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EXPRO STATEMENT OF WORK
ESA EXPRESS PROCUREMENT [PLUS] – EXPRO [+]

COLLISION AVOIDANCE INDUCED SPACECRAFT DESIGN AND OPERATIONS PLANNER

Prepared by	ESA
Document Type	SOW - Statement of Work
Reference	TDE-COL-SOW-00457-OPS-SD
Issue/Revision	1 . 0
Date of Issue	23/01/2026
Status	Approved

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1. Introduction

1.1. Scope of the Document

This document describes the activity to be executed, and the deliverables required by the European Space Agency in relation to "**Collision avoidance induced spacecraft design and operations planner**".

It will be part of the Contract and shall serve as an applicable document throughout the execution of the work.

1.2. Applicable and Reference Documents

1.2.1. Applicable Documents (ADs)

The following documents, listed in order of precedence, contain requirements applicable to the activity:

AD-01	ECSS-M-ST-10C Space project management – Project planning and implementation	ECSS-M-ST-10c-rev-1
AD-02	Generic tailoring of ECSS E-40 and Q-80 for engineering design, analysis software	ESA-TECMTV-ST-016541
AD-03	ECSS-E-ST-40C, Space engineering – Software: Tailoring for Ground Segment Systems	ECSS-E-ST-40C-Rev.1
AD-04	ECSS-Q-ST-80C Rev. 2, Space Product Assurance – Software Product Assurance: Tailoring for Ground Segment Systems	ECSS-Q-ST-80C-Rev.2
AD-05	ECSS-E-TM-E-10-25A, Space engineering - Engineering design model data exchange (CDF)	ECSS-E-TM-10-25A

The Applicable Documents are available through the hyperlinks given in the table above and are made accessible via the ZIP folder included in the TA package on esa-star.

1.2.2. Reference Documents (RDs)

The following documents can be consulted by the Contractor as they contain relevant information:

RD-01	ECSS-E-HB-40-01A, Space engineering Agile software development handbook	ECSS-E-HB-40-01A
RD-02	European Space Agency (2023). ESA Space Debris Mitigation Requirements, ESSB-ST-U-007, Issue 1.	ESSB-ST-U-007-Issue1
RD-03	European Space Agency (2025). ESA Space Debris Mitigation Compliance Verification Guidelines, ESSB-HB-U-002, Issue 3.	ESSB-HB-U-002
RD-04	ISO 24113:2023, Space systems – Space debris mitigation requirements, May 2023	iso.org/standard/83494.html
RD-05	U.S. Government Orbital Debris Mitigation Standard Practices (ODMSP), 2019	usg_orbital_debris_mitigation_standard_practices_november_2019.pdf
RD-06	Zero Debris Technical Booklet, Dec 2024	Zero_Debris_Technical_Booklet.pdf

The Reference Documents are available through the hyperlinks given in the table above or are made accessible via the ZIP folder included in the TA package on esa-star except for RD-04 as it must be procured by the tenderer with a license when needed.

1.2.3. Bibliographic Information (BI)

BI-01	European Space Agency (2024). The Zero Debris Charter.	The Zero Debris Charter [Accessed: January 2026]
BI-02	Collision avoidance requirements verification and guidelines based on DRAMA/ARES.	MIT-COL-MAN-00279-OPS-SD
BI-03	Schaus, V., et al., ESA's collision avoidance system at ESOC – status, recent upgrades and upcoming evolution, 9th European Conference on Space Debris, 2024	https://conference.sdo.esoc.esa.int/proceedings/sdc9/paper/391
BI-04	Siminski, J., Merz, K., et al., ESA's collision avoidance service: Current status and special cases, 8th European Conference on Space Debris, 2021	https://conference.sdo.esoc.esa.int/proceedings/sdc8/paper/296/SDC8-paper296.pdf
BI-05	de la Taille, L., Williams, G., Lazaro, D., Sancho, F., MIAMI: The EUMETSAT Operational Process to Implement a Late Collision Avoidance Maneuver, 2010	https://doi.org/10.2514/6.2010-2296
BI-06	Technical Note - Assessment of Risk Event Statistics (ARES)	Technical-Note-ARES.pdf

The Bibliographic Information Documents are available through the hyperlinks given in the table above.

1.3. Acronyms and Abbreviations

AR	Acceptance Review
ARES	Assessment of Risk Event Statistic
AD	Applicable Document
BI	Bibliographic Information
CCSDS	Consultive Committee for Space Data Systems
CDF	Concurrent Design Facility
CDM	Conjunction Data Message
CFI	Customer Furnished Item
CI/CD	Continuous Integration / Continuous Delivery/Deployment
DRAMA	Debris Risk Assessment and Mitigation Analysis
ECSS	European Cooperation for Space Standardization
GEO	Geo-synchronous Orbits
HEO	Highly Eccentric Orbits
IMA	Items made available
KO	Kick-off
LEO	Low Earth Orbit
MASTER	Meteoroid and Space Debris Terrestrial Environment Reference
TRL	Technical Readiness Level
RD	Reference Document
SSO	Sun-synchronous Orbits

1.4. Background and Objectives

1.4.1. Background

The space debris environment, space traffic, and the associated operational context are very dynamic. The population of space objects changes continuously due to new launches, satellite deployments, fragmentations, collisions, and re-entries. Collision probabilities, conjunction frequencies, and operational constraints evolve as the space environment transforms, making long-term predictions inherently uncertain.

