The High-Latitude Ion Transport and Energetics (HI-LITE) Explorer: A mission to investigate ion outflow from the high-latitude ionosphere

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ABSTRACT

The proposed HI-LITE Explorer will investigate the global ion outflow from the high-latitude ionosphere, its relationship to auroral features, and the consequences of this outflow on magnetospheric processes. The unique nature of the HI-LITE Explorer images will allow temporal and spatial features of the global ion outflow to be determined. The mission's scientific motivation comes from the fundamental role high-latitude ionospheric ions play in the dynamics of the solar wind driven magnetospheric-ionospheric system. These outflows are a major source of plasma for the magnetosphere and it is beleived they play an important role in the triggering of substorms. In addition this paper describes the HI-LITE spacecraft and instruments.

1. INTRODUCTION

The High-Latitude Ion Transport and Energetics (HI-LITE) Explorer has been proposed in response to the NASA Announcment of Opportunity for Small Explorer (SMEX) missions. HI-LITE is uniquely designed to investigate the global ion outflow from the high-latitude ionosphere, its relationship to auroral features, and the consequences of this outflow on magnetospheric processes. HI-LITE will use global imaging to determine the characteristics of the outflow and its effects on the magnetosphere and will thus provide a new and unique perspective of the magnetosphere. For the first time it will be possible to see global images of the ion outflow from the cleft ion fountain and auroral field line region and to clearly distinguish temporal and spatial features. The development of such imaging capabilities is of high priority for space physics (see National Academy Report on Space Science in the 21st Centry, F. L. Scarf, Chairman, 1988). To understand the benefit that HI-LITE will have for magnetospheric physics, consider this: HI-LITE will image global ion outflow over all phases of substorm cycles in one orbital pass over the high-latitude region whereas a similar single map of ion outflow without information on substorm cycle required 18 months of in situ data from the Dynamics Explorer I spacecraft [1]. These images, combined with in situ and ground-based data, will enable us to greatly expand our understanding of the magnetosphere. The specific objectives of the HI-LITE mission are:

1. Determine the morphology of ion outflow with respect to solar wind and geomagnetic storm conditions, and magnetospheric substorm phase, so as to understand the role of these ions in magnetospheric dynamics.
2. Determine the relative importance of the auroral acceleration region and cleft ion fountain as the sources of ions in the magnetosphere.
3. Determine the location and characteristics of transverse ion energization in the cleft ion fountain.
4. Determine the relationship between energy input into the ionosphere and corresponding ionospheric outflow.

The HI-LITE mission requires innovative imaging instruments: i) an 834 Å O^+ imager (OXI) to map the ion outflow, ii) a UV spectrometer to determine ion and electron precipitation (UVIS), and iii) a low energy neutral atom imager to remotely sense the H^+ and O^+ distributions in the energy range from 10 eV to 300 eV (ILENA). These instruments all use current technology and will either be existing designs or developments of existing designs. In addition to the imagers, a plasma ion mass spectrograph (PIMS) will measure the composition, energy, and angular distribution of upflowing ions to provide "ground truthing" for the neutral imager and to provide a reference for combining the imaging data with other in situ measurements. Other simultaneous low altitude and geosynchronous data, such as those from NOAA, DoE and DoD spacecraft, will be used to extend the range of science undertaken and as additional "ground truth".

The HI-LITE mission's scientific motivation comes from the fundamental role high-latitude ionospheric ions play in the dynamics of the solar wind driven magnetosphere-ionosphere system. Ionospheric outflows are produced by energy from the solar wind via ionospheric heating and electrostatic acceleration. These outflows are a major source of plasma for the magnetosphere and it is thought that they play an important role in the triggering of substorms. Although in situ measurements have provided an insight into the role these outflows play, they cannot provide a comprehensive view of the instantaneous configuration over latitude and local time. Indeed, it is clear that these processes are highly time-dependent, and spatially structured, and thus only global imaging on the appropriate timescales will provide further insight into the coupling processes. HI-LITE will produce complete global images at intervals of approximately 5 minutes, thus giving a significant number of images within each phase of a substorm cycle. The HI-LITE images will enable the variations and locations of the ion outflows to be determined, and hence clarify the role of the ionosphere in storms and substorms. The relationship between the outflows and the energy input into the ionosphere will also be established by combining the outflow images with the UV spectrographic images and low altitude data.

Comparison with previous in-situ measurements will be achieved by combining the HI-LITE data with in situ measurements from the ion mass spectrometer and low altitude data from operational satellites. These combined data will provide an important link between the new imaging results from the HI-LITE mission and previous and future in situ measurements in the high latitude region. HI-LITE will also benefit from collaboration with other programs (e.g. the Solar-Terrestrial Energy Program, STEP), data from geosynchronous LANL/DoE spacecraft, other NASA missions (e.g., Wind, Cluster, and Polar), and ground-based observations (e.g. radars and all-sky cameras). Just as HI-LITE will benefit from other programs, an important component of the HI-LITE mission will be the rapid dissemination of data relevant to the scientific community and the general public. We will develop what are in effect "weather maps" of ion outflow from, and energy input to, the high-latitude regions of the Earth's upper atmosphere. Ion outflow and auroral features will be imaged when the spacecraft passes through apogee (i.e., ~45 minutes of the 2.4 hour orbit), providing a series of instantaneous views of the global state of the ionosphere as it reacts to changes in the solar wind and the Earth's magnetosphere. Such information is invaluable to ionospheric and magnetospheric researchers whether they employ ground- or space-based data. We will provide these maps to the community at large on a non-proprietary basis as soon as possible after data are received at the science operations center.

