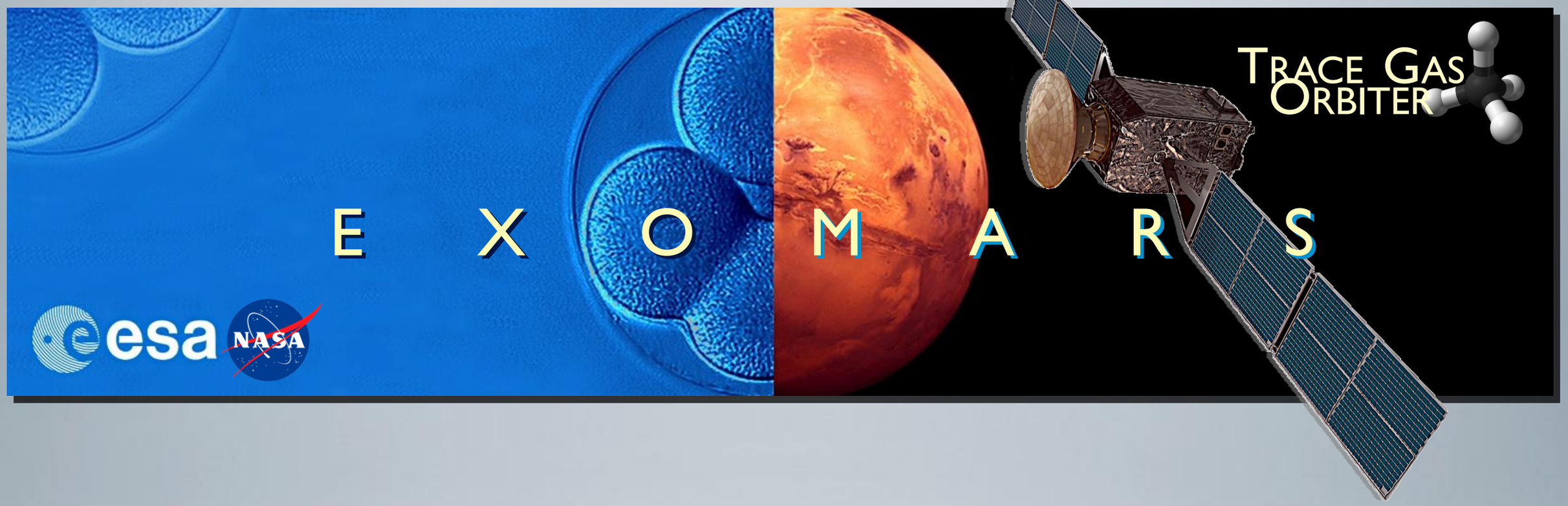


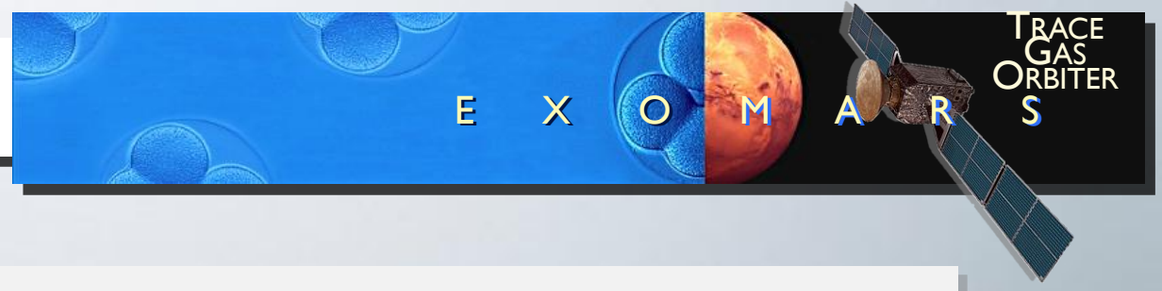
ExoMars 2016 Payload Selection

P. Crane, J.L. Vago

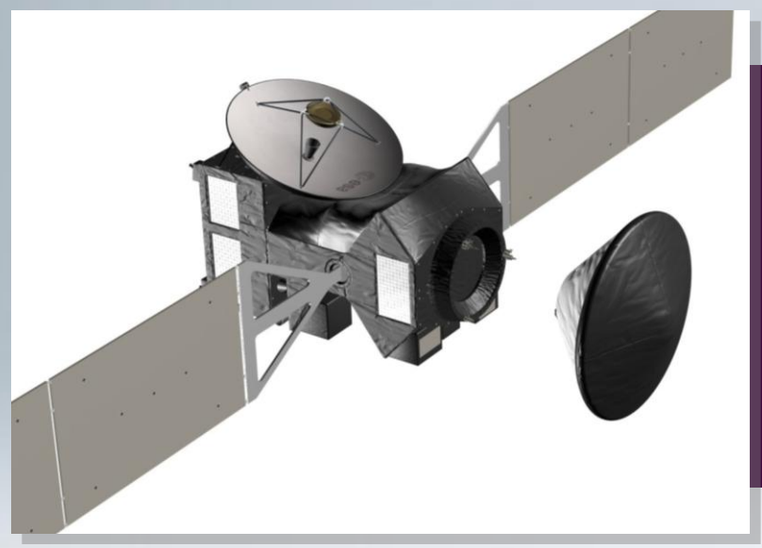
MEPAG #23

30 Sept 2010, Monrovia, CA

Programme Building Blocks



- ESA and NASA have agreed to embark on a joint Mars robotic exploration programme:
  - ➟ Initial missions have been defined for the 2016 and 2018 launch opportunities;
  - ➟ Missions for 2020 and beyond are in a planning stage;
  - ➟ The joint programme's ultimate objective is an international Mars Sample Return mission.

