2010 Call for a Medium-size mission opportunity in ESA's Science Programme for a launch in 2022

Annex

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1 PROPOSAL OUTLINE

The maximum length allowed for proposals under the present Call is 41 A4 pages (11 pt minimum font size) including all appendices. Pages in excess of the page limit will be removed and not considered during the proposal's evaluation. The proposal outline described below should be considered as a guide to proposers, with indicative page limits for each section.

Special emphasis is expected on the science requirements, the mission profile and the model payload. In addition, a preliminary definition of a potential spacecraft design and configuration is requested, including resource budgets (mass, power, data), with the main purpose of evaluating the likelihood that the proposed mission will be compatible with the M-mission programmatic requirements. In the case of planetary science missions, additional emphasis is expected on a reference trajectory and associated space environment.

The expected content of each proposal section is further described in Section 2. Some background information and data from previous ESA missions are collected in Section 3 to provide realistic comparison points and thus to help proposers in evaluating the realism of the proposed mission concepts. Comparison with previous missions can in particular be used to evaluate the realism of the necessary spacecraft platform resources. Additional detailed information relevant to recent mission concept studies can be found in the ESA science website: http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=33170.

Suggested detailed proposal format

a) Cover page (1 page)

   i. Free format, should contain the proposal's title.

b) Proposal contact details (1 page)

   i. Should contain the proposal's title, and name and contact details of the proposal's contact person. It can also contain a list of proposers and their institutions. This will form the back of the cover page when the proposal is printed 2-sided.

c) Executive Summary (2 pages)

d) Introduction (1 page)

e) Scientific objectives and requirements (12 pages)

f) Mission profile proposed to achieve these objectives (2 pages)

   i. Launcher requirements

   ii. Orbit requirements

   iii. Ground segment requirements

   iv. Special requirements

   v. Critical issues

g) Proposed model payload to achieve the science objectives (9 pages)

   i. Overview of all proposed payload elements

   ii. Summary of each instruments key resources and characteristics

      1. Description of the measurement technique
      2. Instrument conceptual design and key characteristics
      3. Performance assessment with respect to science objectives
      4. Resources: mass, volume, power, on board data handling and telemetry
      5. Pointing and alignment requirements
      6. Operating modes
      7. Specific interface requirements: configuration needs, thermal needs (e.g. radiator for focal plane cooling)
      8. Calibration and other specific requirements
      9. Current heritage and Technology Readiness Level (TRL)
      10. Proposed procurement approach
      11. Critical issues

h) System requirements and spacecraft key issues (5 pages)
    i. Attitude and orbit control
    ii. On-board data handling and telemetry
    iii. Mission operations concept (ground segment)
    iv. Estimated overall resources (mass and power)
    v. Specific environmental constraints (EMC, temperature, cleanliness)
    vi. Special requirements
    vii. Current heritage and Technology Readiness Level (TRL)
    viii. Proposed procurement approach
    ix. Critical issues

i) Science Operations and Archiving (2 pages)
    i. Science Operations Architecture and proposed share of responsibilities
    ii. Archive approach
    iii. Proprietary data policy

j) Technology development requirements (2 pages)
    i. Payload technology challenges and technology development strategy
    ii. Mission and Spacecraft technology challenges

k) Preliminary programmatics/Costs (2 pages)
    i. Overall proposed mission management structure
    ii. Mission schedule drivers (technology developments, etc)
    iii. Payload/Instrument Cost
        i. Assumed share of payload costs to ESA
        ii. Estimated non-ESA payload costs
    iv. Overall mission cost analysis

l) Communication and Outreach (1 page)

m) References (1 page)

2 GUIDELINES FOR THE PROPOSAL CONTENT

2.1 Scientific objectives and requirements (proposal section (e))

The scientific goals of the proposed mission should be described, in clear language understandable by scientists who are not necessarily specialists in the field. The proposal should briefly explain how the stated scientific objectives fit in the framework of the goals in the Cosmic Vision 2015-2025 plan and, in general, in the larger pictures of the advancement of knowledge in the field. The timeliness of the proposed mission should also be explained in the context of other existing or planned facilities, both space- and ground-based.

Following the definition of the science goals, the proposal should detail how the proposed mission will effectively lead to their achievement. This includes in particular:

1. Identification of the observable parameters that are relevant to the mission (e.g. galaxy shape, planetary magnetic field, emission/absorption spectra, etc.),
2. Identification of the tasks to be achieved for the mission success,
3. Clear description of the measurement objectives,
4. Measurement or operational requirements to be achieved, such as:
    - i. Performance requirement of a mission-specific observable parameter,
    - ii. Radiometric performance requirements,
    - iii. Observation strategy requirements,
    - iv. Spatial, spectral, temporal resolution,
    - v. Stability and reproducibility requirements,
    - vi. Timing requirements in the execution of the mission.

