hq

Statement of Work
ESA Express Procurement "EXPRO+"

SysNova: R&D Studies Competition for Innovation

AO #3: Asteroid Impact Mission (AIM) Cubesat Opportunity Payloads (COPINS)

TABLE OF CONTENTS:

1 SCOPE OF THE DOCUMENT

This document specifies the work to be performed in the frame of the *SysNova* initiative as defined hereunder and describes the process that will be adopted by the European Space Agency (referred to as "ESA" or "the Agency"). It will become part of the contract and shall serve as a governing document throughout the execution of all work within the *SysNova* initiative.

2 INTRODUCTION

2.1 SysNova approach

The generation of ideas on new space technology concepts and products is an important goal for the European Space Agency. Innovation in space projects often takes place through ¨technology push¨ in ESA technology programmes resulting in the continuous maturing and adoption of new technologies in space missions or when required to meet specific missions.

ESA counts on a number of technology programmes addressing either specific ESA programmes' needs (ARTES for Telecommunications, CTP for Science, EGEP for Navigation, EWD/EOPA/IPD for Earth-Observation, etc.) or generic ones (e.g. ITI, TRP, GSTP). The Agency also has a number of tools to address innovation promotion and qualification of technologies through flight opportunities.

The SysNova initiative is a space systems' assessment scheme complementing other existing mechanisms. SysNova uses "technology challenges" and competition to survey a comparatively large number of alternative solutions. The initiative recognises the critical role of joint studies by both academic and industrial institutions in this exploratory phase.

SysNova is implemented in the frame of ESA's General Studies Programme (GSP) (http://www.esa.int/gsp) which interfaces in different ways with all of ESA's programmes. The GSP main role is to carry out preparatory analyses, laying the groundwork for the Agency's future activities. The assessment studies undertaken by the GSP provide ESA and its Member States with the necessary information on which to base their decisions about the implementation of new programmes and the future direction of space activities.

2.2 Announcement of Opportunity #3 – AIM Cubesat Opportunity Payloads (COPINS)

The Announcement of Opportunity #3 proposes one Technical Challenge described in Annex A to help reflect on the following key technologies:

- Networking Sensors based on CubeSat platforms and Intersatellite links, operating as single sensors or as a whole in an experiment – called COPINS for short.
- Remote sensing of, and/or in-situ measurements on asteroid´surfaces and the interplanetary media
- Deployment and autonomous operation of a number of small satellites in the vicinity of an asteroid either as individual elements, or as part of a distributed system
- Miniaturization of optical, RF and other scientific payload instrumentation
- Exploitation of the above for the purposes of physical characterisation of asteroids, and in particular asteroid mitigation-related research, in order to obtain measurement data not achievable with instrumentation onboard the main AIM spacecraft.

2.2.1 The Asteroid Impact Mission (AIM) and COPINS

The "AIDA" cooperation [RD1] was initiated in 2011 between ESA, DLR (D) and Observatoire de la Côte d´Azur (OCA) (F) on the European side and NASA and John Hopkins University Applied Physics Laboratory (JHU/APL) on the North-American side, to pursue missions of mutual interest, with a common focus on asteroid hazard mitigation, asteroid science and the development of affordable interplanetary missions. The US mission, Double Asteroid Redirection Test (DART) will impact at very high velocity the smaller component of a target binary asteroid with the purpose of demonstrating the kinetic impactor asteroid deflection concept by modifying the relative orbit in a measurable way.
The mission goal for ESA's Asteroid Impact Mission (AIM) is threefold. First, it shall carry out technology demonstrations enabling future science and exploration missions, with a focus on telecommunications. In addition to this it shall perform the required measurement to validate DART´s demonstration, and finally it shall obtain data of scientific significance in the study of the Solar System and its dynamical evolution.
The AIM industrial phase A/B1 will kick off in March 2015. In parallel to this mission assessment work, ESA intends to conduct definition studies for the main elements in the AIM payload, including the Cubesat Opportunity Payload Intersatellite Networking Sensors, COPINS the cubesat-based experiment.

COPINS consists of a set of 2 CubeSat dispensers with a capacity for 3 Units (3U) each and the associated CubeSats that could be deployed and operated as a network of sensors or as separate experiments relevant to the AIM scientific and asteroid mitigation objectives.

3 OBJECTIVES

The general objectives of the SysNova initiatives are:

- To carry out focused and frequent advanced studies of relevance to the exploration of potential technology needs beyond current ESA programmes.
- To facilitate the involvement of both industrial and research teams in ESA concept and technology assessment work.

- To foster technology R&D efforts with a goal demonstration mission in the mid- to long-timeframe
- To explore the potential for technology spin-in and increase the awareness of non-space industrial and research actors of ESA's activities, programmes and priorities.

The objectives of this specific SysNova AO are to:

- Perform advanced studies addressing the Technical Challenges, which are described in Annex A.

