ASTRI – MICRO MOON LANDER (MML)
BY BLUE HORIZON SARL AND OHB GROUP

Goal:
Develop a Micro Moon Lander (MML) that is able to transport a small payload of ~10 kg to the Moon and allow a soft landing in a first step. The lander shall be scalable so that also larger payloads can be transported in a later stage. The technical project shall be accompanied by a business case. Side goals shall be: Improved communication and establishment of new communication and exchange means due to the geographic distances between the different students and their OHB mentors, sharpening of intercultural competencies, pushing of networking.

1 PROJECT MANAGEMENT

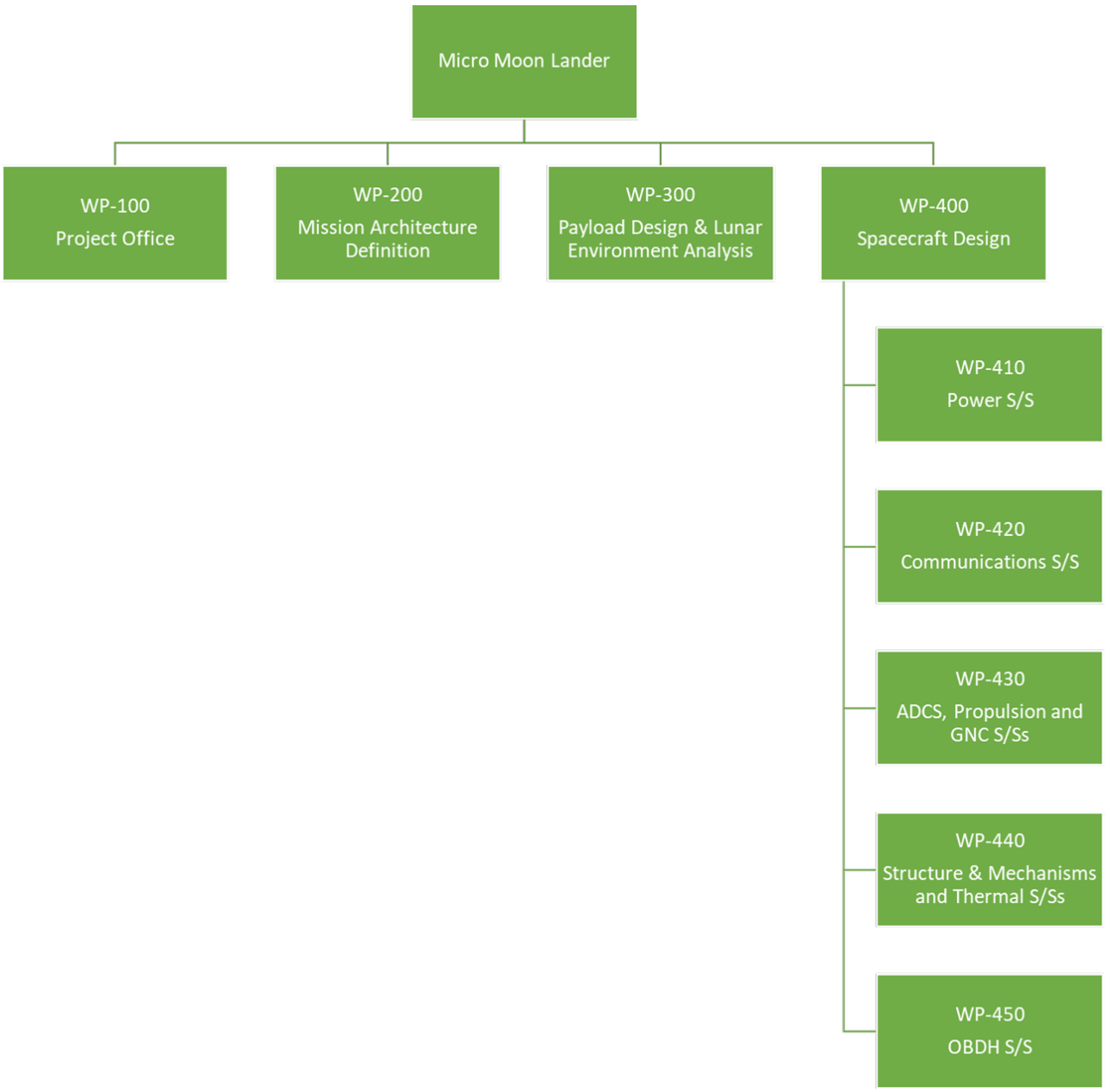
1.1 OVERVIEW

The task breakdown is detailed in what follows. The tasks are bundled into Work Packages (WPs) and WP-managers are assigned as responsibles. There are 9 WPs numbered as WPn00 (i.e. WP100, WP200, etc).