The measurement or operational requirements should be understandable by engineers and will constitute the skeleton for elaborating the Science Requirements Document and the Mission Requirements Document in the study phases. Examples are the duration of the observations, the required signal-to-noise, the wavelength band of interest, the number of observations to be performed, remote sensing and mapping requirements, in-situ particle and field measurements etc.

The proposal should summarise in table form the mission success criteria, which are associated to the minimum science requirements for meeting the mission's science requirements.

2.2 Mission profile (proposal section (f))

The main requirements on the mission profile should be described, such as:

1. Launcher,
2. Preferred orbits and/or trajectories,
3. Operational mode,
4. Mission lifetime,
5. Communication requirements,
6. Ground segment assumptions,
7. Etc.

Alternative mission scenarios (e.g. alternative trajectory/orbit selection, alternative launcher) should be shortly presented in the proposal. The mission profile should not be assumed as definitive, as it will be subject to future analysis and optimisation.

In the case of scientific missions requiring specific interplanetary trajectories, it is expected that the proposing teams will address in more detail estimated spacecraft delta-V requirements, constraints on launch dates and specific space environment characteristics.

2.3 **Model payload** (proposal section (g))

The model payload is the proposed set of instrumentation for achieving the science measurement objectives and the related science goals. Particular emphasis should be given to its definition and description. The model payload concept and its reference instrumentation should be clearly connected to the discussion on the science requirements.

The model payload description should include for each instrument:

1. Description of the measurement technique,
2. Instrument conceptual design and key characteristics,
3. Performance assessment with respect to science objectives,
4. Resources: mass, volume, power, on board data processing, data handling and telemetry,
5. Pointing and alignment requirements,
6. Operating modes,
7. Specific interface requirements: configuration needs, thermal needs (e.g. radiator for focal plane cooling),
8. Calibration and other specific requirements,
9. Current heritage and Technology Readiness Level (TRL, see also section 2.6),
10. Proposed procurement approach,
11. Critical issues.

In the case of planetary and solar system missions, the model payload is expected to consist of an instrument suite to be entirely PI-provided and funded by ESA Member States (or possibly by international cooperation).

In the case of astrophysics missions the payload can include a telescope to be procured and funded by ESA, with focal plane instrumentation provided by consortia funded by ESA Member States (or possibly by international cooperation). In this case the proposal should provide an overall conceptual optical design and address the specific design and performance requirements of the telescope. This includes the provision of main optical design parameters, performance requirements and discussion of accommodation principles (e.g. examples of beam folding/splitting) in case of multiple instruments. Regardless of the approach proposed, the proposed responsibilities of each participant to the mission toward the procurement of the payload should be spelled out clearly.

2.4 **System requirements and spacecraft key factors** (proposal section (h))

The system requirements applicable to the spacecraft platform design should be identified and discussed. These should be derived from the science measurement objectives and the proposed model payload. This includes requirements impacting on the subsystems necessary to support the payload, in particular:

1. Requirements on the Attitude and Orbit Control System: spinner/scanner/3-axis stabilized and associated requirements resulting from the measurement principles, specific pointing requirements,
2. On-board data handling and telemetry requirements (data volume and rates),
3. Mission operations concept (Ground Segment),
4. Specific environmental constraints (EMC, temperature, cleanliness),
5. Other specific requirement(s) of relevance to the space and ground segment design (timing accuracy, on-board software).

The most challenging system requirements should be specifically outlined as design drivers. These requirements will be reviewed and used in future ESA study phases to further iterate the whole mission design, from the ground segment to the space segment, including launcher services and mission operations.

Supported by these system-level requirements and identified design drivers, a basic spacecraft concept should be proposed. It should contain a general description of the overall spacecraft configuration, highlighting how the design and spacecraft key factors meet the requirements. The overall necessary spacecraft resources should be estimated (mass, power) and their compatibility with the selected launcher and mission profile assessed. When relevant, similarity with previous missions can be argued for the resource allocation.

2.5 Science operations and archiving (proposal section (i))

An overview of the envisaged science operations concepts should be provided. Topics to be addressed should include:

1. Community interfaces and interactions,
2. Need, if any, for support from ground-based observations,
3. Scientific mission planning, timelining of observations,
4. Expected volume and format of the acquired data,
5. Quick-look assessment of data,
6. Ground data processing structure (pipelines, etc.) and challenges,
7. Data distribution and archiving.

The proposed approach to management of science operations should be outlined, including: proposed share of responsibilities for the operations, proposed funding source(s) (e.g. national institutes, national funding agencies, ESA Science Programme), and proposed data policy for the mission (e.g. what is the data return foreseen for all involved partners, what data would be publicly available, etc.). The structure of the Science Operation Centre (SOC), its location, overall organisation and link to other existing parties (e.g. Mission Operation Centre (MOC), national data centres) should be discussed.

