of the received carrier phase. The SRE Uplink Modulator generates the ranging tone, which is phase modulated on the uplink carrier and can be transmitted simultaneously with the telecommand subcarrier. The SRE demodulates the received tone and compares the received tone with the phase of the transmitted tone to derive the two-way propagation delay.

The Tracking Computer delivers the actually pointed antenna Azimuth and Elevation angles during autotrack of the received carrier signal.
All radiometric measurement data are delivered through EPOS server to Flight Dynamics for processing.

7.2.3.3.6 Monitoring and Control

The monitor and control (M&C) system allows full local and remote control over the Network Data Interface Unit (NDIU) devices. It is based on the Station Computer (STC), the Monitor and Control Module (MCM) and a Local Man Machine Interface (MMI) on the various devices.
The Station Computer (STC) is composed of a shared server/local workstation machine and a remote workstation located in the Ground Facility Control Centre (GFCC). Mission specific terminal configurations are normally effected through pre-validated macro-procedures, also individual equipment configurations are possible. The STC inter-acts trough the subsystem controller MCM with all the NDIU terminal equipment. In case of failure of M&C system, the NDIU terminal can be operated locally from the individual Local Man Machine Interfaces.

7.2.3.3.7 Frequency and Timing

The frequency reference generation is based on a Caesium Beam Tube with appropriate long term frequency stability. The frequency distribution system coherently derives 5, 10 and 100 MHz signals and amplifies them for distribution to the devices.
The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 5 MHz, 1 kHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

7.2.3.3.8 Test and Calibration

The objective of the test and calibration function is to validate the telemetry and telecommand functions, and to calibrate the Ranging and Doppler function before the operational pass.
The telemetry function is tested with simulated spacecraft telemetry, which is generated in the Portable Satellite Simulator (PSS), frequency converted to the appropriate downlink frequency and injected into the RF Front End via a coupler in front of Low Noise Amplifiers, so called Telemetry Test Long Loop (TTLL) configuration. The telemetry is then delivered in a Data Flow Test (DFT) to the spacecraft control system for verification.
The telecommand function is tested by demodulating and decoding of the uplink signal and comparing it to known telecommand formats. Based on the telecommand received in the PSS the simulated telemetry generation can be altered. The test telecommands originate from the spacecraft control system.
The ranging and doppler function is calibrated by conducting a ranging and doppler measurement in an antenna loopback configuration, in which the uplink frequency is transmitted to Collimation Tower, where the signal is transponded into Downlink frequency and radiated towards the S-band antenna. This calibration measures the station internal signal delay and any frequency offset. For phase calibration of the tracking channels, a manually operable calibration tower is available.
Test tools for integration and performance validation activities are not described.

7.2.3.4 Planned Developments

It is foreseen to migrate the Santiago Station into a commercial tracking services station operated by the Swedish Space Corporation (SSC)-Chile.

7.3 Svalbard (SGS) Station

Figure 87 shows the Svalbard (SGS) Aerial View.

Figure 87: Svalbard (SGS) Aerial View

7.3.1 GENERAL INFORMATION

Svalbard is an island in the Arctic Ocean and part of Norway. Its administrative centre is the town of Longyearbyen.

