ESA-PDX-EXM2-CZ-CCN-000L

PRODEX EXPERIMENT ARRANGEMENT CHANGE NOTICE
Institute: Institute of Atmospheric Physics (IAP) Prague
PEANo: 4000117599 CN No: 2
Contract: MAIGRET-WAM

Title of area affected **Main tasks, work breakdown, cost**	Article(s) of the Arrangement: 2 Initiator of change: IAP
Description of change Procurement, assembly, test and integration of additional WAM sensor assembly (magnetic search coils and electric antenna)	
Reason for change Impossibility to secure WAM sensors according to the original pian of the project. WAM sensor assembly not covered by Ukranian contribution due to political issues between Russia and Ukraine.	
Funds *in addition to* those stipulated in Article 2.1: 71.000 € The grand total now reads 387 800 €.	
Effect on other Arrangement provisions N/A	Commencement of Term 01-12-2018 End of Term 31-12-2020
Institute	
Institute's representative(s): Dr. Zbyněk Sokol, director	Date - 3 -10- 2018
ESA	
PRODEX Office representative: Jens Loehring Veronique Dowsoii Michel Lazerges	Date 17/09/2018

Appendix 1

Work Description

Overall Objective (mission):

The ExoMars Programme consists of two missions to Mars which are planned to be launched in 2016 and 2020. The launch of the latter mission is planned for July 2020 from Baikonur on Proton M. The anticipated arrival to Mars will be in April 2021. The landing is planned by a direct entry from a hyperbolic trajectory, after the dust storm season. The landing site is still to be defined, but must be safe for landing and appropriate for "search for life" science. Anticipated latitudes are between 59 S and 25® N, all longitudes.

The mission will land a Rover, provided by the European Space Agency (ESA), making use of a 2000-kg Descent Module (DM) contributed by the Russian federal space agency (Roscosmos). The DM will travel to Mars on an ESA-provided Carrier Module (CM). Roscosmos will launch the spacecraft composite on a Proton rocket. The Rover will be equipped with a European and Russian suitě of instruments, and with Russian Radioisotope Heating Units (RHUs). The Rover will also indude a 2-m drill for subsurface sampling and a Sample Preparation and Distribution System (SPDS), supporting the suitě of geology and life seeking experiments in the Rover's Analytical Laboratory Drawer (ALD). The Russian Surface Platform (SP) will contain a suitě of instruments which will be mainly concentrated on environmental and geophysical investigations. Within Roscosmos, ExoMars is part of the Russian federal space programme and is supported by the Russian Academy of Sciences.

The ExoMars programme's scientific objectives are:

1. To search for signs of past and present life on Mars;
2. To investigate the water/geochemical environment as a function of depth in the shallow subsurface;
3. To study martian atmospheric trace gases and their sources;
4. To characterise the surface environment.

The ExoMars Surface Platform will conduct environmental and geophysical measurements in support of objective 4. After the Rover is released, the ExoMars Surface Platform will begin its science mission to study the surface and subsurface environment at the landing location. Data relay function will be provided by the Trace Gas Orbiter (TGO) launched as a part of the 2016 ExoMars mission. Whereas the Rover with the Pasteur payload (mass 310 kg, including drill/SPDS and instruments) is designed for a lifetime of 220 sols, the surface platform has anticipated lifetime of 1 Martian year (~670 sols), i.e., April 2021-February 2023 (ExoMars Science Management Pian, v6).

The proposed Surface Platform instruments are defined in the ExoMars 2020 Surface Platform Experiment Proposal Information Package (EXM-SP-EPIP-IKI-0001) of 31 March 2015. This package defines technical, managerial and programmatic data relevant in the context of the Announcement of Opportunity (AO) for European payload elements on the Surface Platform (SP) of the ExoMars 2020 mission. SP has anticipated lifetime of one terrestrial year according to this document. The SP science payload development is the responsibility of Roscosmos, with the exception of the contributions selected through this call.