Yet, in early spacecraft design – often conducted 10 years or more before launch – the expected effort for collision avoidance during the mission needs to be estimated. This creates a significant challenge: mission designers must account for collision avoidance requirements and associated costs for a future space environment that may differ substantially from today's conditions. The object population a decade from now, the frequency of conjunctions, and the operational burden of maintaining safe operations remain difficult to forecast with confidence. Nevertheless, these estimates are critical for project budgeting, system design decisions, and mission feasibility assessments. Furthermore, these assessments need to be revisited and updated at various points throughout the mission lifecycle, particularly during mission extension

reviews and throughout the operational phase, to account for the evolving space environment and actual operational experience.

Existing models allow designers and operators to estimate the fuel budget for collision avoidance manoeuvres. However, those are based on general assumptions and single source space surveillance data. With the introduction of the Zero Debris approach [RD-02] and the proliferation of space surveillance companies, the impact of collision avoidance operations goes beyond fuel estimation and now requires accounting for, among others, mission time loss, required ground support, the concept of operations, response times, and varying data providers. The Zero Debris initiative is a community-driven effort that has been widely adopted across the global space sector. Over 200 companies, research centres, and international organisations, along with more than 20 countries, have committed to the Zero Debris Charter [BI-01], demonstrating broad international support for sustainable space operations. As such, the outputs developed to support collision avoidance is not only important for ESA but for all actors who have adopted the Zero Debris Charter, making these assessments relevant to the entire space community working towards debris-neutral operations.

Current tools for analysing the impact of collision avoidance and for checking compliance with Space Debris Mitigation Requirements, such as DRAMA/ARES are limited to, i.e., a statistical estimate of the to be expected collision avoidance rate for a given mission and orbital evolution in the future debris environment. The Agency can provide DRAMA at kick-off, if requested by the Contractor, and specifically the submodule Assessment of Risk Event Statistics (ARES) (BI-06) software to make use of orbit propagation and time-variant distribution of the orbital debris in different orbital regimes. DRAMA can be downloaded via the Space Debris User Portal. If ARES modifications are needed, the Agency can provide the source code under a specific license agreement. Alternative tools must be justified and should at least have the same functionality to reduce the development effort during this activity.

1.4.2. Objectives of the Activity

This activity aims to create a software model to facilitate state-of-the-art estimates for collision avoidance and disposal efforts. Given the fact that mitigation practices are an integral part of spacecraft operations since two decades, a robust assessment framework could be created, to be used:

- in early mission design (Phase 0/A/B) to assess the feasibility and impact of collision avoidance and disposal compliance on satellite design and operations, and
- by spacecraft operators who need more realistic planning tools for operations and manoeuvre planning.
- to revisit assumptions at mission extension check-points.

2. Work To Be Performed

2.1. Work Logic

The work to be performed is divided into four top-level tasks aligned to the main objectives from the previous section. These are:

1. Review state-of-the-art collision avoidance operations across the industry to identify a modelling approach to abstract those operational concepts, including decision criteria, Conjunction Data Message (CDM) adoption, etc. but considering the adherence to the guidelines and requirements [RD-03, RD-04, RD-05].
2. Curate or create a dataset of uncertainties relevant for collision avoidance in Earth orbit as function of mission size, propulsion, orbital characteristics, space surveillance data provider performances, and operational timeframe, etc.
3. Develop a representation of mission operations (including the ESA context [BI-03, BI-04] but mainly reflecting on industry practices ([BI-05]) within an uncertainty-driven environment for collision avoidance operations to assess the impact of operational choice, including orbital accuracy, attitude modes and shapes, ground station requirements, mission delays, as well as manoeuvre capabilities and needs.
4. Integrate a software prototype in line with [AD-03, AD-04] that will support the trade-offs considering collision avoidance needs in one holistic setting, with a dependency on the aforementioned representation in the context of an increasingly dynamic space environment. An Agile approach is preferred, and when an Agile software development approach is adopted, tailoring shall be applied in accordance with [RD-01].

The tasks are not necessarily meant to be executed in sequence, e.g. the dataset curation and exploration of design parameters could very well be executed in parallel to the collision avoidance process analysis. Furthermore, the software technological foundation of the prototype could be started at an early stage in the project to facilitate fast prototyping in an agile manner [RD-01] (e.g. by reducing the run-time due to an efficient code base).
Tasks 1 - 4 are coupled and should be performed simultaneously. The overall proposed work logic is illustrated in Figure 1.

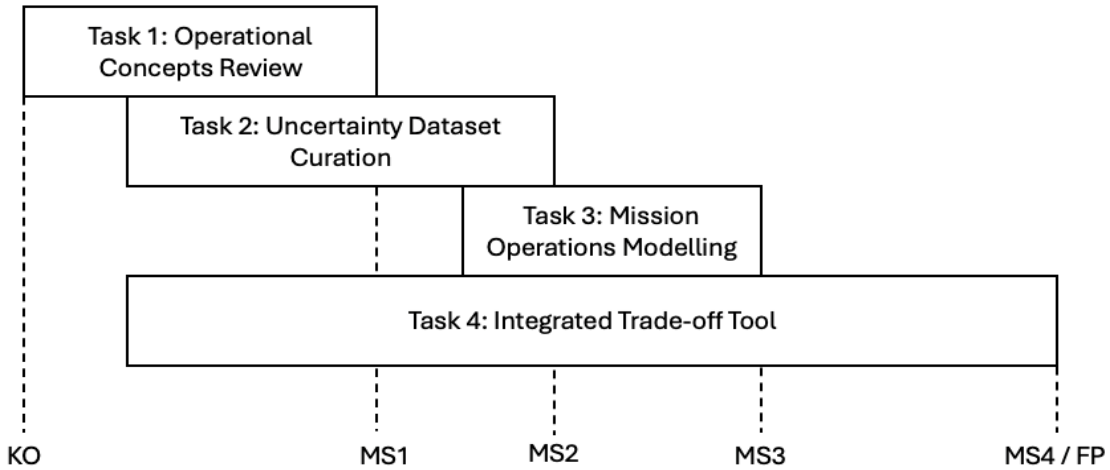

Figure 1: Proposed work logic for activity

2.2. Tasks

2.2.1. Task 1: Review of the state-of-the-art collision avoidance operations

Input	RDs, ADs
Description	Perform a comprehensive collection and review of collision avoidance operations concepts. The aim is to identify the criteria used in practice and to quantify their impact on cost or effort.
Output	Technical documentation describing the reviewed concepts (DD-01)

