EXPLORATORY CALL FOR A MINI-FAST MISSION IN ESA'S SCIENCE PROGRAMME TECHNICAL ANNEX

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1. INTRODUCTION

This document provides technical and programmatic information for preparing the mission concept proposals in answer to the exploratory Call for mini-Fast mission opportunities in the ESA Science Programme (called *mini-F* in this document).

The mini-Fast missions are meant to be science-driven (as for all missions in the Science Programme) with a faster implementation timeline than the F-missions, typically less than 5 years from early selection to launch, and a budget below 50 M€ in 2025 e.c. Given the nature of the Call, the boundary conditions are deliberately minimalistic and will be tuned following the analysis of the Call outcome. However, the basic assumptions will remain unchanged: Fast implementation schedule, implying a high technology readiness level at the time of the mission proposal.

The proposers are invited to focus on the mission and science case description. The launcher cost is neutralised by reserving an allocation of 5 M€ in the Cost at Completion (CaC).

The proposers can access information related to previous ESA missions at http://sci.esa.int/home/51459-missions/.

2. DEFINITIONS AND ACRONYMS

The acronyms and abbreviated terms are defined in Annex A.

3. REFERENCE AND NORMATIVE DOCUMENTS

3.1. REFERENCE DOCUMENTS

RD[1] Ariane 6 User's Manual, Issue 2.0, Feb. 2021, www.arianespace.com link

RD[2] Ariane 6 User's Manual for Multi-Launch Service (MLS), issue 0.0, July 2021, www.arianespace.com link

RD[3] Vega C User's Manual, Issue 0.0, May 2018, www.arianespace.com link

RD[4] SSMS Vega-C User's Manual, issue 1.0, September 2020, www.arianespace.com link

RD[5] ECSS-E-HB-11A, Technology readiness level (TRL) guidelines, Mar. 2017, www.ecss.nl

RD[6] ECSS-E-HB-60-10A, Control performance guidelines, Dec. 2010, www.ecss.nl

RD[7] ESSB-HB-E-003, ESA pointing error engineering handbook, Jul. 2011, www.ecss.nl link

RD[8] ESSB-HB-U-002, ESA Space Debris Mitigation Compliance Verification Guidelines, issue 2.0m 14 Feb 2023 www.ecss.nl link

RD[9] M8 F3 mini-F Call briefing and Q&A link

RD[10] M8 F3 technical annex to the call (see call) link

3.2. NORMATIVE DOCUMENTS

ND[1] ECSS-E-AS-11C, Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment, Oct. 2014, www.ecss.nl link

ND[2] ECSS-E-ST-50-05C Rev. 2, Radio Frequency and Modulation, www.ecss.nl www.ecss.nl link

ND[3] ECSS-U-ST-20C, Planetary protection, www.ecss.nl link

4. SUMMARY OF THE CALL BOUNDARY CONDITIONS

4.1. BOUNDARY CONDITIONS FOR THE MINI-F MISSION

Element	Request	Comments or Guidelines
ESA CaC	≤ 50 M€ (e.c.2025)	Includes all elements to be funded by ESA, including the launch services. Excludes Member State and international partner contributions.
Schedule	preparation phase below 2 years	From early selection to mission adoption
	development schedule below 3 years	From adoption to launch
Science objectives and instruments	The science objectives of this mission are open.	The science instruments shall be defined in relation with the targeted science objectives. The core science objectives and the proposed concept shall be sufficiently robust for enabling technical convergence by following a design-to-cost approach during the phases 0/A.
Launcher	The mini-F mission will nominally be launched by use of shared launch (rideshare) or a shared/dedicated European mini launcher	For mini-F the possibility of proposing passengers or companions to existing missions, in the Science Programme or other programmes, e.g. for reaching far destinations, is not excluded. The mini-F can also be a self-standing mission, launched as passenger with another spacecraft. Non-European launchers to be procured by ESA are excluded.
Spacecraft launch mass	≤100 kg	Recommended upper limit not to exceed in view of the cost and schedule targets.
Platform TRL	TRL ≥ 7 by the mission adoption	ISO scale, see Appendix B. The platform must be compatible with a delivery of the Flight Model within the 4 years following mission selection. The responsibility and implementation schemes are not imposed for this Call. The proposers are invited to describe their favoured implementation scheme, by detailing ESA's role and responsibilities for the spacecraft and payload developments.