2.6 Technology development requirements (proposal section (j))

The boundary conditions applicable to the M-class candidates allow limited technology developments, since the requirement is to meet Technology Readiness Level – TRL ≥ 5 (as described in Table 1 below) by the end of the Definition Phase (Phase A/B1 – currently foreseen at the at end 2014, to be revised depending on the actual mission profile, etc.). This excludes any basic technology development but allows focussed technology verifications and pre-developments, to be achieved typically within 2-3 years.

The proposal should identify the technological development needs (if any) that are required for both the payload and the spacecraft platform, and propose how these developments could be implemented.

TRL 5 does not require a full-scale demonstration of the spacecraft and payload elements. Conversely, it does require that the manufacturing processes of all the spacecraft components, including the science instrumentation, are demonstrated to meet the required performance in the expected environment in orbit. TRL 5 is the minimum technology maturity level that enables the establishment of a meaningful development schedule for the payload and spacecraft development.

Therefore, the technology maturity assessment should start by identifying critical elements of the spacecraft platform and payload which are either new or have never been demonstrated to meet the performance required for the mission success and in the relevant environment. The technology development activities should focus on these critical elements and remove the associated uncertainties through appropriate pre-developments or focussed technology demonstrators.

The proposal should clearly address the consequences of the technology development activities failing to meet the requirements: back-up solutions relying on existing and demonstrated technologies should be identified whenever possible, and their impact on the science objectives discussed. Proposed check-points and milestones should be included in the discussion of a preliminary development plan. An estimate of the development costs should be included in the programmatic analysis (see Section 2.7).

2.7 **Programmatic and cost analysis** (proposal section (k))

A comprehensive view of the proposed mission implementation scenario(s) and overall management approach should be provided, including:

1. A basic programme management plan,
2. A basic integration & verification approach and model philosophy,
3. A basic programme schedule,
4. Preliminary risk analysis,
5. Preliminary cost analysis of the mission elements: technology developments, space segment, operations and ground segment,
6. International partners (if applicable) and their proposed role.

Information regarding specific capabilities and experience in the scientific institutes involved in the proposal and potential collaborative arrangements, expected funding sources outside of the ESA Science Programme and any other relevant programmatic or financial data should be included. The proposal should clearly identify tasks and cost elements that are proposed to be respectively under the responsibility of the ESA Science Programme, scientific institutes using Member States funding, and international partners, if any.

The overall implementation schedule should be based on the reference timeline in Table 2. This reference timeline is indicative and for reference purposes only. The actual timeline will depend on the mission's size and profile, on the presence and role of international partners (if any) and on the evolution of the Science Programme's budget. The proposal should also briefly explain the compatibility of the proposed concept with a late 2020 launch, as discussed in the Call itself.

Readiness Level	Definition	Explanation
TRL 1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development.
TRL 2	Technology concept and/or application formulated	Once basic principles are observed, practical applications can be invented and R&D started. Applications are speculative and may be unproven.
TRL 3	Analytical and experimental critical function and/or characteristic proof-of-concept	Active research and development is initiated, including analytical/laboratory studies to validate predictions regarding the technology.
TRL 4	Component and/or breadboard validation in laboratory environment	Basic technological components are integrated and establish that they will work together.
TRL 5	Component and/or breadboard validation in relevant environment	The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment.
TRL 6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)	A representative model or prototype system is tested in a relevant environment.
TRL 7	System prototype demonstration in a space environment	A prototype that is near, or at, the planned operational system.
TRL 8	Actual system completed and "flight qualified" through test and demonstration (ground or space)	In an actual system, the technology has been proven to work in its final form and under expected conditions.
TRL 9	Actual system "flight proven" through successful mission operations	The system incorporating the new technology in its final form has been used under actual mission conditions.

Table 1: Definition of TRL levels (from "Technology reference levels handbook for space applications" - TEC-SHS/5551/MG/ap – v1.6 - September 2008).

Down-selection of proposals	Q1/2011
Internal (ESA), phase 0 studies	Q2/2011
Industrial assessment (Phase 0/A) and instrument studies	Q3/2011 to Q3/2012
Down-selection process	Q4/2012 to Q1/2013
Instrument AO	Q3/2013
Definition Phase (phase A/B1)	Q2/2013 to Q4/2014
Down-selection process & prime selection	Q1/2015-Q3/2015
Start of Implementation Phase (B2/C/D)	Q4/2015
Launch	By Q4/2022 at the latest

Table 2: Reference implementation timeline for a Medium mission proposed under the present Call for Missions.

Reliable “Cost at Completion” estimates require a detailed definition of the ESA-funded elements and of the mission profile. Table 3 provides, for a typical ESA mission, the average range of fractional cost for the main building blocks which enter into the Cost at Completion models, assuming an overall mission cost of 470 ME (e.c. 2010). It should be used as a rough guide to assist in evaluating the realism of the costing of the proposed missions.

