

The NOMAD Spectrometer Suite on ExoMars Trace Gas Orbiter: Calibration Results

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Abstract

NOMAD (Nadir and Occultation for MARS Discovery) is a suite of three high-resolution spectrometers on-board the ExoMars Trace Gas Orbiter. Observing in the ranges 200-650nm and 2.2-4.3 μ m, the instrument will be able to detect and map a wide variety of Martian gases in unprecedented detail. The instrument was calibrated during March and April 2015; this presentation will describe the results of the tests performed and the expected performance when the instrument begins observing the planet in late 2017.

1. Introduction

The ExoMars Trace Gas Orbiter is a joint ESA-Roscosmos mission consisting of (1) an orbiter, and (2) an entry, descent and landing demonstrator. The mission is scheduled for launch in January 2016; to begin its nominal science mission around Mars in late 2017. The science mission will continue until 2019, covering an entire Martian year. NOMAD is one of the four instruments on-board the orbiter. The three spectrometers cover the UV-visible and infrared ranges, operating in solar occultation, limb and nadir-viewing modes, generating a huge dataset of Martian atmospheric observations during the mission across a wide spectral range [4].

SO channel. The solar occultation channel operates in the infrared, from 2330 to 4540 cm^{-1} (2.2-4.3 μ m) at a resolution of $\sim 0.15\text{cm}^{-1}$, and is an improved copy of the SOIR instrument which was operating on Venus Express [3,8]. The channel consists of an echelle grating in combination with an acousto-optic tunable filter (AOTF): the dispersive element provides the spectral discrimination, while the filter selects the diffraction order [4]. A cooled infrared detector array is used to maximise the signal-to-noise ratio (SNR) as much as possible.

LNO Channel: This operates in a similar way to the SO channel, utilising an AOTF, echelle grating and cooled infrared detector also, but with a slightly reduced spectral range (2630 to 4540 cm^{-1} ; 2.2-3.8 μ m) and resolution ($\sim 0.3\text{cm}^{-1}$) to increase SNR and reduce thermal noise [4]. This channel primarily points nadir, but is capable of making limb and solar occultation measurements if desired, or should the SO channel fail.

UVIS Channel: UVIS operates from 200-650nm at a resolution of $\sim 1\text{nm}$. It is a copy of the miniature grating spectrometer originally designed for the ExoMars lander with two added telescopes for measurements from orbit, rather than from the surface. UVIS can operate in solar occultation, limb, and nadir observational modes [5].

2. Scientific Objectives

When operating nominally, NOMAD has the resolving power to identify many trace gases that exhibit absorption features within the spectral range of the three channels. These include: CO_2 (incl. $^{13}\text{CO}_2$, ^{17}OCO , ^{18}OCO , C^{18}O_2), CO (incl. ^{13}CO , C^{18}O), H_2O (incl. HDO), NO_2 , N_2O , O_3 , CH_4 (incl. $^{13}\text{CH}_4$, CH_3D), C_2H_2 , C_2H_4 , C_2H_6 , H_2CO , HCN , OCS , SO_2 , HCl , HO_2 , and H_2S [1,2,5,6].

The order-of-magnitude increase in spectral resolution over previous instruments will enable spatial and temporal mapping of several isotopologues of potential methane and water will be possible, providing important measurements of the Martian D/H and methane isotope ratios globally. Sensitivity studies [1,6] have shown that in occultation mode, using expected SNR values [4,7], NOMAD should have the ability to measure methane concentrations < 25 parts per trillion (ppt) in solar occultation mode, and 11 parts per billion in nadir mode. Occultation detections as low as 10 ppt could be made if spectra are averaged sufficiently [1]. Using SO and LNO in combination with UVIS,

aerosol properties such as optical depth, composition and size distribution can also be derived [10].

In addition to trace gases, NOMAD will also continue to monitor the major seasonal cycles on Mars, extending existing datasets made by successive space missions in the past decade.

3. Current Status

The first stage of calibration was completed on 5th April 2015. Measurements were made in a thermal vacuum chamber at the Centre Spatial de Liege, at five different instrument temperatures (-12, -7, +5, +15 and +20°C), covering the range of expected temperatures while in orbit around Mars. A limited range of SO measurements were made at a single instrument temperature in air.

During testing, a problem was discovered with the LNO channel detector, which required it to be exchanged for the flight-spare equivalent before delivery to the spacecraft. After a short re-certification and re-calibration campaign (at temperatures of -15 and +10°C) ending on 28th April, NOMAD was ready for mounting on the spacecraft during the first week of May 2015.

A range of calibration measurements were made:

- Mapping of bad detector pixels (SO/LNO/UVIS)
- Pixel response linearity w.r.t. radiance (SO/LNO/UVIS)
- Detector thermal saturation rate/dark current at different temperatures (SO/LNO/UVIS)
- Detector and AOTF spectral calibration using gas cells (SO/LNO)
- Channel spectral calibration using emission lamps (UVIS)
- Detector temperature-dependent spectral calibration (LNO/UVIS nadir)
- Blackbody measurements at various temperatures to correlate observations with SNR model (LNO)
- Straylight calibration (UVIS nadir)

In this presentation, initial results from this extensive range of tests will be presented, demonstrating the 'as-built' performance of NOMAD in comparison to the expected performance [4,7,9] during the instrument design phase. The results from this work will form the basis of the data pipeline that will be used to generate scientific results from the returning data.

4. Summary and Conclusions

NOMAD, a suite of three spectrometers for detection and mapping of gases in the Martian atmosphere, was successfully built, tested and calibrated by IASB-BIRA and its industrial and academic partners. At the time of writing, the instrument has passed all tests and is ready for mounting onto the ExoMars Trace Gas Orbiter satellite.

In late 2017, NOMAD will enter nominal science orbit and begin transmitting back to Earth a new and exciting range of Martian observations. This presentation will outline the results of the calibration campaign, showing how the instrument is expected to perform when orbiting Mars.

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