Ariel

The atmospheric remote-sensing infrared exoplanet large-survey mission

Science Management Plan

October 26, 2020

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1 INTRODUCTION AND SCOPE

The Ariel mission will conduct a survey to characterise a large number of diverse transiting exoplanets by performing simultaneous visible to infra-red atmospheric photometry and spectroscopy.

This Science Management Plan (SMP) aims to ensure the scientific objectives of the Ariel mission are met, to optimise its scientific return, and covers science operations, data generation and management. It identifies and outlines the roles and responsibilities of all parties involved in the Ariel mission.

The SMP provides a mission overview (Section 2), followed by a summary of the mission management scheme (Section 3), a description of the mission products, data rights and publication policy (Section 4) and of the opportunities for participation in the mission (Section 5). Then, the SMP describes the ground segment and operations (Section 6), the definition of the science and programme management and responsibilities (Section 7), concluding with public outreach plans (Section 8).

The SMP is approved by the Science Programme Committee following a recommendation by the scientific advisory structure to the Programme and may be subject to revisions and updates at a later stage through the same approval loop if needed.

2 MISSION OVERVIEW

2.1 Scientific objectives

Ariel will perform a chemical survey of a diverse sample of at least 500 exoplanets orbiting host stars with a range of spectral types. Most Ariel observations will consist of transit and/or eclipse spectroscopy of the atmospheres of warm and hot exoplanets, to address the following fundamental questions:

- What are exoplanets made of?
- How do planets and planetary systems form?
- How do planets and their atmospheres evolve over time?

Known exoplanets display a great diversity of physical parameters, and exhibit a wide range of planetary system architectures, orbiting stars with a variety of properties.

Ariel will measure atmospheric signals from the planet at the level of 10-100 parts per million (ppm) relative to the host stars. It will thus probe the atmospheric composition and thermal structure of transiting planets. The three primary methods Ariel will use are planetary transits (planet passing in front of the host star), planetary eclipses (planet passing behind the host star), and phase-curve observations of the star plus planet system as the planet executes a full orbit. In addition, eclipses can be used to spatially resolve the planets' day-side hemisphere; repeated observations of selected key planets to monitor global meteorological variations will be conducted.

Ariel observations will simultaneously cover the entire 0.5-7.8 μm spectral range, divided into three photometric bands (0.5-0.6, 0.6-0.8, and 0.8-1.1 μm) and three spectroscopic bands (1.1-1.95 μm with R >15, 1.95-3.9 μm with R >100, and 3.9-7.8 μm with R >30, where R is the spectral resolution). The simultaneous coverage of this wide spectral range is key to attaining Ariel's science goals, securing robust relative calibrations enabling tiny signals to be extracted from differences between measurements. The shorter wavelengths will primarily monitor stellar activity, detect the existence of haze and/or clouds in the planetary atmospheres, and provide an estimation of the planetary albedo. The longer wavelengths cover spectral features of various atmospheric constituents, in particular reservoirs of oxygen, carbon, and nitrogen, (e.g., H_2O, CO, CO_2, CH_4, and NH_3), allowing their abundances to be deduced.

2.2 Mission description

The Ariel spacecraft consists of a payload module (PLM) and a service module (SVM).

The PLM houses the telescope and the science instruments, including fine guidance sensors, as well as passive and active cooling equipment providing environment control.

The SVM provides all the necessary infrastructure enabling the proper functioning of the spacecraft, it also houses warm electronics of the science instruments hosted in the PLM.

Ariel will be launched on an Ariane 62 launch vehicle, together with the Comet Interceptor mission, into a transfer orbit towards the operational orbit. In the nominal science phase(s) the Ariel spacecraft will operate from a large halo orbit around the Sun-Earth second Lagrangian point, L2.

The planned mission phases and milestones are as follows:

- Launch (L): T_0
- End of launch and early operations phase, transfer and commissioning phase: L + 3 months
- End of instrument performance verification and science demonstration phase: L + 6 months
- End of nominal science operations: L + 4 years
- End of decommissioning phase: L + 4.25 years
- End of post-operations phase: L + 6 years.

Mission and science operations will be performed by the Mission Operations Centre (MOC) and by the Science Ground Segment (SGS), respectively.

2.3 Observation strategy and expected results

Ariel will acquire the transmitted, emitted and reflected spectra of exoplanetary atmospheres over the visible to thermal IR wavelength range. The planet sample will range from gas giants to earth-sized, primarily focusing on hot and warm planets. Determination of phase-variations will be made primarily on a subset of short period exoplanets orbiting nearby, thus bright host stars: these are the most favourable for this technique.

The Ariel sample focuses on warm and hot exoplanets to take advantage of their well-mixed atmospheres with minimal sequestration of heavy elements. These atmospheres are thus expected to be more representative of the planetary bulk composition than those of colder planets. The host stars are expected to range from spectral types A to M. In excess of five hundred suitable Ariel targets have been identified already; the final sample will likely be mainly drawn from new all-sky surveys of relatively nearby stars (e.g., the NASA TESS mission survey).

The primary science objectives summarised in Section 2.1 call for broadband atmospheric spectral information of a large and diverse sample of known exoplanets covering a wide range of masses, densities, equilibrium temperatures, orbital properties and host-stars. The anticipated total sample size is ~1000 targets. The current observational strategy divides the targets into four different sub-samples, referred to as “Tiers”. Each Tier has a separately defined spectral resolution and signal-to-noise ratio (“depths”), designed to deliver specific science objectives as summarised in Table 1. The optimisation of the sample will evolve until launch and beyond. Ariel’s science will benefit from the substantial anticipated advances in the field in the coming years. The detailed science objectives, the sample size and target demographics, and observational strategy will be refined accordingly.