4 DEFINITION OF TERMS

- **Technical Challenges** – are described in Annex A. They are focused on the key technologies specific to this AO.

  The purpose of the Technical Challenges is to enable combined mission concept assessment and technology research work, on topics of potential relevance to future ESA programmes.

- **Study Team** – The study team shall be composed of experts from both research or academic institutions and Industry. It shall include at least a senior researcher, a junior researcher and an industry core team (see following definitions).

  The curricula vitae (CV) of the study team members mentioned above shall be provided in the Challenge Response. CVs shall highlight publications relevant to the study, and any relevant patents or projects in collaboration with partners of interest to the key technologies being proposed. Evidence of these publications from study team members will be taken into account during the evaluation of the challenge responses under the first evaluation criteria.

- **Senior researcher** - A senior research fellow or professor, with at least five (and preferably more) years of post-doctoral research experience and a proven track record in a research field. This person will be the main responsible for all duration of the activity.

- **Junior researcher** - Either a post-graduate doctoral student or a research fellow with maximum up to five years' experience of post-doctoral research.

- **Industry core team**– A group of interdisciplinary experts who work full-time in an industrial entity. The Industry core team shall comprise as a minimum, experts in spacecraft systems engineering and relevant engineering specialist of the technology product being put forward.

- **Challenge Response** – short 40 pages proposal responding to this AO and addressing the Technical Challenge in Annex A.

- **Challenge Analysis** – A detailed analysis and design of the Technical Challenges in Annex A.

- **Final Review -** Review of the Challenge Analysis by an ESA panel and study teams in a meeting organised by ESA at the end of the contract.
- **LSI** – Large System Integrators are enterprises having at the same time at least one ongoing prime contract for over €200m and concerning space-related infrastructures, launchers or satellites; and in this area either an annual turnover of over €200m or an annual balance sheet total of more than €200m,

  On this basis, the list of LSIs would be, as of June 2009 onwards:
  - Airbus Defence & Space (and its individual subsidiaries)
  - Thales Alenia Space (and its individual subsidiaries)
  - OHB System (and its individual subsidiaries)

5 REFERENCE DOCUMENTS

RD1	SysNova website: http://www.esa.int/Our_Activities/Preparing_for_the_Future/GSP/SysNova
RD2	SysNova - Assessment Questions http://emits.esa.int/emits-doc/ESA_HQ/SEALS-Assessmentquestions.pdf

6 ACRONYMS AND ABBREVIATIONS

ADs	Applicable Documents
AIDA	Asteroid Impact and Deflection Assessment
AIM	Asteroid Impact Mission
AO	Announcement of Opportunity
COPINS	Cubesat Opportunity Payloads Networking Intersatellite Sensors
CTP	Core Technology Programme
EMITS	ESA Invitation to Tender System
ESTEC	European Space Research and Technology Centre
GSP	General Studies Programme
ITT	Invitation To Tender
KO	Kick-Off
LSI	Large Systems Integrators
MS	(ESA) Member States
RDs	Reference Documents

SME	Small and Medium Enterprise
SoW	Statement of Work
TN	Technical Note
TBC	To Be Confirmed (by the Agency)
TBD	To Be Determined (by the contractor)
TRL	Technology Readiness Level
TRS	Technology Reference Study
WPs	Work Packages

7 SYSNOVA APPROACH DESCRIPTION

The following sections explain in detail the organisation of the work in the frame of the SysNova.

7.1 Key acceptance factors

General key acceptance factors (KAF) to participate in the SysNova Calls are the following:

- The bidder shall respond to the Technical Challenge proposed in Annex A with novel concepts (i.e. the solution should not have been the subject of a previous ESA work).
- The Challenge Response submitted by the bidder shall comply with the target price defined in the cover letter to this ITT.
- Use of any facilities in industry, universities and research institutes is allowed but material costs should not exceed 10% of total budget.
- The entity proposed to act as contract prime shall be based in ESA Member States. Participation of sub-contractors outside ESA Member States shall be limited to a maximum of 20% of the total budget.
- Each institution department or industry can participate in only one Study team
- Large Systems Integrators (LSI) may act as contract prime if at no cost to the Agency, or may be subcontractors (receiving funding) providing specialised support, but not both at the same time.
- The study team shall be composed of experts from both research or academic institutions and Industry. It shall include at least a senior researcher, a junior researcher and an industry core team.

- Challenge Responses shall not exceed 40 pages in length, including abstract, technical description and discussion, diagrams and pictures. In addition, up to 5 pages shall be dedicated to the travel and subsistence expenses plan and the presentation of the team (10 additional pages are allowed for attachments i.e. CVs, reference to research papers etc.).
- Challenge Responses shall include a first iteration of the full work (described in Annex A for each study) plus a presentation of the team institutions, members and respective roles in the study. The proposals shall be structured following the contents of the technical notes described in Annex A (see Annex B for detailed instructions on the proposal template).
- The proposing team shall confirm their availability for discussion during a Final Review at ESTEC, in the event that one of the concepts in the Challenge Response is selected for further definition work towards a Challenge Analysis.