Roscosmos has named the Space Research Institute of Russian Academy of Sciences (IKI) to be the leading entity for the development of the SP scientific payload, with the exception of the contributions selected through this call. IKI will manage the development of the SP payload according to Russian standards. The following European contributions to Russian-led instruments are envisaged:

1. Instrument: METEO

- Humidity sensor
- Pressure sensor
- Optical depth sensor
- Solar irradiance sensor
- Magnetometer
- Dust sensor

Contact : A. Lipatov (PI, XXXXXXXXX

2. Instrument: FAST
- Interferometer unit

Contact: A. Shakun (PI) XXXXXXXXX A. Grigoriev XXXXXXXXX

3. Instrument: M-DLS
- Spectroscopic support, procurement and characterisation of diodě lasers, principál optical, vacuum, electronic parts and modules, laboratory M-DLS prototype characterisation, development of the inversion algorithms

Contact: I.Vinogradov (PI)

4. Instrument: Dust Suitě
- Aerosol particle counter
- Electric field sensor

Contact: G. Dolnikov (PI) XXXXXX , A. ZakharovXXXXXXXXX

5. Instrument: MGAP
- Mass spectrometer

Contact: M. Gerasimov (PI) XXXXXXXXX

6. Instrument: MAIGRET
- Wave analyser module

Contact: A. Skalsky XXXXXXXXX

The Wave analyser module which is the subject of this PRODEX proposal is a part of the MAIGRET (MArtlan GRound Electromagnetic Tool) instrument. Its development would be based on our previous cooperation with IKI in theframe of the Resonance and Luna-Resource-Orbiter spacecraft projects, where we work on similar hardware contributions.

The module will be dedicated for the measurement of magnetic-field fluctuations in the frequency band from 100 Hz to 20 kHz. The main scientific targets of the Wave analyser module are:

a) electromagnetic emissions of atmospheric origin: dust storms, wave activity originated in electrical discharges;
b) ionosphere and atmosphere-lithosphere interactions on Mars related to space weather effects;
c) magnetic anomalies on the surface of the planet;
d) internal structure of the planet using electromagnetic sounding methods based on the analysis of the response of deep conductive structures to excitation by time-varying external electromagnetic field of natural origin.

Role of the Institute:

The Institute of Atmospheric Physics (IAP) of the Czech Academy of Science is proposing to develop, build, test, and operáte the Wave analyzer module for the MAIGRET instrument (PI: A. Skalsky, IKI), as a part of the European payload element on the Surface Platform of the ExoMars 2020 mission, with

Dr. Ondřej Santolík having the role of Co-Principal Investigator of the MAIGRET instrument with the overall responsibility for the Wave analyzer module.

Project term (to be) covered by the PRODEXExperiment Arrangement:

Phases B-D, definition and implementation: 2015 – 2020

Further phases:

- launch in July 2020,
- cruise phase: July 2020-April 2021,
- nominal operations: April 2021-February 2023,
- data reduction, submission of data products to the planetary science archives: **2021-2022.**

Brief description ofMain Tasks:

The Wave analyzer module for the MAIGRET instrument will measure magnetic-field and electric-field fluctuations in the frequency band from 100 Hz to 20 kHz and electric field fluctuations up to 8 MHz. The design of the module will correspond to its scientific goals and technical limitations of the instrument. The module will measure both overview spectra and short waveform packets.

The design will be largely based on heritage from the Resonance ELMAVAN instrument, Luna-Resource-Orbiter LEMRA-L instrument, TDS subsystém of the Solar Orbiter RPW instrument, IME-HF analyzer for the TARANIS mission of CNES, and the JUICE RPWI- LFR subsystém, in order to savé the development time in the very tight project schedule. This is a very important aspect of the project.

The Wave analyser module will perform digitization and onboard Processing of the signál from the sensor assembly composed of a horizontál magnetic field search coil, a deployable vertical electric field antenna, preamplifiers and deployment electronics. The signál will be processed by integrated digital logic implemented in an FPGA, performing filtering, decimation and spectral analysis of the signals. This science-based on-board processing allows us to savé spacecraft telemetry and increase coverage by high quality pre-processed scientific data products. The device will contain analog circuits for input signál conditioning, as well as digital data processing and communication circuits. The search coil and electric antenna signals will first pass through anti-aliasing low pass filters. Further processing improves dynamic range and produces 16-bit digital data. All digital processing is doné in an FPGA. Tasks include ADC control and data acquisition, input CIC and/or FIR digital filters with decimation, FFT and power spectrum calculation, data buffering, and communication with the S/C data acquisition and control subsystems (telecommand processing, telemetry packet preparation and transmission).