The HI-LITE Explorer will use the NASA alternative spacecraft architecture, similar to FAST, provided by NASA/GSFC. All spacecraft systems, such as electrical and avionics, are standard units thus significantly reducing cost and development time. Data acquisition, image integration, and instrument control will be handled by a dedicated instrument data processor unit (IDPU). The modest data rate requirements of HI-LITE allows the use of an existing DPU design further reducing cost, risk, and development time. The HI-LITE Explorer will be placed in an elliptical 250 km by 4600 km orbit at an inclination of 65°. It will be spin-stabilized with a nominal spin rate of 1 rpm and look very similar to the FAST spacecraft. The low-inclination orbit reduces the precession of the apogee thus allowing imaging of the northern hemisphere for the complete one year mission while still allowing the PIMS to make in situ measurements of the cusp/cleft and auroral regions at all local times.

2. SCIENCE OBJECTIVES

2.1 Overview

A major objective of space physics is to understand the Earth's magnetosphere and its interaction with the ionosphere and solar wind. Nowhere is that interaction more readily apparent, or more highly variable, than in the high-latitude regions of the Earth's magnetosphere. Input from the solar wind produces significant effects on the Earth's ionosphere including auroral displays and upwelling of ionospheric ions that ultimately become part of the magnetospheric population, and interact back on the ionospheric plasma. When the amount of solar wind mass, energy, and momentum added to the magnetosphere is high, the system becomes highly disturbed and the energy imparted to the system is dissipated explosively through the substorm process. The high-latitude magnetosphere plays a central role in this dynamic energy dissipation process. In the interaction of the solar wind with the ionosphere, the Earth's ionosphere at high latitudes has two principal roles. First, it allows closure of magnetospheric current systems and acts in conjunction with the neutral atmosphere as a damper of plasma motions driven by the solar wind. Second, it acts as an important source of plasma for the magnetosphere, due in part to the energy dissipation associated with the damping process.

We know from statistical sampling of a large number of in situ measurements that ion outflow from the high-latitude regions is substantial[1]. Depending on the level of solar and magnetospheric activity, ionospheric ions can contribute from a small fraction to nearly all of the plasma in the Earth's plasma sheet [2,3]. The exact magnitude of the ionospheric contribution remains uncertain due to lack of definitive, global observations but, as illustrated in Figure 2.1, ionospheric ions that ultimately populate the plasma sheet are predominantly from the high-latitude region. The dynamics of the ion outflow from particular regions within the high-latitude ionosphere are different. The outflow from the polar cap, called the polar wind, is continuously present. It consists of light ions (~few eV H^+ and He^+) and is relatively independent of interplanetary conditions and geomagnetic activity [4]. The outflow from the high latitude auroral regions is much more dynamic, contains heavy ions such as O^+, and is correlated with both geomagnetic and solar activity [5,1]. It is this latter region that is the primary source of ionospheric plasma in the Earth's plasma sheet and is the main focus of the HI-LITE mission.

Since thermal O^+ in the ionosphere is gravitationally bound, its escape from the high-latitude regions requires a pre-energization mechanism [6]. The other major outflowing species, H^+, is not gravitationally bound and acquires its energy above ~1000 km,

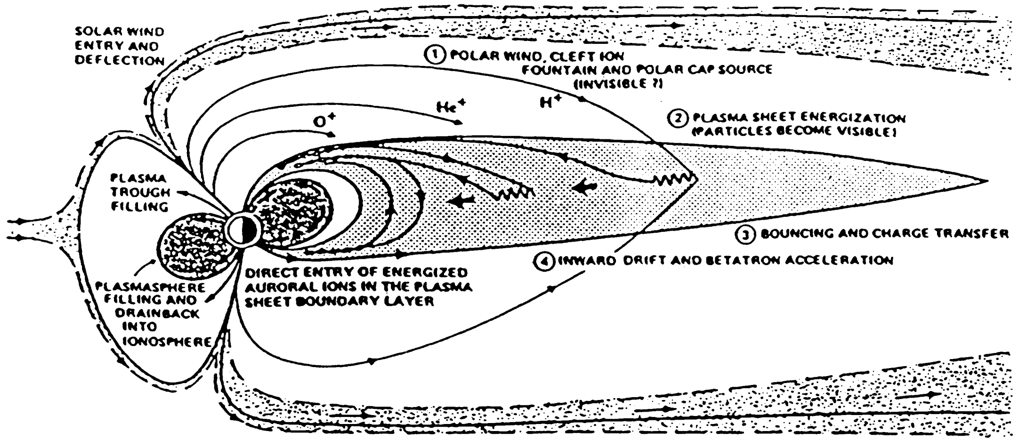

Fig. 2.1 An illustration of the filling process through which plasma from the high-latitude ionosphere populates the different plasma regions of the magnetosphere

where thermal H^+ dominates the cold plasma. Both ion species are limited by charge exchange with the geocorona neutral H . This charge exchange process give rise to an intense flux of neutral O and H in the high-latitude magnetosphere[7]. One of the prime objectives of the HI-LITE mission is to observe these neutrals for the first time.