Activity	% of Total ESA CaC
Total spacecraft industrial activities	approx. 55%
Launcher services (assumes a SF-2B launcher from Kourou)	approx. 15 %
Ground segment and operations (MOC and SOC)	approx. 20 %
ESA project	approx. 10 %

Table 3: ESA Cost at Completion reference building blocks.

2.8 Communication and Outreach (proposal section (l))

Proposers should present a brief overview of potential communication, outreach, and education opportunities that might arise from their mission and how these would be exploited in cooperation with ESA. This should cover the specific scientific goals of the mission, but also how these fit into the wider picture of ESA's space science goals as embodied in the Cosmic Vision 2015-2025 plan, and how they relate to broader aims of scientific literacy and education in Europe.

All aspects of the public dissemination of the missions scientific goals and results should be covered, considering a variety of target audiences including the general public, school children of all ages, and the broader scientific community. All activities will be coordinated by ESA, but will strongly depend on the close engagement and involvement of the scientists and funding agencies involved in each mission.

3 HERITAGE FROM PAST SCIENCE MISSIONS

Data from past ESA science missions which can be used to help in the definition a mission concept and to verify its overall consistency are provided here. The data can also be used for preliminary sizing of the proposed mission concepts, working by analogy.

3.1 Types of missions

Only recent missions (launched after 1995 or currently in implementation phase) with a large ESA participation are discussed in this chapter. The PLATO and Euclid missions have been included even though they are not in implementation phase because they provide useful reference cases of astronomical missions based on the use of the Soyuz-Fregat launcher. The missions are divided into the following categories:

- A: Astrophysics missions
- B: Fundamental physics missions
- C: Heliospheric and magnetospheric missions
- D: Planetary science missions

	Missions	Launch date	Mission end or currently approved mission extension	Launcher
A. Astrophysics Missions				
X-γ ray				
	XMM-Newton	Dec. 1999	*Dec. 2012*	Ariane 5
	INTEGRAL	Oct. 2002	*Dec. 2012*	Proton
UV				
VIS-NIR				
	Gaia	2012	2017	Soyuz Fregat ST
	PLATO	2018	2023	Soyuz Fregat ST
	Euclid	2018	2022	Soyuz Fregat ST
MIR-FIR				
	ISO	Nov.1995	Apr. 1998	Ariane 44 P
	Herschel	May 2009	May 2012	Ariane 5 ECA (shared)
Sub mm				

	Planck	May 2009	*Dec. 2011*	Ariane 5 ECA (shared)
B. Fundamental Physics Missions				
	LISA Path Finder	2012	2013	Vega
C. Heliospheric & Magnetospheric Physics Missions				
	SoHO	Dec. 1995	Dec. 2012	Atlas II-AS
	Cluster	Jul.-Aug. 2000	*Dec. 2012*	Soyuz Fregat ST x 2
D. Planetary Missions				
	Cassini Huygens	Oct. 1997	Jan. 2005 (Huygens probe) (Cassini 2017)	Titan IV-B/Centaur
	Mars Express	Jun. 2003	*Dec 2012*	Soyuz Fregat ST
	SMART-1	Sep. 2003	Sep. 2006	Ariane 5 (ASAP)
	Rosetta	Mar. 2004	Dec 2015	Ariane 5 G+
	Venus Express	Nov. 2005	*Dec. 2012*	Soyuz Fregat ST
	BepiColombo	2014	2021	Ariane 5 ECA

Table 4: ESA heritage on science missions. End dates in italics represent the end of the currently approved extension period.

3.2 Typical orbits

Mission	Orbit type	Orbital parameters
XMM-Newton	HEO	7000 x 114 000 km; i = 40°; P = 48 h
INTEGRAL	HEO	9050 x 153 657 km; i = 52.2°; P = 72 h
Gaia	S/E L2	S/E L2 Lissajous orbit
PLATO	S/E L2	S/E L2 halo orbit
Euclid	S/E L2	S/E L2 halo orbit
ISO	HEO	1000 x 70 500 km; i = 5°; P = 24 h
Herschel	S/E L2	S/E L2 halo orbit
Planck	S/E L2	S/E L2 Lissajous orbit
LISA Path Finder	S/E L1	S/E L1 quasi-halo orbit
SoHO	S/E L1	S/E L1 halo orbit
Cluster	HEO	19 000 x 119 000 km; i = 90°; P = 57 h

Table 5: ESA science mission (excluding planetary science) orbits.

Typical transfer trajectories for planetary missions are described in Table 6. These trajectories are usually highly dependent on the time of launch, the delivered mass, the propulsion selected, and the requirements imposed.

