Daedalus:
ESA's Earth Explorer 10 mission candidate for lower thermosphere-ionosphere studies

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a Phase-0 (pre-feasibility) study programmatic overview

Context: the Living Planet Programme

ESA's Living Planet Programme was originally conceived as an *Earth Observation* strategy to develop our knowledge of the Earth, to preserve the Earth and its environment, and to manage life on Earth in a more efficient way. Since its inception in 1998, the original strategy has been periodically updated, revising the key *challenges* in ***Earth system science*** across five Earth science disciplines: atmosphere, cryosphere, land surface, solid Earth and oceans (ESA SP-1329/2, 2015), and introducing interdisciplinary elements and advances accounting for interactions and interdependencies between disciplines and Earth system components.

Framework: the Earth Explorers

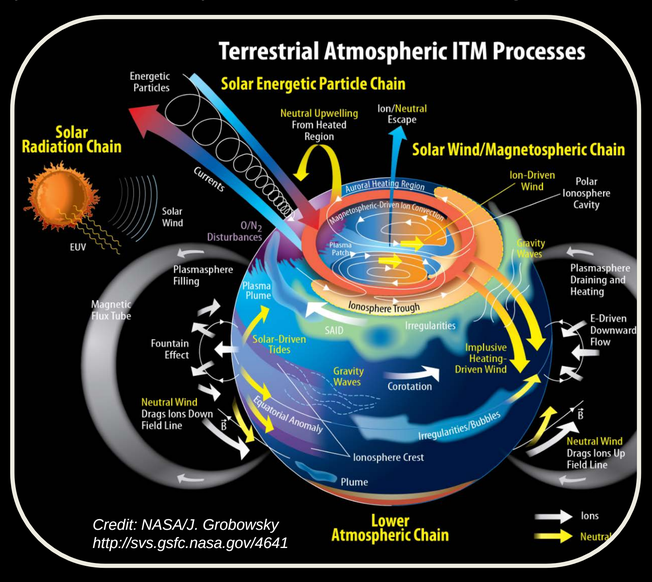
The Earth Explorer (EE) missions respond to the Science & Research element of the Living Planet Programme. Beyond the original 6 Explorers, Biomass (EE-7: forests) and FLEX (EE-8: fluorescence) are currently in development. FORUM (outgoing far-IR radiation) and SKIM (sea surface currents) are nearing completion of an EE-9 competitive Phase-A study.

Daedalus was one amongst 21 proposals retained for EE-10 Phase-0 studies after the 2017 call for mission ideas, alongside *Harmony*, measuring surface deformation with bistatic SAR, and *Hydroterra*, monitoring the diurnal water cycle over Africa and Europe with geosynchronous SAR.

Exploring the atmosphere-space transition region

Daedalus is a lower thermosphere-ionosphere mission concept, targeting the region **between <120 and 200 km** (and above) with a suite of *in situ* instruments for comprehensive plasma and neutral atmosphere measurements on an elliptical orbit, to quantify key electrodynamics and Sun-Earth coupling processes. The original **mission objectives** were to:

1) Determine the energy balance and quantify heating processes in the T-I region, notably Joule heating and energetic particle precipitation,
2) Investigate the causes of variations in the spatial and temporal temperature and composition structure of the T-I region



Q2/2019 — Q4/2020 — Q1/2021 — Q2/2022 — Q3-4/2022 — 2028 (towards solar minimum)

Phase 0 — Mission analysis and needs identification: definition of requirements (See: *ECSS-M-ST-10C Rev. 1*)

RfA ≅ MRD

MRD + SRD

Phase A — Feasibility

RfMS + MRD

Phase B/C — Preliminary/detailed definition

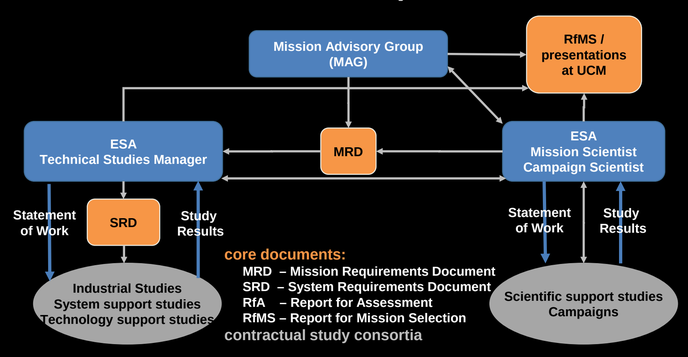
Phase D — Qualification and production

Phase E1/E2 — Utilization (commissioning and operations)