Proposals not complying with these criteria will not be accepted for evaluation.

7.2 AO process

Following the publication of the AO, bidders fulfilling the eligibility criteria shall submit a Challenge Response addressing the Technical Challenges (see Annex A). A maximum of 4 Challenge Responses will be selected, on the basis of the evaluation criteria (see Cover Letter), and funded by ESA for the further analysis and design (Challenge Analysis).

Those Challenge Responses not shortlisted will not be discussed by ESA outside the evaluation panel deliberations, and will not be further considered for ESA support.

Following ESA´s confirmation, the selected Study Team will proceed into the Challenge Analysis phase. This phase shall have a duration of no more than 5 months.

The draft Challenge Analysis report will be delivered to ESA at the end of this phase and be evaluated, within two weeks from its submission, by an internal board of ESA members on the basis of the following **criteria**:

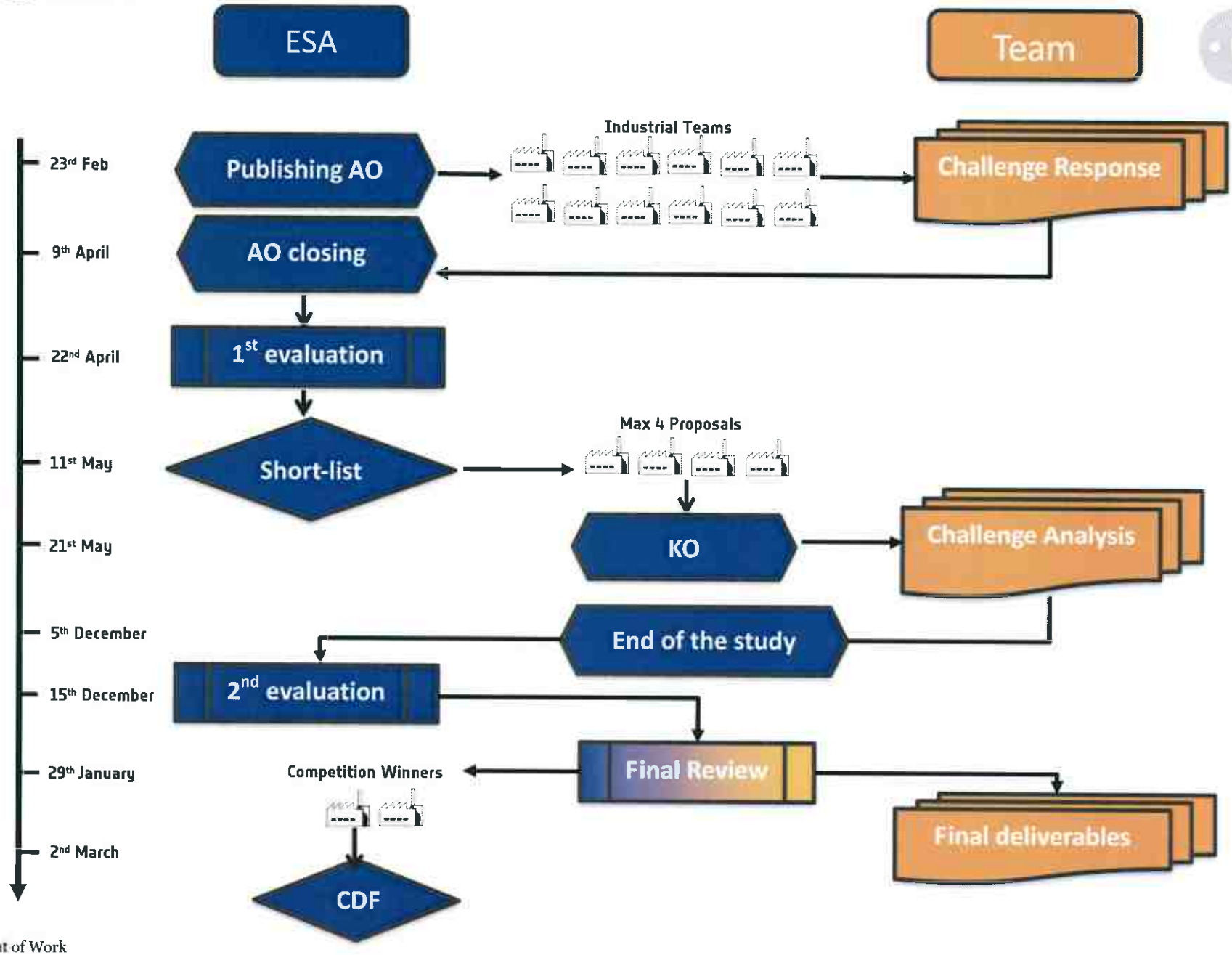
1. **Scientific merit**
2. **Technical feasibility**
3. **Quality of the analyses and credibility of the development roadmaps**

A Final Review will be held one month after the submission of the Challenge Analysis draft final report. This session will involve both Study teams and ESA members.