REQ-01	The Contractor shall perform a literature survey, use own and ESA's operational background on collision avoidance [BI-03, BI-04] to put together a comprehensive overview of **operational collisional avoidance concepts** with the aim to distil impact, cost and effort from the approaches. The findings shall be summarised in DD-01.
REQ-02	The Contractor shall perform a literature survey , use own and ESA's operational background on collision avoidance [BI-03, BI-04] to put together a comprehensive overview of **disposal concepts** with the aim to distil impact, cost and effort from the approaches. The findings shall be summarised in DD-01.
REQ-03	The Contractor shall identify the parameters influencing the cost[1] of collision avoidance in the operational and during the disposal phase. The analysis shall include at least but is not limited to the following parameters: • operational concepts, • ground segment tasking, • decision criteria and timelines, • implementation constraints on the space segment, • co-ordinational and space traffic related aspects, • passivation, retiring or de-orbit strategies.
REQ-04	The collision avoidance concepts should include an assessment of the anticipated changes in the next generation of missions shifting to different technologies (i.e. increased use of electrical propulsion; use of de-orbit technologies, tethers and in-orbit servicing and in-line with the required developments towards Zero Debris [RD-06]) and shifts towards more on-board autonomy.
REQ-05	The collision avoidance concepts shall be assessed in view of their compliance to regulatory guidelines, i.e. the Space Debris Mitigation Requirements [RD-02].
REQ-06	The derived methods shall be documented in the technical note (DD-01).

[1] Please note that cost does not necessarily need to be EUROs, but can be indirect cost quantities, i.e. fuel requirements, estimated working hours, ground station pass bookings, etc. which could be mapped to real monetary cost by modelling hourly rates or cost per items.

2.2.2. Task 2: Uncertainty Dataset Curation

Input	Output from Task 1: technical note DD-01, ADs, RDs
Description	Distil and quantify the parameters influencing the cost for collision avoidance derived from the analysed concepts in Task 1.
Output	Technical documentation describing the dataset (DD-02)

REQ-07	The Contractor shall identify for each of the cost driving parameters[2] for collision avoidance a suitable value range, meaningful discretisation and assessment of the uncertainty.
REQ-08	The Contractor shall consider cross-correlation effects between the multi-dimensional parameter space.
REQ-09	The Contractor shall analyse boundaries of parameter ranges which lead to violation of Space Debris Mitigation Guidelines.
REQ-10	The Contractor shall account for that fact that Space Debris Mitigation Guidelines apply different sets of rules depending on mission characteristics.
REQ-11	The dataset shall be saved in a digital representation which facilitates easy replacement and updates later, aside from program logic.

2.2.3. Task 3: Mission Operations Modelling

Input	Output from Task 1 and 2 (DD-01, DD-02)
Description	Generate a model to evaluate the impact of collision avoidance on s/c operations and operating cost.
Output	Technical note documenting the multi-dimensional, holistic model to assess collision avoidance cost (DD-03).

REQ-12	The model shall have multiple user inputs as per the set of collision avoidance design parameters.
REQ-13	The model shall be capable to output the cost[3] for collision avoidance.
REQ-14	The model shall be capable to state violation(s) of the Space Debris Mitigation Guidelines.

[2] Please note that cost does not necessarily need to be EUROs, but can be indirect cost quantities, i.e. fuel requirements, estimated working hours, ground station pass bookings, etc. which could be mapped to real monetary cost by modelling hourly rates or cost per items.
[3] Please note that cost does not necessarily need to be EUROs, but can be indirect cost quantities, i.e. fuel requirements, estimated working hours, ground station pass bookings, etc. which could be mapped to real monetary cost by modelling hourly rates or cost per items.

REQ-15	The boundaries shall be configurable to allow for switching between different applicable Space Debris Mitigation rulesets at least considering but not limited to ESA Space Debris Mitigation Compliance Verification Guidelines [RD-03], U.S. Government Orbital Debris Standard Practices [RD-05], ISO 24113 [RD-04].
REQ-16	The model shall cover and distinguish at least but not limited to the following classes of mission: large telecommunication mission in GEO, Earth observation in LEO (SSO), constellations in LEO.

2.2.4. Task 4: Integrated trade-off tool

Input	Output from Task 1 (DD-01) and Task 2 (DD-02) and Task 3 (DD-03)
Description	Development of the prototype software program
Output	Incremental functional scopes / versions of the prototype software (SW-01, SW-02, SW-03) in alignment with Tasks 1-3 at the associated milestones. The final version of the prototype software (SW-04), test plan (DD-04), technical note describing the performance and the results of the test scenarios (DD-05), the software documentation (DD-06) in line with the tailored approach from [AD-02, AD-03, AD-04].
Note	As described in this document, the software deliverables SW-01, -02, -03, and -04 refer to different functional capabilities (versions) of the same, to be integrated prototype. These check-points are aligned with the Tasks and should facilitate the agile paradigms for software development. It is expected that the protype can be executed, demonstrated and evaluated by the Agency throughout the project to allow for feedback and iterative improvements. The table in section 4.4.2 resembles this aspect by stating, e.g., that SW-01 functional scope is firstly expected at MS 1, yet to be extended/adapted as needs arise.