Our current knowledge of ion outflow has been acquired from long time-averaged in situ measurements [1,4,8,9,10] which do not provide information on time variability and have not resolved ambiguities in primary source location or energization mechanisms within the high-latitude region. We know the magnetosphere is dynamic on a wide range of time scales with the most significant, yet poorly understood, variations occurring on time scales ~5-10 mins, the characteristic time scale of magnetospheric substorm subprocesses. There are indications that the morphology of magnetospheric substorms is directly related to variations in ionospheric plasma sources [11,12,13,14] and radar observations have resolved short period variations in ion upflows [15,16] but with very limited altitude coverage. However, at present, this relationship can only be considered as speculative since the contributions of escaping ions to the structure of the plasma sheet during quiet times and in the various phases of a magnetospheric substorm are poorly understood [3]. A large part of the difficulty in determining the importance of ion outflow to magnetospheric processes such as substorms is related to the lack of knowledge of global ion outflow on characteristic substorm time scales.

Equally important are the uncertainties in the location of the primary region (or regions) of ion outflow and the dominant mechanism (or mechanisms) for ion acceleration. New optical and neutral atom imaging technologies are now available to monitor the instantaneous spatial distribution of ion outflow from the polar ionosphere and to relate directly this outflow with energy input into the ionosphere. These technologies allow the identification of the role of ion outflow in magnetospheric processes on all time scales of interest. We propose to use these new technologies to determine the instantaneous configuration of ion flow between the high-latitude ionosphere and the magnetosphere. In the following sections, we discuss individual science topics and the unique contributions HI-LITE will make to them.

2.2 The cleft ion fountain and auroral acceleration region as primary sources of magnetospheric plasma

Several studies have indicated that the auroral acceleration region is an important, if not dominant, region of ion outflow [17,18] However, the discovery of the cleft ion fountain[19,20,21,22] and subsequent interpretation of the ion outflow in this region, [20] indicate that it is also an important source of low energy ions in the polar cap, and ultimately, in the plasma sheet. More than 20 years after the discovery of O^+ in the high-latitude region and the realization that the ionosphere is a significant contributor of magnetospheric plasma [23], the primary region of low energy ion outflow remains controversial. Furthermore, the possibilities are diametrically opposite: On the one hand it is supposed that an intense localized cusp is providing the ionospheric ions for the magnetosphere, and on the other hand the source is speculated to be a diffuse extensive region comprising the entire auroral zone. One possibility is that both interpretations of the data are correct. For example, one region is the dominant outflow source for one level of geomagnetic activity, while the other source dominates under other conditions. However, it is important to realize that the failure to resolve this controversy is due entirely to the limitations of in situ measurements. In situ sensors measure the ion flow along the spacecraft trajectory which is a line through the high-latitude volume of latitude, local time, and altitude. Extension of these measurements to other locations depends on orbit precession; requiring months for full local time coverage. Thus, the observations to date have provided a local rather than global view of the high-latitude magnetosphere. The global perspective is produced only by interpretation of a large number of individual, localized measurements which do not resolve temporal or spatial relationships between various regions. Resolution of these issues requires global imaging of the high-latitude ion outflow regions on time scales commensurate with the solar wind-magnetosphere interaction cycle since individual source region may be dominant for specific phases of a substorm or for different levels of solar and/or magnetospheric activity.

The HI-LITE Explorer is uniquely qualified to provide the requisite imaging of terrestrial ion outflow. This imaging is central to the mission and, as such, two imaging instruments on the spacecraft are dedicated to determining outflow of O^+. Using EUV line emissions from O^+, the OXI imager will image the line of sight O^+ density above the HI-LITE Explorer. By imaging the neutral oxygen charge exchanged from O^+ in the Earth's geocorona, the ILENA instrument will provide information on the O^+ energy and density in directions (such as below the spacecraft) where the OXI imager cannot view because of high background counts from cold O^+ at ionospheric altitudes. In addition, ILENA will simultaneously image the outflow of the other dominant ionospheric component, H^+. The combination of the images from these two instruments will be used to build a data base far superior to the in situ measurements, but which will distinguish the primary ion outflow source regions.

2.3 Ionospheric outflow and its relationship to magnetospheric substorms

One of the fundamental dynamical features of the Earth's magnetosphere is the substorm. The ultimate driver for this dissipation is the solar wind which continuously (but at variable rates controlled by the IMF) imparts mass, momentum, and energy to the magnetosphere, a major part of which is stored in the Earth's magnetotail. The onset of a magnetospheric substorm expansion phase is the beginning of the explosive dissipation of this stored energy. Typically this onset occurs in the near Earth magnetotail at distances from 8-20 R_E [24,25]. Some of the energy released during a substorm is transferred to the inner magnetosphere where it appears as ring current enhancement, Joule heating in the ionosphere, and auroral particle precipitation, while the rest of the energy is returned to the solar wind through processes in the deep geomagnetic tail. Eventually, the magnetosphere recovers from the explosive dissipation phase and energy again begins to be stored in the magnetotail until the next substorm is triggered. The entire process of explosive dissipation and recovery takes an average of about one to two hours and recurs every few hours if energy transfer from the solar wind continues at a high rate (i.e., the IMF remains southward). Much of the phenomenology of the substorm process has a firm observational basis. However, substorm expansion and recovery are important features that have not been explained fully despite intense interest in these topics (see review by Fairfield[26]).