Any agreed comments resulting from the Final Review shall be implemented in the Challenge Analysis final report.

Following the Final Review, ESA board will award a prize to the best Challenge Analysis(ses) (the prize is described in paragraph 7.3). However, the Agency reserves the right not to do so in case the quality of the final results are not considered sufficient.

The AO #3 schedule is described in the figure hereafter:



7.3 Prize award

The winning team(s) will be rewarded with:

a) The possibility to participate, with ESA support, in an ESA internal assessment of the selected Challenge Analysis(es) in the Concurrent Design Facility (CDF) and an internal analysis, plus support to Phase A/B system activities and technology development activities for implementation as part of the AIM project, subject to Phase B mission approval.

b) The publication in ESA's web page of an article on the award team's work, the selected technology(ies) concepts and products.

8 STUDY MANAGEMENT, REPORTING AND DELIVERABLES

8.1 Study meetings and reporting

In case of a positive evaluation of the Challenge Response, a negotiation teleconference will typically take place within two months of the closing date of the AO. This teleconference will be used to clarify any open issue, discuss the scope of the proposed Challenge Analysis and agree on the programme of work for the assessment itself. On submitting the Challenge Response, study team members shall commit to make themselves available for this teleconference.

Dates for other meetings will be agreed during this teleconference, if relevant. One progress review at the contractor premises is considered as an option, but will not be part of the baseline plan unless otherwise agreed with ESA. Challenge Analysis start and end dates will be agreed at the negotiation meeting, and if agreement is reached, the activity may start immediately, in which case the negotiation meeting will be considered as the "Kick-Off" meeting.

Other than during the meetings, communication between the Study Team and ESA will be carried out by teleconference and electronic mail. At minimum teleconferences will be held every month, unless otherwise agreed with ESA. Progress reports shall be submitted monthly by email and should include details of any problems encountered and proposed mitigation or correction.

Successful study teams will be required to participate and present the outcome of their work at a 2-days Final Review. This review will be restricted to ESA and the selected study teams. Precise Final Review dates will be communicated by ESA at the study KO.

On submitting the Challenge Response the study team members shall commit to make themselves available for the Final Review.

8.2 Deliverables

The deliverables will include:

- the final report of the activity and any code or data produced as part of the activity (template for the cover in Annex C). The Final Report shall include the following technical notes:
  - Technical Note 1: Physical principles and analyses (Science Objectives)
  - Technical Note 2: Mission concept and preliminary assessment
  - Technical Note 3: Development roadmap
- an executive summary of the final report (one page), highlighting the objectives and the main results of the performed activity, with an emphasis on their relevance for space technologies, including an illustration or relevant image (template in Annex D).
- a summary presentation of the content of the final report to be delivered at the Final Review
- a questionnaire (Annex E) which is aimed at obtaining feedback from the study team on the SysNova initiative, and which shall be completed and submitted to ESA at the end of the contract.

Table 1 List of deliverables

DELIVERABLES	SUBMISSION DEADLINE
- Draft final report including the technical notes	Completion of Challenge Analysis
- Executive summary - Updated final report - Questionnaire - Contract Closure summary	Final Review and presentation (KO+8 months)

All deliverables shall be submitted as per Table 1 by electronic mail to the ESA Technical Officer. The cover page of the final report and the executive summary shall be based on the template provided (Annex C and D respectively). The final delivery shall take place no later than two weeks after the Final Review.

The publication of part of the study results in peer-reviewed technical and scientific journals should be envisaged, always in agreement and with the explicit prior approval of ESA. A publication plan shall be discussed during the Negotiation meeting. In general, publications of results obtained during the study shall be joint publications of the involved entities and ESA researchers, if applicable. Authorship of publications of the study's

research results not obtained as a team shall be agreed between members of the Study Team following standard academic practices.

All publications incorporating some results of the study shall acknowledge the support of ESA and include the ESA contract number and the ESA study title.

The executive summary will be published on ESA's website and should also be available through the contractor's website. Unless prior agreement is made with the Agency, no proprietary information shall be included.

ANNEX A. TECHNICAL CHALLENGES DESCRIPTIONS

See separate document: "**Technical Challenges Descriptions** - Annex A to Statement of Work.doc "

ANNEX B. PROPOSAL TEMPLATE

See separate document: PROPOSAL TEMPLATE FOR "EXPRO" (Appendix 3)

Eligibility Criteria Checklist[1]:

- ☐ **Technical Challenge proposed in Annex A is addressed with novel concepts**
- ☐ **Compliance with the study firm fixed price defined in the cover letter**
- ☐ **Compliance with cost limits on use of facilities**
- ☐ **Prime and subcontractors from ESA Member States. Participation of sub-contractors outside ESA Member States shall be limited to a maximum of 20% of the total budget.**
- ☐ **Each institution department or industry can participate in only one Study team**
- ☐ **Compliance of the role of the LSI as indicated in the SoW**
- ☐ **Study Team includes a Senior researcher, a Junior researcher and an industry core team**
- ☐ **Compliance with the length of the Challenge Response defined in the SoW**
- ☐ **Inclusion of first iteration of Technology Reference Study(ies) being addressed**
- ☐ **Confirmation of availability for the Final Review**

[1] The checklist is to assist you to compile the Challenge Response, but please refer to relevant paragraph of the Statement of Work (7.1)

ANNEX C. COVER PAGE FOR FINAL REPORT

NB Please note that the Final Report will be published on the world-wide web and hence it shall include no propriety information, which should be put aside in a separate report if needed.

SysNova TRS Title

Your subtitle

Challenge Analysis Final Report

Authors: Author 1[1], Author 2[2], Industry author [3],

Affiliation: [1]Institution #1, [2] Institution #2, [3]Company name

Date: ...

Contacts:

Name of Research Centre Contact
Tel: Telephone Number
Fax: Fax Number
e-mail: Email

ESA study manager: Ian Carnelli
Tel: +33153697109
e-mail: Ian.Carnelli@esa.int

SysNova Technology Reference Study No.: 15/XNN
Contract Number: NNNNN

This contract was carried out within ESA's General Studies Programme and funded by the European Space Agency. The view expressed herein can in no way be taken to reflect the official opinion of the European Space Agency

ANNEX D. TEMPLATE FOR EXECUTIVE SUMMARY

SysNova Technical Challenge Title

Your subtitle

Challenge Analysis Executive Summary

Authors: Author 1[1], Author 2[2], Industry author [3],
Affiliation: [1]Institution #1, [2] Institution #2, [3]Company name

ESA study manager name

SysNova Technology Reference Study No.: 15/XNN
Contract Number: NNNNN

Picture:

Please put here a picture, image (format A5, resolution: 300 DPI) representative of the study

Motivation:

Please describe briefly here the scope of the study (max: 40 words)

Methodology:

Please describe here briefly the background of the study and the methods applied to develop the research (max: 150 words).

Results:

Please list here a brief description of the most significant results obtained during the study (max: 4 items).

- …
- …

Publications:

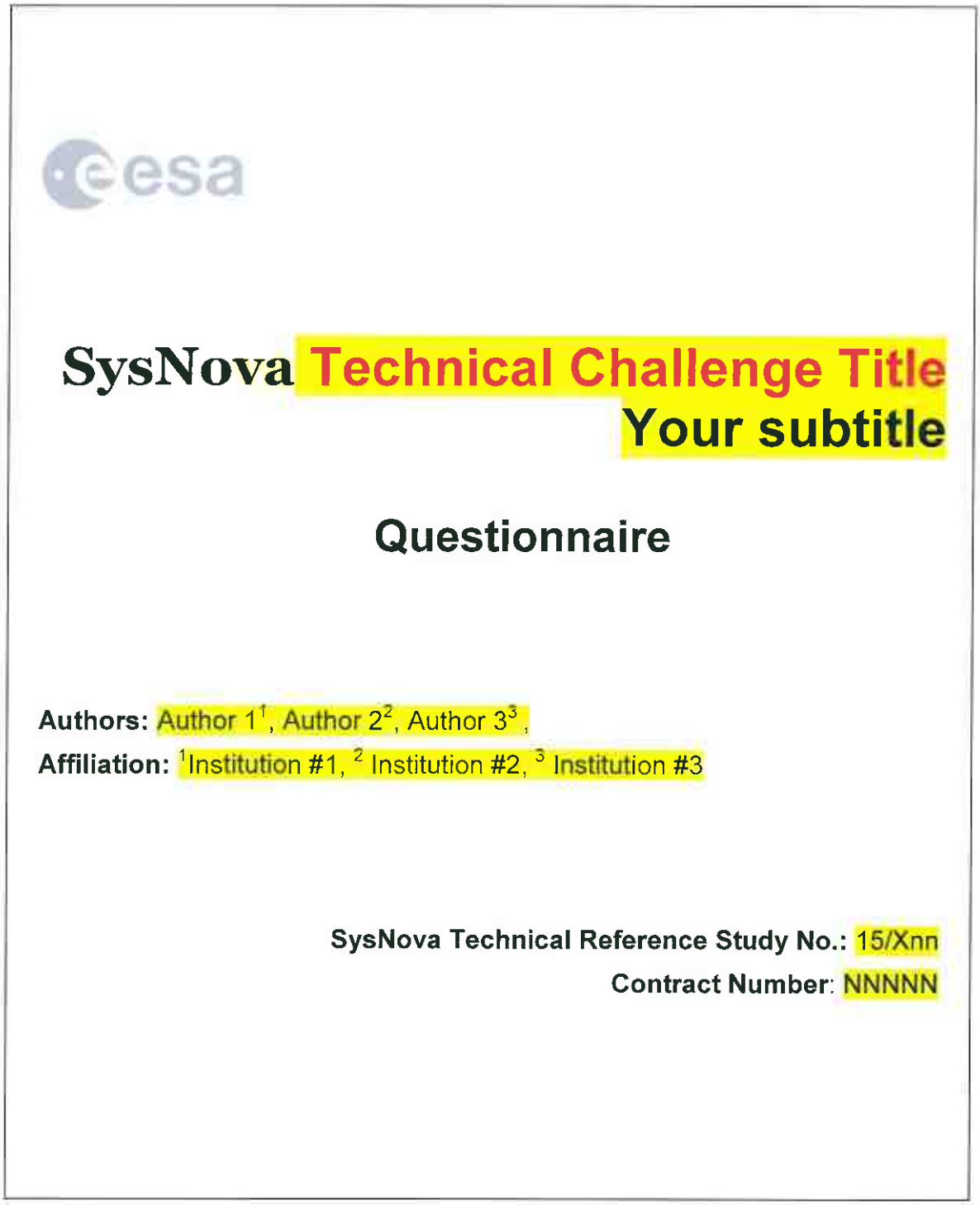
Please list here the complete references to the papers published or submitted for publication during the study in agreement with ESA. Example:

- Author, A., Author, B., "Topic 1*: a critical review*", Proceedings of the 58th International Conference, City, 2007.

Highlights:

Please put here a more extended description of one particularly relevant result obtained or any further/ongoing work (max: 80 words).

ANNEX E. QUESTIONNARE



SysNova Technical Challenge Title
Your subtitle

Questionnaire

Authors: Author 1[1], Author 2[2], Author 3[3],
Affiliation: [1]Institution #1, [2] Institution #2, [3] Institution #3

SysNova Technical Reference Study No.: 15/Xnn
Contract Number: NNNNN

	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	It does not apply/ Don't know
The topic behind this SysNova initiative was interesting and relevant	X	X	X	X	X	X
The ITT package clearly explained what was required	X	X	X	X	X	X
The administrative effort required for this initiative was high (strongly agree), low (strongly disagree)	X	X	X	X	X	X
The interaction with the ESA Technical Officer was important for the success of the initiative	X	X	X	X	X	X
The interaction among all partners in this study was satisfactory	X	X	X	X	X	X
After the SysNova study we will continue this research	X	X	X	X	X	X
After the study we will continue our cooperation with the academic /industrial entity on this work	X	X	X	X	X	X
During this SysNova project we increased our knowledge about ESA and its programmes	X	X	X	X	X	X
The team would be willing to propose themes for new studies *open to other groups* (please specify below)	X	X	X	X	X	X
The project produced non-space spin-offs (please specify below)	X	X	X	X	X	X
The project produced satisfactory results (SA) unexpected events affected results (SD – please specify below)	X	X	X	X	X	X
The budget was appropriate to carry out the work	X	X	X	X	X	X
Other comments	...					

ANNEX F. LAYOUT FOR CONTRACT CLOSURE SUMMARY

Contract Closeout Summary
for
ESA Contract Nr. *[Contract Number]*
[Title of Activity],
hereinafter referred as the "Contract"

F1. Parties, contract duration and financial information

Contractor	
Subcontractor(s) *(state if not applicable)*	
Contract Duration *(insert the dates; see Article 7.1 of the Contract; also per phase, if applicable)*	**From**: **To**:
Total Contract Price and total contract value *(in case of co-funding; state if not applicable)*	**EUR** **EUR**

F2. Recapitulation of deliverable items

Items deliverable under the Contract

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

Items deliverable according to the Statement of Work

Type	Ref. No.	Name/Title	Description	Property of	Rights granted / Specific IPR conditions[1)]
Documentation					
Other					

[1)] *e.g. IPR constraints, deliverable containing proprietary background information (see also 2.1.2 below)*

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, Sub-Contractor(s), third party/ies)***	**Affected deliverable** ***(which documents, hardware, software, etc.)***	**Description impact on ESA's rights to the deliverable[1)]**	**Other/comments**

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

F3. Output from / achievements under the Contract

3.1 Technology Readiness Level (TRL)

Indicate the TRL of the technology developed under the Contract using the classification given below:

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

Note: The TRL shall be assessed by ESA. The Agency's responsible Technical Officer shall verify TRLs 1-4.

3.2 Achievements and Technology Domain

Provide a concise description (max 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			

3.3 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.

3.4 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.

3.5 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 costumers 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.

F4. Statement of Invention

[OPTION 1: NO INVENTION]
In accordance with the provisions of the above Contract, ...*[Company]* hereby certifies both on its own behalf and that of its consortium/Sub-Contractor(s), that no Intellectual Property Right(s) has(ve) been registered 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 above Contract, ...*[Company]* hereby certifies both on its own behalf and that of its consortium/Sub-Contractor(s) that the following Intellectual Property Right(s) has(ve) been registered in the course of or resulting from work undertaken for the purpose of this Contract:

.....