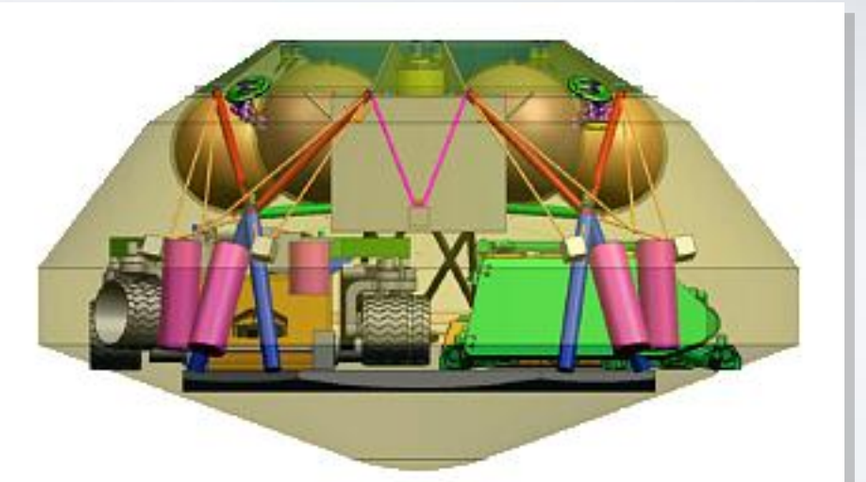


2016 ESA-led mission

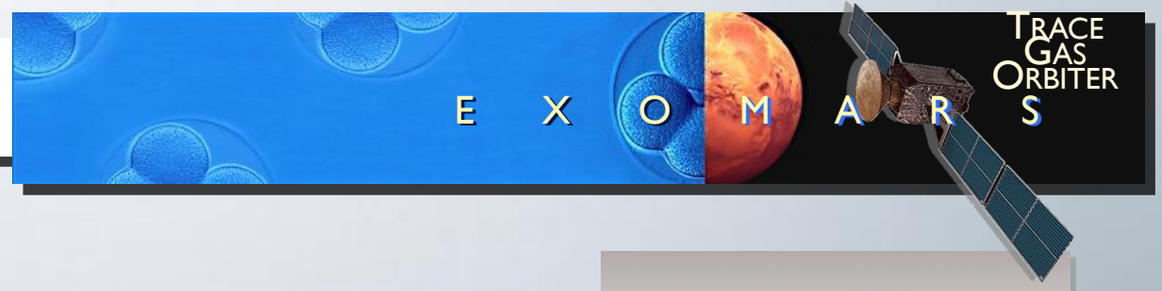
Launcher:	NASA – Atlas V 421
Orbiter:	ESA
Payload:	NASA-ESA
Lander:	ESA

