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Atmosphere and climate explorer plus (ACE+)

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Abstract

Atmosphere and climate explorer plus (ACE+) is an atmospheric sounding mission using radio occultation techniques and is a combination of the two Earth Explorer missions ACE and WATS earlier proposed to ESA.

ACE+ is the response to ESAs second call for Earth Explorer Opportunity Missions in 2001 and was ranked no. 1 out of 25 candidate missions. ACE+ will considerably improve our knowledge about atmosphere physics and climate change processes. The mission will demonstrate a highly innovative approach using radio occultations for globally measuring profiles of humidity and temperature throughout the atmosphere and stratosphere.

The baseline constellation of four small satellites, tracking L-band GPS/GALILEO signals and X/K-band LEO–LEO cross-link signals, will be launched in two counter-rotating orbits with two satellites in each at 650 and 850 km, respectively. The system design is aimed to optimise the science return by proper distribution of the observations in space and time. The LEO–LEO cross-link instrument is driven by accuracy requirements that drive antenna design, transmitter power, and transmitter and receiver stability. Spacecraft design is driven by relatively high power consumption of the instruments, and their pointing requirements. Satellite characteristics include a mass of 160 kg, and available power of 125 W. In order to meet the cost envelope of the Earth Explorer Opportunity Missions the spacecraft will be a simple and robust design and will make use of the latest, but proven, technology. Low-cost launch is envisaged to be with Rockot or START-1, and can take place in 2006–2007. Finally, the ground segment processes data from all satellites, also using data obtained on ground, and distributes it to the meteorological community.

1. Introduction

This extended abstract gives a mission overview and describes options and technical solutions for ACE+. SSC has been selected by ESA to head a team that includes Terma, EMS Technologies, Laben, Astrium, Dutch Space, Danish Meteorological Institute, and the University of Graz, to study the mission in a phase A study. Still being at the start of the study the paper presents different design solutions and sometimes indicates the most likely solution. This is done for the overall system, the payloads, the satellite, and the ground segment. Finally, some of the programmatics of the Earth Explorer Opportunity Mission are presented, which are related to ACE+.

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2. Mission overview

The Atmosphere and Climate Explorer mission (ACE+) was proposed in January 2002 in response to ESA's second call for Earth Explorer Opportunity Missions. The concept involves systematic gathering of data over a 5-year period of precise profiles up to the atmosphere of temperature and humidity around the Earth. These profiles are subsequently used in conjunction with climate modelling and climate prediction techniques developed by meteorological institutions to improve the understanding of the driving forces behind climate change and variability.

The ACE+ mission will contribute, in a significant manner, to ESA's Living Planet Programme under the themes of "physical climate" and "atmosphere and marine environment" with the mission goals:

- to monitor climatic variations and trends at different vertical levels and for each season, in order to improve the understanding of the climate system as well as to detect the different fingerprints of global warming;
- to improve the understanding of climatic feedbacks defining the magnitude of climate changes in response to given forces;
- to validate the simulated mean climate and its variability in global climate models;
- to improve and tune—via data assimilation—the parameterisation of unresolved processes in climate models and to detect inter-annual variations in external forcing of climate.

The mission will demonstrate a highly innovative approach using radio occultations for globally measuring profiles of humidity and temperature throughout the troposphere and stratosphere. A constellation of four small satellites, tracking L-band GPS/GALILEO signals and X/K-band LEO–LEO cross-link signals, will map the detailed refractivity profile and structure of the global atmosphere using a configuration of two counter-rotating orbits with two satellites each at 650 and 850 km, respectively.

The radio occultation technique illustrated in Fig. 1 has so far been studied by ESA using signals from the global navigation satellite system (GNSS) to determine phase and amplitude changes caused by the atmosphere. The observations have been done from

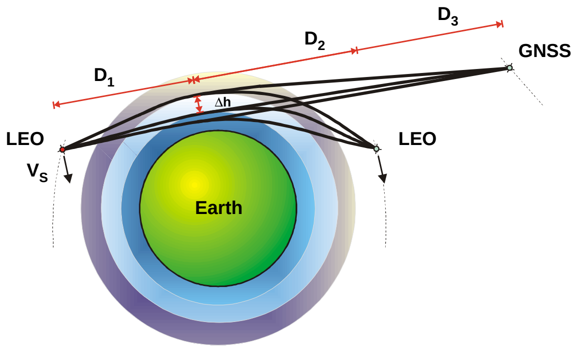

Fig. 1. Outline of the geometry for radio occultation measurements based on LEO–LEO and GNSS/GALILEO–LEO observation schemes.

low earth orbiting (LEO) satellites. In the ACE+ mission, the GRAS-2 instrument will provide such data for GPS and possibly GALILEO with unprecedented coverage.

In order to improve the separation of the contributions of water vapour and temperature in the lower troposphere, without using external data, ACE+ will also actively sound the atmosphere using LEO-to-LEO signal transmission at three frequencies around the 22 GHz water vapour absorption line (10, 17, and 23 GHz). Measurements of the occulted phase and amplitude of the electric field from the LEO transmitter at these frequencies will deduce independent information on temperature and water vapour distributions with an unprecedented accuracy. This technique was suggested in the WATS Core Mission proposal to ESA's Earth Explorer Programme in 2001 and examined in subsequent prephase A studies for the Agency.

3. System design

The overall system is quite well-defined, following the studies of APEW, ACE and WATS. Fig. 2 shows a likely functional architecture for the overall system that consists of the following components:

- GRAS-2 receiver for GNSS radio occultations (GRO) and navigation, consisting of a multiple channel, high accuracy GNSS receiver, fore and aft antennas pointed at the horizon, and a zenith antenna for navigation. The GNSS timing data will also be used to update the spacecraft onboard time.