COORDINATED SCIENCE OPERATIONS OF MARS EXPRESS ORBITER AND LANDER. R. Trautner, A. C. Chicarro, P. D. Martin, European Space Agency, Research and Scientific Support Department, ESA/ESTEC, Noordwijk, The Netherlands (e-mail: Roland.Trautner@esa.int)

Introduction: The Mars Express orbiter carrying the Beagle2 lander will arrive at Mars in late 2003 [1,2]. Both spacecraft carry a comprehensive set of instruments for the investigation of Mars. Many of the orbiter and lander instruments measure the same or similar parameters of the Martian environment. A coordination of these measurements will allow the acquisition of ground truth for the orbiter investigations, and allow the extrapolation of data obtained at the Beagle2 landing site to the global coverage provided by the orbiter. Tables 1 and 2 provide an overview of the orbiter and lander payloads and their science goals, as well as potential areas for the coordination of science operations.

Orbiter and Lander Science Operations: The operations of the Mars Express orbiter instruments are based on a long-term plan called the Master Science Plan (MSP). Its purpose is to schedule the acquisition of science data by the Mars Express spacecraft in a way that is consistent with both the scientific objectives of the mission and the resources available for that data collection [3]. The orbiter data acquisition periods are predefined for each orbit and referenced to the respective orbit pericentre. The orbit design is based on a so-called “frozen ground track”, which allows to enter the planned science sequence at a later point in time in case of complications, while maintaining the original science planning for the continued mission.

The operations approach used for the Beagle2 lander differs significantly from the one used for the orbiter. After a successful landing, Beagle2 will perform an automated sequence of activities in order to reach a safe standby condition for surviving the time until initial contacts. In a first operational phase a number of initial activities are performed, such as post landing assessment, system checkouts and a first acquisition of environmental data, followed by the deployment of the PAW and a first topographic landing site survey. During a second operational phase, activities comprising atmospheric analysis, calibration activities, soil and rock analysis will be performed. A third operational phase will be used to complete the full palette of scientific activities the lander is able to perform, and continue operations until the end of the Beagle2 lifetime.

Coordinated Operations: The planning of coordinated operations on the MEX orbiter side will be part of the Master Science Plan. Opportunities for coordinated operations will be identified in advance, and the corresponding orbiter instrument activities are implemented in the MSP. Most of these opportunities will take place during Beagle2 flyovers, which happen 3-4 times per week on average. Due to constraints like illumination conditions, orbiter altitude etc., only part of the flyovers will be used for coordinated operations. During the nominal Beagle2 lifetime of up to six months, there will be about 40-50 opportunities during orbiter passes. In addition to those, a number of measurements will be done during solar and stellar occultations involving the atmosphere above the landing site.

On the lander side, the planning of science activities will be dominated by a short-term operations plan worked out in the time between radio contacts. Progress will depend on the latest status of onboard systems, achievements during previous operations, and lessons learned as work progresses. In order to allow the coordination of operations, a Coordinated Operations Timeline (COT) will be established, which is essentially a list of lander payload activities corresponding to the orbiter activities during an opportunity for coordinated operations. If the lander conditions (general status, available resources, lander primary science mission) allow to perform these activities, they are incorporated into the lander operations and executed during the corresponding activity period.

Conclusion: The Mars Express orbiter and the Beagle2 lander will provide both remote sensing and in-situ data on the Martian environment. Coordinated operations are planned as part of the orbiter Master Science Plan. A Coordinated Operations Timeline is provided for the incorporation of coordinated activities into the lander operations planning as far as the lander status allows. Coordinated measurements will allow to compare orbiter and lander data on the Beagle2 landing site, obtain ground truth for the orbiter measurements, and allow to apply lessons learned from the data comparison to the global dataset provided by the Mars Express orbiter. It is expected that the coordination of orbiter and lander science operations will maximize the scientific output of the Mars Express mission.

References: [1] Schmidt R., Credland J.D., Chicarro A.F. and Moulinier Ph. (1999) *ESA Bulletin, #98*, 56-66. [2] Sims M., Pillinger C. T., et al. (1999) *Adv.in Space Research*, Vol. 23, 11, 1925-1928. [3] Martin P. D. and Chicarro A. F. (2001) *LPS XXXIII*, Abstract #1495. More information on Mars Express orbiter and Beagle2 lander can be found at http://sci.esa.int/marsexpress/ and http://www.beagle2.com/.