The wave analyser will use a part of the 1 kByte/s digital bandwidth of the MAIGRET instrument to generate compressed data products related to its scientific goals, including the results of the onboard spectral analysis of the search coil and electric antenna signals and waveform snapshots. The components, materials and processes will be also compliant with the temperature range limits of the MAIGRET instrument, leading to operational temperatures from –20 °C to +50 °C and storage temperatures from –50 °C to +50 °C. The mass and power consumption limits of the MAIGRET instrument (1.7 kg and 5W, respectively) will be taken into account in the analyser and sensor assembly design. The electronics board of the analyser will be placed in the MAIGRET box which will be powered by a separate power supply systém of the platform in order to increase the reliability of the instrument. The sensor assembly (a horizontál magnetic field search coil, a deployable vertical electric field antenna, preamplifiers and deployment electronics) will be attached to the outer edge of one of the solar panely

The EXOMARS surface platform is assigned COSPAR planetary protection category IVa, as it is not supposed to carry instruments for the investigations of extant Martian life. Reflecting the category IVa requirements, the bioburden of the Wave analyzer module shall be ≤ 3x105 bacterial spores and the average bioburden of the Wave analyzer module shall be ≤ 300 bacterial spores/m^2 on exposed internal and external surfaces.

The Wave analyzer module will be compatible with Dry Heat Microbial Reduction (DHMR), alcohol deaning (IPA or ethanol) and with damp swab assays as per assay procedure described in ECSS-Q-ST-70-55C (Microbial examination of flight hardware and cleanrooms). Parts qualifications and manufacturing processes when selecting components will be considered with respect to planetary protection requirements as described in ECSS-Q-ST-70-53C (Materials and hardware compatibility tests for sterilization processes). The flight hardware will be assembled and tested in ISO 7 clean room conditions and transported in an appropriate transport Container. The bioburden on the Wave analyzer module at delivery on exposed internal and external surfaces will be assessed and documented. The bio burden monitoring procedures will respect the contamination predictions budgets. Corrective actions in terms of design, shielding and purging in čase the predictions are outside acceptance limits will be defined.

Cleanliness and contamination control is an integrál part of planetary protection tasks as the DHMR treatment could be a potential source of molecular and particular organic contamination. Firstly, the dead bioburden is not removed by DHMR and secondly the exposure to high temperatures might produce contaminants by outgassing. Parts qualifications and manufacturing processes when selecting components will be considered with respect to cleanliness and contamination control requirements as described ECSS-Q-ST-70-01C (Cleanliness and contamination control). The materials will be selected according to the outgassing criteria (TBD) using the ESA outgassing database. (http://esmat.esa.int/Services/outgassing_data/outgassing_data.html).The flight hardware will be assembled and tested in ISO 7 clean room conditions and transported in an appropriate transport Container.

IAP will be responsible as a Co-Principal Investigator institute for the development of the proposed Wave analyzer module for the MAIGRET instrument, as a part of the European payload element on the Surface Platform of the ExoMars 20182020 mission, taking responsibility for project management, interface with ESA and IKI, reviews and documentation. In the frame of the Wave analyzer module for the MAIGRET instrument IAP will be also responsible for the development and delivery of all subsystems (all required models), consisting of sensor assemblies, electronics boards, FPGA firmware and Ground Support Equipment. IAP has experience of building successful VLF receivers beginning with five MAGION missions. More recently, receivers with digital onboard Processing hávе been developed for the Resonance, Luna-Resource-Orbiter, and Solar Orbiter missions. IAP has also developed an HF receiver for the upcoming TARANIS mission and is developing an LF receiver subsystém of the RPWI instrument for the JUICE mission.

OverView of the work breakdown:

1. Project management
    - Tasks related to the PI role of the Wave analyzer module and Co-PI role of the MAGRET instrument
    - Management of the interface with ESA and IKI
    - Planetary protection tasks
    - Input to reviews and documentation

2. The main board of the Wave analyzer module for the MAIGRET instrument.

a) Development and design of algorithms for science-based onboard Processing

- Research of electromagnetic emissions of atmospheric origin
- Research of time-varying electromagnetic plasma waves of natural origin
- Implementation of algorithms for science-based onboard Processing

b) Thermal, mechanical, and electronics design

- Design contribution to the MAIGRET Structural Model (SM) and to the MAIGRET Thermal Model (TM)
- Mechanical, and electronics design of the Instrument Electrical Interface Simulátor (EIS) of the main board of the Wave analyzer module for the MAIGRET instrument.
- Thermal, mechanical, and electronics design of the EQM of the main board of the Wave analyzer module for the MAIGRET instrument.
- Update of the thermal, mechanical, and electronics design for the Flight Model (FM) and Flight Spáre Model (FSM) of the main board of the Wave analyzer module for the MAIGRET instrument.