Where no strict dependency between the tasks is identified, the tasks are kept running in parallel to minimize the overall schedule. The project duration is set to 18 months. Estimated Kick-off is set to April 2018. Final Presentation is scheduled for October 2019.

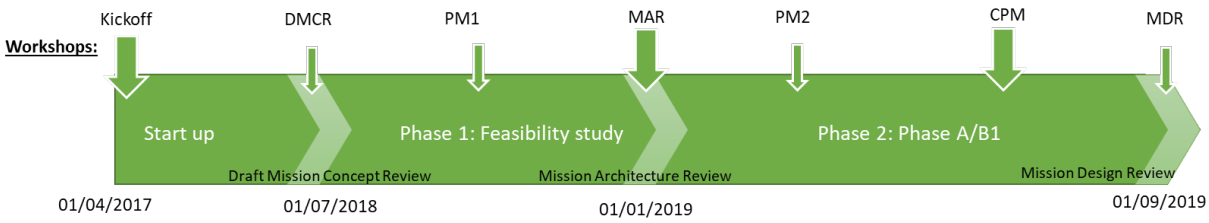
The following gives an overview of the overall project planning.

1.2 WORK BREAKDOWN STRUCTURE



1.2.1 **Planning**

The chart below shows the overall time allocation. All WPs run in parallel:



The project is scheduled over 18 months of which 3 months start up, 6 months Feasibility Study, and a 9 months Phase A/B1. Conference calls: It is planned that students/WP managers meet every week in a conference call or similar to report progress. Two days workshops shall take place every 3 months. Five days workshops shall take place at the beginning of the project, after 9 months and after 15 months. These workshops will take place at one or several places, easy to reach from the various geographic locations in Europe.

There are three Milestones, the Mission Concept Review (MCR), the Mission Architecture Review (MAR) and the Mission Design Review (MDR). They constitute the major delivery points for the identified documentations. Draft Versions of those documents will be made available for the interims workshops. At the end of the study project some time is devoted to the Final Report.

1.2.2 **Workshops**

The table below shows the workshop dates and proposed locations.

Meeting / Workshop	Date	Duration (days)	Location
Kick-off	T0	5	TBD
Draft Mission Concept Review (DMCR)	T0 + 3m	2	TBD
Progress Meeting 1 (PM1)	T0 + 6m	2	TBD
Milestone 1: Mission Architecture Review (MAR)	T0 + 9m	5	TBD
Progress Meeting 2 (PM2)	T0 + 12m	2	TBD
Critical Progress Meeting (CPM)	T0 + 15m	5	TBD
Milestone 2: Mission Design Review (MDR)	T0 + 18m	2	TBD

1.3 LIST OF DELIVERABLE ITEMS

The following deliverables are identified together with the relevant version and deliverable milestone.

WP	Deliverable	Issue	To be delivered for
100	Business Plan	Draft	DMCR
		v1	PM2
		Final	MDR
200	Analysis of Mission Assumptions	Draft	DMCR
		v1	MAR
		Final	MDR
	Mission Requirements	Draft	DMCR
		v1	MAR
		Final	MDR
	System Requirements	Draft	MAR
		v1	PM2
		Final	MDR
	Approach for the definition of System Concept and Mission Architecture	Draft	DMCR
		v1	MAR
		Final	MDR
	Baseline System Concept	Draft	DMCR
		v1	MAR
		Final	MDR
	Baseline Mission Architecture	Draft	PM1
		v1	MAR
		Final	MDR
	Concept of Operations	Draft	PM1
		v1	MAR
		Final	MDR
	Ground Segment Concept and Overall Data Flows Analysis	Draft	PM1
		v1	MAR
		Final	MDR
	Technical Risks associated to Baseline Mission Architecture	Draft	MAR
		v1	PM2
		Final	MDR
	Cost Model and Breakdown for Baseline Mission Architecture	Draft	MAR
		v1	PM2
		Final	MDR
300	Payload Detailed Analysis and Definition	Draft	DMCR

