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Geoscientific Instrumentation Methods and Data Systems Discussions

Interactive comment on "Daedalus: A Low-Flying Spacecraft for the Exploration of the Lower Thermosphere - Ionosphere" *by* Theodoros E. Sarris et al.

Anonymous Referee #1

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General comments: It is clear that the Daedalus concept will introduce a totally new way to probe the Lower Thermosphere-Ionosphere interactions with an ambitious setup of instruments and challenging mission requirements. I have no problems to believe that this mission would upgrade significantly ESA's position in the conquest of the interesting transition zone where our atmosphere meets the near-Earth space. From that basis I'm happy to recommend publishing this manuscript as a GI-article with some further clarifications and minor modifications. However, I find it a bit disturbing that this manuscript has been written very much in the same style as we all write our money proposals. For example, the Conclusions is more like a selling document than a concise review of the major findings from the mission preparatory work. I kindly ask the

authors to make an attempt for a more objective rhetoric at least in the points which I discuss later in this report.

Specific comments: Sections 4.2. and 5.3. do a good job in convincing the reader that Daedalus observations will be based in many respects on a heritage from similar measurements by some earlier missions. The end of Section 3.3. explains how the requirements for Daedalus mission have been derived with comprehensive simulations and model runs. It remains, however, somewhat unclear how consistent the requirements by modelling/simulations are with the performance of the instruments that will come as the heritage from previous missions. Some upgrading of the measurements' performance can be anticipated from today's state-of-art until the days of Daedalus instrument building, but how much such upgrading is needed? In particular, like Section 4.3.5. explains, very high precision in satellite pointing direction will be needed for accurate Joule heating estimates. For us readers it would be valuable to know, whether e.g. GOCE has reached such accuracy in its pointing direction that will be needed for Daedalus. Along the same lines, CO_2 content in LTI is mentioned in Section 5.1 as one of the primary targets by Daedalus, while in the description of NMS CO_2 is mentioned only as an desirable constituent in parenthesis and the values given in Table 2 for CO_2 are difficult to compare with the ppm values given by some other studies on thermospheric CO_2 contents (e.g. by Emmert et al., 2012).

While the heritage of Daedalus mother satellite instrumentation is explained carefully, the description of the cubesat instruments is rather cursory. Most likely the largest technology challenges will be in this part of the mission. As cubesats will have crucial role in accomplishing the breakthrough science by Daedalus, it would be good have a more thorough assessment about the ideal (goal) versus most potential (threshold) payload for the cubesats. I understand that most of the validation and testing work to define the final payload is still ahead, but the proposing team has probably already now collected some knowledge about the performance of miniaturized instruments versus the requirements given in Table 2?

Unprecedented information on altitude gradients in several LTI parameters will be achieved by the combination of the Daedalus mother satellite and its cubesats. As the cubesats will have a slightly different orbit as the mother, the spacecraft will not always probe the same lat-lon regions simultaneously. According to Section 4.3.4 the maximum offset between the measurements by the mother and by the cubes is 60 mins. In stormy conditions 60 mins is a rather long time for the assumption of semi-simultaneous observations, like Fig 3. of this manuscript demonstrates (by four-time increase in Joule heating during one hour). A valuable exercise for this manuscript (and for the next rounds of Daedalus concept validation in ESA) would be to find out how often the mother and cubesats can provide altitude gradients with the demand of simultaneous measurements in the windows of, e.g., 10, 20, and 30 mins.

Technical/minor comments:

Below I list some minor comments which the authors may want to take into account when preparing the next version of the manuscript:

A suggestion for the title: "Daedalus: A spacecraft for in-situ exploration of the Lower Thermosphere-Ionosphere"

Page 1, line 35: "...orders of magnitude between models" -> "...orders of magnitude between models and observation methods"

Page 3, line 17: Please explain the acronym PPOD

Page 5, line 26: When talking about rapid energy releases in the solar wind – magnetosphere – ionosphere system, it is good to remember also the abrupt penetration of magnetospheric electric field to dayside equatorial ionosphere during geomagnetic storms (see e.g. Kikuchi et al., JGR, 2008). Daedalus measurements will most likely be useful also in that research topic.

Page 9: The purpose section 2.1.3. remains unclear to me. The section seems to repeat quite much the message of the questions posed in page 7.

Page 12: Is there a typo in Eq.2? Is the expression after "=" really Joule heating rate or just an assumption for current (as the term "(E + u_n x B)" is missing) ?

The list of models on pages 13-14: Key references would valuable to add as the readers of GI may not be as familiar with these models as e.g. JGR readers would be.

Page 14, line 28: The mission with three year duration would cover all seasons and latitudes, but what would be the coverage in Magnetic Local time?

Page 22, line 30: A significant limitation in field-aligned current estimates by single satellites is the assumption of longitudinal gradients being insignificant when compared to latitudinal gradients. That limitation cannot be overcome by adding particle measurements if also they are provided by a single satellite. The magnetometer recordings by the lower pair of Swarm satellites have provided a solution for this problem. Probably also Daedalus with its mother-cubesat combination can tackle the problem similarly.

Page 23, line 24: The sentence "This expression has been proven to be accurate to better than 1%" is a strong statement and needs therefore also a reference. Does the statement hold for all frequencies? Does it assume something about ionospheric electron content variations?

Page 23, lines 27-28: The definition of TEC is confusing as it mentions vertical column and the path from satellite to receiver (which usually is not vertical) in the same sentence. Please, make clear distinction between Vertical TEC and Slant TEC.

Page 28, line 15: Please explain low I_sp and high I_sp

Page 33, line 12: I wonder why the authors want to highlight GIC as the most important societal relevant application of Daedalus. Is Daedalus really the best asset to gain understanding on processes causing high GIC values? I would rather pick the drag experienced by satellites and space debris as the core application area for Daedalus research. The drag business may not currently be the hottest topic in space weather discussions, but its importance is continuously growing.

Figure 7: I find particularly the MHD results interesting, since they cover also mid and low latitudes. I've understood that MHD approach is good particularly at high latitudes, where it captures the magnetosphere-ionosphere interactions nicely, but I have not seen previously MHD results on Joule heating for mid and low latitudes. These results would deserve some further explanation in the text.

Figure 12: This figure is widely used to demonstrate the complexity of high latitude ionospheric currents. However, from the viewpoint of Daedalus the illustration is still too simple, because it describes ionospheric currents as two-dimensional sheet currents. In reality the currents do not flow in one sheet but in a three dimensional volume and there has been even some speculations on internal current closure inside the ionosphere (Amm et al, JGR, 2011). In favorable conditions Daedalus can contribute to such speculations in unprecedented ways by its mother-cubesat combination.

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