		Proposers are invited to favour the reuse of existing platforms with minimum modifications. As a rule, the platform equipment shall be at TRL ≥ 7 (space qualified for the mission needs and available) before the mission adoption. TRL 6 is nominally required at the time of the mission proposal since the Technology Readiness may drive the schedule and will be one important element of the decision process.
Payload mass	< 20 kg	Recommended upper limit not to exceed in view of the cost target.
Science Payload TRL	TRL ≥ 7 by the mission adoption	The proposed payload must be compatible with a delivery of the Flight Model within the 4 years following the mission selection. The credibility of the payload development and qualification schedule will be an important selection criterion. The proposed payload must rely on significant heritage and fully available technologies. Limited delta-verifications and pre-developments can be envisaged during the definition phase. The payload definition level must reach PDR status before the mission adoption, within ~18 months. Proposers are invited to submit in the proposal their views for the payload development plan, including pre-development and early funding needs (e.g. for long lead items). The role, responsibilities, and heritage of the payload providers must be defined in the proposal. Small modifications reducing the TRL can be envisaged, provided the development remains compatible with the schedule.
International collaboration	Can be envisaged, provided a clear support and commitment from the international partner are available.	Mini-F has to be ESA led. International contribution is not excluded, subject to compatibility with the schedule. Since early firm commitments will be needed, it is recommended to also consider a fully European back-up scenario.
Spacecraft and science operations	Nominal duration of science operations typically < 2 years	The mission operations responsibility scheme is not imposed for this Call. The proposers are invited to describe their favoured operation scheme, by detailing

		ESA's role and responsibilities, for both the spacecraft and science operations. The nominal duration of science operations does not include the cruise phase, nor the disposal (as applicable).

Table 1: Boundary Conditions for the mini-F mission

5. MISSION CONCEPT DEFINITION

Although mini-F missions are nominally viewed as stand-alone missions, the possibility of proposing passengers or companion to other existing missions, in the Science Programme or other programmes, is not excluded. However, any proposed concept must be compatible with the Call boundary conditions and provide an appealing science case.

5.1. QUESTIONS TO BE CONSIDERED IN THE PROPOSAL

In addition to the science case description, the following key questions could be considered during proposal writing:

- What work is needed to start the flight model development? The question applies for both the platform and the payload.
- What work is needed until the mission adoption (within 2 years) for safely enabling the schedule? The question applies for both the platform and the payload.
- Regarding the space segment:
    - What is available now, fully qualified and recurring?
    - What are the elements to be further developed?
    - Who is responsible for what?
- How shall the proposed concept be launched?
    - If self-standing spacecraft with shared launch – are there specific constraints to consider?
    - Relying on an available European commercial service (e.g. to the ISS)
    - If the spacecraft is passenger to some other spacecraft: Which mission?
- Is there a specific time slot for launch foreseen/necessary?
- Who carries out operations (ESA/non-ESA)? The question applies for both the spacecraft and science operations.

5.2. LAUNCH VEHICLES

The proposed launch vehicle shall be nominally one of the European launcher family, namely Ariane 6 and Vega-C on ride-share, or any other available European small launcher. For missions to LEO probably a dedicated small European launcher could be envisaged, while for more demanding other destinations, flying as passenger to some other mission targeting the same destination is likely the sole possibility.

For the purpose of this Call, a 5M€ allocation shall be assumed for the mini-F launch (see Table 10).

5.2.1. Ariane 6

There are two versions of Ariane 6: Ariane 62 and Ariane 64, depending on the number of boosters employed. They are described in RD[1]. Given the ESA CaC constraint for this Call only a ride-share can be envisaged. The MLS configuration is relevant to small/mini satellites with a maximum mass of 500 kg. Available options are described in detail in RD[2].

5.2.2. Vega-C (E)

Vega-C has been conceived for circular, or near-circular Low-Earth Orbits but it can be also used in a variety of other orbits. The Vega-C performance is given in RD[3].

Vega–E is an evolution of Vega-C with a new European cryogenic upper stage, and likely with slightly increased performance. The maiden flight of the Vega-E is planned for 2027 and could be therefore also envisaged for mini-F missions.

There are several launch configurations possible with Vega-C: single launch, dual launch and launch in Small Spacecraft Mission Service (SSMS) configuration. The SSMS configuration is suitable for the launch of nano, micro and mini satellites and therefore an interesting option for mini-F, provided a launch opportunity with a prime passenger can be found.

Available payload volumes and mechanical interfaces are detailed in RD[3] and RD[4].

5.2.3. European small launcher

Currently several small launchers are under development in Europe. Due to the current rapid development and changes in this sector only a non-exhaustive/non-exclusive list of providers is disclosed here. Their use for mini-F missions will need careful considerations concerning timely availability, performance and reliability.

Launcher - Company	Country	Foreseen maiden flight	Website
Maïa Space	France	2025	Maïa Space
Latitude - Zephir	France	2025	Zephire
RFA ONE	Germany	2025	RFA ONE
Isar Aerospace – Spectrum	Germany	2025	Spectrum
HyImpulse – SL1	Germany	2026	SL1
PLD Space – Miura 5	Spain	2026	Miura 5
Orbex – Prime	UK	2025	Prime
Skyrora – Skyrora XL	UK	2025	Skyrora XL

Table 2: Non-exhaustive list of European mini launchers.