Mission	Transfer type	Duration	Remarks
MEX	Direct	~6 months	Insertion into interplanetary transfer, mid-course correction, chemical propulsion
VEX	Direct	153 days	Insertion into interplanetary transfer, mid-course correction, chemical propulsion
Rosetta	4 gravity assists	~10 years	Insertion into interplanetary transfer, EMEE gravity assist, chemical propulsion, during the 10 years transfer, some science operations occur at asteroid flybys
BepiColombo	Gravity assist, low-thrust propulsion	6 years	Insertion into GEO, chemical propulsion to increase altitude, lunar gravity assist, electrical propulsion
SMART-1	GTO + apogee raise	2 months	Insertion into GTO, apogee raising through electric propulsion until moon capture

Table 6: ESA planetary mission transfer orbits.

Typical operational orbits of planetary missions at the target body are described in Table 7.

Mission	Orbit type	Orbital parameters
MEX	Elliptical	Phase 1: 259 x 11 560 km; i = 86°; P = 7.5 h Phase 2: 298 x 10 107 km; i = 86°; P = 6.7 h
VEX	Elliptical	250 x 66 000 km; i = 90°; P = 24 h
BepiColombo MPO	Elliptical	400 x 1508 km; i = 90°; P = 2.32 h
SMART-1	Elliptical	Several alterations, (471-300) x (300 x 3000) km; i=81-90; P~=5 h

Table 7: ESA planetary mission operational orbits.

3.3 Launch vehicle performance

The launch vehicles available to the ESA Science Programme in the timeframe of the present Call for Missions, and compatible with the financial envelope of an M-class mission are listed in Table 8. For Vega and Rockot KM, the mass to the Sun/Earth L1/L2 points is based on the LISA-PF case, that includes a propulsion module for the transfer.

Launcher	Ø[1] [mm]	LEO	HEO	S/E L1 - L2	Escape
Soyuz Fregat[2]	3800	4.3 t @ 800 km	1.4 to 2.6 t depending on orbit	2.1 t	~ 1.5 t Vinf ~2950 m/s
Vega[3]	2380	1.5 t @ 700 km	TBD	450-500 kg	TBD
Rockot KM[4]	2100	~1.0 t @ 800 km	TBD	450-500 kg	NA

Table 8: European launchers compatible with the financial envelope of an M-class mission and available in the timeframe of the present Call for Missions.

3.4 Instrument characteristics and resources

A description of the main characteristics of instruments on some of the recent ESA science missions is given in Table 12 and Table 13 in Section 5 (Appendix) for reference.

3.5 System-level description of science missions

A high-level description of previous science missions is provided in Table 14 and Table 15 in Section 5 (Appendix) for reference.

3.6 Typical mass budget

It is customary to build the spacecraft mass budget by separate modules, such as:

1. Instruments,
2. Payload module,
3. Service module,

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[1] Inner usable diameter of the fairing. The available height is available in the respective User Manuals.
[2] http://www.arianespace.com/launch-services/launch-services-overview.asp
[3] http://www.arianespace.com/launch-services/launch-services-overview.asp
[4] http://www.eurockot.com

4. Other elements, e.g. booster stage or deployable module.

The mass of each instrument should be clearly identifiable, and should be apportioned to the different subsystems as far as possible, i.e.:

1. Optics,
2. Structure,
3. Thermal hardware,
4. Baffles (if relevant),
5. Mechanisms,
6. Focal plane assembly,
7. Electronics units.

A similar level of detail is not required for the platform, for which a high-level mass allocation is acceptable. Table 9 provides a structure for a preliminary system mass budget in accordance with ESA standards.

Module	Subsystem or unit	Current Best Estimate	Design Maturity Margin	CBE + Margin
Instruments				
	Instrument 1			
	Instrument 2			
	Etc.			
Payload Module				
	Telescope			
	Structures and mechanisms			
	Thermal control			
	Etc.			
Service Module				
Module 3 (e.g. booster for interplanetary cruise)				
Nominal dry mass				
System level margin				
Total dry mass				
Propellant mass				
Total wet mass				
Launcher adapter				
Total launch mass				

Table 9: Typical ESA science mission mass budget structure.

A Current Best Estimate (CBE) mass (nominal mass value) should be given for all the units proposed (or subsystems if an insufficient level of design definition is available). A Design Maturity Margin (DMM) should be added to the CBE, depending on the level of maturity of the unit, according to the criteria listed in Table 10.

Level of maturity	Design Maturity Margins
Existing unit (off-the-shelf)	5%
Small modifications to existing unit	10%
Large modifications to existing unit	20%
New design	≥ 20%

Table 10: Design maturity margins.

The nominal dry mass is the sum of the masses of all the modules, including the DMMs. A system level margin should be added on top of the nominal dry mass to give the total dry mass. Typically for Pre-Phase A studies, the system level margin should be at least 20%.