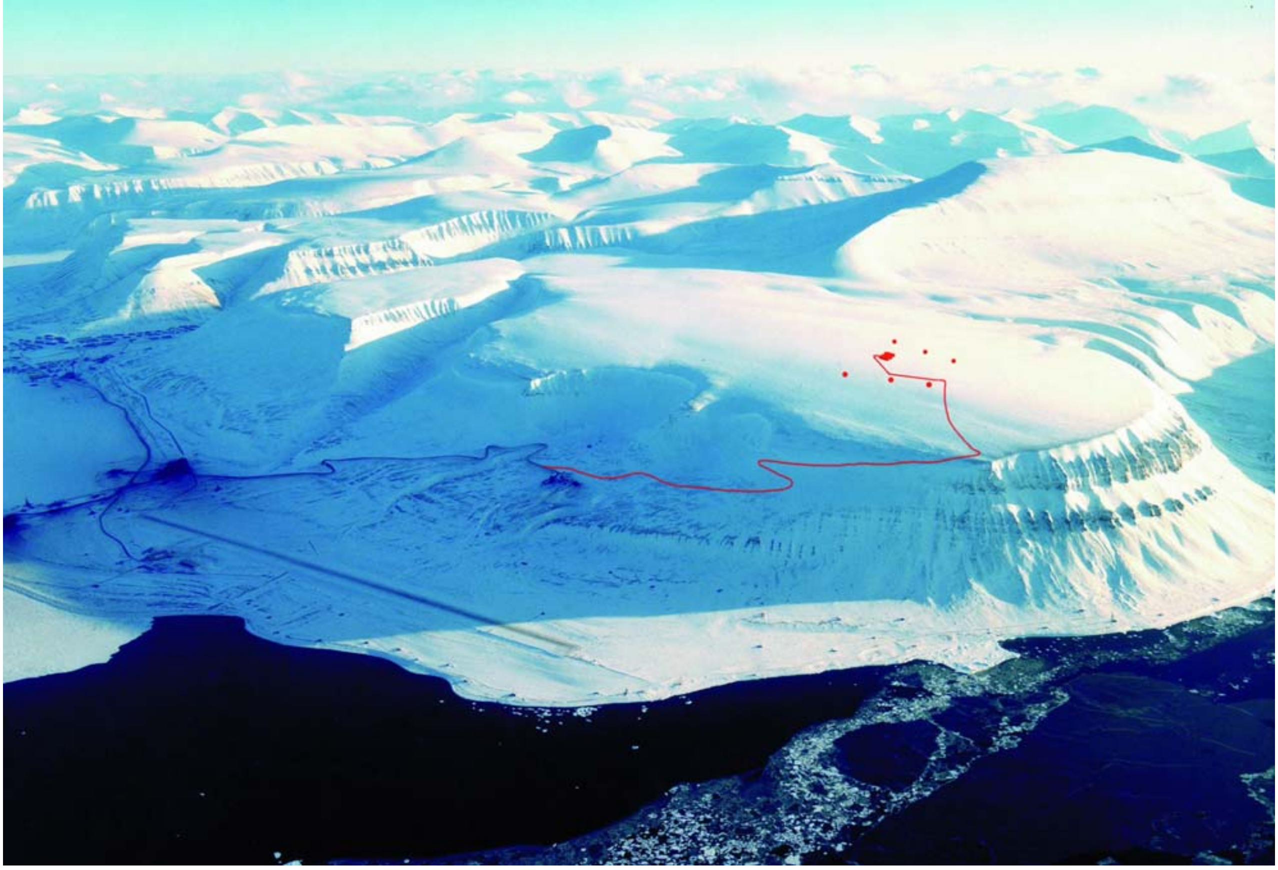

Figure 88: Svalbard (SGS) Area Map

Svalbard Satellite Station (SvalSat) is operated by Kongsberg Satellite Services AS (KSAT) and located near Longyearbyen. Its approximate geographic position is:
Latitude 78° 14' N, Longitude 15° 24' E

7.3.1.1 Access

The easiest way of getting to Svalbard is by airplane from Tromso. The flight from Tromso is approx. 1 hour and 35 minutes. Braathens and SAS fly this route 7-9 times per week. From the airport at Longyearbyern a shuttle bus will take you into town during March-September. In town several services are available; among these there are car, moped and snowmobile rental, as well as a taxi service.
Missing description by car.
There are several accommodation alternatives; but, during peak season, it is important to make reservations well in advance. Accommodation can be arranged through the station manager.

7.3.1.2 Entry Requirements

Entry requirements for the Norwegian part of the Svalbard Island are as for the European Union.

7.3.1.3 Climate

A summary of the weather characteristics for the Svalbard area is given below:

Hottest month	July
Average summer temperature	+6,0°C
Maximum recorded summer temperature	+21,3°C
Coldest month	March
Average winter temperature	-14,0°C
Minimum recorded winter temperature	-46,3°C
Average annual rainfall	200-300 mm

It is not uncommon to have long periods during the winter with temperatures between –20 and –30 °C, usually with a chilling wind. In summertime it is common to have foggy periods.

7.3.1.4 Management

There is no ESA on-site representative at the Svalbard site. The site and all services are managed by KSAT.

7.3.1.5 Local Contact

The local point of contact for the Svalbard station is:

KSAT Station Manager
Mr Sten Christian Pedersen
email: Stenp@ksat.no
Tel + 47 79 02 25 51
Fax + 47 79 02 37 84

7.3.1.6 Logistics

The postal address is:

SvalSat
9171 Longyearbyen
Norway

All heavy material has to be transported by sea, recommended times of transport March to September. In normal circumstances there is a twice-monthly service from the main land.