5.2.4. Other launch vehicles

Proposing passengers or companion to other existing missions, in the Science Programme or other programmes, is not excluded.

Launch services from an international partner may be considered if there is a documented intent from the partner.

Launch from China shall not be considered, as compliance to Export Control Regulations (see section 6.5) cannot be guaranteed.

5.3. MISSION AND SPACECRAFT

The following sections provide some information, data and considerations that can be useful for a preliminary sizing of the mission.

5.3.1. Transfer to the final orbit

Whenever the mission operational orbit is different from the launch orbit, a transfer scenario needs to be defined. This may include propulsive manoeuvres (either by chemical or electric propulsion), orbit resonances and weak stability boundary transfers.

5.3.2. Mass and Power resources

No or minimal changes to the existing platforms will considerably help in meeting the cost and schedule constraints for the mini-F mission. The proposals shall identify the required changes (if any) to be made to an existing platform and show evidence of their potential compatibility with the Call boundary conditions.

Typical mass ranges recommended as a guideline for the mini-F-mission are as follows:

- Science payload mass < 20 kg
- Total spacecraft mass below 100 kg (including the science payload)

No specific power range is defined.

5.3.3. Communications

ESA science missions shall comply with ITU frequency allocation requirements (see ND[2]). ITU assigns frequency bands for the different space telecommunication services. Science missions fall into the Space Research (SR) service category, which is split in two sub-categories depending on the SC distance to Earth in the operational orbit:

1. Near Earth or **Category A** for SC altitude above Earth surface < 2 Mkm (this includes Sun-Earth L1 and L2 missions, for instance),
2. Deep Space SR(DS) or **Category B** for SC altitude above Earth surface ≥ 2 Mkm.

The frequency allocations are reported in the following table extracted from ND[2]. The table also reports the max bandwidth that can be allocated to a single mission for specific bands. Actual allocation will be, in practice, a fraction of that value.

The actual data rate performance depends on theoretical link budgets but is limited by allowed bandwidth regulations and limits due to hardware (e.g. transponder, TWTA power).
This limitation coupled with constraints on the ground station visibility and the onboard memory, puts a limit on the maximum science data volume that can be transmitted to ground in a given time.

Types of mission	Link	Band	Frequencies (MHz)	Max bandwidth allowed	Examples and achievable data rates
LEO, HEO, SEL1/SEL2, Lunar	Up	S	2 025 – 2 110	Not applicable	CHEOPS RX
		X	7 190 – 7 235	Not applicable	Gaia RX
		Ka	40 000 – 40 500	Not applicable	Not used yet. Equipment and Ground infrastructure not yet available
LEO, HEO, SEL1/SEL2, Lunar	Down	S	2 200 – 2 290	6 MHz	CHEOPS Tx (0.6 Mbps)
		X	8 450 – 8 500	10 MHz	Gaia TX (up to 10 Mbps)
		K	25 500 – 27 000	No limitation	Euclid TX (70 Mbps), PLATO TX (40 Mbps)
Earth trailing, SEL4/SEL5, Planetary, Solar	Up	S	2 110 – 2 120	New assignments in this band are formally discouraged	
		X	7 145 – 7 190	Not applicable	Solar Orbiter RX
		Ka	34 200 – 34 700	Not applicable	EnVision (for radio science)
Earth trailing, SEL4/SEL5, Planetary, Solar	Down	S	2 290 – 2 300	New assignments in this band are formally discouraged	
		X	8 400 – 8 450	Function of symbol rate (see ND[2])	Mars Express TX (up to 230 kbps), Solar Orbiter TX (up to 600 kbps)
		Ka	31 800 – 32 300	No limitation	BepiColombo TX, JUICE TX (up to 50 kbps) Envision TX
		Ka	37 000 – 38 000	No limitation	Not used yet. Equipment and Ground infrastructure not yet available

Table 3: Allowed frequency bands and associated bandwidths

5.3.4. Spacecraft Budgets and Margins

This section summarizes the minimum margins to be considered by the proposers at system level.

