In response to the 2016 ESA's call for M5 Mission Proposals

European SpaceCraft for the study of Atmospheric Particle Escape (ESCAPE)

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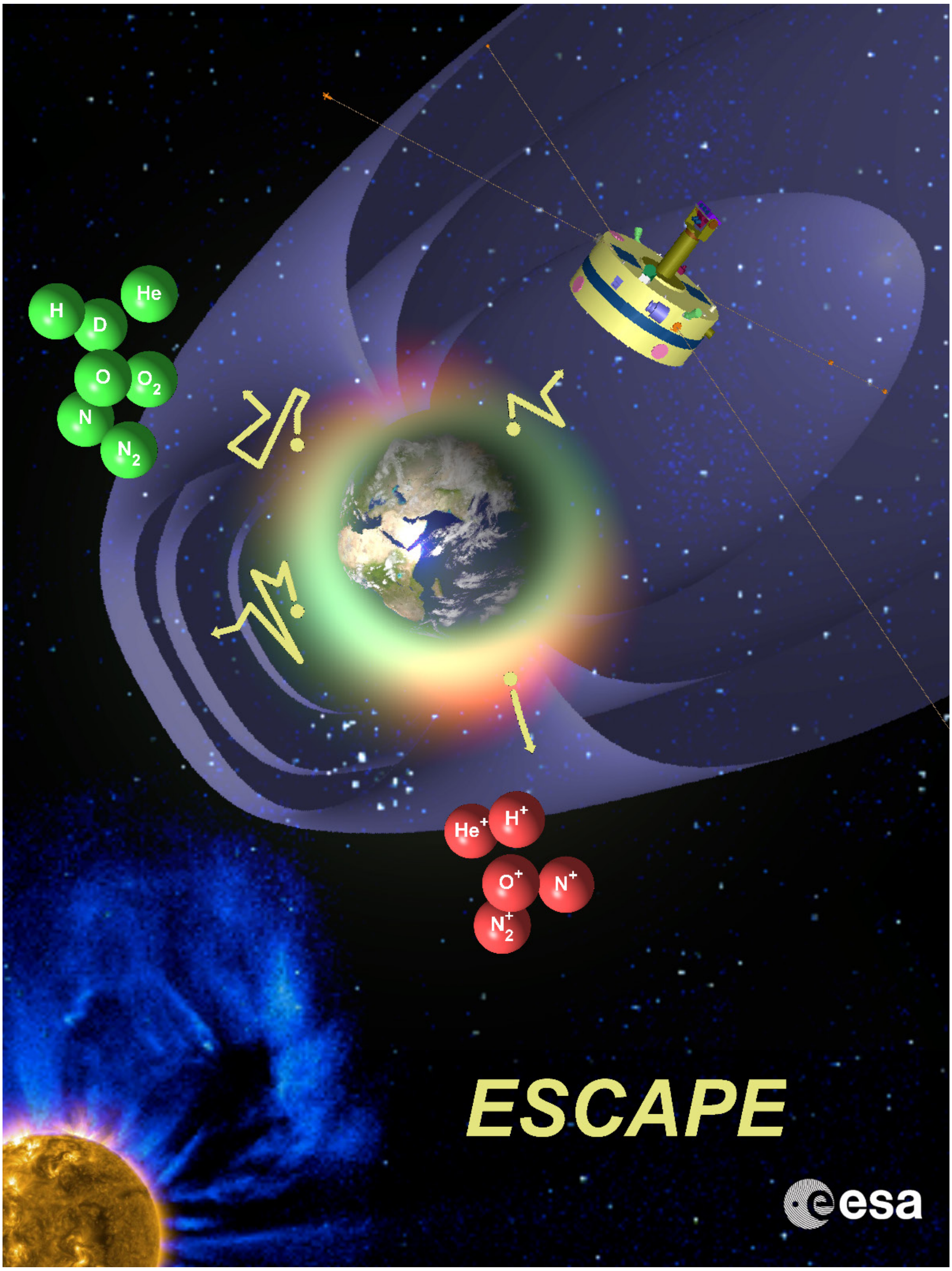