The Agency's rights on such Registered Intellectual Property Rights shall be in accordance with the ESA GCC Part II provisions as amended by the above Contract.
[END OPTION 2]

Annex A
Technical Challenge Description

Overview

The current AO addresses the technical challenge driving new mission concepts involving a number of CubeSats operating together or individually in interplanetary space in support of the objectives of a proposed ESA mission - the Asteroid Impact Mission (AIM) - currently undergoing a Phase A/B1 system study.

AIM has three different objectives relating to technology flight demonstration in interplanetary space, investigation of Near-Earth Object (NEO) mitigation techniques and the acquiring of new scientific knowledge for understanding solar system evolution. In particular:

I. **AIM Primary Objectives**:
   i. To determine geophysical properties of asteroid 68528 Didymos secondary component [AD2]. This includes the shape, mass, surface and shallow subsurface structure as well as the mechanical and thermal properties of the asteroid surface. In addition it shall analyse the asteroid dynamical state.
   ii. To carry out a Telecommunication Engineering eXperiment (TEX) based on the OPTEL-D optical terminal, perform the Moonlet Engineering eXperiment (MEX) based on the MASCOT-2 asteroid lander.
   iii. Release the Cubesat Opportunity Payload Intersatellite Network Sensors (COPINS).

II. **AIM Secondary Objectives**:
   i. To determine the momentum transfer resulting from the impact of the DART spacecraft on Didymos´ secondary component, by measuring the variation of the asteroid´s period and its rotation state, and imaging of the resulting impact crater.
   ii. To characterise the secondary asteroid deep-interior structure.

During the assessment study in the ESTEC Concurrent Design Facility [RD1], a number of different payloads were identified and conceptually defined [AD1] including a Cubesat Opportunity Payload of Intersatellite Networking Sensors (COPINS).

Technology Research Objectives		
#	**Goal**	**Comment**
1	Demonstrate an end-to-end optical communications system (TEX)	The demonstration is based on the operation of the Optel-D optical terminal.
2	Demonstrate asteroid landing on the surface of the secondary component of the binary system (MEX)	The demonstration is based on the release of the MASCOT-2 surface package.
3	Demonstrate CubeSat-based deep-space payload operations	The demonstration is based on the release of Cubesat Opportunity Payload Intersatellite Network Sensors (COPINS).

Table 1 AIM technology research objectives

In parallel to attaining these objective AIM will pursue asteroid research investigations of the asteroid by means of the embarked payload as follows in order of priority:

Asteroid Research Objectives			
#	**Parameter**	**Relevance to goal**	**Supporting instrument(s)**
1	Moonlet size, mass, shape, density	Mass key to momentum, size to shape, volume, gravity to internal structure, operations	• Mass from binary orbit • Shape model from Visual Imaging System (VIS)*
2	Dynamical state of Didymos moonlet (period, orbital plane axis, spin rate and spin-axis)	Key to determine momentum	• VIS
3	Geophysical surface properties, topology, shallow subsurface	Bulk composition, material mechanical properties, and surface thermal inertia.	• VIS for surface features • Thermal InfraRed Imager (TIRI) for surface roughness • Hi-frequency radar for shallow subsurface structure
4	Deep internal structure of the moonlet	Interior can affect absorption of impact energy, "data point" to validate asteroid mitigation models.	• Low-frequency radar • Drift-bys to estimate gravity field (not a must)

Table 2 AIM investigations of asteroid 68528 Didymos

The COPINS payload consists of two or more CubeSats and their deployment systems that are carried on the main AIM spacecraft, and released in the vicinity of the target asteroid Didymos [AD2] with the main AIM spacecraft acting as a communications data relay between the CubeSats and Earth-based ground stations.

Operating CubeSats in interplanetary space in the vicinity of an asteroid puts severe demands on system performance such as radiation survivability of commercial-off-the-shelf electronics, on-board autonomy, guidance navigation and control, communications and propulsion.

Objectives

The current AO therefore aims to investigate concepts which take advantage of exploiting distributed networked or single CubeSat systems [RD2] in order to provide significant contributions to the ESA Asteroid Impactor Mission asteroid research and mitigation assessment objectives. Any concepts may be proposed for the challenge provided they clearly demonstrate a benefit to the AIM asteroid research and mitigation assessment objectives, comply with the nano-satellite constraints, and address the system level issues defined in this challenge description.

Concept of Operations

The ESA AIM mission is part of the "AIDA" international cooperation. A US spacecraft, called Double Asteroid Redirection Test (DART) is envisaged to impact the smaller component of the Didymos binary asteroid at very high velocity. The ESA AIM spacecraft is envisaged to rendezvous with the target asteroid in advance, in April 2022 and characterise the binary system before/during/after the impact event.