Parameter	Margin	Comments
SC dry mass	25%	The nominal total spacecraft dry mass (excluding the 25% system margin) must be evaluated by including the maturity margins (If no detailed design exists 20% design maturity margin is recommended; for a recurring element 5-10%) at equipment or subsystem level. The total spacecraft dry mass shall include the total platform dry mass plus the allocated payload mass. **The payload level margin included in the allocated payload mass shall be clearly identified**. Propellant mass shall be calculated with the total dry mass at launch including system margin.
Delta Velocity	5%	The total delta-velocity capability of the spacecraft shall include this system level margin.
Power	30%	The total power demand of the spacecraft shall include this system level power margin. The payload level power margin shall be clearly identified.
Pointing	100%	The pointing accuracy, knowledge and stability error predictions shall include this system level margin.
Data Rate	50%	The calculation of the total payload data rate shall include this system level margin
Data Volume	50%	The calculation of the total payload data volume shall include this system level margin.
Communication Link	3 dB	The communication link budget for all mission phases shall be calculated with a minimum nominal margin of 3 dB.
Heat Rejection for cryogenic systems	20-100%	The calculated heat rejection capacity of the cryogenic systems which are operating at temperature below 100K shall include the following system level margin: - 20% for systems operating between 50K and 100K - 50% for systems operating below 50K - 100% for systems operating below 2K

Table 4: Recommended System Contingencies and Margins

5.3.5. Pointing Requirements

Science measurement requirements imply in most cases requirements on spacecraft pointing accuracy and knowledge. Those may have significant impact on the spacecraft design and cost.

Pointing requirements are specified through pointing error indices introduced in the ESA pointing error engineering handbook [RD[7].
A simplified description of the most common of such indexes is (see Figure 1 below):

Absolute Pointing Error (APE): difference between a wished direction and the actual one at any given time.
This is a measure of the spacecraft capability of pointing accurately. In many cases, the APE represents the difference between the line of sight of an instrument and the required direction of the target. As such, it may be derived e.g. from the need to keep the light coming from the target within the focal plane surface or inside a slit, in some cases of spectroscopy.

Relative Pointing Error (RPE): difference between the instantaneous direction and the average one in a given time interval. This is a measure of the pointing stability of the spacecraft over a relevant observation time. For imaging systems, such error causes image blurring, i.e. its maximum allowed value may be derived from the required spatial resolution of an instrument.

Absolute Knowledge Error (AKE): difference between the actual direction and the measured one at a given time.
This defines the required performance for AOCS sensors onboard. Attitude knowledge is always part of the pointing error. However, it may be the driving requirement in case attitude is reconstructed on ground by e.g. image postprocessing.

Relative Knowledge Error (RKE): the equivalent index of the AKE but applied to the RPE.

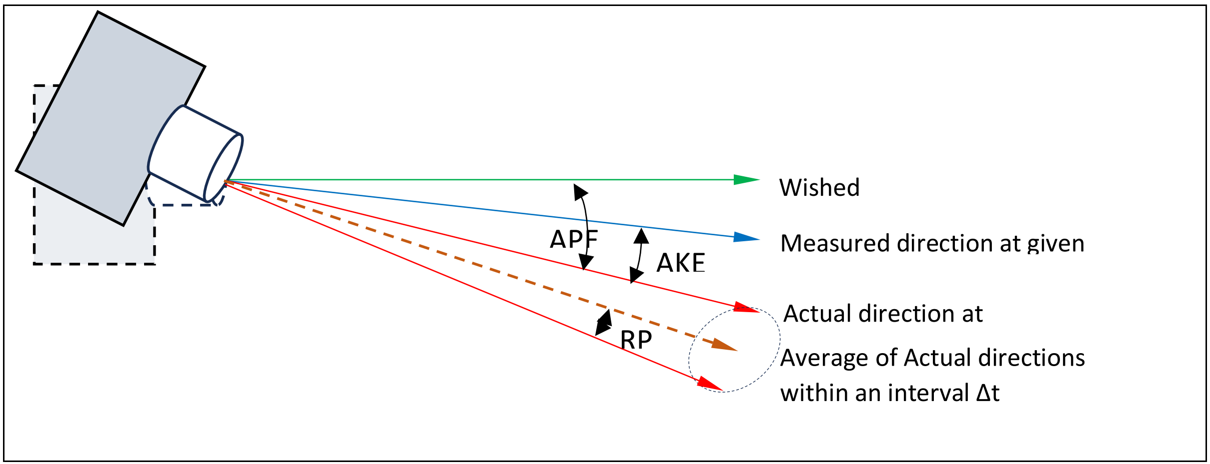

Figure 1: Explanation of pointing errors

All pointing errors are random functions of time, requiring a statistical specification often using Gaussian distribution. The limit value is often expressed as a 2-σ value, i.e. corresponding to 95% of the cases.

The proposer is expected to express and justify the critical pointing requirements for the proposed mission, i.e. those driving the science measurement performance and possibly the spacecraft cost. In some cases, the use of on-board AOCS sensor may not be sufficient to comply with pointing requirements (in particular, RKE) if they are very tight. Then, the use of the instrument measurements in the AOCS loop may improve considerably the pointing performance. This has been implemented in many astronomy missions either by directly using the science instrument data or by adding a dedicated Fine Guidance Sensor (FGS) in a science instrument focal plane.