Phase F — Disposal

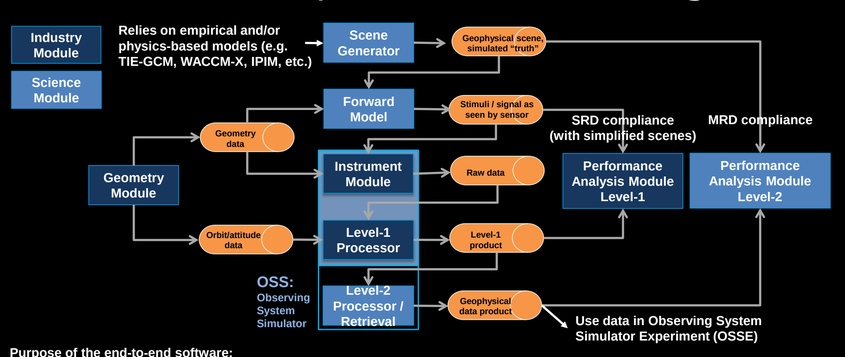
Milestones: KO of scientific/industrial activities (3 selected candidates/2 parallel system study (industry) consortia) — Mission Definition Review ♦ — ♦ KO Phase A — ♦ **ACEO** recommendation + **PB-EO** decision (2 candidates) — Preliminary Requirements Review ♦ — ♦ **UCM** + **ACEO** recommendation + **PB-EO** decision (1 selected EE-10 mission) — ♦ Launch (Vega-C)

Phase 0/A activities and study interfaces



ACEO - Advisory Committee for Earth Observation; an independent peer-review body of scientific experts providing advice to ESA
UCM - User Consultation Meeting; open consultation of the Earth Observation scientific community to support mission selection
PB-EO - Programme Board for Earth Observation; board of ESA Member State delegates coordinating European and national EO activities, and making recommendations to ESA's governing organ representing the Member States, the Council.

Mission end-to-end performance simulator (generic)



Purpose of the end-to-end software:
Phase 0/A/B1 - confirm that mission objectives and requirements can be met by mission concept (mission performance assessment) provide error metrics, analyze sensitivities, assess performance of algorithms, compare against observed data
Phase B2 - simulate the mission end-to-end: observations, instruments, products
Phase C/D/E - validate and calibrate the end-to-end (processing) chains and models

Pathway to mission selection

Earth Explorer candidates are selected for preparation (Phase-0 and –A) or implementation (end of Phase-A) based on criteria of 1) relevance to the ESA research objectives for EO (science strategy, including major societal issues), 2) needs, usefulness and excellence, 3) uniqueness and complementarity, 4) degree of innovation and advancement of European EO capabilities, 5) feasibility and maturity, 6) timeliness, and 7) programmatics (schedule, cost, risks, synergies).

Phase-0/A activities shall substantiate the above through separate *scientific* (1-4) and 2 parallel *system/industrial* (5-6) contract studies to:

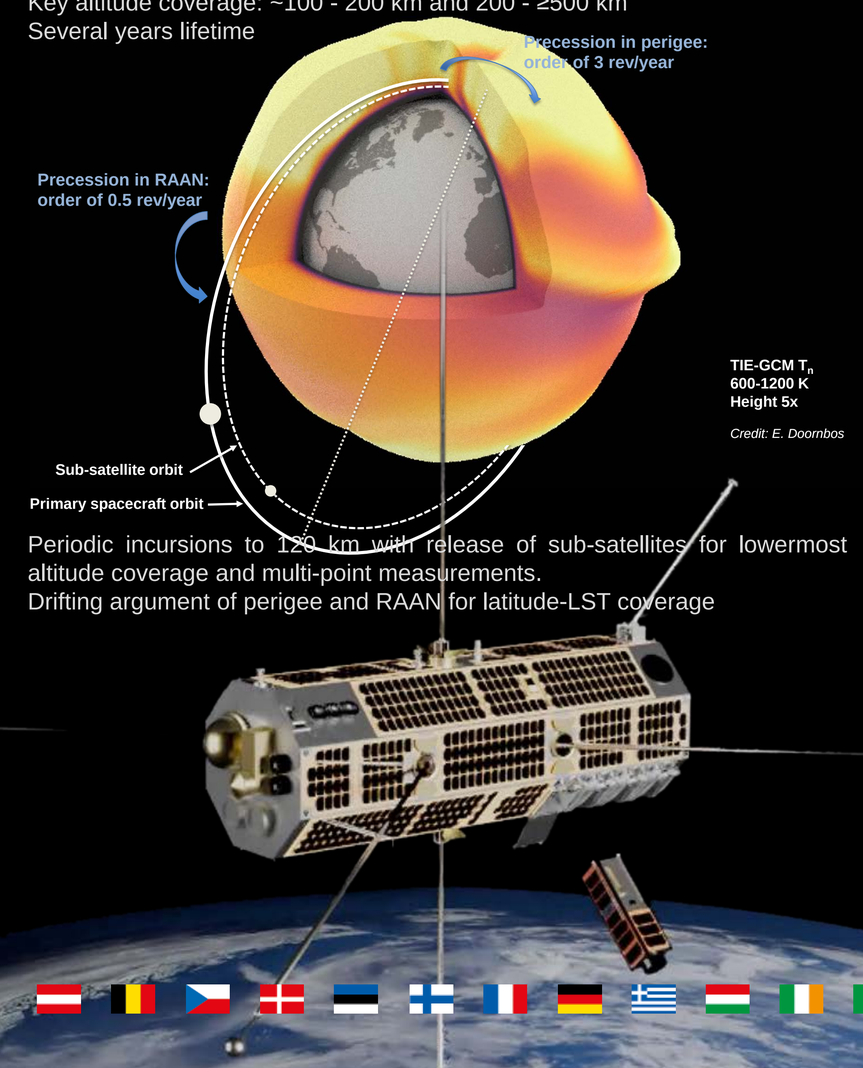
1) Consolidate the science case and the **mission requirements** (**MRD**)
2) Assess the scientific feasibility and performance (Science Readiness Level), ultimately through **E2E performance simulations** (**SRL-5** by end of Phase-A), tested and validated in realistic conditions/scenarios
3) Evaluate the mission's potential scientific and/or societal **impact**
4) Support and improve the scientific maturity (SRL) with observational **campaign data** to test and consolidate the mission or measurement concept, the observing technique, and/or requirements; typically by deploying instrument demonstrators to prove sensitivity to the geophysical parameters (SRL-4), and later to "simulate" representative measurements (products) with error budgets, which can also be used to prototype and assess algorithms and to test the robustness of the E2E simulator (SRL-5)
5) Establish the technical requirements (**SRD**), feasibility, mission concept and **architectural baseline**, and evaluate preliminary trade-offs
6) Support the technical maturity (Technical Readiness Level) though **technology pre-developments** or risk retirements (**TRL-5** by end of Phase B1: breadboard/component validated in relevant environment)