7.3.2 STATION SERVICES

Figure 89 shows the Svalbard (SGS) Site Plan.

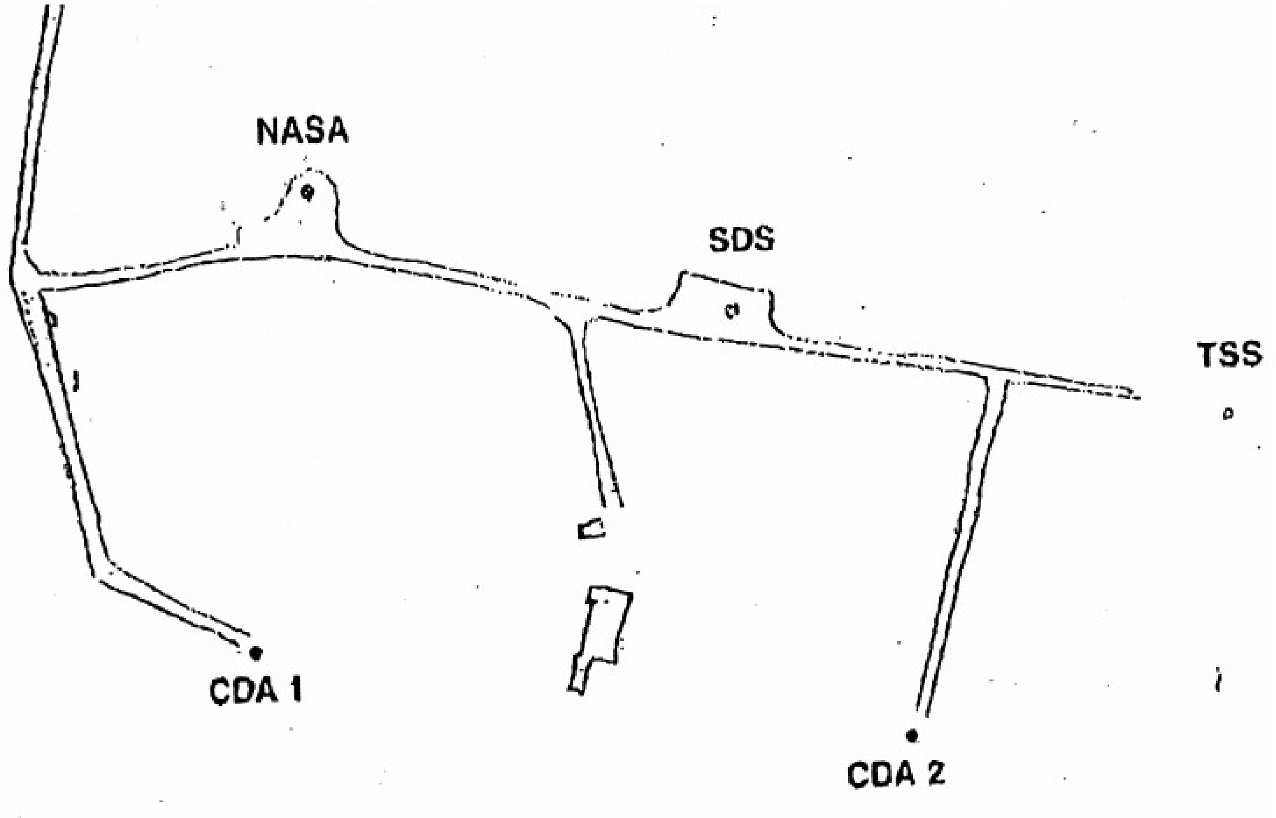

Figure 89: Svalbard (SGS) Site Plan

7.3.2.1 Security

The site is guarded 24/7. An access control and surveillance system is installed.

7.3.2.2 Power

Missing

7.3.2.3 Air Conditioning

The station air conditioning system supplies air to the main buildings equipment rooms at a temperature of 21°C + 10%, with a controlled humidity of 50% - 60% relative humidity.