The propellant mass should be calculated from the total dry mass depending on the delta-V needs. The propellant mass calculation will depend on the propulsion system selected, which will be subject to further trades and reviews if the mission proposal is accepted. The sum of the total dry mass and the propellant mass gives the total wet mass.

To compare this with the launcher capability, the launcher adapter mass must also be accounted for. In the case of an atypical spacecraft diameter requiring a tailored launcher adapter, an additional DMM should be added to the launcher adapter mass estimate derived from the corresponding launcher User Manual.

A mass allocation of at least 5% of the dry mass should be used as an estimate for the harness mass.

3.7 Typical power budget

The same list of units as provided for the mass budget can be used to derive a preliminary power budget. Special emphasis on payload power requirements is requested. Each unit should be given a power CBE, on top of which a DMM should be added depending on the unit's maturity. Power DMMs should follow the same rule as mass DMMs (5%, 10%, 20% and >20% as in Table 10). An additional system-level margin of at least 20% of the nominal S/C power requirement should be included.

Nominal (or average) power consumption figures should be provided, as well as peak power consumptions (with their numbers and durations) if applicable. Such peak powers can drive the design of the power subsystem (power generation capability versus power storage capability) if significantly higher than the nominal power levels.

3.8 ESA ground network

Table 11 shows key performance parameters for the main ESA ground stations. The 35 m stations are typically used for deep space missions while other missions would use the 15 m antennas:

Ground station	Size	Receive Band	Transmit band	G/T ratio[5]
New Norcia	35 m	S & X (& Ka[6])	S & X	49.5 (& 54.9)
Cebreros	35 m	X & Ka	X & Ka[7]	50.8 & 55.7
Kourou	15 m	S & X	S & X	29.9 & 41.4
Maspalomas	15 m	S & X	S	29.2 & 37.5
Perth	15 m	S & X	S & X	26.6 & 42.5
Malargue (under construction)	35 m	X & Ka	X & Ka[8]	50.8 & 55.7

Table 11: ESA ground stations.

Typical data rate capabilities vary from 20 kbit/s to 8 Mbit/s, depending on the spacecraft distance from Earth, the ground stations' size, the transmissions band and whether it is in down- or up- link.

[5] Ratio of antenna gain to system equivalent noise temperature, calculated for 10 degrees of elevation
[6] No upgrade to Ka band reception is currently planned
[7] No upgrade to Ka band transmission is currently planned
[8] No upgrade to Ka band transmission is currently planned

4 LIST OF ACRONYMS

AOCS	Attitude and Orbit Control System
AKE	Absolute Knowledge Error
APE	Absolute Performance Error
ASAP	Ariane Structure for Auxiliary Payloads (Ariane 5)
BC MMO	BepiColombo Mercury Magnetospheric Orbiter
BC MPO	BepiColombo Mercury Planetary Orbiter
BOL	Beginning Of Life
CaC	Cost at Completion
CBE	Current Best Estimate
CCD	Charge Coupled Device
CDF	Concurrent Design Facility
CSG	Centre Spatial Guyanais
CV	Cosmic Vision
DMM	Design Maturity Margin
ECA	Evolution Cryotechnique type A (Ariane 5)
EM	Electro Magnetic
ESA	European Space Agency
FIR	Far Infra Red
FoV	Field of View
GEO	Geostationary Earth Orbit
GTO	Geostationary Transfer Orbit
HEB	Hot Electron Bolometer
HEMT	High Electron Mobility Transistor
HEO	High Eccentric Orbit
I/F	InterFace
IR	Infra Red
ISO	Infrared Space Observatory
JWST	James Webb Space Telescope
LEO	Low Earth Orbit
LPF	LISA Path Finder
NA	Not Applicable

NIR	Near Infra-Red
NTD	Neutron Transmutation Doped
MEX	Mars EXpress
MIR	Mid Infra Red
MOC	Mission Operations Centre
MOS	Metal Oxide Semiconductor
PDE	Performance Drift Error
P/L	PayLoad
PLM	PayLoad Module
R&D	Research and Development
RPE	Relative Performance Error
S/C	Spacecraft
S/E	Sun/Earth
SMART	Small Mission for Advanced Research in Technology
SNR	Signal to Noise Ratio
SOC	Science Operations Centre
SoHO	Solar and Heliospheric Observatory
SVM	SerVice Module
TBD	To Be Determined
TM/TC	TeleMetry/TeleCommand
TPS	Thermal Protection System
TRL	Technology Readiness Level
UV	Ultra Violet
VEX	Venus EXpress
XMM	X-ray Multi-mirror Mission

5 APPENDIX (REFERENCE INFORMATION)

The following tables contain reference information for instrument on recent ESA missions and some general system level characteristics for the same missions. All data for the missions currently under definition or implementation are approximate and subject to evolution.

