A Unified Proposal to the CSA Space Science Program (SSP) for a Mission in Space Environment: Report to the SuperDARN Consortium

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This proposal is for a small, unified, spacecraft mission (UP) that combines the scientific objectives of the Polar Outflow Probe (POP) and the Bistatic Observations using Low Altitude Satellites (BOLAS). It aims to address the interests of all Canadian POP and BOLAS Co-Investigators. It is premised on complete support from the Canadian Space Environment (SE) community under CSA's present 5-year plan.

Here is a brief discussion of the scientific objectives and mission characteristics of UP. This is followed by a statement about the programmatic status of UP in the CSA's Space Science Program (SSP).

UP Scientific Objectives

BOLAS background

Bistatic **O**bservations using **L**ow **A**ltitude **S**atellites (BOLAS) is an auroral-zone experiment on a spacecraft comprising two payload packages that are separated by a 100-m tether. Its objective is to improve the understanding of two classes of ionospheric dynamic processes that redistribute plasma energy in its flow from the sun to the low atmosphere. These are fluid instabilities near the peak of the ionospheric F region and microscale instabilities in the collisionless topside plasma. Attention would be given to the fluid processes near the F-region peak that give rise to density irregularities, such as the gradient-drift instability. Spaceborne BOLAS radio instrumentation is to be used to view these irregularities from low-earth orbit (LEO), providing a new perspective on the shape of density structures. In the area of microscale plasma instabilities, the simultaneous observation of thermal and suprathermal particles and concomitant waves would lead to improved models of the formation of ion conics, cavitons and other phenomena. These processes are an integral part of the transport phenomena that control energy and mass flux in the collisionless topside auroral ionosphere. As well, the electron density distributions are to be determined tomographically using transmissions from the GPS satellites to GPS receivers aboard BOLAS.

A payload carrying ELF-HF radio receivers is to be coordinated with ground radio facilities like SuperDARN to probe the high-latitude irregularities hitherto only observed from the ground. The receivers would measure the direction of arrival, signal delay and other parameters of transionospheric waves, as shown in the accompanying figure. Particle detectors would study spontaneous auroral processes.

POP background

The Polar Outflow Probe (POP) is a microsat mission to investigate plasma and atmospheric outflow processes in the 300-2000 km altitude region of the polar ionosphere. The mission extends current polar ionospheric research to a new domain - simultaneous neutral and charged particle study of the three-way

coupling between the ionosphere, the thermosphere, and the magnetosphere. The scientific thrust of the POP mission is to quantify the detailed characteristics of the topside polar ionospheric plasma populations, and to explore the possible role of the neutral populations in ionospheric outflow processes.

The primary science objective of POP is to study the detailed quantitative relationship between the solar electromagnetic (EUV) energy input, the photo-ionization of the upper atmosphere, and the outflow of the resulting plasma and accompanying neutrals to the magnetosphere. The secondary science objective is to explore the electrodynamic half of the equation. It will explore the relationship between solar wind energy input via magnetospheric electron precipitation and convection electric field, and electron ionization, plasma energization and outflow in the dayside cleft and auroral zone.

The original complement of POP instruments includes an imaging radio frequency ion mass spectrometer (IRM), a neutral mass and velocity spectrometer (NMS), and a suprathermal electron imager (SEI). This complement of instruments would make simultaneous, quantitative measurements of composition and velocity distributions of ions, neutrals, and electrons in the topside ionosphere.

Combining BOLAS and POP in UP

The significant scientific and technical overlaps between BOLAS and POP make it very desirable to have a single unified proposal (UP) that combines many of their respective objectives in a single mission. We propose to merge the science programs in BOLAS and POP by making topside-ionosphere measurements at high latitude, at least in the Canadian sector.

While there is more than one mission concept, the basic experiment concept has only one spacecraft. The science agenda includes essentially all the POP measurements. We retain the POP concept of an observatory operation aimed at systematic gathering of particle data over the mission lifetime, 6 months. An observational rationale of gathering case-study evidence from ground HF radars will continue as in BOLAS: predicted orbital track plus geophysical activity will be used to decide whether a particular pass should be recorded. The direction-of-arrival of waves from SuperDARN , CADI or other sources will be determined by using the two receivers to deduce the E-field polarization ellipse. The correlative observations of particles and wave fields will only be made at one point and so the dimension measurement for structures such as VLF cavitons will not be possible. However, an improved measure of the polarization of the associated electrostatic wave fields will be gained through the co-located receivers which operate from ULF through HF, as before.

In bringing together the scientific objectives of the two original missions, benefits are realized from their complementary natures. Transversely accelerated ions (TAI) contribute to ion outflows. TAIs are associated with electrostatic ion and electron waves. Wave measurements at the relevant frequencies by the receivers will bring a new dimension to the original POP investigation. TAIs are thought to occur in both auroral and polar regions. They are an important example of combining the polar focus of POP and the auroral focus of BOLAS, leading to a better understanding of the boundary between the two regions.

The single-satellite, basic-spacecraft, concept has a number of common technical requirements. The BOLAS-type STEM antennas (nominally 6 m) will enhance the stability of the spinning UP bus. Both original experiments required suprathermal electron and ion detection and GPS receiver capability. Putting the HF receivers on one spacecraft simplifies the direction-of-arrival measurement of waves. Only one dual-frequency GPS receiver is required for the ionospheric tomography in the basic concept. The BOLAS altitude range (~350 to ~600 km) can be accommodated within that of POP (300 to 2000 km), and the POP

orbital inclination of ~80° satisfies the requirement of BOLAS that the inclination be ≥65°. Both original proposals sought a range of local times. Finally, there are similar requirements in the mission support areas of satellite control, telemetry and command, and data archiving.

CSA Program Status of UP

Neither POP or BOLAS was approved by CSA following the 1996 Small-Payloads Announcement of Opportunity in which they competed. The science agendas nevertheless received very positive peer reviews. Not wanting to lose the considerable momentum developed in 1996, the POP and BOLAS Principal Investigators, Andrew Yau (U. Calgary) and G. James (CRC) respectively, investigated potential international collaborations that would address their scientific objectives at lower cost to the CSA. Their conclusion was that the only way to address the unique Canadian priorities of their proposals was to continue with a CSA-led concept.

Yau and James came to the conclusion that UP should be submitted early in 2000 as an unsolicited proposal to CSA/SSP. This position came after a period in the last 8 months of informing the SE community in Canada and gathering support for it. In summer 1999, CSA/SSP had encouraged the proponents to follow the unsolicited proposal route. Now, SSP does not accept as sufficient the support gathered and says that UP must compete in a new "Small-Payloads" competition. The problem is that the relevant Announcement of Opportunity by CSA/SSP for small payloads, originally planned for 1999, has suffered continuing delays. One of the reasons for the delay is that the CSA/HQ industrial policy for microsatellite procurement is being worked on. SSP officials have considered going back to the old two-stage selection, in which the science part of a proposal is first reviewed. If successful, implementation could be the subject of a later Request for Proposals to industry.

Contacts with potential foreign collaborators have been made. Possible widening of SuperDARN collaboration to outside the Canadian zone may be feasible once the primary approval cycle at CSA has been completed. CSA/SSP has two small orbital spacecraft (ACE, MOST) under development with no confirmed plans to launch either. This effectively puts pressure on the UP team to work with CSA to identify launch possibilities before any serious development begins.

The UP proponents still hope that an expeditious proposal review-acceptance cycle that takes into account progress already achieved in POP and BOLAS can be achieved for UP. Strong support from SuperDARN, at least the Canadian part, is an important foundation of the proposal.