7.3.2.4 Communications

ESOC is connected via the ESA Operations Network (OPSNET) by redundant 128 kbps ISDN on-demand connectivity to the KSAT Tromsø Network Operations Centre (TNOC). KSAT operational communication infrastructure connects from Tromsø to the Svalsat station via redundant fibre optic sea cables.

7.3.3 SVALBARD-3 (SG-3) TERMINAL

Figure 90 shows the Svalbard-3 (SG-3) antenna, which provides S-band transmit, and S- and X-band receive capability (S/SX).

Figure 90: Svalbard-3 (SG-3) Antenna

7.3.3.1 Services and Performance

The Svalbard-3 (SG-3) terminal provides the following services:

- Tracking
- Telemetry
- Telecommand
- Radiometric Measurements (Ranging, Doppler, Meteo)

Table 18 details the Svalbard-3 (SG-3) Performance Characteristics. For the definition of individual characteristics see 5.6.

1	Rev. 2.4		41	DOWNLINK	
2	18-Sep-2008	SVALBARD-3 (S / S X)	42	L-band RX band [MHz]	N/A
3	TERMINAL	SG-3	43	L-band Polarization	N/A
4	Longitude	15 deg 24' 28.03" E	44	L-band G/T [dB/K]	N/A
5	Latitude	78 deg 13' 47.18" N	45	S-band RX band (MHz)	2200-2300
6	Altitude [m]	501.2934	46	S-band Polarization	RHC, LHC
7	Antenna Diameter [m]	13	47	S-band G/T [dB/K]	23
8	S-band Beamwidth [deg]	Rx: 0.63 Tx: 0.68	48	X-band RX band [MHz]	7500-8500
9	X-band Beamwidth [deg]	Rx: 0.19	49	X-band Polarization	RHC, LHC
10	Ka-band Beamwidth [deg]	N/A	50	X-band G/T [dB/K]	32
11	Antenna Speed [deg/s]	Az: 15 deg/s El: 10 deg/s	51	Ka-band RX band [MHz]	N/A
12	Azimuth Range [deg]	+/- 540	52	Ka-band Polarization	N/A
12	Elevation Range [deg]	-5 to +183	53	Ka-band G/T [dB/K]	N/A
14	Search / Acquisition Aid	Search	54	Modulation Schemes	CORTEX compliant
15	Tilt Facility	Rotating Tilt Axis	55	Carrier Freq Search Range	+/- 0.5 MHz
16	Tracking Mode	Auto / Program	56	Subcarrier Frequency	Up to 1.2 MHz
17	Angular Data Accuracy (autotrack+pointing error)	80 mdeg	57	Data Rates	S- Band Cortex: 256 Kbps (subcarrier) 10 Mbps (Direct PCM) X-band up to 300Mbps
18	FUNCTIONALITIES		58	Data Coding Scheme	R-S, Convolutional and Concatenated
19	TM/TC Standards	PCM, CCSDS	59	INTERFACES	
20	TM/TC Redundancy	YES	60	TM/TC Connectivity	TCP/IP SLE (CORTEX)
21	Comms Redundancy	NO	61	Rng/Dop Connectivity	TCP-IP / FTP UTDF
22	Ranging	CORTEX compliant	62	Meteo Connectivity	TCP-IP / FTP UTDF
23	Doppler	YES	63	Angles Connectivity	TCP-IP / FTP UTDF
24	Meteo	YES	64	Pointing Format	TLE
25	Autotrack Antenna Angles	YES	65	Tracking Interface (ESOC)	EPOS
26	Delta-DOR	NO			
27	Radio-Science	NO			
28	Frequency & Timing	Tbc			
29	UPLINK				
30	S-band TX band [MHz]	2025-2120			
31	S-band Polarization	RHC, LHC			
32	S-band EIRP [dBm]	98			
33	X-band TX band [MHz]	N/A			
34	X-band Polarization	N/A			
35	X-band EIRP [dBm]	N/A			
36	Ka-band TX band (MHz)	N/A			
37	Ka-band Polarization	N/A			
38	Ka-band EIRP [dBm]	N/A			
39	Modulation Schemes	CORTEX compliant			

40	Subcarrier Freq. [kHz]	100 Hz to 100 kHz			

Table 18: Svalbard-3 (SG-3) Performance Characteristics

7.3.3.2 Antenna Horizon

Figure 91 shows the Svalbard-3 (SG-3) Antenna Horizon Mask.