As baseline, the targets to be observed in the Ariel core survey form the Mission Reference Sample (MRS). The MRS is derived from the Mission Candidate Sample (MCS), i.e., the complete list of existing targets observable by Ariel according to the adopted strategy. This is a two-stage process whereby the scientific priority of the targets in the MCS is defined by the Ariel Science Team (AST, see Section 3) in accordance with maximising the science return of the mission; then a scheduling exercise will take place with an algorithm which accounts for this prioritisation. This scheduled list of targets forms the MRS. The MCS will be continuously updated, with the goal of having a consolidated version six months before launch. The MRS must be available by the start of the nominal science operations, and will be updated if necessary, on a monthly basis throughout the mission.

The orbital properties and the ephemeris of a star-planetary system define the timing of exoplanet transit and eclipse events, constraining the mission planning. Optimised scheduling can ensure that up to 90% of the mission time can be devoted to time-constrained core survey observations while complementary science observations will be accommodated outside these time-constrained slots for 5% to 10% of the time.

A Science Demonstration Phase (SDP) will be conducted before the start of the Nominal Science Operations Phase (NSOP), to demonstrate scientific and operational readiness to conduct the NSOP (see Figure 3). The SDP will be conducted operationally in a manner similar to that of the NSOP, but will have a schedule tailored to cover the diversity of targets to be observed in the NSOP for all targets in the MRS in the modes foreseen. The planned duration of the SDP observations is one month. The SDP will also include a timely data release with an associated major public conference where the observational results will be presented to and discussed with the general community (see Section 4.2).

TIER 1: RECONNAISSANCE SURVEY		
Observational strategy	**Science outcome**	**Expected N0. of planets**
• Low resolution spectroscopy (5+ spectral resolution elements covering the 1.10 – 7.80 µm range) with average SNR ≥ 7 • All planets in the sample • Transit or eclipse	• What fraction of planets are covered by clouds? • What fraction of small planets have still retained H_2? • Colour-colour diagrams • Constraining/removing degeneracies in the interpretation of mass-radius diagrams • Albedo, bulk temperature & energy balance for a subsample	800+
TIER 2: DEEP SURVEY		
• Spectroscopic measurements for a subsample (e.g., 50% of sample) • R~10 for 1.10< λ<1.90 µm; R~50 for 1.95<λ<3.90 µm; R~15 for 3.90<λ<7.80 µm, with average SNR ≥ 7 • Transit and/or eclipse	• Main atmospheric components for small planets • Chemical abundances of trace gases • Atmospheric thermal structure (vertical/horizontal) • Cloud characterisation • Elemental composition	400+
TIER 3: BENCHMARK/REFERENCE PLANETS		
• Spectroscopic measurements • R~15 for 1.10< λ<1.90 µm; R~100 for 1.95<λ<3.90 µm; R~30 for 3.90<λ<7.80 µm, with average SNR ≥ 7 achievable in 1-2 observations • Transit and/or eclipse, repeated in time	• Detailed knowledge of the planetary chemistry and dynamics • Weather, temporal variability • Elemental composition	50+
TIER 4: BESPOKE OBSERVATIONS & PHASE-CURVES		
• Phase-curves, eclipse mapping, bespoke observations • Multiple-band photometry/spectroscopy with SNR ≥ 7	• Detailed knowledge of the planetary chemistry and dynamics • Spatial variability	10+

Table 1 Summary of the four tiers of the Ariel core survey.

3 OVERVIEW OF THE MISSION MANAGEMENT SCHEME

The overall Ariel mission management scheme and the responsibilities of key contributors to the Ariel mission are introduced in this section and their relations sketched in Figure 1.

The overarching responsibility for all aspects of the Ariel mission rests with ESA's Directorate of Science.

ESA is responsible for the overall Ariel mission, and in particular for (see more details in Section 7.1.1):

- The development of the space segment, consisting of a spacecraft split into a service module (SVM) to be provided by ESA, and a payload module (PLM), to be provided by the Ariel Mission Consortium (AMC), carrying the scientific instruments;
- The development of the ground segment, in particular the MOC and the Science Operation Centre (SOC, part of the SGS), as detailed in Section 6;
- The launch services procurement;
- The mission and science operations (jointly with the AMC), covering early operations, commissioning and all subsequent in-orbit operation phases, including the de-commissioning and disposal of the spacecraft.

During the development and commissioning phases, an ESA-appointed Project Manager will be responsible for implementing and managing ESA's activities. After a successful in-orbit commissioning review, a Mission Manager will take over the responsibility for the mission throughout its routine and any extended phases.

Funded by national Funding Agencies, within the remit of a Multi-Lateral Agreement (MLA[1]), including ESA and the national Funding Agencies, the AMC is responsible for (see more details in Section 7.2):

- Providing the payload elements, comprising: (i) the complete PLM, (ii) the warm payload units to be accommodated in the SVM; both according to the agreed interfaces and schedule;
- Contributing to the integration and tests of the payload elements at spacecraft (S/C) level, in coordination with the S/C industrial prime contractor and under the control of ESA;
- Supporting the payload safety, maintenance and operations throughout the mission lifetime;
- Providing contributions to the Science Ground Segment (SGS), through the Instrument Operations and Science Data Centre (IOSDC), as detailed in Section 6.2.2.

NASA is contributing focal plane modules and electronics for the Fine Guidance Sensor (FGS), pursuant to the relevant Memorandum of Understanding between ESA and NASA.

The responsibility for the AMC activities rests with the Consortium Principal Investigator (PI) and the Co-PIs, assisted by the Consortium Project Manager (CPM). To manage the work of the distributed AMC, seven groups will assist the PI to coordinate the work. These are the Consortium Co-PIs Board, the Consortium Management Team (CMT), the Consortium Science Coordination Group (CSCG), the Consortium Science Team (CST), the Consortium Instrument

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1 In case of conflicting provisions, precedence will be given to the MLA, over the present SMP.