2018 NASA-led mission

Launcher:	NASA – Atlas V 531
Cruise & EDL:	NASA
Rover 1:	ESA
Rover 2:	NASA



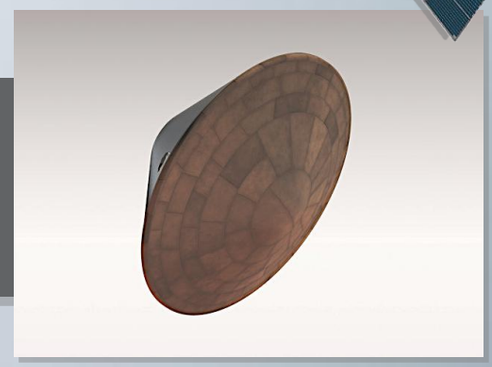
Mission Objectives



2016

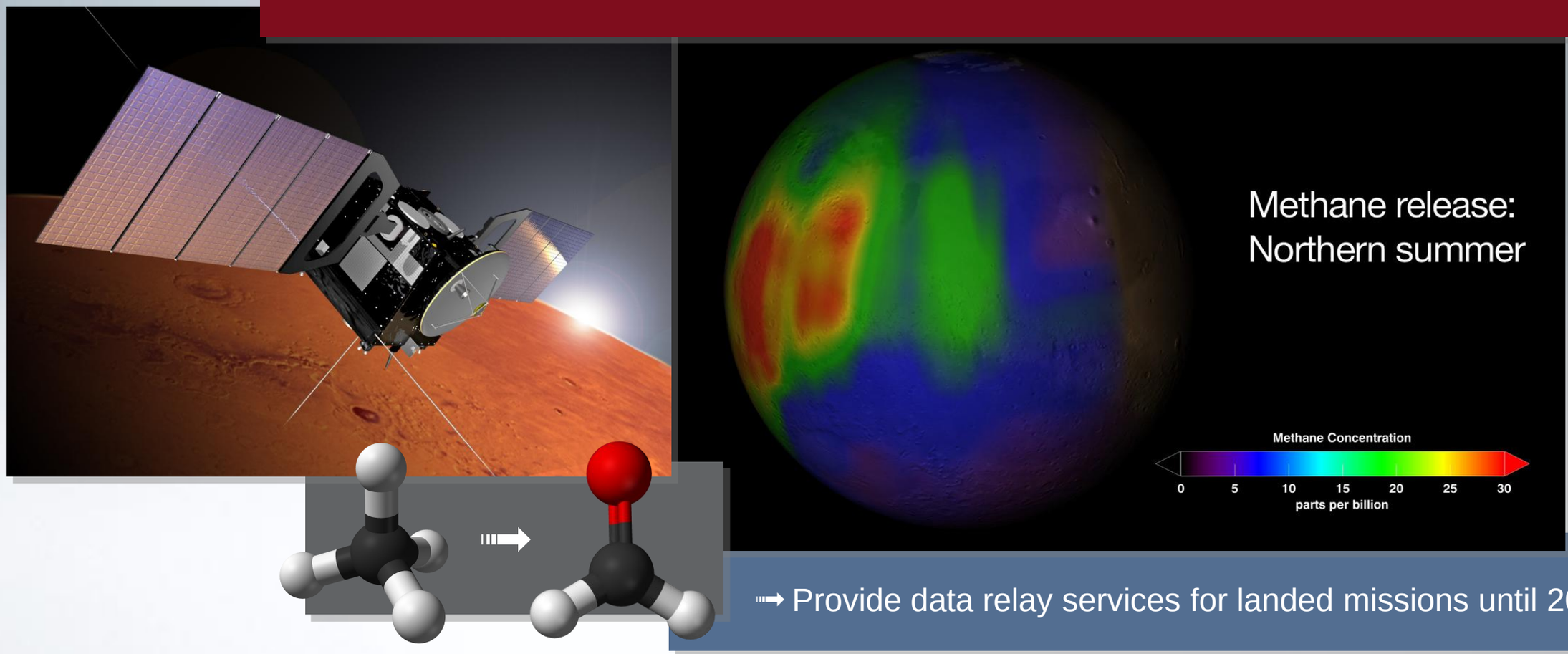
TECHNOLOGY OBJECTIVE

➟Entry, Descent, and Landing (EDL) of a payload on the surface of Mars.



SCIENTIFIC OBJECTIVE

➟To study Martian atmospheric trace gases and their sources.



➟ Provide data relay services for landed missions until 2022.

Scientific Goals

PRIORITISED GOALS (as indentified by the JIDT)

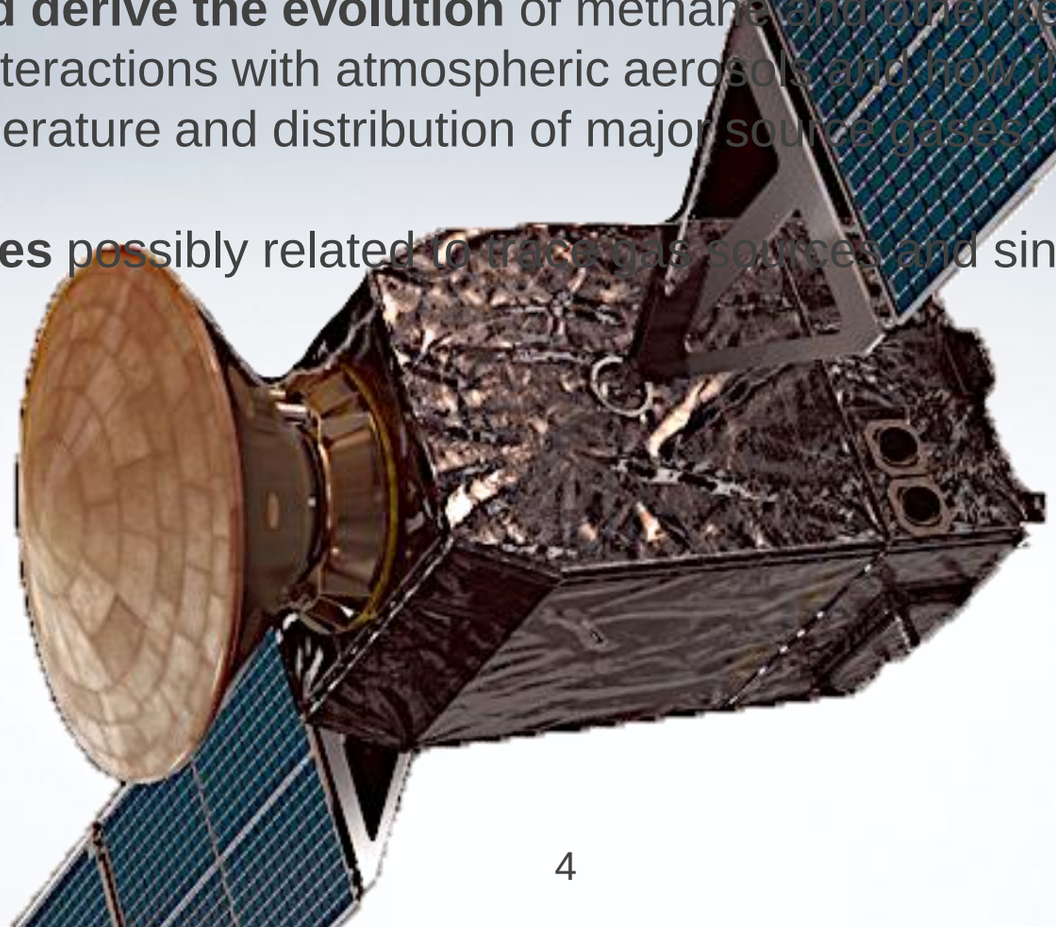
1.Detect a broad suite of atmospheric trace gases and key isotopes;

Identified molecules of interest include: CO_2, CO, H_2O, H_2O_2, NO_2 N_2O, O_3, CH_4, C_2H_2, C_2H_4, C_2H_6, H_2CO, HCN, H_2S, OCS, SO_2, HCl, CO and their isotopologues.

2.Characterise the spatial and temporal variability of methane and other key species, ideally representing families of photochemically important trace gases (HOx, NOx, hydrocarbons, etc.) and their source molecules (e.g. H_2O);

3.Localise sources and derive the evolution of methane and other key species and their possible interactions, including interactions with atmospheric aerosols and how they are affected by the atmospheric state (temperature and distribution of major source gases, e.g. water); and

4.Image surface features possibly related to trace gas sources and sinks.