		v1	MAR
		Final	MDR
	Lunar environment analysis	Draft	DMCR
		v1	MAR
		Final	MDR
	Ranking of lunar landing sites wrt business potential	Draft	DMCR
		v1	MAR
		Final	MDR
	Payload User Manual	Draft	MAR
		v1	PM2
		Final	MDR
	Cost Model and Breakdown for Payload	Draft	MAR
		v1	PM2
		Final	MDR
	Technical Risks associated to Payload Design	Draft	MAR
		v1	PM2
		Final	MDR
	Payload Requirements	Draft	PM1
		v1	MAR
		Final	MDR
400	Spacecraft Design Description and Justification File	Draft	PM1
		v1	MAR
		Final	MDR
	File folder containing entire Spacecraft Configuration	Draft	MAR
		v1	CPM
		Final	MDR
	S/C User Manual	Draft	PM2
		v1	CPM
		Final	MDR
	Technical Risks associated to S/C design	Draft	MAR
		v1	PM2
		Final	MDR
	Cost Model and Breakdown for S/C	Draft	MAR
		v1	PM2
		Final	MDR
	S/C Development model philosophy	Draft	PM2
		v1	CPM
		Final	MDR
4x0	<all deliverables>	Draft	PM1
		v1	MAR
		Final	MDR

All documents are delivered as searchable Adobe® Documents together with the native MS Word/Excel format. It is expected that after v1 intermediate versions are produced (v2, v3 etc) before delivery of the final version.

1.3.1 Work Package Description

1.3.1.1 Project Office

PROJECT:	ASTRI - Commercial Micro-Moon Lander (MML)			WP REF: **100**
WP-Title:	**Project Office**			Sheet **1** of **1**
Contractor:	**N/A**			
Major Constituent:	-			Issue Ref: **1**
Start Event:	**Kick-Off**	Planned Date:	**T0**	
End Event:	**End of Project**	Planned Date:	**T0+18m**	Issue Date: **08/12/2017**
WP-Manager:				

Objective:

- Project Management and Coordination
- Document Configuration
- Business plan write-up

Required Inputs and Conditions:

- Kick-Off
- Constant feedback loop with WP200, WP300, and WP400

Tasks Description:

- Single point of interface with stakeholders for all technical and programmatic matters
- Reporting of project status
- Meeting & workshop management
- Document configuration, Management and tracking of status of deliverables, project closure documentation
- Business plan write-up including: value proposition, definition of commercial product, product lines, market analysis, competitor analysis, business model, analysis of legal environment etc

Outputs:

- Business plan

Tasks specifically excluded:

- None

1.3.1.2 Mission Architecture Definition

PROJECT:	**ASTRI - Commercial Micro-Moon Lander (MML)**			WP REF: **200**
WP-Title:	**Mission Architecture Definition**			Sheet **1** of **1**
Contractor:	**N/A**			
Major Constituent**:**				Issue Ref: **1**
Start Event:	**Kick-Off**	Planned Date:	**T0**	
End Event:	**End of Project**	Planned Date:	**T0+18m**	Issue Date: **08/12/2017**
WP-Manager:				

Objective:

- To list mission assumptions and provide top-level mission requirements
- To design-to-cost the overall mission architecture
- To identify the system drivers, define trade-off tree
- To provide overall cost model for the mission as well as main technical risks

Required Inputs and Conditions:

- Kick-Off
- Constant feedback loop with WP100, WP300 and WP400

Tasks Description:

- Setup and keep track of all mission and system-level assumptions until end of project
- In coordination with WP100 provide top-level mission requirements
- Provide system-level requirements (ground segment, space segment, launch segment)
- Identification of driving requirements and corresponding system drivers;
- For the space segment: preliminary apportionment of requirements to platform & payload
- Provide mission statement, mission concept. Perform classical mission analysis. Provide mission architecture made up of the following elements: 1) commercial product, 2) payload, 3) spacecraft, 4) trajectory (selection of landing site, lunar transfer, LOI, landing, total delta-v etc), 5) communications architecture, 6) ground segment, 7) launch scenario (date, time, vehicle, primary vs secondary etc), 8) mission operations, 9) mission concept. Trade-off between promising candidate architectures.
- Determine mission lifetime in coordination with WP100, WP300 and WP400
- Develop Concept of Operations including all mission phases from launch until end of life
- Define the mission end-to-end data flows and characterise them in terms of data rate, frequency (e.g. continuous or intermittent) and timeliness taking into account the overall system requirements
- Define the relevant processing chains and its constituting functional elements, its external interfaces and allocate the relevant data streams to the processing chains
- Define the Ground Segment concept and outline the corresponding architectural elements including a description of the related tasks, performance and interfaces
- Identify conceptual elements of the ground system that allow the implementation of a reusable and sustainable system

Outputs:

- Technical Note “Analysis of Mission Assumptions”
- Technical Note “Mission Requirements”
- Technical Note “System Requirements”
- Technical Note “Approach for the definition of System Concept and Mission Architecture
- Technical Note “Baseline System Concept”
- Technical Note “Baseline Mission Architecture”
- Technical Note “Concept of Operations”
- Technical Note “Ground Segment Concept and Overall Data Flows Analysis”
- Technical Note “Cost Model and Breakdown for Baseline Mission Architecture”
- Technical Note “Technical Risks associated to Baseline Mission Architecture”

Tasks specifically excluded:

- Detailed definition of payload and spacecraft (see WP300 and WP400)

1.3.1.3 Payload Design

PROJECT:	**ASTRI - Commercial Micro-Moon Lander (MML)**			WP REF: **300**
WP-Title:	**Payload Design and Lunar Environment Analysis**			Sheet **1** of **1**
Contractor:	**N/A**			
Major Constituent**:**				Issue Ref: **1**
Start Event:	**Kick-Off**	Planned Date:	**T0**	
End Event:	**End of Project**	Planned Date:	**T0+18m**	Issue Date: **08/12/2017**
WP-Manager:				

Objective:

- To design-to-cost an innovative commercial payload for the lunar surface able to withstand the challenging lunar environment for a significant amount of time.

Required Inputs and Conditions:

- Kick-Off
- Constant feedback loop with WP100, WP200 and WP400

Tasks Description:

- Payload Detailed Analysis: 1. Requirements analysis - analyse and consolidate payload functional and performance requirements (identify payload sub-systems in terms of functions, operations [mode, duty cycle, constraints], internal and external interfaces. 2. Payload functional analysis and definition. 3. Payload mechanical configuration and define the architecture of its supporting sub-systems: thermal, electrical, data handling; 4. Payload failure tolerance and propose redundancy concept 5. Payload calibration and budgets
- Lunar environment analysis with respect to lander commercialisation opportunities: 1) Overview of lunar environment with a focus on 1.1 radiation environment, 1.2 thermal environment and 1.3 Earth visibility, 1.4 other; 2) SWOT analysis of lunar environment for the establishment of a recurring business with the payload (weeks to months to years); 3) Key enabling technologies and technology gap analysis for enabling recurring business on the Moon (for present and future payloads)
- Landing site analysis with respect to lander commercialisation opportunities

Outputs:

- Technical Note “Payload Detailed Analysis and Definition”
- Technical Note “Payload User Manual”
- Technical Note “Payload Requirements”
- Technical Note “Lunar environment analysis”
- Technical Note “Ranking of lunar landing sites wrt business potential”
- Technical Note “Technical Risks associated to Payload Design”
- Technical Note “Cost Model and Breakdown for Payload”

Tasks specifically excluded: None

1.3.1.4 S/C Design and System Engineering

PROJECT:	**ASTRI - Commercial Micro-Moon Lander (MML)**			WP REF: **400**
WP-Title:	**Spacecraft Definition and System Engineering**			Sheet **1** of **1**
Contractor:	**N/A**			
Major Constituent**:**				Issue Ref: **1**
Start Event:	**Kick-Off**	Planned Date:	**T0**	
End Event:	**End of Project**	Planned Date:	**T0+18m**	Issue Date: **08/12/2017**
WP-Manager:				