Scientist Team (CIST), the IOSDC Management Team (IOSDCMT) and the Product Assurance Management Team.

The PI is the formal point of contact to ESA for science and mission related issues. The CPM is the point of contact to ESA on programmatic and technical matters. Day-to-day contacts between the Consortium and ESA will be via the members of the Consortium teams with responsibility for the particular areas of work and the appropriate ESA personnel.

The AMC internal structure and participation mechanisms are not regulated by ESA. The AMC foresees two levels of membership: Ariel Consortium Supporting Scientists (CSS) and Ariel Consortium Member Scientists and Engineers (CMS). CSS are members of the scientific community who actively support the Ariel mission. Requests to join the AMC as CSS will be evaluated and approved by the Co-PIs Board. After two years of active participation, CSS may apply to become CMS; this decision will be taken in consultation with the relevant national co-PI. CMS members are those who actively participate in the provision of hardware, software or contribute with other scientific or engineering expertise, and have been active members of the AMC for at least two years. CMS will have access to all Ariel core programme data.

The Ariel Science Team (AST) will be appointed by ESA after the Ariel mission adoption. The AST will be asked to review and endorse top-level requirements (in all areas of the mission) that impact science return, and to monitor all aspects of the subsequent implementation. Details of the AST composition and responsibilities are reported in Section 7.1.2.

The Ariel Mission Consortium will be responsible for the preparation and periodic update of the Mission Candidate Sample (MCS) list, which will be publicly available through a website maintained by the AMC. The Ariel Science Team will supervise and will be closely involved in the preparation and periodic update of the MCS list and will be responsible for defining the scientific priorities for the generation of the Mission Reference Sample to be observed by Ariel. The AMC will be responsible to implement the MRS through a scheduling exercise which follows the AST guidelines and aims at maximising the science yield. The MRS will be endorsed by the AST and reviewed under the responsibility of the ESA Advisory Structure before launch and in the course of operations as needed.

ESA Ariel Project Scientist (PS) will chair and coordinate the AST activities and will be the agency's interface with the AMC for all scientific matters.

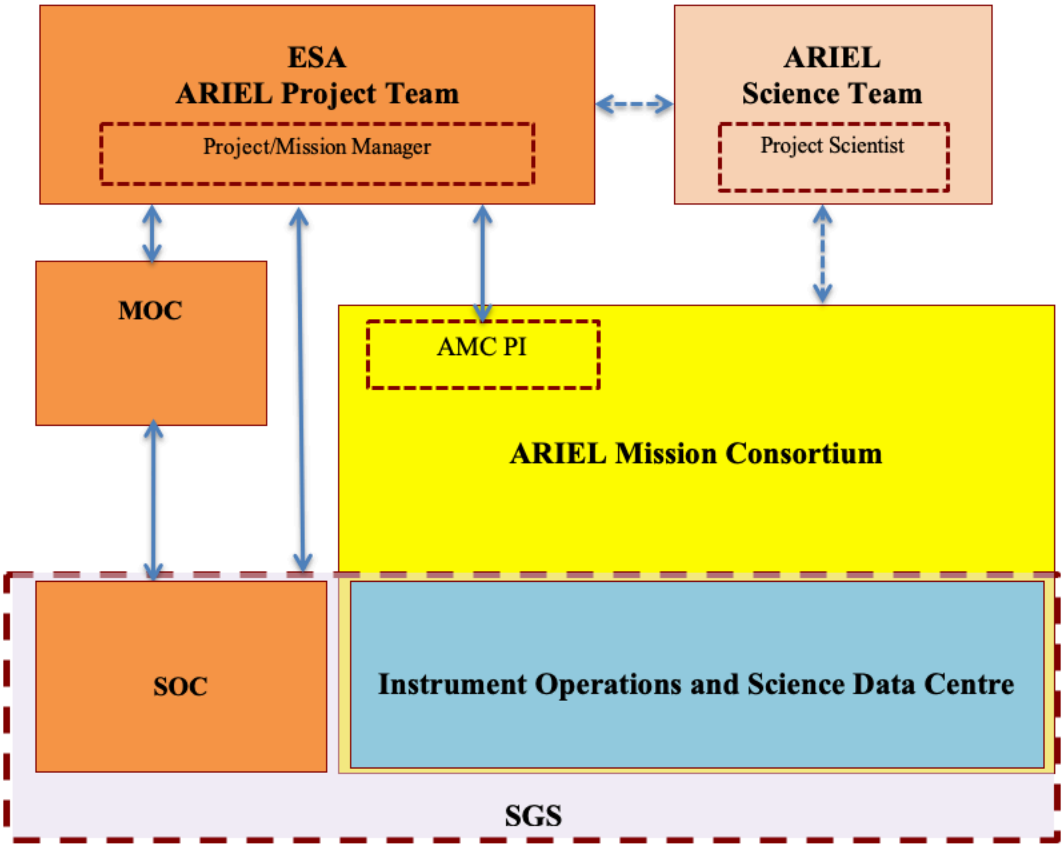

Figure 1. Overview of the Ariel mission management scheme.

Note: Arrows indicate main reporting (solid line) and coordination (dashed line) relations.

4 DATA PRODUCTS AND DATA RIGHTS

4.1 Data products

Ariel data products are classified according to the categories shown in Figure 2, defined as follows:

Level 0:

- These are the lowest level Ariel data, formed by compressed and time ordered telemetry packets sent from the MOC to the SOC.