Ionospheric ions from the high latitude regions may play a significant role in both substorm onset and recovery since these ions populate the Earth's plasma sheet at distances where principal substorm processes occur (Figure 2.1). Baker et al.[11] argued that a reduction of the plasma sheet half-width during the substorm expansion phase should lead to a demagnetization of O^+ ions and enhanced growth of a large-scale ion tearing instability believed to initiate the substorm explosive growth. The substorm recovery phase (commencing ~30 min after substorm onset), is the least understood interval of the entire dynamical cycle. However, it is well documented that larger relative oxygen ion densities are observed in the plasma sheet after the expansion phase than during the growth phase [12]. This O^+ must be supplied from the high latitude region during the substorm. In addition, the ionospheric ions in the plasma sheet may cause important differences between strings of multiple substorms and isolated substorms.

Considering the potential importance of ionospheric ions in the substorm process, there have been suprisingly few investigations of the ionospheric ion source and its dependence on interplanetary and substorm conditions[13]. Part of the problem in investigating the ion source morphology with in situ measurements is the difficulty in determining the dominant region of ion outflow is described above. However, in the case of substorms the difficulty with the in situ measurements is much greater than a simple spatial issue since different segments of the high latitude region may be important at different phases of the magnetospheric substorm. Hence, in situ measurements provide either a snapshot of ion outflow in a very localized region or a statistical sample of a large region lacking any sort of temporal information. Neither of these can be used to determine the importance of ionospheric ions in the substorm process on a global scale.

The resolution of these issues requires global imaging of ion outflow over timescales appropriate to the substorm process (a series of ~5 minute snaphots over total characteristic times of ~1 hour). This is a fundamental element of the HI-LITE mission. HI-LITE will provide global imaging of ion outflow using OXI at the rate of one image every 3-5 minutes over an interval of approximately 45 minutes as HI-LITE passes through apogee. Over the ~1 year lifetime of the HI-LITE spacecraft, we will observe several hundred substorms. The phase and timing of these substorms will be determined from the HI-LITE UVIS images and from complementary data from LANL/DoE geosychronous spacecraft [27]. With these measurements, spatial variations of the ion outflow will be separated from temporal changes related to the substorm process and the importance of the ionospheric ions to the substorm process will be determined. Based on concurrent, simultaneous observations of the HI-LITE instruments and low altitude data, we will determine the relative positioning of ion outflow and magnetospheric boundaries. For example, from the shape of the upwelling "plume" we will determine whether the ion outflow occurs on sunward or antisunward convecting field lines and how the outflow is related spatially to substorm features such as westward travelling surges, which are at the base of the evening side of the substorm current wedge[28]. The observations of the spatial distribution will be combined with magnetic mapping using current models [29] to assess the expected magnetotail plasma injection region [24,30].

2.4 Energy input into the ionosphere and its relation to ion outflow

The high latitude ionosphere has several sources of energy input that vary with local time, latitude, magnetic activity, and relative phase of magnetospheric substorms. In addition, ion outflow is now considered the result of multiple processes acting at all altitudes on field lines from below 1000 km to several Earth radii. In the cold ionosphere at ~250 km altitude, O^+ is gravitationally bound with a scale height of only a few hundred km and interacts strongly with neutral hydrogen atoms. Thus, outflowing O^+ at heights well above 1000 km requires an energy source to escape the gravitational and charge exchange barriers. The source of this energy is generally thought to be ion-neutral frictional heating. We make the distinction here between this type of heating and Joule heating in that the latter does not allow for the neutral thermospheric wind at F-region altitudes, which can be significant under time-varing conditions[31]. However, one-to-one correlation of heating and ion outflow has been done only episodically, and the most complete analysis [32] detected no direct correlation between high-altitude (>10,000 km) ion outflow and heating at ionospheric altitudes. Early work had suggested that cleft ion outflows are directly related to solar wind electron precipitation [33]. However, no direct connection has been made between regions of particle energy input into the ionosphere and regions of upflowing ions. A third source of energy input to the ionsphere is low frequency wave power which has recently been investigated systematically by Heppner et al.[34]. Using a statistical data base of DE-1 AC electric field measurements from 4 - 512 Hz at ionospheric altitudes, they concluded that a large amount of the observed wave energy was from Alfvén waves which have been shown to be very efficient heaters of O^+ ions[35]. These data imply that a large component of ion outflow is neither correlated with ion-neutral heating nor particle precipitation. The picture of ion outflow inferred from low and high altitude databases are vastly different. Loranc et al. [36]used data from the DE-2 spacecraft to show that the general latitude and local time range of upflows of thermal ions mirrors that of high-altitude energetic ions [1] except that the fluxes are significantly lower at high altitudes than those observed at ionospheric altitudes.

The HI-LITE explorer offers a chance to systematically and quantitatively examine the relationships between energy inputs and ion ouflows. The set of imaging instruments on the spacecraft combined with the on-board ion mass spectrometer will allow a quantitative evaluation of ion outflow flux associated with particle precipitation and heating. Using spectroscopic UV imaging from UVIS, it will be possible for the first time to obtain the precipitating proton energy input from doppler shift of the Lyman-alpha line and electron energy input from absorption of LBH bands. Since UV imaging can be made on both the sunlit and nightside auroral oval, this energy input can be determined at the base of the cleft ion fountain as well as the rest of the auroral acceleration region. The UVIS will make whole orbit, large area, "global" cross track measurements of the proton energy input which will be used to estimate the local proton contribution. The measurements will allow estimation of the proton energy input as a function of magnetic activity for comparison with theory. Ion outflow measurements from OXI and ILENA will be combined with the UVIS instrument to determine the correlation between ion outflow and proton and electron input into the ionosphere. The relationship between ion-neutral frictional heating and ion outflow will be examined by using ion drift measurements made by instruments on DMSP spacecraft passing through an auroral arc imaged by OXI. We expect at least one such interval in each HI-LITE orbital pass.