REQ-17	The software shall define several cost quantities[4] and combinations thereof as possible output.
REQ-18	The Contractor shall generate test scenarios for the classes of space missions as per REQ-16 and the collision avoidance and disposal concepts which have been analysed in Task 1 in the Literature Survey.

[4] Please note that cost does not necessarily need to be EUROs, but can be indirect cost quantities, i.e. fuel requirements, estimated working hours, ground station pass bookings, etc. which could be mapped to real monetary cost by modelling hourly rates or cost per items.

REQ-19	The Contractor shall perform test evaluations on real mission scenarios (from Task 1) with full complexity to demonstrate the capability to output the correct reference cost. This can be regarded as integration tests.
REQ-20	The software shall be extended continuously throughout the project at the moment the results from Task 1-3 become available. Intermediate versions SW-01, SW-02 and SW-03 can be associated to the following functional scopes: SW-01 – shall provide the cost model, the input parameters configuration, a command line interface for running the tool, and the software engineering tooling and pipeline to build and deploy the tool SW-02: – shall incorporate the data set from Task 2 in an easily exchangeable (later updateable) digital model. SW-03: – shall integrate the holistic modelling of mission operations in view of collision avoidance.
REQ-21	The Contractor shall propose a reduced software documentation approach based on [AD-03].
REQ-22	The performance of the tool shall be assessed by at least profiling CPU time in functions, call graph analysis and checking for memory leaks.
REQ-23	The runtime shall be suitable for quick iterations facilitating the use in concurrent design studies, e.g., less than 20 min of runtime.
REQ-24	The tool shall respect data exchange mechanism, scientific units and parameter descriptions as per [AD-05].
REQ-25	The tool shall be delivered as source code together with project setup, documentation and API docs, development tooling infrastructure to support the agile development throughout the activity (CI/CD pipeline) via ESA's GitLab instance.
REQ-26	The tool shall handle multiple design scenarios at the same time.
REQ-27	The tool shall present the result in adequate form (i.e. multi-dimensional maps) to intuitively explore the trade-space and highlight regions where no solutions are possible.
REQ-28	A license check shall be performed, and any finding or non-compliance shall be addressed by the Contractor for the final product.

3. Agency Undertakings

3.1. Customer Furnished Items

N/A

3.2. Items Made Available by the Agency

IMA-01	Dataset of Conjunction Data Messages (CDMs) from ESA mission (when required for the scope of the activity as per the Bidder's proposal).	provided at KO

3.3. Other Agency Undertakings

Detailed explanation of the ESA collision avoidance process and procedures in case the Bidder's proposal indicates that the tenderer(s) is (are) not familiar with it can be provided after Kick-Off. The information can be made available through a mini-series of meetings with experts in the Space Debris Office.

4. Requirements For Management, Reporting, Meetings And Deliverables

The standard requirements for Management, Reporting, Meetings and Deliverables (Appendix 3 to the Contract) shall apply, taking account of the following specific requirements for the present activity, which shall prevail in case of conflict.

4.1. Management

4.1.1. General

MAN-01	The Contractor shall implement effective and economical management for the project.
MAN-02	The Contractor's nominated Project Manager shall be responsible for the management, execution of the work to be performed and, in the case of a consortium, for the coordination and control of the consortium's work (including the submission of the deliverables to the Agency).
MAN-03	All communications to the Agency, affecting technical terms and conditions of the activity, shall be addressed in writing to the Agency's representatives nominated in the Contract.
MAN-04	During the course of the Contract the Agency shall be afforded free access to any plan, procedure, specification or other documentation relevant to the programme of work.
MAN-05	The Contractor shall implement the appropriate management communication lines and ensure a single management authority for all tasks.
MAN-06	The Contractor shall set up and conduct the project management for all aspects according to [AD-01].

4.2. Reporting

4.2.1. Minutes of Meeting

The Contractor is responsible for the preparation and distribution of Minutes of Meetings held in connection with the Contract. Electronic versions shall be issued and distributed to all participants, to the Agency's Technical Officer and to the Agency's Contracts Officer not later than five (5) days after the meeting concerned.

The minutes shall clearly identify all agreements made and actions accepted at the meeting.

4.2.2. Bar-chart Schedule

The Contractor shall be responsible for maintaining the bar chart for work carried out under the Contract, as agreed with the Agency.

The Contractor shall present an up-to-date chart for review at all subsequent meetings, indicating the current status of the Contract activity (WP's completed, documents delivered, etc.).

The Contractor shall provide the underlying data for the bar-chart as a Microsoft Project file or another equivalent format.

4.2.3. Progress Reports

Every month, the Contractor shall provide a Progress Report in electronic format to the Agency's representatives, covering the activities carried out under the Contract. This report shall refer to the current activities shown on the latest issued bar chart and shall give:

- Action items completed during the reporting period;
- Description of progress: actual vs schedule, milestones and events accomplished;
- Reasons for slippages and/or problem areas, if any, and corrective actions planned and/or taken, with revised completion date per activity;
- Events anticipated during the next reporting period (e.g. milestones reached);
- Milestone payment status.

4.2.4. Problem Notification

The Contractor shall notify the Agency's representatives (Technical Officer and Contracts Officer) of any problem likely to have a major effect on the time schedule of the work or to significantly impact the scope of the work to be performed.

4.2.5. Technical Documentation

As they become available and not later than the dates in the schedule, the Contractor shall submit for the Agency's approval Technical Notes, Task/WP Reports, etc.

Technical documentation to be discussed at a meeting with the Agency shall be submitted electronically two (2) weeks prior to the meeting.

4.3. Meetings

Progress Meetings can take place as appropriate between review meetings.