c) FPGA and software design

- FPGA and software design of the Instrument Electrical Interface Simulátor (EIS)of the Wave analyzer module for the MAIGRET instrument.
- FPGA and software design of the EQM board of the Wave analyzer module for the MAIGRET instrument.
- Update of the FPGA and software design for the Flight Model (FM) and Flight Spáre Model (FSM) of the Wave analyzer module for the MAIGRET instrument.

d) Assembly/manufacturing

- Manufacturing and assembly of the Instrument Electrical Interface Simulátor (EIS)of the Wave analyzer module for the MAIGRET instrument (main board, delivered to IKI)
- Manufacturing and assembly of the EQM main board which will stay at IAP for future testing and analysis purposes
- Manufacturing and assembly of the Flight Model (FM) of the main board of the Wave analyzer module for the MAIGRET instrument (delivered to IKI).
- Manufacturing and assembly of the Flight Spáre Model (FSM) of the main board of the Wave analyzer module for the MAIGRET instrument (delivered to IKI).

e) Testing activities

- EGSE development
- Functional testing of the Instrument Electrical Interface Simulátor (EIS) of the Wave analyzer module for the MAIGRET instrument (delivered to IKI).
- Functional, thermal vacuum, and vibrational testing of the EQM main board.
- Functional, thermal vacuum, and vibrational testing, as well as the cleanliness and contamination control of the Flight Model (FM) of the main board of the Wave analyzer module for the MAIGRET instrument
- Functional, thermal vacuum, and vibrational testing, as well as the cleanliness and contamination control of the Flight Spáre Model (FSM) of the main board of the Wave

analyzer module for the MAIGRET instrument.

3. The sensor assembly of the Wave analyzer module for the MAIGRET instrument.

   a) Thermal, mechanical, and electronics design

      - Thermal, mechanical, and electronics design of the EQM of the sensor assembly of the Wave analyzer module for the MAIGRET instrument.
      - Update of the thermal, mechanical, and electronics design for the Flight Model (FM) and Flight Spare Model (FSM) of the sensor assembly of the Wave analyzer module for the MAIGRET instrument.

   b) Assembly/manufacturing

      - Manufacturing , assembly, and integration of the EQM sensor assembly which will stay at IAP for future testing and analysis purposes
      - Manufacturing, assembly, and integration of the Flight Model (FM) of the sensor assembly of the Wave analyzer module for the MAIGRET instrument (delivered to Thales).
      - Manufacturing, assembly, and integration of the Flight Model (FM) of the sensor assembly of the Wave analyzer module for the MAIGRET instrument (delivered to Thales).

   c) Testing activities

      - Functional, thermal vacuum, and vibrational testing of the EQM sensor assembly
      - Functional, thermal vacuum, and vibrational testing, as well as the cleanliness and contamination control of the Flight Model (FM) of the sensor assembly of the Wave analyzer module for the MAIGRET instrument.
      - Functional, thermal vacuum, and vibrational testing, as well as the cleanliness and contamination control of the Flight Spare Model (FSM) of the sensor assembly of the Wave analyzer module for the MAIGRET instrument.

Projed output at the end of the term specified in the PRODEX Experiment Arrangement in terms of:

- Design and documentation contribution to the Structural Model (SM) of MAIGRET, in cooperation with IKI
- Design and documentation contribution to the Thermal Model (TM) of MAIGRET, in cooperation with IKI
- Instrument Electrical Interface Simulator (EIS)of the Wave analyzer module for the MAIGRET instrument (main board, delivered to IKI)
- EQM board which will stay at IAP for future testing and analysis purposes
- Flight Model (FM) of the Wave analyzer module for the MAIGRET instrument (main board and sensor assembly, delivered to IKI).
- Flight Spare Model (FSM) of the Wave analyzer module for the MAIGRET instrument (main board and sensor assembly, delivered to IKI)
- Input to all documentation packages for IKI reviews. IKI will manage the documentation according to Russian standards. No self-standing WAM documentation is foreseen to be delivered at WAM level.

Major Milestoneš (if any): • MAIGRET SM and TM delivery – December 2015 (in cooperation with IKI). • Wave analyzer module EIS delivery to IKI– December 2017. • Wave analyzer module FM and FSM delivery to IKI/Thales – February 2019 (TBC).