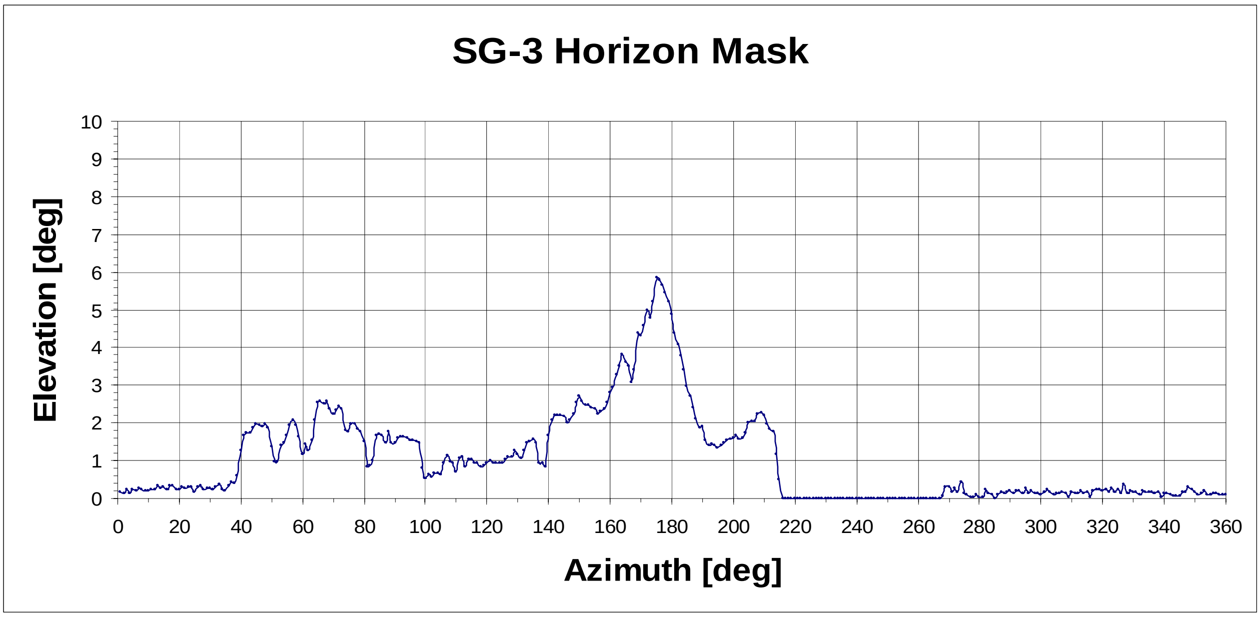

Figure 91: Svalbard-3 (SG-3) Antenna Horizon Mask

7.3.3.3 Functional Description

Figure 92 shows the Svalbard-3 (SG-3) Block Diagram, which is used for the functional description.