The final presentation shall take place to a public audience, within twelve (12) months of Contract closure. During the course of the activity the Agency will decide on the format for the final presentation (e.g. dedicated meeting, conference, specific event).

Additional meetings may be requested either by the Agency or the Contractor.

With due notice to the Contractor the Agency reserves the right to invite Third Party(ies) to meetings to facilitate information exchange.

For each meeting the Contractor shall propose an agenda in electronic form and shall compile and distribute hand-outs of any presentation given at the meeting. Should the Contractor wish to invite Third Party(ies) to meetings, the prior approval of the Agency shall be sought.

The following meetings shall be planned:

- Kick-Off meeting (KO)
- Progress meetings related to milestones (PM)
- Intermediate technical status review meetings involving the core team at approx. monthly intervals via tele-/online conferences
- Final presentation (FP)

KO and FP meeting shall be conducted at ESOC in Darmstadt, Germany. Other meetings shall be organized in agreement with the Agency either at Contractor(s) premise or via teleconferencing.

The Contractor shall take and distribute the minutes of all meetings.

4.4. Deliverable Items

In addition to the documents to be delivered according to section 4.2 here above, the following items shall also be delivered.

The draft version of the documentation shall be sent to the Agency's Technical Officer in electronic format not later than two (2) weeks before the documentation is to be presented.

All documents shall bear the appropriate copyright notice. In all cases, this shall include the title, ESA Contract number, deliverable number, date, status (draft), version and/or revision number. The information shall be repeated consistently in the header or footer of every page.

4.4.1. Documentation

DOC-01	All documentation shall be delivered as an electronic searchable, indexed and not encrypted PDF.
DOC-02	Source files for documents (e.g. Word file) and graphics shall be maintained and included into the set of deliverables at contract end.
DOC-03	The Agency recommends delivering the files to, and maintaining a repository at, an ESA SharePoint folder (for which the Agency will provide access).
DOC-04	The Contractor shall ensure that electronic documents do not contain any harmful code (e.g. virus).

DOC-05	The draft version of the documentation shall be sent to the Agency's Technical Officer in electronic format not later than two weeks before the documentation is to be presented.
DOC-06	All documents shall bear the appropriate copyright notice. In all cases, this shall include the title, ESA Contract number, deliverable number, date, status (draft), version and/or revision number. The information shall be repeated consistently in the header or footer of every page.
DOC-07	Documents shall be free of any restrictions in terms of full text search, copying, printing, commenting and revising. Large documents also require change logs and the use of hyperlinked table-of contents and cross references.
DOC-08	The delivered documents shall be free of all commercial or confidential information, which should be provided under separate cover if necessary. No copyright nor dissemination restrictions shall be indicated.
DOC-09	Technical documents from Subcontractors shall be submitted to the Agency only after review and acceptance by the Prime Contractor(s) and shall be passed to the Agency via the Contractor's formal interface to the Agency.
DOC-10	Software documentation shall make use of the templates given in the applicable, tailored, standards [AD-01].

Doc ID	Title	Milestone
DD-01	Technical Report on Operational Collision Avoidance Concepts	end of Task 1, MS 1
DD-02	Technical Report on Collision Avoidance Design Parameters	end of Task 2, MS 2 and FP
DD-03	Technical Report on the Modelling of the Collision Avoidance Impact	end of Task 3, MS 3 and FP
DD-04	Test Plan	End of Task 3, MS 3 and FP
DD-05	Technical Report with Performance Assessment Results and Results of the Test Scenarios	Task 4, FP
DD-06	Software documentation	Task 1-4, MS 1, MS 2, MS 3, FP
DD-07	FR: Final Report	Task 1-3, FP
DD-08	ESR: Executive Summary Report	MS 4 / FP
DD-09	CCD: Contract Closure Documentation (digitally submitted and approved in esa-star, see Contract)	MS 4 / FP

(**) Definitions of Deliverable Documents

The above table is the required documentation to be provided by the Contractor(s). The Contractor(s) can propose additional deliverables.

4.4.2. Software

Code	Title	Milestone	Delivery
SW-01	Prototype source code project setup with GitLab CI/CD automation, cost model, command line utility with configurable input parameters	MS 1, MS 2, MS3, FP	ESA Gitlab
SW-02	Integration of the digital data representation	MS 2, MS3, FP	ESA Gitlab
SW-03	Holistic model implementation	MS 3, FP	ESA Gitlab
SW-04	Final version of the prototype program; cost analysis for all mission classes possible and plausible; violations against SDM standards are reported	FP	ESA Gitlab

5. Schedule And Milestones

5.1. Duration

The duration of the work **shall not exceed 18 months** from kick-off to end of the activity (delivery of the draft Final Report and Software).

5.2. Milestones

The following milestones shall apply:

Milestone	Description	Events Timeline
KO	Kick-Off	T0
MS 1	Completion of Task 1 and SW-01	T0 + 5m
MS 2	Completion of Task 2 and SW-02	T0 + 10m
MS 3	Completion of Task 3 and SW-03	T0 + 15m
MS 4 / FP	Final report, completion of Task 4	T0 + 18m

Timing of milestone events in above table are indicative.

MI-01	The negotiation, and milestone meetings shall take place by video- or tele-conference.
MI-02	Progress Meetings shall be held at approximately monthly intervals, by video- or teleconference.
MI-03	The final presentation shall take place at the Agency's premises, to a public audience, within twelve (12) months of Contract closure. During the course of the activity the Agency will decide on the format for the final presentation (e.g. dedicated meeting, conference, specific event).
MI-04	Additional meetings may be requested either by the Agency or the Contractor.
MI-05	With due notice to the Contractor the Agency reserves the right to invite Third Party(ies) to meetings to facilitate information exchange.
MI-06	For each meeting the Contractor shall propose an agenda in electronic form and shall compile and distribute hand-outs of any presentation given at the meeting.