Appendix 2

FINANCIAL PLAŇ

Definition and implementation of the Wave analyzer module for the MAIGRET instrument as a part of the European payload element on the Surface Platform of the ExoMars 2020 mission

Institute of Atmospheric Physics, Czech Academy of Sciences

Starting date: December 2015

Ending date: December 2020

INSTITUTE COSTS	**Phase B**	**Phase C**	**Phase D**	**Total**
	Dec 2015-May 2016	Jun 2016-Dec 2017	Dec 2017 – Dec 2020	Dec 2015-Dec 2020
Salaries + insurance				
IAP staff (9 employees, funded in part by IAP) 1. XXXXXXXXXXXX 2. XXXXXXXXXXXX 3. XXXXXXXXXXXX 4. XXXXXXXXXXXX 5. XXXXXXXXXXXX 6. XXXXXXXXXXXX 7. XXXXXXXXXXXX 8. XXXXXXXXXXXX 9. XXXXXXXXXXXX	18 000	18 000	18 000	54 000
Additional engineers hired for the project	10 000	10 000	15 000	35 000
Total salaries:	28 000	28 000	33 000	89 000

Smáli Equipment, components, software	15 000	15 000	35 000	65 000
Services	30 000	30 000	60 000	120 000
Travel	18 000	18 000	18 000	54 000
Search coil procurement	0	0	27 000	**27 000**
Institute overhead	9 100	9 100	14 600	32 800
Total	100 100	**100 100**	**187 600**	**387 800**

FIGUŘE 1: Financial Pian in of Euros

Equipment to be purchased via PRODEX (in Euros) for information only:

Equipment	**Phase B**	**Phase C-D**	**Total**
Flight/EM parts & PCB • Main board (notes 9))	23 000	327 000	**350 000**
• Preamplifier and deployment PCB (new item)		5 000	**5 000**
• Add. components		21 000	21000
Qualified assembly	0	32 000	**32 000**
Total	**23 000**	**385 000**	**408 000**

Additional funds for equipment to be purchased via PRODEX is 21 000 € (for information only).

Notes:

1) Funding request is conditional to the selection of Wave analyzer module for the MAIGRET instrument as a part of the European payload element on the Surface Platform of the ExoMars 2020 mission.
2) The salaries for the remuneration of work on defmition and implementation of Wave analyzer module which will be carried out by IAP personnel are in accordance with Czech PRODEX rules (XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX
maximum 8000 EUR per year and person for IAP stan, anu maximum 20000 EUR per year for an engineer hired for the project). The labor cost funded from PRODEX corresponds to 0.9 FTE in phases B and C, increased to 1.1 FTE in phase D. IAP contributes by institutional funding toward the labor cost of 4.5 FTE, increased to 5 FTE in phase D.
3) Travel expenses are calculated using an average cost of 900 EUR per person for a short trip. We expect the necessity of 10 trips in each phase of the project, with 2 persons participating, on average.

4) "Smáli Equipment, components, and software" include the components for development and breadboarding, transport equipment, manufacturing and integration of mechanical parts for the sensor assembly, and necessary licenses for the PCB and FPGA development software.

5) Services include the manufacturing of PCBs for development and breadboarding, fast shipping Services, main board and sensor assembly testing expenses, and assembly of the EIS and EQM boards

6) Institute overhead is 10%, in accordance with Czech PRODEX rules (http://www.msmt.cz/vyzkum-a-vyvoj/evropska-kosmicka-agentura-program-vývoje-vedeckych?lang=1)

7) The "Flight/EM parts & PCB" budget includes the flight components and qualified flight PCB manufacturing for 3 models of the main electronic board and sensor assembly with the preamplifier and deployment electronics: Flight Model (FM) of the Wave analyzer module (main board and sensor assembly); Flight Spáre Model (FSM) of the Wave analyzer module (main board and sensor assembly); one EQM board and sensor assembly which will stay at IAP for future testing and analysis purposes. FM development also includes software adjustments during the cruise phase.

8) The Qualified assembly of 2 models (FM and FSM) will be doně in an ISO 7 clean room.

9) Budget for main board was reduced by 5 000 €.

10) All changes described here were agreed between IAP and the Ministry of Transport. Prices for search coil procurement are covered by appropriate quotation.