whilst ensuring full **traceability** from the mission's overarching scientific objectives (in MRD) down to technical requirements expressed in the SRD.

The scientific mission definition is overseen and endorsed by the **Mission Advisory Group** (**MAG**), an appointed group of independent experts from the scientific community.

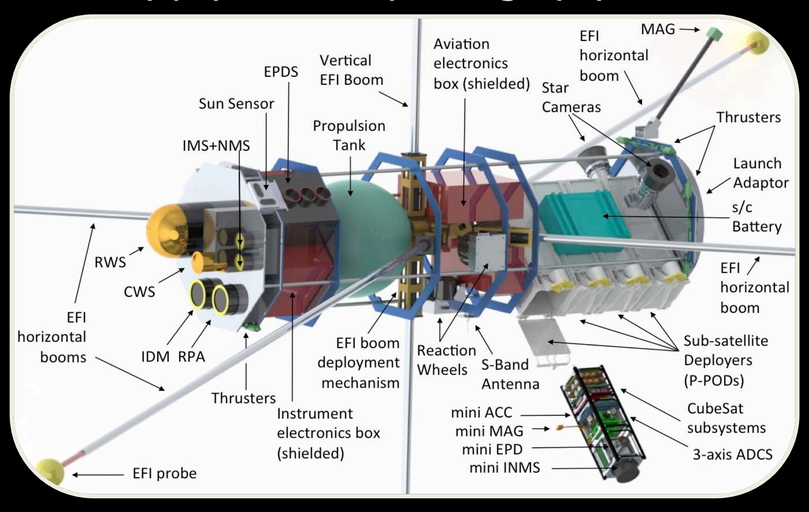
Preliminary orbit and operations concept

Nominal sampling: ≥16 Hz (~1 km along-track resolution)
Preliminary orbit: ~150 km perigee, ~2000 km apogee, high inclination (≥85°)
Key altitude coverage: ~100 - 200 km and 200 - ≥500 km
Several years lifetime



Periodic incursions to 120 km with release of sub-satellites for lowermost altitude coverage and multi-point measurements.
Drifting argument of perigee and RAAN for latitude-LST coverage

Preliminary payload concept and geophysical data



Plasma: drift (***v***$_i$), temperature (T_i, T_e), density (n_i, n_e), ion composition, TEC
Neutral atmosphere: wind (***u***$_n$), temperature (T_n), density (ρ), composition
Particles: e^-, p^+/ion and energetic neutral atoms precipitation fluxes
Fields (AC/DC): magnetic (***B***), electric (***E***)
Derived: Joule heating, conductivity

Current Mission Advisory Group[3] and References

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+ proposing team,
+ science consortia,
+ industry consortia,
and other contributors

Member of:
[1] original proposing team
[2] Mission Advisory Group
[3] science studies
[4] ESA

Sarris et al, 2019, GIMDS/D, doi.org/10.5194/gi-2019-3

Web portal: daedalus.earth

www.esa.int/Our_Activities/Observing_the_Earth/The_Living_Planet_Programme

Questions for CEDAR:

- What are community requirements of T-I spaceborne *in situ* measurements for model / parameterizations development, assessment, verification, as well as data driven exploitation and assimilation?
- What are community thoughts on major open T-I science questions (also from an Earth system science perspective), on coupling to the lower atmosphere and magnetosphere, and synergies with current efforts?
- What are the best models for scene generation and OSSEs?

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