5.3. Reviews

The following reviews shall be held:

5.3.1. MS 1 Review

- Date: T0 + 5 months
- Location: Teleconference / Online Meeting
- Input: All deliverables associated to Task 1 and SW-01 of Task 4, Milestone Presentation
- Output: MS 1 Acceptance, signed MoM

5.3.2. MS 2 Review

- Date: T0 + 10 months
- Location: Teleconference / Online Meeting
- Input: All deliverables associated to Task 2 and SW-02 of Task 4, Milestone Presentation
- Output: MS 2 Acceptance, signed MoM

5.3.3. MS 3 Review

- Date: T0 + 15 months
- Location: Teleconference / Online Meeting
- Input: All deliverables associated to Task 3 and SW-03 of Task 4, Milestone Presentation
- Output: MS 3 Acceptance, signed MoM

5.3.4. MS 4 Review – Final Presentation

- Date: T0 + 18 months
- Location: ESOC
- Input: All deliverables associated to Task 4 and SW-04 of Task 4, Milestone Presentation
- Output: MS 4 Acceptance and Final Presentation, signed MoM, entering Warranty Period

ANNEX A. Requirements

A.1. Quality and Product Assurance

QA-0001	The Contractor shall be responsible for the quality of the deliverables, but ESA reserves the right to request visibility on the state if the deliverables at any time during the activity and warranty. This includes the possibility for code reviews at any time during the project.
QA-0002	The Contractor shall be responsible for maintaining software metrics, such as - Number of lines of code - Execution time (total and task-wise) - Number of routines - Software Problem Reports (via a Gitlab issue tracking or equivalent) The agency shall have access to these metrics upon request.
QA-0003	Unit testing for all major functionality of the code shall be implemented and executed in line with [AD-02].
QA-0004	Where the modelling of physical processes is concerned, this shall be accompanied of reference data and test cases supporting that the intended accuracy is achieved. Divergences shall be documented, and knowledge gaps identified.

A.2. Acceptance

AT-0001	All final software, data files, scripts, job control files, and documentation files resulting from the Tasks shall be installed at ESOC 2 weeks before the final presentation.
AT-0002	The Final Acceptance period shall be two weeks.
AT-0003	Acceptance Testing of software developed by the Contractor will be carried out by the Contractor at ESOC and witnessed by ESA. It will cover: – Verification of compliance with the requirements – Verification of the reliability, via extended duration tests
AT-0004	The Final Acceptance period shall allow ESA to perform hands-on tests. Final Acceptance shall only be given after successful completion of this period.
AT-0005	Any acceptance done by ESA shall solely relate to technical validation aspects. It shall not relate to any contractual or legal aspects and shall, in particular, not affect the Contractor's obligations as detailed in this document, which shall continue also after the acceptance.

A.3. Implementation Requirements

TR-01	All end-user executables, data files, and documentation files shall be self-contained, i.e. no external libraries, programs or licenses shall be required unless explicitly agreed with the Agency.
TR-02	All end-user executables, data files, and documentation files shall be compatible with the Linux, Mac, and Windows operating systems supported by DRAMA 4.1.0 and MASTER 8.2.3 and above.
TR-03	The developed software shall be compatible with a maintained version of the GCC compiler suite.
TR-04	The use of COTS, open source and shared or free software items as part or in support of the implementation shall be subject to approval by the Agency and – The foreign items, their role and dependencies and their place of implementation must be clearly identified – The legal framework for each of the items must be highlighted
TR-05	The handling of parameters (via the argument lists, or named commons, also if contained in include files) shall be fully documented in the subroutine or function header. Doxygen, sphinx or functional equivalent syntax shall be used for this purpose.
TR-06	The Contractor shall deploy mechanisms/tools to enable automated generation/synchronisation of the software design documentation and the software code. In case of use of existing software, the Contractor shall justify it and analyse the compatibility with the system requirements.
TR-07	Each header shall describe the functionality of the module, followed by its input and output parameters by name, array size, type and content. Further embedded comments shall be introduced whenever necessary for the understanding of the source codes (this can be identified during code reviews by the Agency).
TR-08	The software development environment shall make use of the git version control system. The ESA GitLab shall be the main collaboration platform, including code version control, code review processes, issue tracking, and coding milestone planning.
TR-09	The Contractor shall make sure that all COTS items used for software development are maintainable for at least 5 years since the time of delivery or otherwise covered by long term support plans. The use of COTS items requires prior approval by the Agency.

TR-10	Any proposed open-source item for usage within the activity shall contain a demonstration of significant community support and wide user base, before approval.
TR-11	The Contractor shall verify that all hardware and software supplied can be reasonably maintained for at least 5 years after the time of delivery
TR-12	All activities, reports, correspondence, deliverables and tools covered by this SoW shall be in English.