2.5 Determination of the spatial variation of transverse ion energization and the neutrals produced through charge exchange

A region of intense O^+ transverse ion energization to energies ~10 eV has been identified extending from ~2,000 to ~10,000 km on the dayside of the magnetosphere. The localized and infrequent nature of the observations in this region has lead to two different interpretations. Lockwood et al.[37] have called the region the upwelling ion region and observed it from ~0900 to ~1300 magnetic local time (MLT). The plume of upwelling ions from this dayside source is dispersed by convection over the polar cap [21,37]. Although the association of the upwelling ions with field-aligned currents suggested that Joule heating was an important energy source, Moore et al. [38] were unable to identify the driving energy source using in situ measurements from one pass through the region. Recently, however, Whalen et al.[39] have obtained data with higher temporal and energy resolution and concluded from the satellite and earlier rocket observations that the localized upwelling ion region is the high-altitude, dayside component of a Transverse Ion Energization (TIE) region which is an annulus covering all local times but at lower altitudes on the night side. Peterson et al.[40] have noted that the source of the nearly stationary dayside thermal O^+ population with intensity comparable to H^+ at altitudes of ~2-3000 km observed just equatorward of the TIE or upwelling ion region is uncertain. These different interpretations are the direct result of a lack of a global view of the cleft ion fountain. Statistical surveys of the fountain from DE-1 produced ion outflow maps where local time and seasonal variations of the outflow were averaged together as the orbit configuration changed. Such averaging makes it impossible to compare ion outflow rates as a function of local time or altitude to determine the extent of the base of the fountain.

The ILENA instrument will provide the global view of the base of the cleft ion fountain and TIE regions needed to determine the correct interpretation of previous in situ data (see paper by Hesse et al., this issue). Using a combination of the PIMS and ILENA measurements, we can thus determine if the source of the stationary O^+ equatorward of the upwelling ion region is photoionization of neutral O at ~2,000 km altitudes, simple transport of O^+ from the ionosphere below, or the result of processes driven by the entry of solar wind plasma into the cusp/cleft ionosphere.

2.6 Resolution of the ambiguities in the ion acceleration mechanism

As described previously, a major element of the HI-LITE mission will be to determine the dominant region(s) of ion outflow and resolve the controversy between a localized cleft ion fountain source and an extended source over the entire auroral zone. However, additional ambiguities have proven to be unresolvable with present in situ measurements in the high-latitude region. These include the mechanism or mechanisms that pre-accelerate cold ionospheric O+ to energies of 10 to 100 eV. The possible pre-acceleration mechanisms are known to be mass dependent from the observations of energized H^+ and O^+. Two suggested mechanisms are Joule heating [36,41] and wave heating [34].

In the steady state limit, these two mechanisms produce fundamentally different latitudinal distributions of ion outflow. If current-driven wave heating is responsible for the ion pre-energization, then ion outflow maximizes at the location of maximum shear in convection, i.e., at the reversal. If another wave source is important, then ion outflow maximizes wherever those waves maximize, which may not necessarily coincide with any feature of the convection pattern.

However, an important new insight into the relationship between the upflows and Joule heating processes comes from recent advances in our understanding of ion convection, particularly on the dayside. During periods of extreme magnetic activity, Lockwood et al.[42] have shown that intense ion heating is found on the trailing edge of the convection boundary as the boundary expands and contracts. In addition, Jones et al.[15] and Winser et al. [43] have shown that ion upflows are associated with the region behind a moving convection shear. This effect demonstrates the important role of the neutral wind in the heating. DE-1 and -2 data obtained simultaneously on the same field line have been used to demonstrate that ionospheric Joule heating in the absence of a neutral wind is not directly related to ion outflow[32]. Furthermore, convection patterns and models (both empirical and conceptual) have been traditionally steady-state in nature. This means that the rate at which open flux is generated by reconnection at the dayside magnetopause is identical to that with which flux is closed by reconnection in the tail. This must hold on time scales which are long compared with the substorm cycle - but the very concept of storage of open flux in the tail lobe during the substorm growth phase reveals that it does not hold on time scales shorter than a substorm cycle. Observations of the response of convection to changes in the IMF [44] show that traditional convection patterns must be considered as the long-term average of two almost independent flow patterns[45,46,47]. The first is driven by the generation of open flux by dayside reconnection and produces strongest flows on the dayside which dominate during the growth phase of substorms. Because the Joule heating and any ion heating associated with field aligned currents will be greatest on the dayside for such flows, one obvious prediction is that the cleft ion fountain will dominate during substorm growth phases. The second component of the overall convection pattern is driven by reconnection in the geomagnetic tail, which gives dominant flows and field-aligned currents on the nightside - hence nightside upflows dominate during expansion and recovery phases of substorms.

These simple predictions will be easily tested by studies of the global upflow morphology determined from OXI and ILENA as a function of substorm phase, as determined by the UV imager. UVIS will produce an image of the precipitating regions every 3-5 minutes over a wide geographic area incorporating the auroral regions and polar cap. Using spectroscopic techniques, the pre-cipitated energy distribution of the electrons and protons will be determined from the images. The global particle induced conductivities will be estimated from such energy distributions.