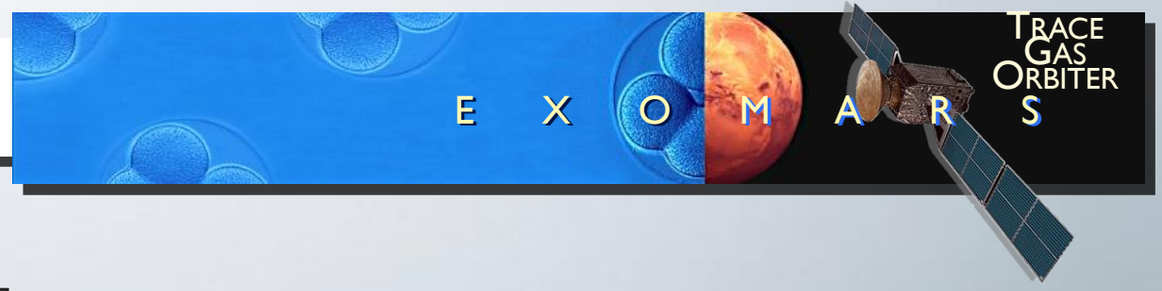
Solicitation & Selection(1/2)

- ESA's ExoMars Spacecraft bus design is mature.
  - PDR is in December 2010
  - Driving factor for the timescale of the selection
- ExoMars Trace Gas Orbiter (TGO) Announcement of Opportunity (AO):
  - AO released on 15 January 2010;
  - Used NASA's SALMON AO format as vehicle for the call:
  - **All electronic submission** (First time for an AO)
  - **Unique process to allow non-US(ESA) PIs to submit proposals**
  - NASA's NSPIRES system on the internet was utilised to release the AO, to provide responses to questions, and to submit proposals;
  - Notices of Interest (NOI) were due on 19 February 2010;
  - Proposals due on 15 April 2010
  - TMC, Science, and **Accommodation** Reviews
  - Selections Announced on 2 August 2010

Solicitation & Selection(2/2)

- Entire solicitation and selection was jointly conducted by ESA and NASA.
  - All Reviews, TMCO, Science, and Accommodation, included NASA and ESA participation.
  - Both agencies protocols for selection were followed
  - Selection letters were physically signed by both agencies

Evaluation Flow



Proposals Received 15 April

Science and Technical Merit Evaluation

Science Plenary

NASA Categorization Committee

TMC Evaluation

TMC Plenary

Annex 1 I/F Data

MEP PDD Assessment

ISCC Early Phase April-May

ISCC Plenary

Instrument/Spacecraft Compatibility Review

NASA/ESA Payload Recommendation

Instrument/Spacecraft Compatibility Check (ISCC)

ESA PB-HME Approval

ESA SSEWG

ExoMars TGO Announcement 2 August

Pre-selection Meeting Weiler/Southwood

NASA Selection Official Approval

NASA Steering Committee

Target: 20 July 2010

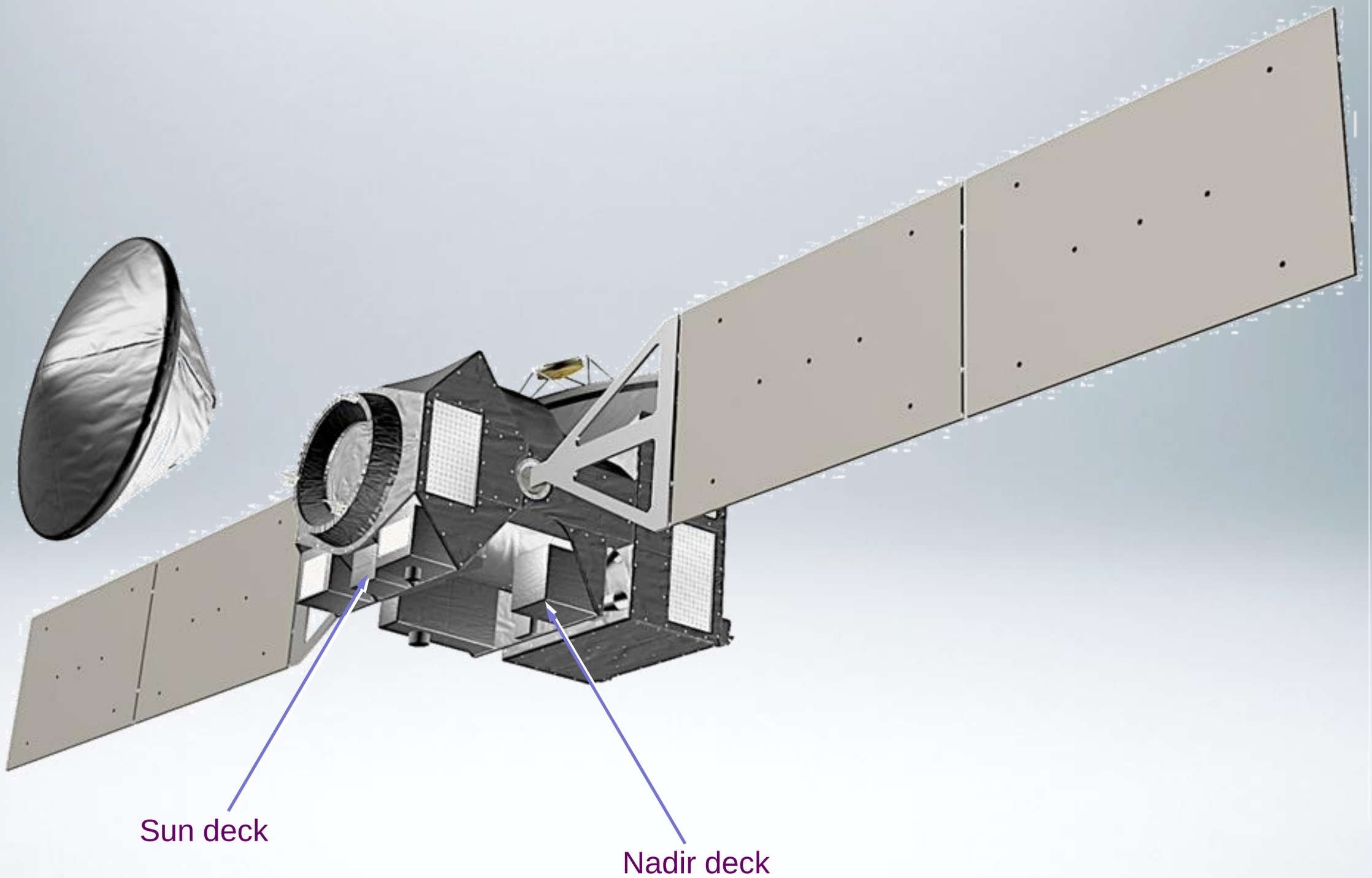
2016 ExoMars Trace Gas Orbiter Mission:

Accomplishments: Selected Payload

PRIORITISED GOALS	PAYLOAD		
1. **Detect a broad suite of atmospheric trace gases** and key isotopes with high sensitivity (≤ ppt):	**MATMOS** (10^{-2} ppt)	**USA**, CAN F	H/W Science
2. **Map their spatial and temporal variability** with high sensitivity (≤ ppb):	**NOMAD** (10^{-1} ppb)	**B**, E, I, UK USA, CAN	
3. **Determine basic atmospheric state** by characterising P, T, winds, dust and water aerosol circulation patterns:	**EMCS** (P, T, dust, ices, H_2O)	**USA**, UK F	
	MAGIE (Full hemisphere WAC)	**USA** B, F, RUS	
4. **Image surface features** possibly related to trace gas sources and sinks.	**HiSCI** (HRC 2 m/pixel)	**USA**, CH UK, I, D, F	

Excellent coverage of high-priority objectives.

Accommodation Study

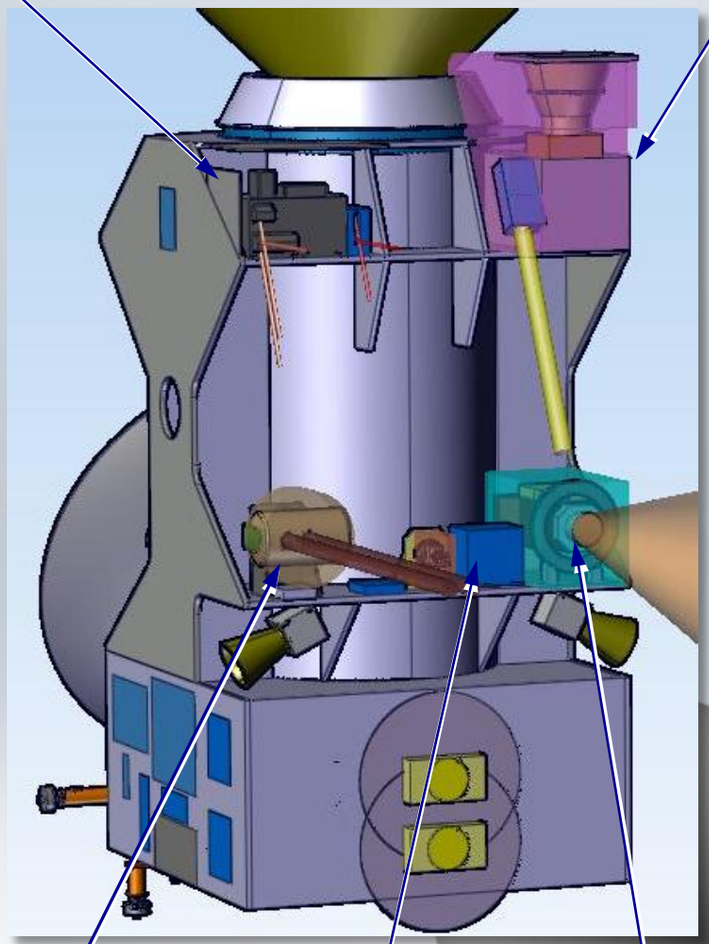


Instrument Accommodation

Payload

NOMAD +Z

MATMOS –Z



EMCS +Z

MAGIE Centre

HiSCI –Z

MATMOS

PI: Paul Wennberg Caltech

Co-PI: Victoria Hipkin Canadian Space Agency

Mission: Using IR (2.3–11.8 μm) solar occultation measurements, MATMOS will: 1) Search for atmospheric chemical tracers of geological and biogenic activity. 2) Quantify the lifetimes of diagnostic gases and establish the role of heterogeneous chemistry. 3) Quantify the exchange of water, CO_2 and their isotopologues with the surface and clouds, providing unique insight into the CO_2, dust, and water atmospheric cycles. 4) Help to understand upper atmosphere coupling for improving the description of atmospheric escape processes.

Teaming: Caltech (CIT) (PI), JPL (PM) (all US), ABB Bomem (CDN) via CSA.

Instrument: MATMOS is a Solar occultation Fourier Transform InfraRed spectrometer (SFTIR) with a co-aligned solar imager that will detect, profile, and map to parts per trillion (ppt) sensitivity trace gas species. To enable an investigation of chemical lifetimes, MATMOS will measure trace oxidants, clouds, and dust, and will make high precision profile measurements of major species, such as CO, O_3, H_2O, and their isotopologues together with temperature and pressure.

Important Features

- MATMOS will detect and quantitatively analyze trace gases of importance for understanding the exchange processes between surface and subsurface, and atmosphere.
- Addresses three of the mission's four science objectives.
- High sensitivity to a broad suite of trace gases will enable science success.
- High resolution Solar FTIR occultation is a powerful technique for detection of trace gases, at the ppt level.
- The coupling to a solar imager provides important data.
- Crucial FTS core is based on the robust ACE FTS design.
- The proposal reflects broad experience in methods for applying space-based Fourier Transform Spectrometer (FTS) systems to atmospheric applications, from data acquisition through data reduction.

