DRAFT

POINT PAPER

Utility of SESS Sensors on Polesitter Spacecraft

Purpose:

Advise the DOC/NOAA on the utility of SESS instruments on a polesitter spacecraft for addressing NPOESS EDRs

Background:

- The NOAA-NESDIS Office of Systems Development is currently developing innovative concepts for future environmental monitoring spacecraft. A particularly poignant concept is that of a polesitter satellite that, as its name implies, is maintained in a station-keeping orbit above either the northern or southern geographic pole. The basic idea behind current polesitter approaches exploit both the gravitational minima at the Earth-Sun Lagrangian points and the force derived from the radiant solar pressure on a large solar sail to maintain the spacecraft in a station-keeping orbit above the pole. Typical locations for the polesitter range from 900,000 km (~140 R_E) to 3,900,000 km (~570 R_E).
- The NPOESS IPO is responsible for satisfying user requirements for 13 SESS EDRs. At present the IPO intends to satisfy the SESS requirements on the NPOESS satellite – a polar-orbiting spacecraft at ~800 km altitude. A polesitter spacecraft could address some SESS EDRs. The NESDIS Office of Systems Development requested support from the SESS Government Advisory Team (GAT) for a consideration of how effective a polesitter might be in addressing the NPOESS SESS EDRs. This paper documents the findings of the GAT in this regard.

Discussion:

- The GAT believes that there is great utility in having a polesitter spacecraft address several of the NPOESS EDRs. A summary of the GAT findings is provided in the following table. The key to the utility column is; +++ = excellent, ++ = good, + = marginal, and 0 = no utility. The EDRs for which utility exists are then described in further detail. A functional description of the polesitter instrumentation for addressing these EDRs is provided at the end of this section.

IORD-II	EDR Title	Utility	Comment
4.1.6.7.1	Auroral Boundary	+++	Improved temporal monitoring & latency
4.1.6.7.2	Auroral Energy Deposition	+++	Improved temporal monitoring & latency
4.1.6.7.3	Auroral Imagery	+++	Improved temporal monitoring & latency
4.1.6.7.4	Electric Field	+	Some observations of auroral motions
4.1.6.7.5	Electron Density Profile	+	Good ancillary data – poor vertical resolution
4.1.6.7.6	Geomagnetic Field	0	In-situ measurement preferred – no utility
4.1.6.7.7	In-situ Plasma Fluctuations	0	In-situ measurement preferred – no utility
4.1.6.7.8	In-situ Plasma Temperatures – T_i & T_e	0	In-situ measurement preferred – no utility
4.1.6.7.9	Ionospheric Scintillation	++	Observation of polar patches + beacon Tx
4.1.6.7.10	Neutral Density Profile	+	Good ancillary data – poor vertical resolution
4.1.6.7.11	Medium Energy Charged Particles	0	In-situ measurement preferred – no utility
4.1.6.7.12	Energetic Ions	0	In-situ measurement preferred – no utility
4.1.6.7.13	Surpa-thermal through Auroral Energy Particles	0	In-situ measurement preferred – no utility
P^3I	Neutral Winds	+	Some observations of auroral motions

- Auroral Boundary – A polesitter spacecraft with a UV imager could provide an excellent platform for monitoring the auroral boundary. Knowledge of the auroral boundary is required by radar operators and communication officers to assess the impact of the aurora on system performance (DoD). Knowledge of the auroral oval (size) is also required for general situational awareness purposes (DoD/DOC). The current NPOESS functional architecture will permit *periodic* monitoring of *segments* of the auroral oval. A polesitter spacecraft offers the possibility of continuous monitoring the entire auroral oval. Thus, a polesitter could provide a substantial improvement in the monitoring of the auroral boundary over NPOESS.

- Auroral Energy Deposition – The primary usage of the auroral energy deposition is for global situational awareness during periods of increased levels of geomagnetic activity (DOC/DoD). The auroral energy deposition is also important for monitoring the ionospheric electrodynamics and for thermospheric specification models (DoD/DOC). The IORD requires a measurement of auroral particle precipitation over a specific energy range although the underlying key requirement is for the total energy input. Thus, a UV imager on a polesitter spacecraft could facilitate the real-time monitoring of the energy deposition of the entire high-latitude region (total hemispheric auroral power input) and an improvement over the current NPOESS approach.