One way to resolve the pre-energization mechanism would be to image field-aligned currents and plasma convection. However, at present this is not possible. Instead, HI-LITE will make use of public domain in-situ data from operational weather satellites and, where available ground-based data, to provide measurements of field-aligned currents and plasma convection in localized regions. These observations, such as the location of the convection reversal boundary, will be related to the global ion outflow. The convection reversal boundary will also be determined globally with similar resolution to the HI-LITE observations by in-corporating data from satellites, radars and magnetometers using the AMIE technique [48]. These correlations will be used to test the Joule and/or ion-neutral frictional heating models.

2.7 Correlation of Neutral atom imaging, ion imaging, and in situ ion measurements

The ion imaging techniques in this investigation are state-of-the-art but based on proven technologies. Given the uniqueness of these measurements and the pioneering aspect of explorer missions, it is important to provide some "ground truth" tests of the technology. To do this, a mass spectrometer is included on the HI-LITE explorer to provide direct in situ observations of ion outflow including mass discrimination.

In addition, ancillary, public domain data from DMSP and NOAA satellites will be available on nearly a once per orbit basis to correlate the in situ measurements with global images from the HI-LITE explorer.In addition to providing a ground truth mea-surement for the ion imaging experiments, the comparison of in situ measurements and global imaging will provide a unique determination of how local measurements are related to global ion outflow. As indicated above, several controversies have resulted from the global interpretation of local in situ measurements. Comparison of the two techniques will resolve these controversies and will provide insight for current and future missions such as ISTP and Grand Tour Cluster (GTC) which rely on in situ single or multiple spacecraft measurements.

2.8 Interstellar Neutrals

Our knowledge of interstellar neutral gas penetrating the heliosphere stems primarily from remote sensing optical resonance scattering observations[49,50]. The first attempts to measure the interstellar neutral gas composition directly were carried out on the LDEF mission using the foil exposure technique developed at the University of Bern [51,52]. Mobius et al. [53] have reported the observation of interstellar ^{4}He, ionized inside the Earth's orbit, and picked up by the interplanetary magnetic field. Recently, Witte et al.[54] have observed interstellar species on ULYSSES. Direct measurements have yet to be reported for the isotopic composition of interstellar H or He. The primeval D/H ratio in the early solar system can be inferred from the solar wind He isotopic composition. The first direct determination of the deuterium abundance in the local interstellar gas will thus be an important cornerstone for understanding of the early history and geochemical evolution of the solar system, and will also be valuable astro-physical information for the isotopic evolution of the interstellar medium during the past 4.5 b.y.

Whereas He isotopes can be measured using the foil technique, ILENA is well suited for measurement of the interstellar H composition. The instrument can directly measure the neutral atoms of the interstellar wind with velocities ranging from 20 to about 70 km/s, depending on the season of the year. These neutrals will be distinguished from any ambient exospheric neutrals by their direction of arrival and their substantially larger energies. Particularly favorable conditions occur from April through July when the H, D, He, and O energies of the interstellar species are within the primary energy window of the ILENA instrument (10 to 200 eV), and when the Earth will be at the location where a fraction of 2 to 4% of neutral H and D survive ionisation by charge exchange and UV-irradiation. Count rates in the ILENA instrument are estimated to be ~100 to 1000 s^{-1}, sufficient to determine direction, temperature, and chemical composition (H, He, O) of the interstellar gas. Furthermore, due to low background inherent in the coincidence TOF-technique employed, ILENA will measure the D/H and the ^{3}He/^{4}He isotopic abundance ratios.

3. INSTRUMENTATION

The HI-LITE instrument complement has been specifically chosen to address the scientific objectives detailed in the introduction. A combination of techniques is needed to achieve these objectives. EUV 834 Å imaging will provide direct measurements of the global O^+ concentrations. Neutral atom imaging uses charge exchange with the geocorona to obtain both H^+ and O^+ concentrations over a defined energy range. In the following sections we give brief descriptions of each of the HI-LITE instruments. More detailed instrument characteristics can be found in the papers by Hesse et al. and Ghielmetti et al. (this issue) for ILENA, Mende and Jamar (this issue) for UVIS, and Chakrabarti et al. (this issue) for OXI.

3.1 OXI

The OXI instrument on HI-LITE will be able to remotely sense upflowing O^+ ions by obtaining upward looking images of 834 Å emission. The 834 Å transition can be excited in a number of ways. In the lower thermosphere the dominant source is photoionization and excitation of atomic oxygen by solar EUV radiation. Two other sources, photoelectric ionization and excitation of atomic oxygen and resonant scattering of the solar 834 Å feature, each contribute about 10% to the total emission rate. The resulting emission from the Earth's lower thermosphere and ionosphere is quite bright (~ 1000 R). In addition, it has the character of both the atomic oxygen distribution, since most of the source is due to ionization and excitation of O, and the ionospheric O^+ distribution, since once the 834 Å photons are emitted in the lower thermosphere they must scatter through the F-region O^+ ions on their way into space. The upflowing oxygen ions that we are interested in will be illuminated by 834 Å photons from the sun and ionosphere. These ions will resonantly scatter some of the photons down towards the OXI instrument. The expected 834 Å brightness from the upflowing ions is very low (~0.1 R). Hence, OXI must be highly sensitive yet have a large dynamic range to allow for images of the brighter ionosphere to be obtained. The adopted design will observe 0.1 R 834 Å emissions in a single satellite spin (1 minute) and is based on a sounding rocket instrument (WIDGET-Wide Angle Geocoronal telescope [55]), flown in 1992.