Legend: imaging (i) atmospheric composition (a) water (w) temperature&pressure (tp) surface materials (s) dust&aerosols (da)

Acronym	Instrument	Institute	Science Goals
HRSC	Super/High-Resolution Stereo Color Imager	DLR, Berlin (D)	Characterization of the surface structure, topography and morphology at high spatial resolution (up to 10m/pixel) / super resolution (up to 2m/pixel) (i). Characterization of terrain composition and surface physical properties at high spatial resolution (s). Characterization of atmospheric. phenomena (tp,da).
OMEGA	IR Mineral. Mapping Spectro-meter	IAS, Orsay (F)	Characterization of the composition of surface materials, space and time distribution of the various classes of silicates, hydrated minerals, oxides and carbonates in soils and rocks, (s), and of ices and frosts (w), at medium resolution. Study the distribution of atmospheric CO_2, CO (a), H_2O (w) and aerosols (da).
MARSIS	Subsurface-Sounding Radar/Altim.	Univ. of Rome, JPL (I / USA)	Primary objective: map the distribution of water in the upper crust of Mars (inventory, mechanisms of transport and storage, stability at the surface) (w). Subsurface geo-logic probing (s), surface characterization (i), ionosphere sounding.
PFS	Atmospheric Fourier Spectro-meter	CNR-IFSI, Rome (I)	Global monitoring of the 3D temperature field in the lower atmosphere (tp); measure-ments of CO (a), H_2O (w), search for other atmospheric components; D/H ratio (a); atmospheric aerosols (da); atmospheric radiance balance (tp), global circulation. Surface temp. and thermal inertia (tp); restrictions of mineralogical composition of the surface layer (s); nature of surface condensates (a,w); pressure and height local determination (CO_2 altimetry) for selected regions (tp).
SPICAM	UV and IR Atmospheric Spectrometer	CNRS, Verrieres (F)	Investigate key issues about ozone (a), its coupling with H_2O, aerosols (da), atmos-pheric vertical temperature structure (tp), ionospheric studies. H_2O abundances and vertical profiling of H_2O (w) and aerosols (da). Ozone detection, O_3 absorption. Verti-cal profiles of CO_2, temperature, O_3 (a), clouds and aerosols (da).
ASPERA	Energ. Neut. Atoms Anal.	SRI, Kiruna (SW)	Plasma investigations, study and imaging of atmospheric escape (a,w)
MaRS	Radio Sci-ence Ex-periment	Univ. Köln, (D)	Sounding of the Martian atmosphere to derive vertical density, pressure and tempera-ture profiles (tp), ionospheric sounding; bistatic radar experiments (s); study of gravity anomalies.

Table. 1. – Mars Express orbiter payload and science goals

Acronym	Instrument	Institute	Science Goals
GAP	Gas Analysis Package	Open University (UK)	Search for evidence of life past or present on Mars. Quantitative and stable isotopic measurements of gases such as H_2, N_2, O_2 and CO_2; Processing and determination of some of the Noble gases (Ne, Ar, and Xe) (a) as well as anticipated trace constitu-ents such as CH_4; either direct gas analysis (atmosphere), or analysis of gases liber-ated / created from sample heating / chemical processing (s) (*e.g.* conversion of or-ganic compounds and other forms of carbon (e.g. carbonates) to CO_2 by combustion). Processes of atmospheric evolution, circulation and cycling (a); analyze gases trapped in rocks and soils (s); low temperature geochemistry; fluid processes, organic chemistry, formation temp. ; rock ages, surface expos. duration.
ESS	Environmental Sensor Suite	Univ. Leices-ter, Open Univ. (UK)	Atmospheric temperature (tp); total accumulated radiation dose; momentum and rate of impact of aeolian transported Martian dust (da); concentration of oxidising vapours in the atmosphere (a) at a discrete time; UV flux (a,da); wind speed and direction, air temperature and pressure (tp); atmospheric density during entry / descent.
XRS	X-Ray Spec-tro-meter	Univ. Leicester (UK)	Primary goal of the XRS is to determine, in-situ, the geochemical composition, and by inference, the mineralogical composition and petrological classification, of the Martian surface material at the landing site (s)
MBS	Mössbauer Spectro-meter	Univ. Mainz (D)	Identification of Fe bearing phases; oxidation state of iron bearing minerals; identification of Fe carbonates, sulphates, nitrates etc.; determination of Fe oxides and the magnetic phase in the Martian soil; detection of nanophase and amorphous hydrothermal Fe minerals that could preserve biological materials (s).
SCS	Stereo Camera System	MSSL (UK) Space-X (CH)	Stereo imaging; construction of a Digital Elevation Model (DEM); panoramic imaging (i); Multi-spectral imaging of rocks and soils to determine mineralogy (s); Observations of the sun (absorption from water vapour) (w); determination of atmospheric optical density and aerosol (dust and water ice) (i,da,w); observations of Phobos & Deimos (spectral characteristics); Observations of dust properties (da); Observe optical effects due to CO_2 ice crystals. Observe transitory or seasonal changes (dune migration (s), surface frosts (a,w), clouds, haloes, dust devils (tp)).
MIC	Microscope	MPI Lindau (D)	Study physical / structural properties of surfaces, geophysical analysis (i,s); image dust and surface material particles (i,da); characterize samples for analytical instruments; assist chem. analysis (s); identify biostructures in samples; sky images (da)
PLUTO	Planetary Underground Tool	DLR Köln (D)	Serve as a soil sample acquisition device for GAP; perform in-situ temperature measurements (tp) as function of time and depth in the subsurface; investigate soil mechanical properties (s)

Table 2. – Beagle2 Lander payload and science goals