Level 1:

- These are the lowest level Ariel science products, formed by unpacked and uncompressed Level 0 data. Level 1 data are raw images (for photometric channels) or spectral-images (for spectroscopic channels) in Analog-to-Digital Units (ADU).

Level 1.5:

- These are higher level science images (for photometric channels) or spectral-images (for spectroscopic channels). Level 1.5 images, in units of e^{-}/s, are calibrated and detrended for instrumental effects (bad or saturated pixels, detector non-linearity, pixel cross-talk, dark current, bias and gain variations, persistence, pointing jitter).

Level 2:

- This is the highest level science output produced by the systematic pipeline data processing performed at the SOC. Level 2 data are spectrally resolved light-curves of the target star plus planet(s); intensity is in flux units.

Level 3:

- These are the science data product resulting from the processing of Level 2 data. Level 3 data are corrected for potential residual instrumental systematics and time-dependent trends of astrophysical origin (e.g., stellar activity) and consist of broad-band spectra of exoplanets.

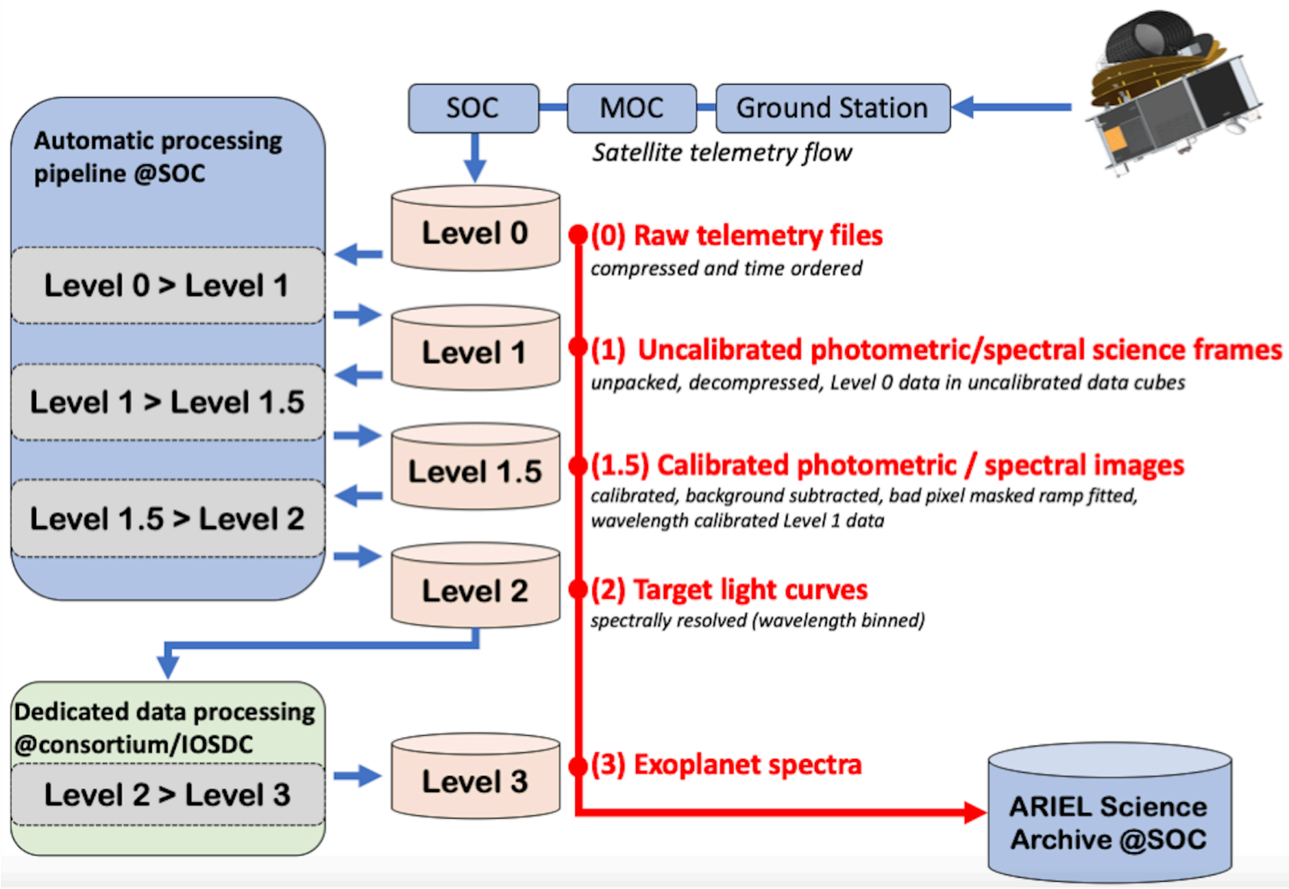

Figure 2. Schematic of Ariel Science and Housekeeping (HK) processing and data flow (left part) and description of science data products contents.

The consolidated Level 0 data are provided by the MOC to the SOC. The SOC performs systematic "hands-off" pipeline processing of the Level 0 data to generate the Level 1, 1.5, and 2 data products which are ingested into the Ariel science archive. This processing and archive ingestion will be conducted throughout the mission as data become available by the SOC, and using software provided by the IOSDC. Data products are made available to the astronomical community through the archive as described in Section 4.2.

4.2 Data release and data rights

Data processing up to Level 2 and archive population is done continuously throughout the mission. To guarantee homogeneous, consistent and scientifically validated data product deliveries to the community, periodic data releases are planned throughout mission (see Figure 3).

The release of all Ariel data will be in accordance with the following approach (see also Figure 3):

1. All data will be released after processing, consolidation and quality control are completed. These processes are expected to take about a month after the last required observation is taken and no longer than two months.