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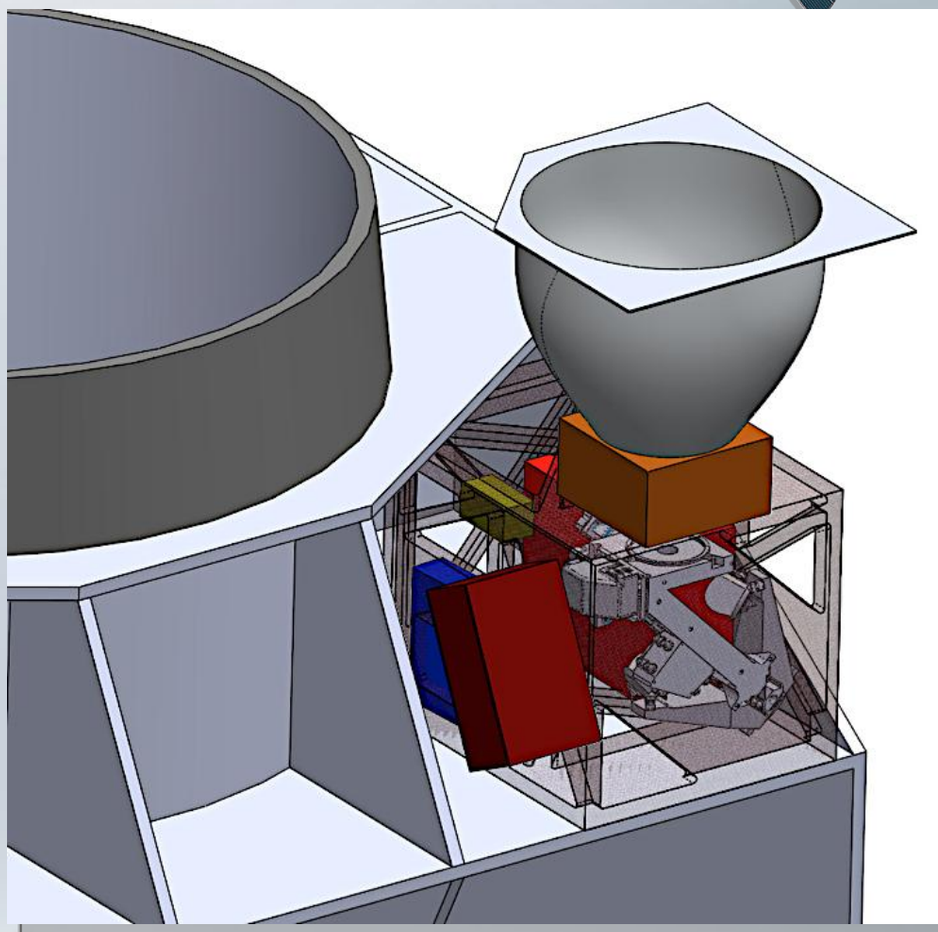
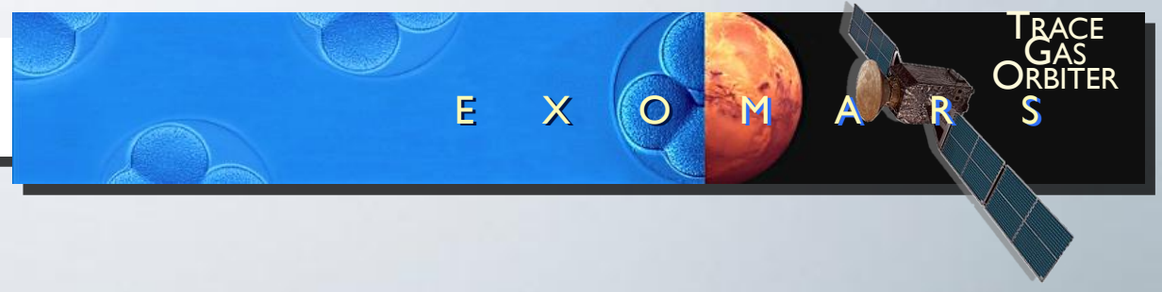


NOMAD



PI; Ann Carine Vandaele; IASB-BIRA

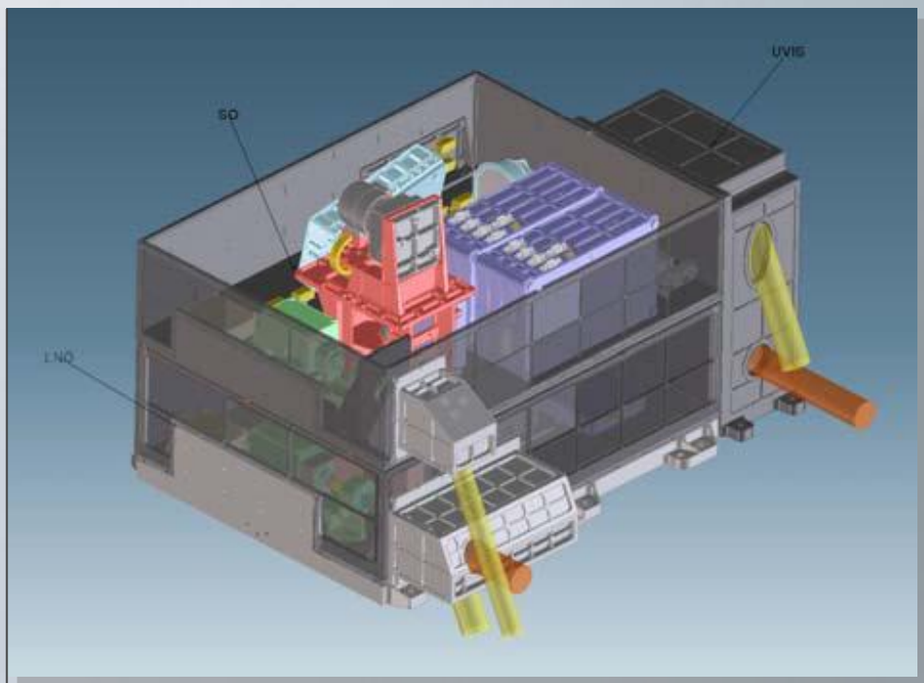
Mission: Perform a spectroscopic survey in UV, Vis and IR wavelengths covering the 0.2-0.65μm and 2.2-4.3μm spectral ranges; Detect a broad suite of trace gases and key isotopes, including atmospheric composition, isotopologue detection, escape processes, methane chemistry, and related geophysical and biogenic activity. Characterize the trace gas spatial and temporal variability

Teaming: IASB-BIRA (B) (PI/PM), IAA-CSIC (E), IDR/UPM (E), IFSI (I), Open Univ. (UK), NASA participation is at Co-I level only.