A.4. Software Engineering Requirements

SER-01	All software must be developed and verified in compliance with [AD-02]. A reduced documentation approach shall be proposed by the Contractor, e.g. using the tailoring from [AD-03] and [AD-04].
SER-02	All computer code shall be written according to the coding guidelines used for the existing code and existing exceptions shall be brought in line with these when encountered. In case of new code, the coding standard shall be defined and agreed with the Agency. The selection of programming language and guidelines are subject to Agency approval.
SER-03	The Contractor shall set up and conduct quality and configuration management for all items to be produced according to [AD-02].
SER-04	The Contractor shall define and follow a software life cycle including phases, their inputs and outputs, and joint reviews as defined in [AD-02]. The setup and usage of a continuous integration (CI) environment is requested. The infrastructure available at the Agency can be requested.
SER-05	The Contractor shall provide a fully automatic build procedure for each delivery and shall provide on-site support, if needed for the build, during the activity and warranty. The complete procedure shall be documented. The fully automated build procedure shall be captured within the Continuous Integration pipelines and the automated processes configured and run at the Contractor's premises shall be cloned/mirrored at ESA premises. This is applicable to this work to guarantee maintainability of the system.
SER-06	The Contractor shall perform Testing on the CI platform required at Contractor premises and shall include into the CI pipeline those tests which can be automated and are agreed with the Agency. These shall be part of the delivery.
SER-07	The output of each phase and their status of completion, submitted as input to joint reviews, shall be specified in the software life cycle definition, including documents in complete or outline versions, and the results of verification of the outputs of the phase.
SER-08	The Contractor shall encapsulate all platform specific code in a neutral interface to minimise the effort in changing the platform if this became desirable or necessary.

SER-09	Interfaces and programming shall make use of recognized international standards if applicable, i.e. there is a relevant international standard in the field. The applicability shall be part of the software design justification and subject to approval.
SER-10	All code shall go through automated quality checks, checked by pre-commit and GitLab CI. The ruleset shall be defined in agreement with the Agency.
SER-11	The GitLab Flow workflow shall be followed (https://docs.gitlab.com/ee/topics/gitlab_flow.html).
SER-12	All contributions by the Contractor shall happen in feature branches with merge requests on GitLab.
SER-13	All merge requests are suspect to approval by ESA. A manual code review is done at this stage and requests for change can be passed back to the Contractor. Rejections are also possible but rare. ESA commits to review those merge request as soon as possible, to avoid long waiting times.

A.5. Verification & Testing Requirement

TA-01	The Contractor shall carry out all unit, system and integration tests
TA-02	The Contractor shall be responsible for producing any necessary item to support testing, including test programs, input data samples, command procedures.
TA-03	Acceptance tests shall be carried out at the final installation environments and sites
TA-04	The Contractor shall make use of an issue-tracker while developing the software to which the Agency has access. The agency will provide such a service at the KO.

ANNEX B. LAYOUT FOR CONTRACT CLOSURE DOCUMENTATION
(v2018-10)

Contract Closure Documentation
for
ESA Contract No. 4000XXXXXX/26/D/AP
"Collision Avoidance Induced Spacecraft Design and Operations Planner (Expro+) – T709-902SD",
hereinafter referred as the "Contract"

Section 1 – Parties, Contract Duration and Financial Information

Contractor		[CONTRACTOR NAME AND COUNTRY]
Subcontractor(s) *(state if not applicable)*		[NAME AND COUNTRY]
Contract Duration *(insert the dates agreed for kick-off and end of Contract)*		**From**: **To**:
Total Contract Price (*including all CCNs, Work Orders, Call of Orders*) and Total Contract Value *(in case of co-funding; state if not applicable)*		**EUR** EUR
Broken down as follows:	**Original Contract Price** and original Contract Value (*in case of co-funding; state if not applicable*)	**XXX EUR (XXX EUR)** EUR
	CCN x to n **Work Order x to n** **Call-Off Order x to n**	**EUR** in total **EUR** in total **EUR** in total

Section 2 – Recapitulation of Deliverable Items

2.1 Items deliverable under the Contract

If any of the columns do not apply to the item in question, please indicate "n/a".

Table 2.1.1 - Items deliverable according to the Statement of Work and Article 2 of the Contract

Type	Ref. No.	Name / Title	Description	Replacement Value (EUR)/ Other	Location ([5])	Property of	Rights granted / Specific IPR Conditions ([6])
Documentation							
Hardware							
Software			*(Delivery in Object code / Source code?)*				
Other							

Table 2.1.2 – Items deliverable under Article 7 of the Contract (*if applicable*)

The Contractor, after agreement with the Agency with respect to the disposal/transfer of Inventory Items/Fixed Assets under the Contract, shall submit the Inventory/Fixed Asset Record as attachment to the CCD. For each Item/Fixed Asset, the information as requested by Appendix 3 to the Contract shall be provided in the Record.

[5] *In case the item is not delivered to ESA, please indicate the location of the deliverable and the reason for non-delivery (e.g. loan agreement, waiver, future delivery, etc.)*
[6] *e.g. IPR constraints, deliverable containing proprietary background information (see also Table 2.1.3 below)*

Table 2.1.3 – Customer Furnished Items and Items made available by the Agency

[Option 1]
There was no Customer Furnished Items or Items made available by the Agency.

[Option 2]
Any Customer Furnished Items and/or Items made available by the Agency to the Contractor and/or its Subcontractor(s) under the Contract, are listed in the following List of Customer Furnished Items and Items made available by the Agency. The following tables certify which of the Items have been returned to the Agency and which of the Items remain in the custody of the Contractor, and/or a Subcontractor(s) and/or a Third Party(ies) for further ESA work or for other purposes.