Mission and Instruments		Wave band	Type	Mass [kg]	Average power [W]	Detector
XMM	EPIC	0.10 to 15 keV	Imager	235	240	2 MOS CCDs and a pn CCD at or below -140 ^{o}C
	RGS	0.35 to 2.5 keV	Grating spectrometer	248	140	18 MOS CCDs at or below -100 ^{o}C
INTEGRAL	IBIS	20 keV to 10 MeV	γ -ray imager	677	240	Coded mask telescope with CdTe elements and CsI scintillators at 10 ^{o}C
	SPI	20 keV to 8 MeV	γ -ray spectrometer	1309	384	Coded mask telescope with Ge detectors at or below 85 K
	JEM-X	3 to 35 keV	X-ray monitor	68	62	Coded mask telescope with a Micro Strip Xe gas chamber around 0 ^{o}C
Gaia	3 integrated instruments	250 to 1000 nm	Spectrometer, photometric and astrometric instrument	740 (PLM mass)	1486	106 CCDs at 163 K
JWST	NIRSpec	0.6 to 5 µm	Spectrometer	276	30	2 HgCdTe detectors at 34 K
	MIRI	5 to 28 µm	Imager, spectrograph, coronograph	126	65	Si:As detectors at 7 K
Herschel	HIFI	157 to 625 µm	Spectrometer	229	350	5 pairs of SIS and 2 pairs of HEB mixers at 2 K

	PACS	55 to 210 μm	Photometer, spectrometer	133	102	2 bolometers and 2 Ge:Ga photoconductor arrays at 0.3 K
	SPIRE	194 to 672 μm	Imager, Fourier Transform Spectrometer	91	95	Bolometers with NTD Ge temperature sensors at 0.3 K
Planck	LFI	25 to 80 GHz	Multi frequency microwave imager	94	86	HEMT radio receivers at 20 K
	HFI	90 to 1000 GHz	Multi frequency microwave imager	244	310	Bolometer array at 0.1 K
LPF	LTP	NA	Position measurement of test masses	150	150	NA

Table 12: Instrument characteristics on some of ESA's astronomy and fundamental physics missions.

Mission and Instruments		Full Name / Description	Mass [kg]	Power [W] (typical/peak) or average
SMART-1	EPDP	Electric Propulsion Diagnostic Package	2.4	18
	SPEDE	Spacecraft Potential Electron and Dust Experiment	0.8	1.8
	KATE	Ka band TT&C Experiment	6.2	2
	D-CIXS	Demo Compact X-Ray Spectrometer + X-ray monitor	5.2	18
	SIR	SMART-1 Infrared Spectrometer	2.3	4
	AMIE	Advanced Moon Micro Imager Experiment	2.1	9
BC-MPO	BELA	BepiColombo Laser Altimeter	13.3	36.1
	ISA	Italian Spring Accelerometer	5.7	12.1
	MERMAG	Mercury Magnetometer	1.8	4.6
	MERTIS	Mercury Thermal Infrared Spectrometer	3.3	13.0
	MGNS	Mercury Gamma ray and Neutron Spectrometer	5.2	4.5
	MIXS	Mercury Imaging X-ray Spectrometer	7.3	16
	MORE	Mercury Orbiter Radio science Experiment	3.5	37

	PHEBUS	Probing of Hermean Exosphere by Ultraviolet Spectroscopy	7.5	3.8
	SERENA	Search for Exosphere Refilling and Emitted Neutral Abundances (Neutral and ionised particle analyser)	5.6	22.4
	SIMBIO-SYS	Spectrometers and Imagers for MPO BepiColombo Integrated Observatory System (High resolution and stereo cameras, Visual and NIR spectrometer)	11.1	32.5
	SIXS	Solar Intensity X-ray Spectrometer	2.0	2.5
Huygens	HASI	Huygens Atmospheric Structure Instrument	6.3	15/85
	DWE	Doppler Wind Experiment	1.9	10/18
	DISR	Descent Imager / Spectral Radiometer	8.1	13/70
	GC/MS	Gas Chromatograph / Mass Spectrometer	17.3	28/79
	ACP	Aerosol Collector and Pyrolyser	6.3	3/85
	SSP	Surface Science Package	3.9	10/11

Table 13: Instrument characteristics on some of ESA's planetary science missions.