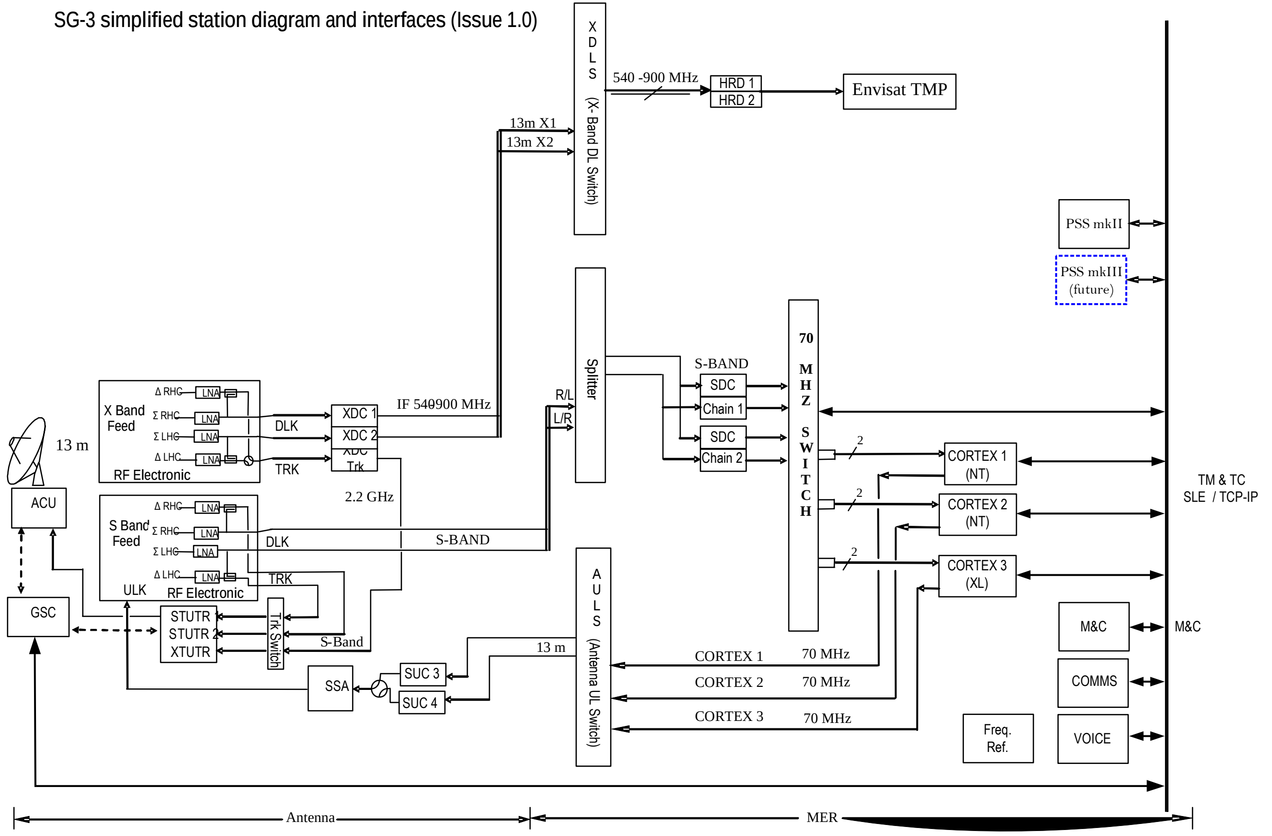

Figure 92: Svalbard-3 (SG-3) Block Diagram

7.3.3.3.1 Antenna

The S-band transmit and S- and X-band receive (S/SX) Cassegrain antenna is fitted with a shaped 13m parabolic main reflector and a dichroic hyperbolic subreflector with heater (X-band pass through, S-band reflection), in an elevation over azimuth over tilt-axis mount. Auto-tracking of the S- and X-band signals is possible by a single channel monopulse tracking system. An S- and X-band test signal injection with reflective converter (S-band only) allows for signal delay calibration. An air-conditioning system provides cooling and heating to the antenna pedestal and the Apex equipment box. The antenna is mounted inside a radome.

The antenna pointing is performed by the Antenna Control Unit (ACU), which affects the three axes using drive amplifiers, motors and gearboxes. Optical position encoders deliver the azimuth and elevation readings to the ACU.

The incoming electromagnetic wave is conveyed via the reflector and subreflector into the S-band feed, which together with its polarizer matches the free space electromagnetic field configuration to the waveguide modes. The coexisting receive and transmit signals for each polarization are

separated by a diplexer filter. The receive waveguide branches are fed to Low Noise Amplifiers (LNAs), which amplify the RHC and LHC signals. The S-band signals are down-converted to 70 MHz and routed to the 70 MHz switch (SMSW) and further transferred for telemetry processing.
The X-band feed behind the dichroic subreflector allows X-Band reception. The RHC and LHC signals are down-converted to 750 MHz for high rate demodulation.
The uplink signal coming from the telecommand processing at 70 MHz is delivered to the S-Band up-converter (SUC) and further to the S-Band solid state power amplifier for transmission.
The S-Band feed matches the incoming waveguide electromagnetic mode with the free space field configuration. It circularly polarises the uplink signal coming from the diplexer and conveys the high power RF flux from the S-Band feed to the antenna subreflector and Main reflector where it is radiated to free space.
The S-band error tracking signals in both polarisations are derived in waveguide mode couplers and routed to the Tracking Low Noise Amplifiers (LNAs). These delta-signals are added onto the Tracking Sum channels. In S-band the tracking polarisation selection is defined by the ACU. The signals are processed in the Tracking receivers in Cross-correlation mode, which derives the error signals for the ACU to point the antenna in autotrack mode. The X-Band tracking signal is first down-converted to S-Band in order to be processed by the Tracking receiver. In X-Band only autotrack of one selectable polarisation is possible.