Objective:

- To design an innovative micro moon lander S/C

Required Inputs and Conditions:

- Kick-Off
- Constant feedback loop with WP100, WP200 and WP300

Tasks Description:

- Define spacecraft concept: platform and payload
- Perform functional analysis at spacecraft level
- Perform overall system engineering including managing the 8 subsystems (sub-WPs): Power, Communications, ADCS, Propulsion, GNC, Structure & Mechanisms, Thermal, OBD
- Perform and coordinate 1. Design and physical configuration, 2. Requirements engineering of the space segment, 3. Interface management (both functional and physical) 4. V&V activities to follow in later phases.
- Establish and manage baseline configuration of the S/C
- Establish the satellite performance and resource budgets and define their margin philosophy, including but not necessarily limited to:
    - Cost: HW, SW and labor
    - Mass and Mass Properties
    - Alignment and stability
    - Electrical Power and Energy
    - Heat Generation and Dissipation
    - Delta-V and Propellant
    - Telemetry and Telecommand
    - Frequency Plans
    - Radio Frequency links (TT&C, mission data)
    - Memory Usage
    - Computer(s) load
    - Mapping, pointing and geolocation budgets
    - Perturbation forces, torques and momentum management

- Perform and coordinate cost engineering effort of the space segment
- Target reliability of S/C, propose reliability/redundancy concept, Quantify availability of commercial service to customer
- Elaborate scalability concept for lander
- Define S/C operational modes, basic FDIR concept and level of autonomy in coordination with WP200
- Develop and implement overall approach to 1) protect S/C against harmful radiation (with a particular focus on the operational phase on the lunar surface, use inputs from WP300) and 2) ensure EMC of all onboard equipment
- Coordinate with WP100, WP200, WP300 to ensure overall suitability of space segment design wrt overall mission architecture.

Outputs:

- Report “Spacecraft Design Description and Justification File”
- File folder containing entire Spacecraft Configuration, including functional and physical block diagrams, Product tree, Specification tree, CAD models, S/C level budgets etc
- Technical Note “S/C User Manual”
- Technical Note “S/C Development model philosophy” (including roadmap for (rapid) prototyping)
- Technical Note “Technical Risks associated to S/C Design”
- Technical Note “Cost Model and Breakdown for S/C”

Tasks specifically excluded:

None

1.3.1.4.1 Power S/S

PROJECT:	**ASTRI - Commercial Micro-Moon Lander (MML)**			WP REF: **410**
WP-Title:	**Power S/S**			Sheet **1** of **1**
Contractor:	**N/A**			
Major Constituent**:**				Issue Ref: **1**
Start Event:	**Kick-Off**	Planned Date:	**T0**	
End Event:	**End of Project**	Planned Date:	**T0+18m**	Issue Date: **08/12/2017**
WP-Manager:				

Objective:

- To design the power subsystem of the S/C

Required Inputs and Conditions:

- Kick-Off
- Constant feedback loop with WP400

Tasks Description:

- Power S/S requirements analysis and write-up, trade-off options and define concepts and implementation
- Analyse development status and outline critical areas and required technology development;
- Power S/S design for all mission phases: LEOP, lunar transfer, descent and landing, operational phase on lunar surface, etc
- Functional architecture and physical architecture of S/S: power generation, power regulation & control, power storage, power distribution, power harness.
- Detailed power budget for all S/C and P/L operational modes
- Outline the interfaces between different units and sub-systems;

Outputs:

- Technical Note “S/C Power Subsystem Detailed Design”
- Technical Note “S/C Power Requirements”
- Technical Note “Technical Risks associated to Power S/S Design”
- Technical Note “Cost Model and Breakdown for Power S/S”

Tasks specifically excluded:

None

1.3.1.4.2 Communications S/S

PROJECT:	**ASTRI - Commercial Micro-Moon Lander (MML)**			WP REF: **420**
WP-Title:	**Communications S/S**			Sheet **1** of **1**
Contractor:	**N/A**			
Major Constituent**:**				Issue Ref: **1**
Start Event:	**Kick-Off**	Planned Date:	**T0**	
End Event:	**End of Project**	Planned Date:	**T0+18m**	Issue Date: **08/12/2017**
WP-Manager:				