3.2 UVIS

UV spectrographic imaging makes use of spectral imaging of several lines in the 1000-1500 Å range to determine the electron and proton energy input into the atmosphere. By aligning the spectrometer slit perpendicular to the orbital plane and parallel to the spacecraft spin axis, a two-dimensional image of auroral emissions is produced as the spacecraft spins. The third "dimension" is the wavelength of the emissions. Since the aurora is generally brighter than the daylit atmospheric background in this wavelength range, the auroral oval can be monitored on both the day and night sides. An added advantage of the far UV (FUV) wavelength range is that opacity of the underlying lower atmosphere eliminates the Earth's albedo contamination of the measurements. These advantages were adequately demonstrated by the DE and Viking FUV imaging experiments [56,57]. However, these previous FUV imaging experiments were limited in their wavelength resolution because of the wide bandwidth of transmission filters in the FUV waveband. By using a spectrometric imager instead of transmission filters, the wavelength resolution is improved to the point that it is possible to measure specific emission lines in the 1000 to 1500 Å range. These lines are used to determine electron and proton energy input into the atmosphere.By measuring the doppler shift of the very intense Lyman alpha emissions generated by charge exchanged precipitating protons, the energy of the precipitating protons is determined. These emissions are extremely bright (3.6 kR on the dayside, 7.9 kR on the nightside[58] and images can be obtained once per spacecraft spin.There are a number of UV emission spectral features in the FUV which provide diagnostics of the electron energy flux and the mean energy of the precipitating electrons. Different components of the LBH bands in the FUV frequency range are absorbed to differing degrees by atmospheric O_2. By taking the ratio of these band components, the amount of absorbing O_2 and thus altitude of the emissions is determined [59]. The energy deposition and flux of the electrons is determined from the absolute intensity of the LBH and the OI(1356 Å) lines. The intensity of the 1273 Å line is somewhat independent of the mean energy of the electrons which defines the depth of electron penetration into the atmosphere. From the ratio of the intensity of this line and the combination of the other lines above 1300 Å, which do depend on the penetration depth, the mean energy of the precipitation can be calculated. The measured absolute intensities can be related uniquely to the total precipitated energy flux. These techniques require a high sensitivity instrument because in weak diffuse auroras the FUV line strengths are only a few tens of R.

3.3 ILENA

Neutral atom imaging is a new technique that enables global imaging of magnetospheric plasmas to be undertaken[60]. Briefly, the Earth's geocorona acts like an imaging screen for ions in the ionosphere/magnetosphere. These ions charge exchange with the Earth's geocorona producing neutral atoms. The neutrals produced in this reaction leave the interaction region with essentially the same energy as the outflowing ion. In addition, the direction of the neutral is that of the ion at the moment of the interaction, i.e., the combination of gyromotion and motion along the field. The neutral then travels in a almost straight line to the imaging point, modified only by gravitational acceleration. For the lowest energies (~10eV), this leads to an appreciable angular distortion, estimated to be < 14° for 10eV O_+ at a distance of $1R_E$ from the source region. For energies of 30eV and above, the angular deflection is less than 4.6°, below the limit of the angular resolution of 6°x6° for each pixel. Therefore, energy channels above 30 eV will make it possible to produce an image of the input ion energy and direction by collecting and analyzing the neutrals. Despite the distortion, energies below 30 eV can be used for imaging at distances closer to the source, and will provide the total low energy source flux in any case. Both the density of the Earth's geocorona and the cross sections for H^+ and O^+ on H and O neutrals are well known. It is thus possible to calculate a neutral flux leaving an interaction region for any specified O^+ or H^+ distribution.

Neutral atom imaging in space has been demonstrated by Roelof [60] for relatively high energies. To measure neutral atoms in the HI-LITE energy range (10-300 eV), a specially designed instrument is required. ILENA takes advantage of the narrow lobe scattering that occurs in atom-surface collisions with little energy loss [61] and high neutral-to-ion conversion efficiency on cesiated surfaces[62]. The concept of combining such a converter surface with a spectrograph has been described by Herrero and Smith [63]; the approach here differs in that a Cesium surface converts the neutral atoms to negative ions and a time-of-flight (TOF) is used instead of a magnetic mass spectrograph. ILENA uses a spherical wide-passband electrostatic analyzer as a low resolution energy spectrograph which at the same time provides high light trapping efficiency by multiple surface reflections and solid angle attenuation [64]. The spectrograph enhances sensitivity by measuring all energies and all masses of interest simultaneously without scanning magnetic or electric fields. Thus, ILENA combines components with previous spaceflight heritage to achieve our desire of high sensitvity and low background levels.

3.4 PIMS

PIMS will address the requirements for in situ ionospheric ion outflow measurements in support of the goals of the HI-LITE mission. These measurements will be crucial in providing ground-truth information about the escaping flux of ionospheric plasma, thus facilitating the quantitative interpretation of the images to be obtained from other HI-LITE instruments. PIMS is derived from extensive experience with low energy ion observations using the B-field Electrostatic Energy and Pitch angle Spectrometer (BEEPS), the SuperThermal Ion Composition Spectometer (STICS), the Dynamics Explorer Retarding Ion Mass Spectrometer (RIMS), and the GGS/Polar Thermal Ion Dynamics Experiment (TIDE). The PIMS instrument, which is a new version of BEEPS, provides a compact lightweight, low power capability which is in every way comparable with that of TIDE, except that it has a considerably smaller sensitivity per sector (by a factor of ~15-20) and has lower mass resolution. Because the emphasis for HI-LITE is on the outflows of the major ionospheric species rather than on detailed composition measurements including minor species, this approach is well-justified. PIMS is a "top hat" hemispherical electrostatic energy analyzer feeding a toroidal magnetostatic mass analyzer. Detection is by means of a single circular MCP assembly which images the mass and angle distributions in radius and azimuth, respectively. Three masses (H^+, He^+, and O^+) can be imaged simultaneously, so that the only swept variable is energy. PIMS is designed for a useful range of 0.3 to 300 eV with 12-bit resolution.