2. Data recorded during the Science Demonstration Phase, foreseen to last about one month before the start of the Nominal Science Operations Phase (see Section 2.3), will be released immediately after processing, consolidation and quality control up to Level 2 products. This subset of data will include targets previously observed by JWST, enabling a direct comparison of the data quality achievable with Ariel. The data release will be coupled with a workshop with the open community to discuss the quality and scientific significance of the Ariel data.

3. The data release during the NSOP will be performed according to the Tiers described in Table 1 for up to Level 2 (see Section 4.1) products, according to the following proprietary periods:

   - Tier 1 data public immediately after quality control is completed;
   - Tier 2 data public 6 months after quality control is completed;
   - Tier 3 data public 6 months after quality control is completed;
   - Tier 4 data public 1 year after quality control is completed.

4. Level 3 science products will be made public after their publication in peer-reviewed journals (see Section 4.3).

All data collected as part of the Core Survey will be released as described above.

The aforementioned data release policy does not apply to observations for Complementary Science (see Section 5.3). Complementary Science data will remain proprietary to the proposers for six months after the delivery of up to Level 2 processed data.

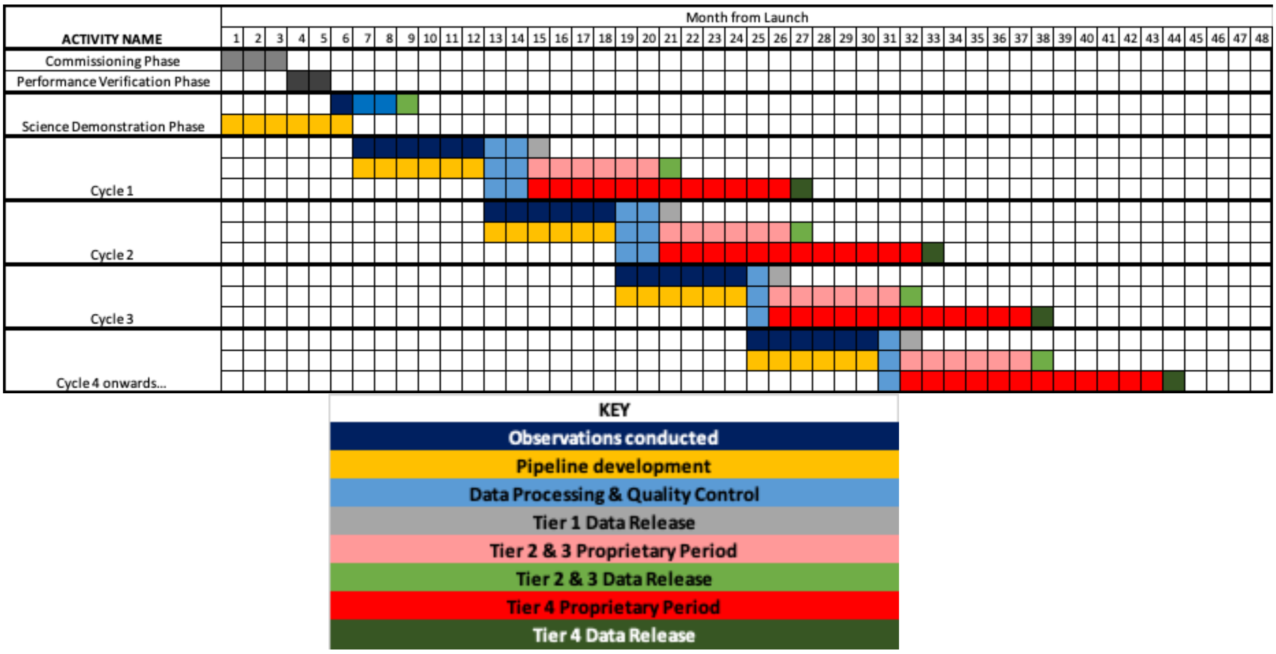

Figure 3. Timeline of mission phases and data releases

Note: The Nominal Science Operations Phase (NSOP) will start nominally in month 7 after launch, i.e., after the Science Demonstration Phase (SDP).

4.3 Publication policy

The AMC will apply the following policy to publications dedicated to targets in the MRS list:

- Any Co-PI or AMC Scientist, or any PhD student or postdoc working with a Co-PI or an AMC Scientist, has the right to co-authorship of any paper published by the CST to which he or she has contributed to (either prior to or after the observations which provide data for the publication);
- The Consortium Co-PIs Board will devise a method of quantifying individuals' contributions to the project;
- All papers by the CST based on Ariel data and performances must be endorsed by the Co-PIs Board;
- All disputes concerning publication rights will be referred to the Co-PIs Board for arbitration.

The above publication policy does not apply to data from the Complementary Science programme (see Section 5.3). The authors of papers resulting from the Complementary Science programme should acknowledge AMC and ESA in the acknowledgement section.

The publication policy specified above does not apply to public Ariel data, but authors will be invited to acknowledge AMC and ESA in the acknowledgement section.

5 PROGRAMME PARTICIPATION

There are four ways for members of the scientific community to participate in the Ariel mission:

- Become member of the AMC (see Section 3)
- Become member of the ESA-appointed AST (see Section 5.1)
- Participate in the definition of the MRS list (see Section 5.2)
- Participate in the definition of the Complementary Science programme (see Section 5.3).

5.1 Community Scientist in the Ariel Science Team

The role and functions of the Ariel Science Team (AST) are described in Section 7.1.2.