7.3.3.3.2 Tracking

The SG-3 tracking of spacecraft is possible by pointing the antenna in program track mode based on orbital predictions or autotrack mode using the received signal.
For program track the antenna Azimuth and Elevation pointing angles are derived from predicted Two Line Elements (State Vectors) in the Ground Station Controller (GSC). For autotrack the antenna Azimuth and Elevation pointing angles are derived from error signals proportional to the direction of highest electrical field strength received. These pointing angles are made available to the Ground Station Controller (GSC)for delivery for orbit determination purposes.

7.3.3.3.3 Telemetry

The 70 MHz signals are delivered to the Cortex processing equipment for telemetry processing, and delivers SLE conformant telemetry services.
The X-band 750 MHz signals are delivered via an X-band Downlink Switch (XDLS) to the ENVISAT Telemetry Processor System.
The telemetry chains are redundant and the various switches allow flexible signal routing.

7.3.3.3.4 Telecommand

The Cortex receives SLE conformant Telecommand data via the KSAT network and OPSNET from the Spacecraft Control Systems. The Uplink Modulator (ULM) provides the Phase Shift Key (PSK) modulation of the telecommand bit stream onto a sub-carrier, which is then used to phase modulate the uplink carrier at 70 MHz. Via the Antenna Uplink Switch (AULS) the uplink signal is routed to the antenna S-band uplink.
The telecommand chains are redundant and the various switches allow flexible signal routing.

7.3.3.3.5 Radiometric

The Doppler and Ranging measurements are provided by the Cortex processing equipment.
The Antenna Control Unit delivers the actually pointed antenna Azimuth and Elevation angles during autotrack of the received carrier signal.
All radiometric measurement data are delivered through the KSAT network and OPSNET to Flight Dynamics for processing.

7.3.3.3.6 Monitoring and Control

The monitoring and control (M&C) system allows full local and remote control over the terminal. In case of failure of the monitoring and control system, the terminal can be locally operated from the individual equipment Local Man Machine Interfaces.

7.3.3.3.7 Frequency and Timing

The frequency reference generation is based on a Caesium Beam Tube with appropriate long term frequency stability. The frequency distribution system coherently derives 5 MHz signals and amplifies them for distribution to the devices.
The time reference is based on Universal Time Coordinated (UTC), and synchronised with the Global Positioning System (GPS) delivered time. The time is distributed without the calendar year via IRIG-B 5 MHz and 1 pulse per second (pps) signals. The calendar year is configured separately on the devices.

7.3.3.3.8 Test and Calibration

The objective of the test and calibration function is to validate the telemetry and telecommand functions, and to calibrate the Ranging and Doppler function before the operational satellite pass.
The telemetry function is tested with simulated spacecraft telemetry, which is generated in the Portable Satellite Simulator (PSS), frequency converted to the appropriate downlink frequency and injected into the antenna via an injection point in the waveguide before the S-LNAs, so called Telemetry Test Long Loop (TTLL) configuration. The telemetry is then delivered in a Data Flow Test (DFT) to the spacecraft control system for verification.
The telecommand function is tested by demodulating and decoding of the 70 MHz uplink signal and comparing it to known telecommand formats. Based on the telecommand received in the PSS the simulated telemetry generation can be altered. The test telecommands originate from the spacecraft control system.
The ranging and doppler function is calibrated by conducting a ranging and doppler measurement in an antenna loopback configuration, in which the uplink frequency is transponded to the downlink frequency. The emulated transponding involves reception of the uplink frequency by the test antenna and conversion to the downlink frequency in the Reflective Converter (RFLC) with subsequent transmission via the antenna injection point back into the main antenna. This calibration measures the station internal signal delay and any frequency offset.
For phase calibration of the S- and X-band tracking channels, a remote controllable calibration tower is available. An S-band reflective converter allows for loopback tests.
Test tools for integration and performance validation activities are not described.

8 ESTRACK COOPERATIVE NETWORK

The ESTRACK Cooperative Network is the conceptual expansion of the ESTRACK Augmented Network, in order to allow to receive tracking service from cooperating space agencies terminals for ESA spacecraft, and also to deliver tracking service from ESA terminals to cooperating space agency's spacecraft control centers.