Instrument: NOMAD is a high-resolution, UV/visible/IR spectrometer observing in the 0.2–0.65 and 2.3–4.2 μm spectral ranges. It will operate in solar occultation, limb and nadir modes.

Important Features

- High Spectral Resolution;
- Adresses high priority objectives;
- Discovery potential is high;
- Detects molecules like O_3
- Important modeling and theory efforts;.
- The Solar Occultation channel has significant flight heritage, and is a build-to-print copy of the Solar Occultation in the Infrared (SOIR) / Venus Express (VEX) instrument presently in orbit around Venus with only minor modifications.
- All six primary participating organizations have extensive, recent applicable experience in the successful development of similar space flight instruments



EMCS

PI: Tim Schofiled JPL

Mission: Measure 4-D global fields for temperature, pressure, dust, ices, and water vapor in the Martian atmosphere (both during day and night) with a vertical resolution of 5 km (half scale-height) and coverage of 0–90 km. EMCS will map daily, global, pole-to-pole profiles of temperature, dust, water, and CO_2 ices, and water vapor. The measurements will cover all local times. These profiles will be assimilated into Mars General Circulation Models (GCMs) to generate global, interpolated fields of measured and derived parameters, such as wind.

Teaming: JPL (PI, PM) (US), Oxford U (UK), Reading U (UK), Cardiff U (UK), LMD (F).

Instrument: EMCS is an infrared, limb sounding, filter radiometer which uses 9 spectral channels from 12–45 μm. The 270° elevation/azimuth articulation allows daily, global, pole-to-pole coverage of Mars from the 74 ± 10° inclination TGO orbit. Uncooled (290 K), 21-element, linear thermopile arrays in each spectral channel permit atmospheric profiles to be derived from limb staring observations. Its spectral channels are distributed between two identical boresighted telescopes: one uses mid-IR interference filters, and the other uses mesh filters.

Important Features

- EMCS will satisfy several of the AO scientific objectives.
- Characterization of the spatial and temporal variation of methane and other key species and the localization of source regions contribute directly to the major goals.
- Well-designed instrument with strong heritage, and should meet the science goals in the proposal.
- Design and all technologies involved in the modifications comfortably fit in TRL 9.
- The EMCS team provides a detailed description of spacecraft accommodation and constraints, and the instrument's compliance to those criteria.
- The EMCS instrument is predominantly a build-to-print copy of the MRO Mars Climate Sounder (MCS) and the LRO Diviner instrumentation, with only minor modifications to two of the nine spectral filters, and to the spacecraft interfaces.
- The Ground Data System (GDS) at the JPL Science Operations Center (SOC) makes use of MCS heritage software, processes, & personnel.
- A very strong teaming arrangement is proposed, with JPL leading instrument development, supported by the same subcontract organizations that were successfully utilized on the MCS and Diviner instruments.
- Data products are fully described, based largely on experience with the MRO/MCS data management and archiving.

MAGIE

PI: Bruce Cantor Malin Space Science System

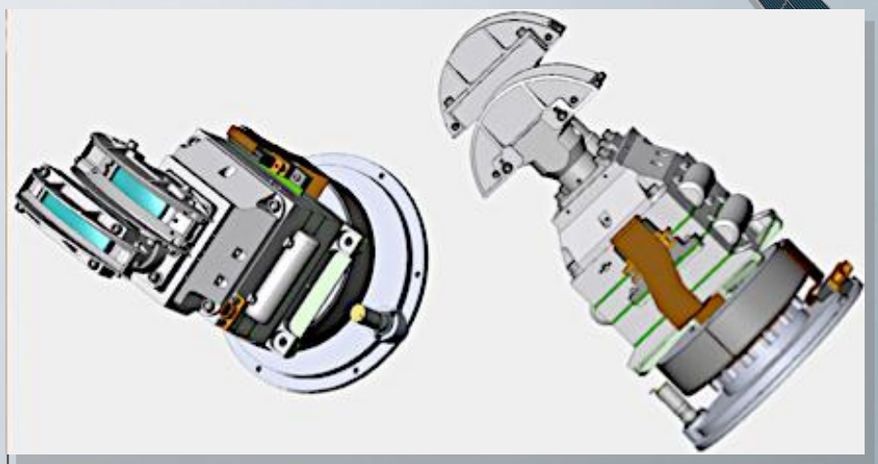
Mission: Provide meteorological context for trace gas observations; map the occurrence of atmospheric ozone; provide geologic/surface context for trace gas observations; and extend the daily global meteorological record of the MGS MOC and the MRO MARCI instruments.

Team: Malin Space Science Sys (MSSS) (PI, PM), Lightworks Optical, Alliance Space Systems, Barr Assoc, Cubic Defense Systems (all US); B, F, RUS science participation.

Instrument: MAGIE is a pushframe imaging system that acquires images in two visible and two UV bands. Mounted on a yaw turntable, MAGIE maintains a cross-track orientation to acquire global swaths of terminator-to-terminator limb-to-limb views at 4–6.4 km/pixel scale, and ~300 x 300 km subframes at 400 m/pixel. MAGIE consists of a camera head and a Digital Electronics Assembly connected by cable. The camera head includes the optics, a CCD detector, electronics, power conditioning, and a turntable sub-system that allows the instrument to keep its scan direction appropriately aligned independently of the spacecraft yaw attitude.