To acknowledge the major legacy potential of Ariel and to gather independent advice for optimising the exploitation of the Ariel mission by the general scientific community, up to five Community Scientists will be appointed to the AST, through an ESA-run selection process. Up to three Community Scientists are expected to cover science areas augmenting those of the AST members from the AMC and from international partners (e.g., they will have expertise in fields such as Solar System planetary science, data science, protoplanetary discs). A further two Community Scientists will be selected in scientific areas relevant for the Complementary Science programme (see Section 5.3). The main responsibility of the Community Scientists will be to advise on the means to optimise the use of Ariel data by the broader scientific community, including the interests of the scientific community that will be involved in the Ariel complementary science programmes (see Section 5.3).

The Community Scientists are expected to provide support to the outreach activities of ESA.

The Community Scientists will have the same data access and publication rights and rules as the other members of the AMC (see Sections 4.2 and 4.3).

The Community Scientists will be selected through an Announcement of Opportunity (AO) to be issued by ESA after the Ariel mission adoption and open to scientists in the ESA Member States. Scientists involved in the AMC (programmatic, scientific, or technical) top-level management or being responsible for hardware or software development and procurement activities are not eligible. Candidates will have to describe in the proposals their expertise, the relevance of their contribution to the mission, their time commitment to the AST activities and their willingness to take up specific and time-limited tasks as assigned by the AST. The proposals should include the explicit endorsement and support from their institutions.

The proposals will be evaluated by ESA and the selection of the Community Scientists will be made after consultation of the AMC PI. The appointments will be made for three years, renewable. With the exception of expenses incurred while travelling to AST meetings, ESA will not fund any other Community Scientist activities. At the end of each year, Community Scientists will have to submit a report on their Ariel related activities to ESA. At the end of each interval, ESA will decide whether to extend the appointment. Should a Community Scientist position become vacant, it will be filled by competitive selection via an AO process.

5.2 Participation in the definition of the Mission Reference Sample list

5.2.1 Participation to the definition of the MRS list for the core survey

The MCS and MRS lists are produced by the AMC, following the guidelines of the AST (see Section 3). The MCS and MRS lists are frequently updated and made available to the open community through a website maintained by the AMC. A system will be put in place to collect inputs from the wide community to both the MCS and the priority setting.

Regular workshops (e.g. every 1-2 years depending on the Phase of the mission) will be organised by the AMC aimed at informing and receiving inputs and feedback from the open community on the target selection for the Ariel core survey.

5.2.2 Participation to the definition of the MRS list for the core survey through an open call

A fraction of schedulable time (up to 5%) can be allocated to published targets which are either not already included in the MCS, or are planned to be observed with a different priority in the MCS, or using a different observational strategy.

The selection of these targets will be performed through an open ESA-run call, to be completed nine months (TBC) before launch, in close coordination with the AST to guarantee full consistency with the core survey plans. A second ESA-run call could be envisaged during the NSOP, if needed. The targets eventually selected through the ESA-run call will be processed for possible inclusion in the MRS list according to the same rules considered for all other candidates in the MCS (see Sections 5.2.1 and 3).

Individuals/teams selected through such call will participate in the publication of data for the selected targets with the AMC. Data rights described in Section 4.2 will apply also to these data. The authors shall abide to the publication policy described in Section 4.3.

5.3 Participation in the complementary science programme

Science time that cannot be scheduled for the exoplanetary core survey science (Section 5.2), will be used for time-unconstrained Complementary Science (e.g. Solar System, Stellar observations, sparsely sampled exoplanet phase curves, etc.). This time is anticipated to be between 5 and 10% of the available science time. The AST will be involved in the definition of priorities for complementary science themes.

The observations for Complementary Science will be inserted at opportune moments within the schedule (when no time-constrained observations of exoplanets from the MCS are schedulable). This therefore implies that the proposed Complementary Science observations cannot be temporally constrained and can be inserted at any suitable point in the schedule when the target is visible. Since the majority of the unscheduled time will be in relatively short time blocks, the bulk of the Complementary Science observation windows available is expected to be of durations between 0.5 and 4 hours.

The selection of observations for the Complementary Science will be through an open ESA-run call.

Processing of data from the Complementary Science programme up to Level 2 will be performed by the SOC as for other data (see Section 4.1). The proposers will retain exclusive data rights for six months after data up to Level 2 are delivered to them (see Section 4.2).

6 GROUND SEGMENT AND OPERATIONS

As indicated in Section 3, ESA will be responsible for the launch, early operations, commissioning and operations of the spacecraft.

ESA will establish an Ariel Mission Operations Centre (MOC) and a Science Operations Centre (SOC). ESA-provided ground station(s) will ensure the necessary telecommanding and telemetry capabilities.

6.1 Mission Operations Centre

The MOC is responsible for the operation of the spacecraft, and in particular for the following tasks:

- Performing uplink of the satellite and payload telecommands and receiving telemetry through the ground stations and communications network;
- Monitoring the spacecraft health and safety;
- Monitoring the payload safety and reacting to contingencies and anomalies according to procedures provided by the AMC;
- Performing mission planning of spacecraft activities;
- Alerting the SOC to all significant anomalies or deviations from nominal behaviour of the satellite and payload for onward transmission to the AMC as relevant;
- Executing procedures to safeguard the spacecraft and payload and preserve data integrity;
- Performing maintenance of the satellite's on-board software;
- Performing uplinks of payload on-board software updates as generated, validated and delivered by the AMC via the SOC;
- Providing flight dynamics support, including determination and control of the orbit and attitude of the satellite;
- Handling provision of the science and housekeeping telemetry to the SOC;
- Producing and providing ancillary data to the SOC (orbit files, pointing information, housekeeping telemetry, etc.);
- Supporting the SGS on all aspects concerning spacecraft operations.

6.2 Science Ground Segment

The Science Ground Segment (SGS) consists of the ESA SOC, and the IOSDC provided by the AMC.