The mutual exchange of tracking service is based on internationally agreed CCSDS technical standards and on agreements reached in the Interagency Operations Advisory Group (IOAG). The IOAG has defined the SLE interface with the Telemetry services "Return-all-Frames (RAF)" and "Return-Channel-Frames (RCF)", and the Telecommand service "Command-Link-Transmission-Unit (CLTU)" for the provision of tracking services. The exchange of Radiometric measurements based on Ranging, Doppler, Angular during Autotrack and Delta-DOR measurements for orbit determination follows the CCSDS Orbit Data Message data exchange format.

The following lists existing cooperations and associated technical capabilities:

8.1 CNES

A frame contract for mutual TTC support has been established between CNES and ESA.

Based on the CNES X.25 Passerelle gateway infrastructure access to terminals of the CNES 2 GHz network is available. This capability was used e.g. during the ESA/ENVISAT and Eumetsat/Metop-A LEOPs, where the Kerguelen station was made available to ESA. CNES is in the process to validate a new SLE based gateway in line with CCSDS and IOAG recommendations.

Also based on the same X.25 Passerelle gateway CNES can interface to ESTRACK Core and Augmented network terminals. For the CNES Helios-2A, Syracuse-3A and Syracuse-3B LEOPs special solutions based on native Cortex interfaces were provided to enable tracking services from Perth and Santiago. The same solution will be used for the upcoming Helios-2B LEOP support. Interfaces based on SLE are readily available.

8.2 DLR

A frame contract for mutual TTC support has been established between DLR and ESA.

Based on SLE services DLR provides access to their Weilheim terminals. This has been operationally validated in 2008 for backup support to ESA/INTEGRAL. ESA/Cluster-II and ESA/XMM are intended to follow.

ESA provides SLE based services from all ESTRACK Core and Augmented network terminals. This was used for DLR/TerraSAR-X using Malindi via ESOC.

8.3 SSC/USN

Based on SLE services SSC provides access to their Esrange terminals, and in collaboration (PrioraNet) with Universal Space Network (USN) access to their terminals in North pole (Alaska), South point (Hawaii), Dongara (Western Australia). This capability was used for the Metop-A LEOP.

ESA provides SLE based services from all ESTRACK Core and Augmented network terminals to SSC.

8.4 KSAT

Based on SLE services KSAT provides access to their Svalbard terminals, and the Troll Antarctica terminal.
ESA provides SLE based services from all ESTRACK Core and Augmented network terminals. A customer specific solution based on native Cortex interfaces were implemented for Kompsat-2A using Malindi and Maspalomas via ESOC.

8.5 NASA

An ESA-NASA cross support agreement for mutual provision of tracking support exists.
Based on SLE services NASA/DSN provides access to their Deep Space Network (DSN) terminals located at Goldstone (USA), Canberra (Australia), Robledo (Spain). This is used for ESA/Rosetta, ESA/MEX and ESA/VEX.
ESA provides SLE based services from its ESTRACK Core network terminals in Cebreros, Kourou, New Norcia and Perth. This was used for ESA/Ulysses and ESA/SOHO. It has been also validated for NASA/JPL missions, e.g. NASA/MODY and NASA/MGS. Recent LEOP supports were provided to NASA/Phoenix and NASA/DAWN.
Multi-Agency baseline Delta-DOR measurements are conducted for ESA/VEX to increase the Venus Planetary Orbit accuracy, and preparation for the NASA/Phoenix Mars Orbit insertion. In addition, ESA/MEX supported the NASA/Phoenix Entry, Descent and Landing (EDL) by NASA/Phoenix signal spectrum recording.

8.6 JAXA

Based on bilateral interface definitions JAXA provides access to their terminals in Masuda and Katsura. This is used for Emergency support. The future interface will be based on SLE.
ESA provides access to the ESTRACK Core and Augmented network terminals using the same interface. This was used for ADEOS-2 and OICETS. Interfaces based on SLE are readily available.
Multi-Agency baseline Delta-DOR measurements were supported for JAXA/Hayabusa.

8.7 CNSA

An ESA-CNSA cross support agreement for mutual provision of tracking support is under preparation. ESA provided SLE based tracking services from Kourou, Maspalomas and New Norcia for CNSA/ChangE-1.

8.8 RFSA

ESA will provide SLE based tracking services to RFSA/Phobos-Grunt.