The table below provides (for information) some pointing requirement formulations for an instrument line of sight (LoS) as a directional half cone angle .

Parameter	**LoS (arcsec)**	**Δt**	**Probability (%)**
ARIEL			
Absolute Pointing Error (APE) in coarse pointing mode	10.0		99.7
Absolute Pointing Error (APE) in fine pointing mode	1.0	-	99.7
Relative Pointing Error (RPE) in fine pointing mode	0.23	10 h	99.7
XMM			
Absolute Pointing Error (APE)	30.0	-	95.0
Relative Pointing Error (RPE)	6.0	2 min	95.0
Absolute Knowledge Error (AKE)	10.0	-	99.7

PLATO			
Absolute Pointing Error (APE)	270	-	99.7
Relative Pointing Error (RPE)	0.8	2.5 s	95.0

Table 5: Examples of Pointing Requirements Formulation

5.4. GROUND STATIONS

The reference for ground stations is the ESA ESTRACK network. This network is currently in evolution, with some 15 metre stations being retired from service or handed over to third parties. Considering the mission timescale, the following stations can be assumed:

Ground Stations	LEOP	Transfer Cruise	Critical Phases	Science Phase
Cebreros (X/XKa) 35 m		X	X	X
Malargüe (XKa/XKa) 35 m		X	X	X
New Norcia-1 (X/XKa) 35 m		X	X	X
New Norcia-3 (X/XKa and X/XK) 35 m		X	X	X
New Norcia-2 (X/SX) 4.5 m	X			
Kourou (SX/SX) 15 m	X	X	X	X
Kiruna-1 (S/SX) 15 m	X	X	X	X
Kiruna-2 (S/SX) 13 m	X	X	X	X

Table 6: Available ESTRACK Core Network Ground Stations

Additionally, stations from the Augmented Network consisting of commercial antennas can also be considered:

Name	Antenna diameter [m]	Frequencies (Tx / Rx)	Note
South Point (Hawaii)	13	S X/S X	
Santiago (Chile)	9	S/S	
Dongara (Australia)	13	S /S X	8000-8500 MHz RX X-band
Svalbard (Norway)	13	S /S X	7500-8500 MHz RX X-band
Troll (Antartica)	7.3	S X/S X	

Table 7: ESTRACK Augmented Network ground stations.

Finally, stations from the Cooperative Network consisting of antennas owned by Cooperating Space Agencies could also be considered (preferably as back-ups only or during critical operations such as LEOP). Their availability should be explicitly confirmed by the owning entity.

Alternative to use of ESA ground station also other commercially available stations or services could be envisaged. When considering stations beyond the core ESTRACK network, their capability to comply with the frequency allocations specified in 5.3.3 shall be checked.

6. MISSION IMPLEMENTATION CONSTRAINTS

6.1. ESA MISSION CLASSIFICATION

In 2024 ESA has introduced a mission classification scheme. The purpose of such classification is to provide a framework to define the management, engineering and product assurance approach to be applied to an ESA mission.

There are four categories of missions defined:

Mission Class	Mission Characteristics	Mission Description	Typical Mission Examples
ALPHA (high criticality)	✓ Top class missions ✓ Extremely critical and strategic for ESA. ✓ Budget > 400 M€ ✓ Lifetime > 7 Years.	✓ Critical strategy/safety (e.g. human spaceflight) ✓ Requirements are high, acceptable risk is very low. ✓ Performances to be met whatever it takes	✓ Aeolus-2 ✓ ARGONAUT ✓ EarthCARE ✓ MetOP-SG ✓ MTG ✓ VIGIL ✓ …
BETA (medium criticality)	✓ High class missions, ✓ Highly critical and strategic for ESA ✓ Budget 200 to 400M€, ✓ Lifetime 5 to 7 Years,	✓ Requirements are relatively high, and the acceptable risk is low. ✓ Finding the best compromise between risk and cost to deliver the mission	✓ Copernicus ✓ Comet-I ✓ EnVision ✓ FLEX ✓ HARMONY ✓ Sentinel Missions ✓ …
GAMMA (low to medium criticality)	✓ Medium class missions, (e.g. hosting New Space type of mission) ✓ Medium critical and strategic for ESA Budget 25 to 200M€ ✓ Lifetime 2 to 5 Years,	✓ Requirements are moderate with a non-negligible risk. ✓ Mission is designed according to a hard cost limit (affordability approach)	✓ Aurora ✓ Camila ✓ MicroGeo ✓ RAMSES ✓ SCOUTs ✓ WISDOMS ✓ …
DELTA (low criticality)	✓ Low class mission, ✓ Low critical and strategic for ESA ✓ Budget < 25M€, ✓ Lifetime <2 years	✓ Requirements are very limited with a significant risk. ✓ Almost full delegation to industry (Minimum requirements but increased risk)	✓ YPSAT

Table 8: ESA Mission Classification

The classification of a mission is dependent on a set of conditions that include allocated budget, development time, operational needs, etc. The classification is performed in phase 0/A by the Agency.