The SGS performs long term planning and scheduling of the observations to be conducted by the S/C, receives science data and housekeeping telemetry from the MOC, generates science data products at multiple processing levels, and makes them available to the community through the Ariel science archive. The SGS is the point of contact between the mission and the user community for all aspects, including provision of information and help.

6.2.1 Science Operations Centre

The SOC is the only interface to the MOC during routine operations and is responsible for the following tasks:

- Operating the planning tool delivered by the IOSDC to generate the long-term observation plan based on the MRS list and scheduling of the observations including the provision of the corresponding operations requests to MOC;
- Handling of payload operations and maintenance requests from the AMC and issuing them to the MOC, as appropriate, to optimise the quality of the Ariel data;
- Integrating and operating the AMC-provided Level-0 to Level-2 data processing pipeline to produce validated data products up to Level-2 (see Section 4.1). This includes the necessary calibration information;
- Operating the AMC provided quality control pipeline for the Level-1 and Level-2 data processing;
- Providing science data and data products, including ancillary data, to the AMC;
- Developing and operating the Ariel archive (mission database and science data archive) to archive and distribute the data products (Levels 1 to 3) to the community;
- Making data processing tools available to the community, with the support of the AMC;
- Supporting the scientific user community.

The SOC will take the lead in the overall design and engineering of the SGS, and will organise and manage the end-to-end tests that are needed to validate the SGS uplink and downlink systems, interfaces, and operational processes.

6.2.2 Instrument Operations and Science Data Centre (IOSDC)

The Instrument Operations and Science Data Centre (IOSDC) provided by the AMC will take responsibility of the following tasks relevant for the SGS:

- Developing a long-term scientific mission planning tool, generating an initial long-term observation plan, and delivering this tool to the SOC for further use during the operations phase;
- Providing the documentation (procedures, manuals, etc.) necessary for the operation, calibration, and data processing specific to the payload;
- Performing the payload calibration and providing calibration files and scripts to the SOC;
- Maintaining the payload on-board software and procedures;
- Developing and operating the Instrument Workstation for real time monitoring of the payload, which includes the Quick-Look Analysis software and procedures;
- Developing and operating the Health Monitoring and Observation Quality system, in partnership with the SOC;
- Developing and delivering to the SOC the data processing pipelines (Level-0 to Level-2);
- Defining the quality control metrics for Level-1 and Level-2 data and developing the data quality pipeline;
- Developing and operating the Level-2 to Level-3 data processing pipeline to produce and deliver to the SOC Level-3 data;
- Supporting the SOC with access to tools for the data analysis, and with responding to user requests on payload specific matters;
- Maintaining all software provided to the SOC;
- Participating in pre-flight SGS integration and testing.

7 SCIENCE AND PROJECT MANAGEMENT

7.1 ESA responsibilities

The overall mission management, spacecraft, launch vehicle and launch services, mission operations, ground station(s), the SOC and the MOC will be provided under ESA responsibility.

7.1.1 ESA provisions

ESA will be responsible for the overall mission design and implementation and for the scientific outcome of the mission; in particular ESA will lead the following activities:

- Development of the space segment, which includes the design, procurement, integration and verification of the S/C, through:

    - Management of the development of the SVM and the S/C level Assembly, Integration and Verification (AIV) activities;
    - Overseeing of the development of the payload elements (PLM including scientific instruments, and warm payload units to be accommodated in the SVM), under the responsibility of the AMC (see Section 7.2);
    - Providing AIRS detector arrays and V-grooves to the AMC.

- Development of the ground segment, which includes the design, procurement, integration, and verification of:

    - The MOC and ground stations network, according to the tasks described in Section 6.1;
    - The SGS, with:

        - The SOC, according to the tasks described in Section 6.2.1;
        - The IOSDC, under the responsibility of the AMC (see Section 6.2.2).

- Overseeing of the mission scientific performance, in close collaboration with the AMC, coupling the S/C performance and the data processing at ground segment level;
- Provision of the launch and launch operations;
- Operations of the mission, including early operations, in-orbit commissioning, all subsequent in-orbit operation phases until de-commissioning of the spacecraft, and the post-operations phase;
- Management of the project and mission as a whole, including all technical and programmatic aspects (cost, schedule, risk and contingencies).

During all phases of the mission the Project Scientist will provide advice on scientific issues. During the development phase, the Project Scientist will advise the ESA Project Manager on technical matters affecting scientific performance, including the ability of the spacecraft to support achievement of the mission's goals. The Project Scientist will monitor the state of implementation and readiness of the instrument operations and data processing and archive systems.

After the in-flight commissioning phase, the Project Scientist will continue to be the main interface with the community on scientific aspects and will provide scientific advice to the

Mission Manager. The Project Scientist will monitor the creation of the scientific products, their archiving and provision to the scientific community.

7.1.2 Ariel Science Team

The AST will be appointed by ESA after the Ariel mission has been adopted. The Ariel Project Scientist will chair the AST.

The AST will consist of:

- The AMC PI and up to seven members from the AMC, covering main areas relevant for the scientific objectives of the mission;
- Up to 2 members appointed based on ESA agreements with NASA and other international partners;
- Up to five "Community Scientists", including two experts in fields relevant for the complementary science (see Section 5.1).

The actual number of members and composition of the AST may change according to the different phases of the mission development.

The AST will advise ESA on all aspects of the mission potentially affecting its scientific performance. It will assist the Project Scientist in maximising the overall scientific return of the mission within the established boundary conditions. It will act as a focus for the interests of the scientific community in Ariel.

The AST members will have the same data access and publication rights and rules as the members of the AMC (see Sections 4.2 and 4.3).

The AST will be asked to review and endorse top-level requirements (in all areas of the mission) that impact science return.