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Executive Summary

	ESCAPE Summary Table
Element	**Explanation**
Question	**How and at what rate is Earth slowly losing its atmosphere to space?**
Specific Goal #1	**Build a quantitative and comprehensive picture for 500-2000 km altitudes** - Determine exospheric altitude density profiles and temperature profile as a function of different drivers such as solar EUV, solar wind and geomagnetic conditions. - Establish isotope ratios for both neutrals and ions and compare them with those found at the Earth's surface and in other solar system objects. - Determine exospheric altitude profiles of ion/neutral ratios and estimate ionisation/neutralisation efficiencies. - Measure temporal and spatial variations of the density of major exospheric species. - Correlate such variability with upper atmosphere parameters, and with different incident energies when particle precipitation is present.
Specific Goal #2	**Determine the dominant escape mechanisms, and their dependence on the drivers** - Estimate thermal escape flux for neutral and ion species for different conditions. - Estimate the prevailing escape mechanisms and the relative importance of thermal or non-thermal escape for different driver conditions. - Estimate the response of the ionisation/neutralisation efficiencies, isotope fractionation and the N/O ratio to different drivers. - Estimate the degree of recirculation of plasma after it has left the ionosphere.
Spacecraft	- Single slowly spinning spacecraft (~3 rpm) with a despun platform. - Cold gas (Kr or Xe) propulsion for attitude control. - Moderate (Cluster level) magnetic cleanness and EMC requirements
Payload	**Payload for in-situ measurements** - INMS: Cold ion and neutral mass spectrometer ($M/\Delta M$ ~1100, 10^{-3}–10^{3}/cc per 5 sec) - WCIMS: High time resolution cold ion analyser ($M/\Delta M > 50$, per 5 sec) - MIMS: Light hot ions ($M < 20$, N/O separation, 5 eV/q – 40 keV/q) - NOIA: Heavy hot ions ($M > 10$, N_2/O separation, 10 eV/q – 30 keV/q) - EMS: Energetic ions (H^+, He^+, O^{++}, N^+, O^+, N_2^+, 20–200 keV) - ESMIE: Ionospheric photoelectrons & magnetospheric electrons (5 eV – 20 keV) - SLP: Plasma density, E-field, spacecraft potential (Langmuir probe) - MAG: Magnetic field (5nT accuracy) - WAVES: Electromagnetic waves (5 Hz – 20 kHz) **Payload for remote measurements and for line-of-sight information** - UVIS: UV imaging spectrometer (85–140 nm, optional: O^+ 83 nm, He 58 nm, He^+ 30 nm) - ENAI: Energetic neutral atoms imager (2 – 200 keV) - AMC: Aurora monitoring and airglow camera (O 630 nm, N_2 670nm) **Mandatory subsystems (by ESA)** - Two DPUs (hardware), two 5 m rigid booms for MAG and search coil, 15-20 m wire booms for SLP, Active spacecraft potential control (ASPOC)
Orbit	- elliptic Earth orbit (~500 km x 33000 km altitude with ~10 hr orbital period) - high-inclination (~90°) to cover polar cap and EISCAT_3D observation area - no need of orbit manoeuvres to change apogee
Resolution	* temporal < 1 minute & vertical < 150 km at 500–2000 km altitude
Duration	* 3 year nominal mission with instrument designed to operate for 5 years
Radiation	* Shielding of ~5 mm aluminium equivalent will keep dose < 50 krad for 3 years
Downlink	- 19 Gbit/day with 30 W RF transmitter to ESA stations; >10 GByte onboard memory
Science Operations	- ESA (ESOC/ESAC) is responsible for operation, data collection/archiving/distribution. - Real-time detection of the radiation belts to change to a reduced operational mode.
Data policy	- Level 2 (calibrated) data delivery within 6 months. - Key parameters or equivalent data (open access) within 12 months.
Collabo-ration	* USA (NASA) and Japan (JAXA): instrument provision (EMS, WCIMS, UVIS, AMC) * EISCAT: conjugate ground-based 3-D observations (ions and electrons at > 500 km)
Cost	370 M€ (140 M€ for spacecraft and ESA-built subsystems, Operations: 70 M€, Launch of Ariane 6.2: 75 M€, ESA internal cost: 35, contingency 50 M€)

Scientific goal:

The purpose of the ESCAPE mission is to **obtain the composition and flux of the atmospheric escape from the Earth and understand its effect on the evolution of the atmosphere** (Cosmic Vision Theme 1). Although this subject including escape from planetary atmospheres has been studied for many years, the existing data are incomplete for estimating even the basic values of the escape rate for different driver conditions. To answer these questions, the ESCAPE mission will measure both neutrals and superthermal ions of major atmospheric species H, He, O, N, O_2, N_2, NO, and CO_2 in the exosphere/upper ionosphere in the altitude range 500–2000 km, as well as major hot ions (H^+, He^+, O^+, N^+, N_2^+) in the upper ionosphere, plasmasphere, polar cap, and inner magnetosphere. As a unique measurement, the variability of the isotope ratios in both space and time will be examined for the first time in the geospace environment.