Objective:

- To design the communications S/S of the S/C. The communications S/S includes all communications between the space segment and the ground segment, i.e. both TMTC and Payload Data Downlink

Required Inputs and Conditions:

- Kick-Off
- Constant feedback loop with WP400

Tasks Description:

- Communications S/S requirements analysis and write-up, trade-off options and define concepts and implementation
- Analyse development status and outline critical areas and required technology development;
- Communications S/S design for all mission phases: LEOP, lunar transfer, EDL, operational phase on lunar surface. Selection of frequency bands, modulation scheme, related antenna designs etc
- Functional architecture and physical architecture of S/S
- Analysis of ITU compliancy
- Detailed data budget, link budget
- Outline the interfaces between different units and sub-systems;

Outputs:

- Technical Note “S/C Communications Subsystem Detailed Design”
- Technical Note “S/C Communications Requirements”
- Technical Note “Technical Risks associated to Communications S/S Design”
- Technical Note “Cost Model and Breakdown for Communications S/S”

Tasks specifically excluded:

None

1.3.1.4.3 ADCS, Propulsion and GNC S/Ss

PROJECT:	**ASTRI - Commercial Micro-Moon Lander (MML)**			WP REF: **440**
WP-Title:	**ADCS, GN&C and Propulsion S/Ss**			Sheet **1** of **1**
Contractor:	**N/A**			
Major Constituent**:**				Issue Ref: **1**
Start Event:	**Kick-Off**	Planned Date:	**T0**	
End Event:	**End of Project**	Planned Date:	**T0+18m**	Issue Date: **08/12/2017**
WP-Manager:				

Objective:

- To design the three subsystems ADCS, Propulsion and GN&C of the S/C.

Required Inputs and Conditions:

- Kick-Off
- Constant feedback loop with WP400

Tasks Description:

- Propulsion S/S requirements analysis and write-up, trade-off options and define concepts and implementation
- Analyse development status and outline critical areas and required technology development;
- Propulsion S/S design for all mission phases requiring orbital maneuvers
- Functional architecture and physical architecture of S/S
- Propulsion S/Ss key tradeoffs: selection of engines, thrust, Isp, etc
- Coordinate on Delta-V budget with WP400 and WP-200
- Outline the interfaces between different units and sub-systems;

- GN&C S/S requirements analysis and write-up, trade-off options and define concepts and implementation
- Analyse development status and outline critical areas and required technology development;
- GN&C S/S design for all mission phases requiring GN&C, with a particular focus on EDL
- Functional architecture and physical architecture of S/S
- Sensor and actuator selection, development of control algorithms
- GN&C performance simulator in Matlab/Simulink or other
- Outline the interfaces between different units and sub-systems;

- ADCS S/S requirements analysis and write-up, trade-off options and define concepts and implementation
- Analyse development status and outline critical areas and required technology development;
- ADCS S/S design for all operational modes
- Functional architecture and physical architecture of S/S
- Sensor and actuator selection, development of control algorithms

- ADCS performance simulator in Matlab/Simulink or other
- Outline the interfaces between different units and sub-systems;

Outputs:

- Technical Note “S/C Propulsion Subsystem Detailed Design”
- Technical Note “S/C Propulsion Requirements”
- Technical Note “Technical Risks associated to Propulsion S/S Design”
- Technical Note “Cost Model and Breakdown for Propulsion S/S”
- Technical Note “S/C GN&C Subsystem Detailed Design”
- Technical Note “S/C GN&C Requirements”
- Technical Note “Technical Risks associated to GN&C S/S Design”
- Technical Note “Cost Model and Breakdown for GN&C S/S”
- Technical Note “S/C ADCS Subsystem Detailed Design”
- Technical Note “S/C ADCS Requirements”
- Technical Note “Technical Risks associated to ADCS S/S Design”
- Technical Note “Cost Model and Breakdown for ADCS S/S”

Tasks specifically excluded:

None

1.3.1.4.4 Structure & Mechanisms and TCS S/Ss

PROJECT:	**ASTRI - Commercial Micro-Moon Lander (MML)**			WP REF: **450**
WP-Title:	**Structure & Mechanisms and Thermal Control S/Ss**			Sheet **1** of **1**
Contractor:	**N/A**			
Major Constituent**:**				Issue Ref: **1**
Start Event:	**Kick-Off**	Planned Date:	**T0**	
End Event:	**End of Project**	Planned Date:	**T0+18m**	Issue Date: **08/12/2017**
WP-Manager:				

Objective:

- To design the two subsystems Structure & Mechanisms and Thermal Control of the S/C.

Required Inputs and Conditions:

- Kick-Off
- Constant feedback loop with WP400

Tasks Description:

- Structure & Mechanisms S/S requirements analysis and write-up, trade-off options and define concepts and implementation
- Analyse development status and outline critical areas and required technology development;
- Structure design, including analysis of configuration options, definition of the configuration baseline and visualization of the configuration
- Design of all mechanisms necessary for the mission
- Functional architecture and physical architecture of S/S
- Mechanical loads analysis for launch (quasi-static, sine and random loads, shock & acoustics etc)
- Mechanical analysis for lunar landing
- Outline the interfaces between different units and sub-systems;

- Thermal Control S/S requirements analysis and write-up, trade-off options and define concepts and implementation
- Analyse development status and outline critical areas and required technology development;
- Thermal Control S/S design for all mission phases with particular focus on the operational phase on the lunar surface (in coordination with WP300 and WP400)
- Functional architecture and physical architecture of S/S
- Analysis of thermal environment: worst-case analyses
- Trade passive vs active control, selection and placement of potential thermistors, radiators, heaters etc
- Outline the interfaces between different units and sub-systems;

Outputs:

- Technical Note “S/C Structure & Mechanisms Subsystem Detailed Design”
- Technical Note “S/C Structure & Mechanisms Requirements”
- File folder containing CAD model of S/C
- File folder containing finite-element model of S/C
- Technical Note “Technical Risks associated to Structure & Mechanisms S/S Design”
- Technical Note “Cost Model and Breakdown for Structure & Mechanisms S/S”
- Technical Note “S/C TCS Subsystem Detailed Design”
- Technical Note “S/C TCS Requirements”
- File folder containing thermal simulations
- Technical Note “Technical Risks associated to TCS S/S Design”
- Technical Note “Cost Model and Breakdown for TCS S/S”

Tasks specifically excluded:

None

1.3.1.4.1 OBDH S/S

PROJECT:	**ASTRI - Commercial Micro-Moon Lander (MML)**			WP REF: **460**
WP-Title:	**OBDH S/S**			Sheet **1** of **1**
Contractor:	**N/A**			
Major Constituent**:**				Issue Ref: **1**
Start Event:	**Kick-Off**	Planned Date:	**T0**	
End Event:	**End of Project**	Planned Date:	**T0+18m**	Issue Date: **08/12/2017**
WP-Manager:				

Objective:

- To design the OBDH S/S of the S/C.

Required Inputs and Conditions:

- Kick-Off
- Constant feedback loop with WP400

Tasks Description:

- OBDH requirements analysis and write-up, trade-off options and define concepts and implementation
- Design of main processing unit, payload data storage unit, handling of onboard time, onboard data bus architecture, data harness
- Concept for monitor & control of platform and payload health, receiving TCs, transmitting TM, communications security (encryption), essential TCs, fail-safe operations, command queue(s), FDIR
- Functional architecture and physical architecture of S/S
- Outline the interfaces between different units and sub-systems: low speed data bus(es), high speed data bus(es), RS422, SpW or the likes
- Refine the trade-off on-board vs. ground processing on specific data streams, in coordination with WP400

Outputs:

- Technical Note “S/C OBDH Subsystem Detailed Design”
- Technical Note “Overview of S/C Onboard Software Architecture”
- Technical Note “S/C OBDH Requirements”
- Technical Note “Technical Risks associated to OBDH S/S Design”
- Technical Note “Cost Model and Breakdown for OBDH S/S”

Tasks specifically excluded:

None