Due to the foreseen budget category, gamma or even delta would be likely applicable for mini-F. For missions in class gamma or delta, relaxations of the ECSS Standards are allowed, in particular in the areas of electronic components and materials and processes, where industrial practices and standards may be considered acceptable.

Failure tolerance affecting safety is not tailorable and it is independent from mission class. The relevant requirements are specified directly in ECSS Q-40 and in the launcher safety regulations. In general failure tolerance is normally iterated during the study phase and later decided by the Programme/Project.

6.2. SPACE DEBRIS MITIGATION

In October 2023, ESA has issued a new Space Debris Mitigation Requirements Document (RD[8]), that is applicable to all ESA projects.
The new requirements are more stringent than the policy in the previously applicable ISO standard. They apply mostly to spacecraft in Earth orbit, i.e. all Earth-bound orbits including orbits around Sun-Earth Lagrangian points. However, a subset of requirements is applicable also to Lunar orbit.

Hereafter, is a summary of the main practical mission constraints stemming from the new requirements:

1. Spacecraft shall not release any object in space (e.g. telescope cover) in nominal operations
2. Spacecraft shall be passivated at the end of their mission, i.e. energy from batteries and propulsion system shall be depleted.
3. Spacecraft shall have sufficient capability to perform collision avoidance manoeuvre, if warned of incoming debris on its trajectory.
4. Spacecraft shall be disposed of at the end of the mission. The spacecraft reliability at end of mission shall allow a disposal manoeuvre with 90% probability of success
5. The disposal shall be achieved by one of the following means, in order of preference:
    - Immediate Earth atmospheric re-entry after end of mission
    - Disposal in an orbit with a natural orbital decay leading to Earth re-entry in less than 5 years and cumulative spacecraft collision probability (from its end of life until re-entry) with space objects larger than 1 cm below 10^{-3}
    - If not operating in, nor crossing, the LEO protected region, disposal in a graveyard orbit that satisfies both following conditions: (a) Long-term perturbation forces do not cause it to cross the protected regions within 100 years and (b) cumulative collision probability with space objects larger than 1 cm is below 10^{-3} for up to 100 years after the end of life.
    - It does not cross the GEO protected region for at least 100 years with a probability >90%.
6. Uncontrolled re-entry is not allowed if casualty risk is > 10^{-4}

LEO and GEO protected regions are shown in Figure 2 below.

Except for very small satellites launched at low altitudes, one practical consequence for the spacecraft design is the need to implement a propulsion disposal manoeuvre at end of life.

As an example, a mission in the Sun-Earth Lagrange points L1 or L2, will comply with the requirement by performing a ~10 m/s delta-V manoeuvre at the end-of-life. This transfers the SC into a heliocentric orbit that does not cross the protected regions for at least 100 years with a probability >90%.

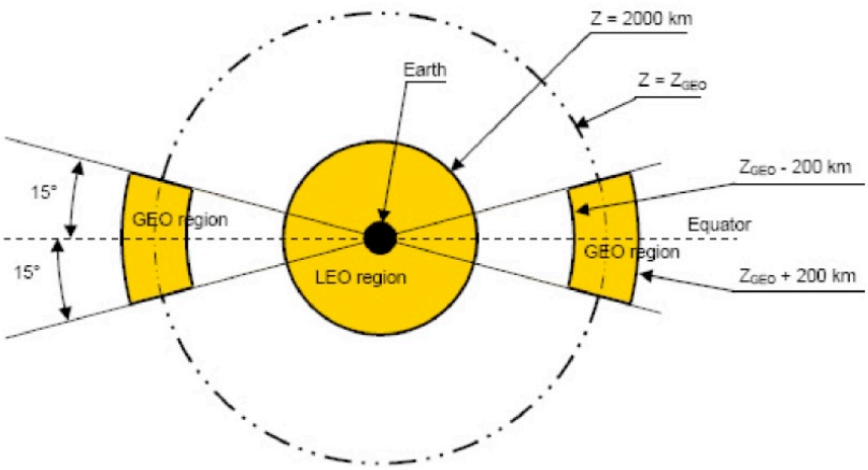

Figure 2: LEO and GEO protected regions RD[8].

When fragments of the SC may survive an uncontrolled re-entry, a controlled re-entry manoeuvre has to be performed to mitigate the risk of ground casualty. The delta-V required for this manoeuvre must be included in the sizing of the propulsion subsystem. This requirement applies to the SC as well as any other large debris generated by the mission, such as launch vehicle upper stages, multi-SC adapters, ejected covers etc.