Mission	Launch	Mission profile	Mass	Propulsion & AOCS	TT&C	Power
GAIA[9] (as of June 2010)	Soyuz 2-1b with ST fairing, Fregat upper stage and a dedicated adapter, from Kourou	Direct transfer to Lissajous orbit around Sun-Earth L2 5.5 year nominal mission, 1 year extension All-sky scan for 3D Galaxy map Total delta V: 278 m/s	PLM dry: 739 kg SVM dry: 928 kg Propellant: 289 kg cold gas: 57 kg Adapter: 75 kg	Spinning S/C Bi propellant and cold gas micro propulsion APE < 60 arcsec continuous RPE < 20 mas over 4.5 s	X-band phased array antenna 4-8 Mbps for ~5h/day	Power BOL: 1895 W with 15 m^2 Triple junction solar cells. Li-ion batteries: 15.9 kg
Plato[10] (as of 2008 CDF study)	Soyuz 2-1b with ST fairing, Fregat upper stage and 1666-SF adapter, from Kourou	Direct transfer to large amplitude halo orbit around Sun-Earth L2 6 years nominal lifetime 3 phases for different FoVs and observation durations Total delta V < 70 m/s	PLM dry: 1263 kg SVM dry: 526 kg Propellant: 65 kg Adapter: 90 kg	3 axis stabilised Mono propellant APE: 0.2 arcsec with Fine Guidance Sensor RPE: 0.2 arcsec over 20 s	X-band 47.5 Gbits/day 4.3 Mbps for ~3h/day	Power BOL: 889 W with 6.4 m^2 of Triple Junction Solar cells Li-Ion batteries: 6.2 kg
Euclid[11] (as of 2008 CDF study)	Soyuz 2-1b with ST fairing, Fregat upper stage and 1666-SF adapter, from Kourou	Direct transfer to large amplitude halo orbit around Sun-Earth L2 5 years nominal lifetime Wide extra galactic sky survey in step and stare mode Total delta V < 80 m/s	PLM dry: 664 kg SVM dry: 684 kg Propellant: 101 kg Adapter: 90 kg	3 axis stabilised Mono propellant and cold gas micro propulsion APE: 10 arcsec RPE: 25 mas over 375 s	X- and K-band with upgrades at Cebreros 800 Gbits/day 49.5 Mbps for ~4h/day	Power BOL: 597 W with 2.9 m2 of Triple Junction Solar cells Li-Ion batteries: 6.5 kg

Table 14: System level description of astrophysics missions.

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[9] http://sci.esa.int/gaia
[10] http://sci.esa.int/plato
[11] http://sci.esa.int/euclid

Mission	Launch	Mission profile	Mass	Propulsion & AOCS	TT&C	Power
Huygens[12]	Carried on-board Cassini (NASA launch)	Separation from Cassini for 20 day cruise before entering Titan atmosphere. 2:27 h descent plus 1:10 h on surface	318 kg (probe) (incl. 96 kg TPS)	Spinning S/C, descent stabilized through parachute	S band to Orbiter	300 W available through LiSO2 primary batteries
SMART-1[13]	Ariane 5 on Adapter for auxiliary payload from Kourou	Insertion into GTO, apogee raising through electric propulsion until moon capture Total delta V to Orbit < 3.5 km/s	S/C dry: 286 kg Propellant: 82 kg (Xe) P/L total: 19 kg S/C Total: 370 kg	Monopropellant AOCS, 3-axis stabilized, main engines: Electric Propulsion (Plasma)	500 kbits/s X band up- and down-link Ka band down-link	225 W science mode 1493-1765 W cruise mode with Solar arrays
VEX[14]	Soyuz 2-1b, Fregat upper stage, from Baikonur	Direct insertion into interplanetary transfer through Fregat stage, Venus orbit insertion	Launch Mass: 1270 kg Propellant: 530 kg	3-axis stabilized, Bi-propellant main propulsion	S/X band with TM up to 262 kbps	800-1100 W available with Solar arrays
BC – MPO[15]	Ariane 5 launch from Kourou (together with MMO)	Insertion into GEO, chemical propulsion to increase altitude, lunar gravity assist, electrical propulsion, insertion into Mercury orbit using chemical propulsion	Launch Mass: 2300 kg S/C dry: 520 kg P/L total: 65 kg	3-axis stabilized, nadir pointing, bi-propellant chemical, Xe-Plasma Engine main propulsion	X/Ka band TM with 50 kbps average	600 W available with Solar arrays
MEX[16]	Soyuz 2-1b, Fregat upper stage, from Baikonur	Direct insertion into interplanetary transfer through Fregat stage, Beagle 2 lander separation from hyperbolic, Mars orbit insertion	Launch Mass: 1223 kg S/C dry: 555 kg P/L total: 116 kg	3-axis stabilized, bi-propellant chemical main & attitude thrusters	X band TM (<230 kbit/s) and S band TC	650 W available with solar arrays, batteries for eclipse

Table 15: System level description of planetary missions.

[12] http://sci.esa.int/huygens
[13] http://sci.esa.int/smart1
[14] http://sci.esa.int/venusexpress
[15] http://sci.esa.int/bepicolombo
[16] http://sci.esa.int/marsexpress