Customer Furnished Items

				ESA DECISION		
Item Name	ESA Inventory Number	Location	Insurance Value	Confirmation of Receipt	Deliver to ESA or to another entity	Leave at (Sub-) Contractor's Disposal under a loan agreement

Items made available by the Agency

Item Name	ESA Inventory Number	Location	Replacement Value	Deliver to ESA or to another entity	Leave at (Sub-) Contractor's Disposal under a loan agreement

Table 2.1.4 - Background information used and delivered under the Contract (see Article 6.3 of the Contract)

The following background information has been incorporated in the deliverable(s):

Proprietary Information (*title, description*)	**Owner** (*Contractor / Subcontractor(s)/ Third Party(ies*)	**Affected deliverable** (*which documents, hardware, software, etc.*)	**Description impact on ESA's rights to the deliverable ([7])**	**Other comments**

[7] *if not explicitly stated otherwise, the contractual stipulations shall prevail in case of conflict with the description provided in this table*

Section 3 – Statement on Intellectual Property Rights generated under the Contract

[OPTION 1: NO INVENTION]
In accordance with the provisions of the Contract …… [Contract Number], …… [Company] hereby certifies both on its own behalf and that of its consortium/Subcontractor(s), that no Intellectual Property Right(s) (as defined in the Contract, under the section 'Definitions') has(ve) been generated in the course of or resulting from work undertaken for the purpose of this Contract.**[END OPTION 1]**

[OPTION 2: INVENTION]
In accordance with the provisions of the Contract …… [Contract Number], …… [Company] hereby certifies both on its own behalf and that of its consortium/Subcontractor(s) that the following Intellectual Property Right(s) (as defined in the Contract, under the section 'Definitions') has(ve) been generated in the course of or resulting from work undertaken for the purpose of this Contract:

- Intellectual Property Rights ("IPR") suitable for registration (i.e. "Registered Intellectual Property Rights" as per definition in the Contract) and their current status (Registered – In the process of being registered – Foreseen for registration – Not foreseen for registration)

  ……

  Should any Intellectual Property Rights be indicated as being foreseen for registration or in the process of registration, the Contractor undertakes to notify the Agency's Technical Officer when:
  - registration of any such IPR(s) is rejected
  - registration of any such IPR(s) is obtained (and will provide the registration details)

- Intellectual Property Rights ("IPR") not suitable for registration (i.e. not being "Registered Intellectual Property Rights" as per definition in the Contract)

  ……

The Agency's rights in the Intellectual Property Rights listed above shall be in accordance with the Contract.**[END OPTION 2]**

Section 4 – Output from / Achievements under the Contract

4.1 Technology Readiness Level (TRL)

Indicate the TRL of the technology developed under the Contract using the classification given below (for additional information on definitions, please refer to ECSS-E-AS-11C):

Initial TRL	Planned TRL as activity outcome	Actual TRL at end of activity

1	Basic principles observed and reported
2	Technology concept and/ or application formulated
3	Analytical and experimental critical function and/ or characteristic proof of concept
4	Component and /or breadboard validation in laboratory environment
5	Component and /or breadboard critical function verification in a relevant environment
6	Model demonstrating the critical functions of the element in a relevant environment
7	Model demonstrating the element performance for the operational environment
8	Actual system completed and accepted for flight 'flight qualified'
9	Actual system 'flight proven' through successful mission operations

Note: The TRL shall be assessed by ESA. The Agency's responsible Technical Officer shall verify TRLs 1-4 while TRLs 5-9 shall be assessed through an ESA-internal formal procedure.

4.2 Achievements and Technology Domain

……..
Provide a concise description (max two hundred (200) words) of the achievements of the Contract and its explicit outcome (including main performances achieved): please refer to the final documentation (e.g. Final Report).

Please indicate the Technology Domain (TD 1 to 25) of the development (*please tick off*):

	1	On-Board Data Systems		14	Life & Physical Sciences
	2	Space System Software		15	Mechanisms & Tribology
	3	Spacecraft Electrical Power		16	Optics
	4	Spacecraft Environment & Effects		17	Optoelectronics
	5	Space System Control		18	Aerothermodynamics
	6	RF Payload and Systems		19	Propulsion
	7	Electromagnetic Technologies and Techniques		20	Structures & Pyrotechnics
	8	System Design & Verification		21	Thermal
	9	Mission Operations and Ground Data Systems		22	Environmental Control Life Support
	10	Flight Dynamics and GNSS		23	EEE Components and Quality
	11	Space Debris		24	Materials and Processes
	12	Ground Station System & Networking		25	Quality, Dependability and Safety
	13	Automation, Telepresence & Robotics			

4.3 Application of the Output/Achievements

Please tick off as appropriate:

☐ Possible use in programme:

……..
Please indicate the service domain (see table) relevant to a possible application

	1	Earth Observation
	2	Science
	3	Human Spaceflight and Exploration
	4	Space Transportation
	5	Telecommunications
	6	Navigation
	7	Generic Technologies and Techniques
	8	Security
	9	Robotic Exploration

☐ Actual use in programme:

……..
Please describe the specific programme and application or mission for which the output of this Contract is or will be used.

4.4 Further Steps/Expected Duration

Please tick off as appropriate:

☐ No further development envisaged.

☐ Further development needed:

……
Please describe further development activities needed, if any, to reach TRL 5/6 including an estimate of the expected duration and cost.

4.5 Potential Non-Space Applications

……
Describe any potential non-space applications or products that may benefit from the technology that has been developed. Emphasize potential markets and customers where known.

……..
Describe the principle features of technology that would be required in a technology demonstrator for any identified non-space application. Include an estimate of the resources in time and money that would be required.

<table>
<tr><td colspan="2">The above statements provided in the various sections of this Annex A “Layout for Contract Closure Documentation” for ESA Contract No. 4000xxxxxx/xx/XX/XXX/xxx [insert the corresponding contract number] have been made after due verifications.

The Contractor furthermore certifies that all its obligations with regard to Fixed Assets, if any, have been fulfilled.

If required by ESA, an updated version shall be provided for incorporating amendments requested by ESA.</td></tr>
<tr><td colspan="2">Name of Contractor:
[insert Contractor name]</td></tr>
<tr><td>Authorised signatory:

[insert Authorised signatory full name]</td><td>

[signature of the Authorised signatory]</td></tr>
<tr><td colspan="2">Date:
[insert date]</td></tr>
</table>