Members of the AST are expected to monitor and give advice on all aspects of the Ariel mission which affect its scientific performance. They will perform specific scientific and/or technical tasks, as needed during development and operation, and will be invited to participate in major project reviews as observers.

The AST will be in charge of:

- Maximising the scientific return of Ariel within the programmatic constraints, while ensuring that the development and operations of the mission remain compatible with its main scientific objectives;
- Optimising the scientific performance of the payload and spacecraft;
- Supervising and being closely involved in the preparation and periodic update of the MCS list and being responsible for defining the scientific priorities for the generation of the MRS;
- Monitoring the collection of ancillary data sets to complement the Ariel scientific data;
- Optimising the calibration and processing of the data to high quality data products and their ingestion into the Ariel Science Archive for public dissemination;

- Supervising and authorising the release of scientific data products to the community in a timely manner;
- Optimising the analysis and exploitation of Ariel data;
- Within the data right rules (see Section 4.2) and publication policy rules (see Section 4.3), monitoring publications of results;
- Promoting public awareness and appreciation of the Ariel mission and its scientific results, and supporting ESA outreach efforts.

7.2 Ariel Mission Consortium responsibilities

The AMC will hold the following responsibilities:

- Developing, procuring, calibrating, testing and delivering to ESA all the payload elements part of the space segment. These comprise:
    - The complete PLM (telescope assembly, AIRS and FGS instruments, calibration source, and thermal shield assembly);
    - The warm payload units (ICU, TCU, FCU and cryocooler) to be accommodated in the SVM;
- Formulating, optimising, and maintaining the MCS list and generating the MRS list, following Tier requirements, through a scheduling exercise, based on the "recipe" provided by the AST;
- Providing post-delivery support to the S/C prime contractor for the integration, test and calibration of the payload elements at spacecraft level;
- Providing to ESA the necessary support for the commissioning, payload calibration and operations in-orbit;
- Providing the AMC elements of the SGS according to the tasks specified in Section 6.2.2 for the IOSDC.

ESA will review the AMC contributions, including the SGS elements and science preparation activities, at each main project review and/or with dedicated scientific reviews.

7.3 Steering Committee

A Multi-Lateral Agreement (MLA) will be established between ESA and the Funding Agencies (FAs) to formalise the commitments and deliverables of all parties. In case of conflicting provisions, the MLA will prevail over the present SMP. A Steering Committee with representatives from the national FAs and ESA will be set up to oversee the timely fulfilment of the obligations of all parties to the MLA and address any issues that may arise in that context.

The Steering Committee will participate in the periodic milestone reviews of the AMC to monitor its status and progress.

8 Public outreach

ESA will have overall responsibility for the science communications, educational and outreach activities related to Ariel. ESA will have the right to use any data acquired by Ariel for outreach purposes, in coordination with the holders of the data rights as applicable, as covered by the ESA Rules on Information, Data and intellectual Property (ESA/REG/008).

A public outreach activity will be established in close collaboration between ESA, the relevant bodies funding the provision of the scientific payload in the Member States, and other institutions involved in the mission. Such outreach activity will be based on a regular flow of science results from the mission presented in a manner suitable for communication and public outreach purposes. Such outreach activity necessitates the timely availability of suitably processed data and the full involvement of the various scientific teams engaged.

Formal dedicated agreements regarding public outreach activities will be established between ESA, the relevant funding authorities, and other institutions involved in the mission. The terms and conditions contained in these agreements will be applicable on the relationships between the funding authorities and the various scientific investigators. These agreements will take account of any necessary project-specific science-to-public-outreach balance. The implementation of such agreements will be tracked by the Steering Committee defined in Section 7.3 and as part of the standard project reviews.

The authorities funding the provision of the payload in the Member States (Funding Bodies) and other institutions involved in the mission will prepare a public outreach agreement involving ESA, the relevant Funding Bodies, the AMC, and any other relevant organisations. Interactions between these parties will have to guarantee consistency between all applicable documents and policies.

Acronyms

ADU	Analog-to-Digital Units
AIRS	Ariel Infra-Red Spectrometer
AMC	Ariel Mission Consortium
AO	Announcement of Opportunity
AST	Ariel Science Team
CIST	Consortium Instrument Science Team
CMS	Consortium Member Scientist
CMT	Consortium Management Team
Co-PI	Co-Principal Investigator
CPM	Consortium Project Manager
CSCG	Consortium Science Coordination Group
CSS	Consortium Support Scientist
CST	Consortium Science Team
ESA	European Space Agency
ESAC	European Space Astronomy Centre
ESOC	European Space Operations Centre
FA	Funding Agency
FCU	FGS Control Unit
FGS	Fine Guidance System
G/S	Ground Station
HK	House Keeping
ICU	Instrument Control Unit
IR	Infra-Red
IOSDC	Instrument Operations Science Data Centre
IOSDCMT	Instrument Operations Science Data Centre Management Team
JWST	James Webb Space Telescope
L2	2^{nd} Sun-Earth Lagrange point
MCS	Mission Candidate Sample
MLA	Multi-Lateral Agreement
MOC	Mission Operations Centre
MoU	Memorandum of Understanding
MRS	Mission Reference Sample
NASA	National Aeronautics and Space Administration

NSOP	Nominal Science Operations Phase
PI	Principal Investigator
PLM	Payload Module
ppm	Parts Per Million
PS	Project Scientist
s/c	Spacecraft
SCS	Sensor Chip Systems
SDP	Science Demonstration Phase
SGS	Science Ground Segment
SMP	Science Management Plan
SNR	Signal-to-Noise Ratio
SOC	Science Operations Centre
SVM	Service Module
TBC	To Be Confirmed
TCU	Telescope Control Unit
TESS	Transiting Exoplanet Survey Satellite