6.3. PLANETARY PROTECTION

ESA Planetary missions shall comply with the categories and associated requirements reported in ND[3].

6.4. TECHNOLOGY READINESS

Once a mini-F mission concept is selected, the overall spacecraft development must be compatible with a fast implementation schedule of less than 5 years, nominally consisting of ~ 2 years for the preparation phase (phases 0/A/B) and ~3 years for the development phase (C/D).

The proposed platform and payload must be compatible with a delivery of the Flight Models within the 4 years following the early mission selection. PDR level should be reached within 18 months.

The platform must rely on existing technologies and should be derived from flight proven platforms, aiming at maximising reuse. Therefore, TRL 6 is required at the time of the mission proposal for all platform elements. Technology Readiness Level (TRL) 7 (as defined in Appendix B) is also nominally required for all platform elements at adoption (end of Phase B).

It is recommended to have all payload elements at TRL ≥ 5 already at the time of the mission proposal. In case the payload features some critical element at TRL 4 with a credible path to reach TRL 5 within ~ 2 years, the proposer is invited to also consider a back-up scenario with a TRL ≥ 5 and lower performance.

When assessing the technology readiness, the following guidelines shall be considered:

- Reference to heritage shall consider potential obsolescence of components, subsystems and human expertise.
- If a technology has already flown but for a different application and in a less demanding environment, its TRL is ≤ 4.

6.5. EXPORT CONTROL

In case the mission is planned with international partners, due consideration shall be paid to export control regulations, in particular the US International Traffic in Arms Regulation (ITAR), Export Regulations Administration (EAR) and European export rules.

Such regulations may prevent or put major constraints on important mission activities (such as satellite design, assembly, testing and launch) and could seriously jeopardise the mission feasibility.

7. PROGRAMMATIC ASSUMPTIONS

7.1. RESPONSIBILITIES

The share of responsibilities between ESA and the Member States on the payload elements shall be clearly identified in the proposal.

For an ESA-led mission, the nominal scheme is to have the spacecraft launch and operations (MOC) carried out by ESA. The science operations are led by ESA (SOC) with contributions from the Member States to be defined in the proposal. In case other schemes are proposed, their feasibility will be assessed based on the proposal content.

7.1.1. Payload Provision

As a rule, any Member State payload provision shall be commensurable with the lead Member State funding capability and overall compatible with the mini-F mission constraints.

7.2. MISSION REFERENCE SCHEDULE

Table 9 provides the reference schedule to be assumed for the mini-F missions:

Event mini-F	Date or duration	Note
Mini-F workshop with SPC to define way forward	Q4 2025	Following steps will be defined after the workshop
Preparation phase	below 2 years	from proposal selection to mission adoption
Development schedule	below 3 years	from adoption to launch

Table 9: Reference schedule for the mini-F-mission

7.3. MISSION COST ELEMENTS

ESA Cost at Completion (CaC) target is 50 M€ (2025 e.c.) for the mini-F mission. The CaC covers all ESA activities following the mission adoption, in particular:

- The spacecraft development phase C/D/E1
- ESA contributions to Payload
- The MOC and SOC developments
- The launch services
- The nominal in-orbit operations, including disposal at the nominal end of life.

Table 10 provides an indicative cost breakdown for an ESA stand-alone mini-F mission.

Element mini-F	% of total CaC
Spacecraft and Payload contribution under ESA responsibility	55%
Launch Vehicle	10%
Operations (MOC and SOC)	10%
ESA Project	10%
Margin	15%

Table 10: Indicative cost breakdown for mini-F

APPENDIX A - ABBREVIATIONS AND ACRONYMS

Abbreviation	Definition
ACS	Attitude Control System
AIT	Assembly, Integration and Testing
AIV	Assembly, Integration and Verification
AME	Absolute Measurement Error
AOCS	Attitude and Orbit Control System
APE	Absolute Pointing Error
AU	Astronomical Unit
Bps	Bits per second
CaC	Cost at Completion
CDR	Critical Design Review
CoG	Centre of Gravity
DHS	Data Handling System
DLS	Dual Launch Structure
DSN	Deep-Space Network
e.c.	Economic Condition
ECSS	European Cooperation for Space Standardisation
EM	Engineering Model
EMC	Electromagnetic Compatibility
EoL	End of Life
ESA	European Space Agency
ESAC	European Space Astronomy Centre
ESOC	European Space Operations Centre
ESTEC	European Space Research & Technology Centre
FM	Flight Model
FoR	Field of Regard
FoV	Field of View
GEO	Geostationary Earth Orbit
GL	Gravity Loss
GTO	GEO Transfer Orbit
HEO	High Elliptical Orbit
HGA	High Gain Antenna
ISO	International Organisation for Standardisation
ITU	International Telecommunication Union
Kbps	Kilobits per second
LEO	Low Earth Orbit
LEOP	Launch and Early Operations Phase
LGA	Low Gain Antenna
LoS	Line of Sight
LV	Launch Vehicle
MAR	Mission Adoption Review
Mbps	Megabits per second
MLI	Multi-Layer Insulation
MLS	Multi Launch Service
MOC	Mission Operations Centre
MoI	Moment of Inertia
MRD	Mission Requirements Document
MSR	Mission Selection Review
N/A	Not Applicable
PA	Product Assurance
PAS	Payload Adapter System
PDD	Payload Definition Document
PDR	Preliminary Design Review
PFM	Proto Flight Model