- Auroral Imagery – This is perhaps the most important Space Weather application for a polesitter spacecraft (DoD). The auroral imagery EDR supports the needs of high-latitude radar operators by allowing identification of "hot spots" within the auroral zone that may be a source of clutter in their observations (DoD). The real need is for continuous monitoring of the auroral zone within the field of view of both fixed-site and mobile radars. It is recognized that the NPOESS architecture cannot fully satisfy users' needs. However, a polesitter spacecraft with a UV imager monitoring the full auroral zone in real time would adequately satisfy these needs and is therefore a substantial improvement over NPOESS.

- Electric Field – This EDR is best satisfied by an in-situ measurement (or derived measurement) of the local electric field within the ionosphere at both high and low latitudes. Measurements of the electric field are required for general situational awareness (DOC) and as inputs to global space weather specification and forecast models (DoD/DOC). A polesitter spacecraft with a UV imager could contribute to the high-latitude requirement by observing the continuous, large-scale motions of plasma-density structures within the auroral zone and polar cap. However, polesitter observations cannot full satisfy user needs.

- Electron Density Profile – The electron density profile (EDP) EDR addresses user requirements within three broad categories; 1) requirements leading to general situational awareness (DOC), 2) requirements to correct for changes in electromagnetic wave propagation induced by the ionosphere (DoD/DOC), and 3) requirements to calculate and forecast ionospheric disturbances that impact military and civilian systems (DoD/DOC). The EDP requirements are best satisfied by a limb-scanning (RF or optical) sensor that can clearly discern the discrete Chapman layers (D-, E-, and F-layers). NPOESS provides the preferred geometry for scanning the ionospheric limb. However, a UV imager on a polesitter spacecraft could augment the NPOESS measurements by providing a broader view and continuous observations of the high-latitude ionosphere.

- Ionospheric Scintillation – High-latitude ionospheric scintillation is of considerable concern to users of HF comm (DoD/DOC). Scintillation at high latitudes is primarily due to density irregularities associated with auroral blobs and polar-cap patches. The NPOESS requirement is for a direct measurement of scintillation in terms of the amplitude and phase fluctuation indices, S_4 and δ_ϕ, respectively, at VHF, UHF, L-band and S-band frequencies. With respect to a polesitter, these indices could most easily be measured using a beacon transmitter coupled to an array of ground receivers within the auroral zone and polar cap. The utility of the polesitter could also be augmented by using a UV imager to monitor the presence and motions of auroral blobs and polar-cap patches.

- Neutral Density Profile – The neutral density profile EDR primarily supports user requirements to specify the atmospheric neutral density for orbital tracking and prediction (DoD). This EDR is best satisfied using a limb-scanning UV sensor operating in LEO. A UV imager on a polesitter could augment the limb-scanned neutral density data by providing spectrally resolved measurements of the total atmospheric content over a broad field-of-view and some limited altitude-resolved data.

- Neutral Winds – This EDR is classified as a pre-planned product improvement (P^3I). Neutral winds contribute to the electrodynamics of the high-latitude E-region and are an important component in thermospheric modeling (DoD). The preferred space technique for the measurement of neutral winds is Fabry-Perot interferometry on a satellite in LEO. A polesitter spacecraft could marginally contribute to the measurement of neutral winds by observing the motions of neutral density structures or inferring the drag effect on the neutrals by the motions of auroral structures and polar-cap density patches.

- Instrumentation – The assumed functional instrumentation for a polesitter spacecraft addressing SESS EDRs are a UV imager and a beacon transmitter. The stressing requirements for the UV imager are its ability meet the spatial resolution and sensitivity requirements for the auroral EDRs. The threshold requirement for the auroral spatial resolution is <100 km over the entire polar cap ($\sim 2.4 \times 10^7$ km^2) with a pointing requirement of anywhere from 5-to-22 arc seconds (polesitter at 9.0×10^5-to-3.9×10^6 km). The imager must also be able to detect quiet to very active auroral. The refresh rate (full disk polar-cap image) should be □ 15 minutes. Regarding the RF beacon, this transmitter may need to have a fairly narrow beam ($0.1 – 0.3^o$) in order to illuminate the polar regions with sufficient power. Nominal transmit frequencies of 150, 400, and 1066 MHz are recommended.

Conclusions

- The GAT finds that there is significant merit in using a polesitter satellite to address several SESS EDRs. The extent of the EDR satisfaction is clearly dependent on the instrumentation and the spacecraft systems. The GAT finds that the auroral boundary and auroral imagery EDR could be fully satisfied through the use of a UV imager of sufficient sensitivity and resolution. It is also possible that the auroral energy deposition EDR could, in principle, be fully satisfied. The polesitter could also contribute to the high-latitude measurement of several other EDRs although, this contribution may be of marginal value.

Recommendation:

- None. Information only.

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