Important Feature

- MAGIE investigations will provide 50 important daily atmospheric maps to compare with the measured trace gas data.
- MAGIE wide angle camera can meet all of the wide angle imaging goals.
- This implementation would provide an extension of existing data and support the trace gas measurements.
- The team has recognized the limitations imposed by the spacecraft and has identified the work needed to implement a compatible system.
- The science team is a good combination of expertise from the US and Europe, and appears well qualified to carry out the proposed investigations.
- The MAGIE instrument design features a compact and well thought-out optical, electrical, and mechanical architecture.
- MAGIE's data acquisition concept stores full resolution images and only sends points of interest in full resolution when selected by the team



HiSCI

PI: Alfred McEwen; Univ. of Arizona

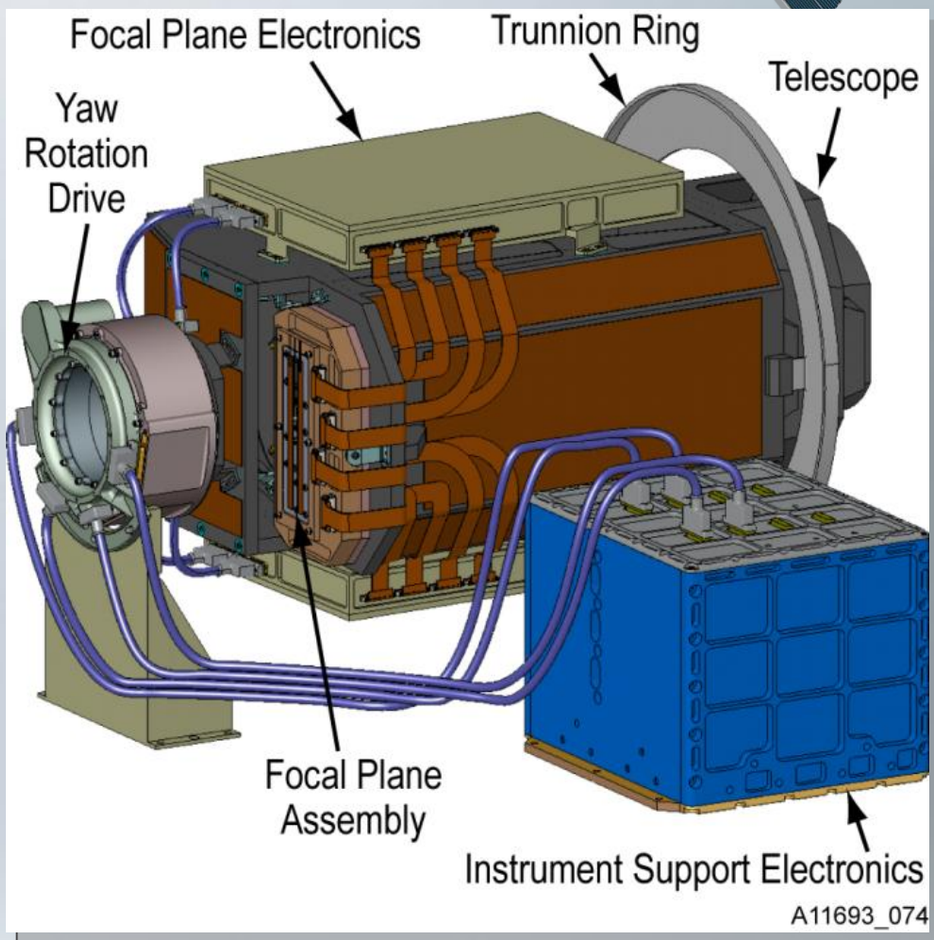
Mission: Understand active surface processes that effect atmospheric exchange on Mars through quantification of current activities by producing well-calibrated measurements of color and topography. Perform follow-up studies where trace gas release has been discovered, by quantifying surface color, topography, and active processes over specific regions.

Team: UArizona/LPL (PI, PM), BATC, UBern (CH).

Instrument: HiSCI uses an all-reflective telescope with Zerodur optics, a graphite composite structure, which points 10° off-nadir, and an off-axis three-mirror (powered, simple conic) anastigmat telescope. With the fold mirror, it has a 6.4-m focal length. The optical design is diffraction-limited over the entire FOV, and has points for field and Lyot stops. It uses "pushbroom" imaging and a multi-spectral module consisting of four CCD arrays with bi-directional TDI. Color filters are bonded to each CCD.

Important Features

- Well suited for locating and studying geology targets that might be implicated in trace gas emissions.
- Sets high standards for calibration accuracy and repeatability over time.
- Design goal is to provide the best quality imaging consistent with the resources of ExoMars TGO.
- Role of the imaging system on mission seems well thought out and documented.
- The instrument has a well thought-out design that is explained in an excellent discussion at the system and component levels.
- The High resolution Stereo Color Imager (HiSCI) proposal team has developed a clearly traceable set of instrument design requirements which are linked to measurement requirements, and also derive from mission parameters drawn from the E-PIP.
- The HiSCI instrument Integration and Test program is very well conceived, thorough and clearly explained.
- The University of Arizona (UA)/Ball/University of Bern (UBE) team is exceptionally strong, with a record of successful instrument developments, previous working relationships, and significant resources in both skilled team members and facilities.
- HiSCI will be operated from the existing MRO/HiRISE Operations Center (HiROC), reusing existing facilities, infrastructure, processes and personnel.



Conclusions

ExoMars Trace Gas Orbiter Payload

The Mars science community responded to the AO with several excellent proposals;

The selected instrument payload covers all the scientific priorities and includes redundancy in several areas;

The science outcome of this payload will provide new insights into our understanding of Mars and key atmospheric processes of potential astro-biological relevance.