These measurements will lead to (1) **the first-time quantitative and comprehensive observations of the entire exosphere** and upper ionosphere (500-2000 km altitude) that will allow quantitative modelling of the thermal escape, and (2) determination of the dominant non-thermal escape mechanisms that allows the evaluation of the **relative importance of thermal and non-thermal escape**, both important in modelling the composition of the atmospheric escape under different internal and external drivers (solar UV, solar wind, magnetospheric and ionospheric conditions).

The proposed measurements will also (a) contribute to fundamental physics and chemistry questions on **how the isotopes fractionate** and **operating ionisation/neutralising efficiencies in space environment** (Cosmic Vision Theme 3), and (b) serve as an important reference for understanding the evolution of the atmospheres of other planets (comparative planetology) because the majority of the basic escape mechanisms working on planets or in the past Earth are expected to be operating at the present Earth.

Contributions from the ESCAPE's measurements to other science fields include: (c) history of N/O ratio of the Earth that influences biology activities (astrobiology), (d) dynamic modelling of the exosphere for a better understanding of exospheric light contamination pertinent to astrophysical spectroscopy observations, (e) dynamics at the topside ionosphere, (f) exospheric effects on the ionosphere-plasmasphere coupling through chemistry, transport, and electric field, and (g) magnetospheric-ionosphere coupling with the orbit covering various routes of ion transport between the two regions.

Measurements required to achieve the science goals:

All measurements will be made with flight-proven or equivalent instruments on board a single slowly spinning (3 rpm) spacecraft equipped with a despun platform for the remote sensing measurements. To maximise the utility of the despun platform, the spin axis will point to the Sun with a pointing accuracy < 1°. The orbit has high-inclination (~90°) with perigee and apogee at ~500 km x 33000 km altitudes (~10 hr orbital period) to cover the polar cap, inner magnetosphere, exosphere, and topside ionosphere at all local times. Latitudinal drift of the apogee allows coverage of all altitudes in the polar cap. A high-inclination orbit will optimise geomagnetic conjugate observations with the EISCAT_3D ground-based radar facility, which will yield for the first-time continuous 3D volume measurement of the ionosphere over 10°–20° latitudinal range at the geomagnetically conjugate region of the spacecraft in northern Europe.

The spacecraft includes a full suite of particle instruments: hot and energetic ion instruments with N/O separation capability, cold ion and neutral instruments with isotope separation capability ($M/\Delta M \approx 1100$) down to as low as 10^{-4} cm^{-3} for ions and $>10^{-1}$ cm^{-3} for neutrals, and hot electron instrument with capability of identifying photo-electron peaks. The spacecraft potential is controlled to < 2~3 V level to allow the measurement of cold ions and photoelectrons. The spacecraft potential will be monitored with a Langmuir probe on two 15-20 m wire booms, and pitch-angles of ions and electrons will be measured using a magnetometer on a 5 m rigid boom. Two spacecraft DPUs are used for handling the data, one on the main spacecraft platform and the other on the despun platform.

The spacecraft includes an imaging UV spectrometer on the despun platform to obtain line-of-sight integrated images of various emission lines, including the nitrogen ions and neutrals through nitrogen emission lines (85–140 nm for N, N^+, O; and at 83 nm for O^+, 58 nm for He, and 30 nm for He^+) with sensitivity of >0.1 count s^{-1} R^{-1}. An altitude resolution of < 100 km is obtained.

The other payloads included are for monitoring the background conditions: aurora monitor to determine the energy injection to the ionosphere on a global scale, simplified wave measurements with a search coil on a separate 5 m rigid boom, and an energetic neutral atom (ENA) imager for monitoring the geomagnetic storm/substorm activity.

The total mass and power of the scientific payload, including shielding, is less than 150 kg and 150 W. The total mission budget including 3 year operations is about 370 M€ for ESA.

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