PI	Principal Investigator
PLM	Payload Module
PM	Propulsion Module
PSD	Power Spectral Density
PSF	Point Spread Function
QM	Qualification Model
RD	Reference Document
RF	Radio Frequency
RMS	Root Mean Square
RPE	Relative Pointing Error
RSS	Root Sum Square
SAA	Solar Aspect Angle
SC	Spacecraft
SciRD	Science Requirements Document
SDC	Science Data Centre
SEL***x***	Sun-Earth Lagrangian point (***x*** = 1,2,3,4,5)
SEP	Solar Electric Propulsion
SNR	Signal to Noise Ratio
SOC	Science Operations Centre
SPC	Science Programme Committee
SSMS	Small Spacecraft Mission Service
SSO	Sun Synchronous Orbit
SVM	Service Module
TBC	To Be Confirmed
TBD	To Be Defined
TM	Telemetry
TWTA	Travelling Wave Tube Amplifier
UTC	Coordinated Universal Time

APPENDIX B - DEFINITION OF TECHNOLOGY READINESS LEVEL (TRL)

Technology Readiness Level	Milestone achieved for the element	Work achievement (documented)
TRL 1 - Basic principles observed and reported	Potential applications are identified following basic observations but element concept not yet formulated.	Expression of the basic principles intended for use. Identification of potential applications.
TRL 2 - Technology concept and/or application formulated	Formulation of potential applications and preliminary element concept. No proof of concept yet.	Formulation of potential applications. Preliminary conceptual design of the element, providing understanding of how the basic principles would be used.
TRL 3 - Analytical and experimental critical function and/or characteristic proof-of-concept	Element concept is elaborated and expected performance is demonstrated through analytical models supported by experimental data/characteristics.	Preliminary performance requirements (can target several missions) including definition of functional performance requirements. Conceptual design of the element. Experimental data inputs, laboratory-based experiment definition and results. Element analytical models for the proof-of-concept.
TRL 4 - Component and/or breadboard functional verification in laboratory environment	Element functional performance is demonstrated by breadboard testing in laboratory environment.	Preliminary performance requirements (can target several missions) with definition of functional performance requirements. Conceptual design of the element. Functional performance test plan. Breadboard definition for the functional performance verification. Breadboard test reports.
TRL 5 - Component and/or breadboard critical function verification in a relevant environment	Critical functions of the element are identified and the associated relevant environment is defined. Breadboards not full-scale are built for verifying the performance through testing in the relevant environment, subject to scaling effects.	Preliminary definition of performance requirements and of the relevant environment. Identification and analysis of the element critical functions. Preliminary design of the element, supported by appropriate models for the critical functions verification. Critical function test plan. Analysis of scaling effects. Breadboard definition for the critical function verification. Breadboard test reports.

Technology Readiness Level	Milestone achieved for the element	Work achievement (documented)
TRL 6: Model demonstrating the critical functions of the element in a relevant environment	Critical functions of the element are verified, performance is demonstrated in the relevant environment and representative model(s) in form, fit and function.	Definition of performance requirements and of the relevant environment. Identification and analysis of the element critical functions. Design of the element, supported by appropriate models for the critical functions verification. Critical function test plan. Model definition for the critical function verifications. Model test reports.
TRL 7: Model demonstrating the element performance for the operational environment	Performance is demonstrated for the operational environment, on the ground or if necessary in space. A representative model, fully reflecting all aspects of the flight model design, is build and tested with adequate margins for demonstrating the performance in the operational environment.	Definition of performance requirements, including definition of the operational environment. Model definition and realisation. Model test plan. Model test results.
TRL 8: Actual system completed and accepted for flight ("flight qualified")	Flight model is qualified and integrated in the final system ready for flight.	Flight model is built and integrated into the final system. Flight acceptance of the final system.
TRL 9: Actual system "flight proven" through successful mission operations	Technology is mature. The element is successfully in service for the assigned mission in the actual operational environment.	Commissioning in early operation phase. In-orbit operation report.