The launch of the AIM spacecraft would be in 2020 on the Soyuz-Fregat launcher from Kourou into a direct escape trajectory and would arrive at the asteroid after approximately 22 months transfer. During the rendezvous phase, the distance to the Sun and Earth is close to 1 AU and from 0.5 to 0.1 AU respectively.

After an initial measurement phase, the AIM spacecraft would be manoeuvred to within 10 km of the binary asteroid. Before DART´s impact, the COPINS CubeSats would be released, and the main spacecraft would then retreat to a distance of 100 km, ready for the impact event not more than one month later. The CubeSats would perform their mission up to 2 months after the impact date, i.e. for 3 months in total, using an inter-satellite link with the main spacecraft's communications system for telecommand, housekeeping and payload telemetry data relay with the ESA ground stations network.

Nano-satellite Sensing Techniques

As a minimum, the following payload level issues should be addressed as part of the challenge response and if selected addressed in detail during the challenge analysis:

- Strategies to use the COPINS system to acquire data that is relevant to addressing AIM asteroid research and mitigation assessment objectives
- Measurement requirements for sensor and instrumental techniques to be considered
- Technical analyses and specifications of the sensing techniques
- Evaluation of the performance related to the sensing techniques
- Sensor development roadmaps (if applicable)

Nano-satellite Constraints

The nano-satellites to be considered in the study shall be constrained to:

1. Form factor: CubeSat standard [AD3]
2. Total volume: two 3U CubeSat deployers are embarked on the main AIM spacecraft, giving a total of 6 units (litres) of internal volume available to accommodate all CubeSats in the COPINS payload
3. Total Mass: up to 9 kg are allocated for all CubeSats in the COPINS payload
4. Size: up to 3U for each CubeSat
5. Design lifetime: storage (non-operational) during interplanetary cruise plus minimum 3 months in the interplanetary environment at the asteroid
6. Inter-satellite link: S-band ISL unit and antenna(s) shall be provided by ESA as Customer Furnished Item and carried on each CubeSat with the following characteristics (TBC):
    a. <200 g transceiver mass + 2 antennas of 60 g each for omni-directional coverage
    b. 1 W receive and 3 W transmit electrical power consumption
    c. Full duplex
    d. Data rate (two-way) of up to 1 Mbps with main AIM spacecraft
    e. Total data volume of up to 1 Gbit allocated for the whole mission
    f. 3 months maximum data relay duration by AIM
7. Interfaces with main spacecraft: as specified in [AD1]
8. Separation conditions: 0.5-2 m/s velocity provided by deployer along 3-axis vector provided by main spacecraft (see [AD1] for accuracy).

Mission/System Level Issues

As a minimum, the following mission and system level issues and trade-offs shall be addressed as part of the Challenge Response and if selected, studied in detail as part of the Challenge Analysis:

- Strategies for deployment (including e.g. possible modification to the release velocity if relevant and duly justified), formation/station acquisition, and sensor observations before/during/after the impact event if relevant.

- COPINS Mission scope including maximum and minimum range to asteroids and to AIM spacecraft, maximum duration, timing of deployment and of the communication with the AIM spacecraft
- Level of autonomy on-board the CubeSats needed to execute their mission taking into account communications round-trip delays, time between Earth ground station contacts in the AIM operational scenario
- High availability of the CubeSats and the need for real-time measurements/data transmission during the time-critical impact event if relevant, given the close proximity to the impact ejecta plume.
- Guidance, navigation and control of the CubeSats with respect to the target asteroid and its irregular gravity field [AD2], including the need for a ranging/Doppler function on the S-band ISL link
- Distributed system design and operational performance (number of spacecraft, relative position and pointing, formation control)
- On-board Data payload processing and networking architecture between CubeSats, and between the CubeSats and the main AIM spacecraft
- Nano-satellite design: trade between s/c size, individual performance, number, and total cost (including technology development activities)
- Development schedule: trade technology maturity against compatibility with hardware delivery for integration in AIM and associated AIV activities by the 2nd quarter 2019, and provide back-up solutions for items with critical schedule risk.
- Components: cost-effective approaches to ensure survivability of Commercial-Off-The-Shelf (COTS) electronics components with respect to the expected radiation environment [AD3] during the mission lifetime.

The deliverables will include three technical notes:

- Technical Note 1: Physical principles and analyses
    - Science Objectives
    - Science Requirements
- Technical Note 2: Mission concept and preliminary assessment
    - Description of the measurement requirements for sensor and instrumental techniques to be considered
    - Description of the mission and system-level aspects
    - Description of the operational scenario
- Technical Note 3: Development roadmap

Applicable Documents

[AD1] AIM Payload Interface Document (see link on cover letter)
[AD2] Didymos Reference Model (see link on cover letter)
[AD3] CubeSat Design Specification (see link on cover letter)

Reference Documents

[RD1] AIM3P CDF report (see link in SOW)
[RD2] AIM3P Mission and Payload Operations Scenarios (see link in SOW)