3.5 IDPU

The HI-LITE IDPU is based on the existing SwRI SC-2A spacecraft computer. First developed in 1987, the original SC-2 flew successfully on STS-42. The IDPU is an off the shelf unit and only interface boards will need to be developed; thus greatly reducing development time and cost. The IDPU provides command, telemetry, and computational support to the OXI, PIMS, ILENA, and UVIS instruments. It also provides both a communications path to the MUE's central processor, and a telemetry link via the downlink card in the MUE. A 40 MB buffer memory in the IDPU stores data prior to transmission. The heart of the IDPU is the 80C186/80C187 based central processing unit. Operating at 12.5 MHz, the CPU delivers approximately 800k operations/sec . The processor is equipped with a generous amount of RAM, EEPROM, and UVPROM memory as well as priority interrupt ports and two RS-422 interfaces.

The IDPU provides a dedicated, intelligent controller interface for OXI. Since the event rate is relatively slow (< 50 k/s), events can be processed in firmware. The interface card is a modified version of the central processor described above. An event is signalled to the interface through a hardware interrupt. The WSZ signals are presented as three, 12-bit digital words. the controller reads spacecraft position (via the MUE) and applies the necessary offsets to the sensor x,y coordinates to position the event in terms of absolute sky position.PIMS and ILENA are of low complexity and the interfaces to these instruments will be processed on a single board. The PIMS interface is a simple buffer memory with a small front end data transfer circuit. The IDPU will send a synchronization signal to the sensor at a rate of spin rate x 1024. The sensor will then burst transmit mass/sector measurements corresponding to its present energy setting. The CPU will maintain energy and azimuth values in its own registers and use these values, in conjunction with the mass and sector values transmitted by PIMS, to form the absolute data storage address in the PIMS data memory. The ILENA interface is a simple histogrammer. The sensor presents the IDPU with the bin number, mass, and energy for each event. the IDPU maintains spacecraft azimuth in CPU registers and is thus able to store the ILENA event in the correct location for absolute sky position. A single card supports the UVIS instrument interface and provides a 40MB buffer memory. The UVIS instrument provides an intensity reading for each pixel in its array. The interface card sums the intensity readings for each position in an "all-sky" memory dedicated to UVIS. This card's function is similar to that described earlier for ILENA. Using the same 4MB dynamic RAM devices used on the NASA Cassini spacecraft, the IDPU will provide a buffer storage of 40MB. A paging mechanism will allow the 20-bit address field generated by the CPU to address the 40MB. At the composite data rate (i.e. all instruments) of 20 kbps, the 40MB buffer will store approximately 4.4 hours of data. As the HI-LITE instruments will only operate for about 40-45 min per orbit this gives an on-board storage capacity of about 6 orbits. This is sufficient to allow all apogee passes to be stored and telemetered to Wallops Flight Facility (WFF). The fifth IDPU card is a combination A/D converter and MUE interface. The MUE interface is able to read data from all cards in the computer. The A/D subsystem gives the IDPU the ability to read analog signals from a wide variety of sources. For HI-LITE, the A/D will be used for reading analog housekeeping data from the sensors.

4.SPACECRAFT DESIGN

4.1 Spacecraft Configuration and Requirements

The HI-LITE spacecraft uses standard GSFC alternative architecture sub-systems, similar to the NASA FAST Small Explorer spacecraft. Due to the imaging instruments fan shaped fields-of-view a spin-stabilized spacecraft is required with its spin axis orbit normal. Figure 4.1 shows possible instrument and spacecraft sub-systems configuration. The similarity to FAST (with the exception of HI-LITE's lack of booms) is obvious despite the widely differing mission objectives of the two spacecraft. Table 4.1 summarises the instruments and spacecraft sub-systems weight and power requirements. Standard NASA weight and power requirements for SMEX sub-systems have been used throughout and required contingency has been built into both weight and power requirements. All HI-LITE instruments are designed to operate from -10 C to +50 C. The overall HI-LITE thermal design considerations are very similar to those of the FAST spacecraft and will be accomplished by proper selection of thermal coatings, blankets, and minimal heater power.

The HI-LITE spacecraft is required to have a certain level of cleanliness due to the sensitivities of the instruments. Electrostatic, electromagnetic, and magnetic cleanliness are required for particle measurements. This will be accomplished by proper selection of materials, shielding, conductive and grounded external surfaces, shield termination design, grounding technology, power distribution, and battery interconnection design. Water and oil are contaminants of the microchannel plates that are used in the ILENA, OXI, and PIMS instruments. Purging of these instruments, with dry nitrogen, will be required and will be specified in the contamination control plan. A good vacuum in the sensor interior is necessary to prevent contamination of OXI, ILENA, and PIMS MCPs and ILENAs converter surface. Only materials with low intrinsic outgassing such as metals, ceramics and non-water adsorbing polymers will be used. Sensors will be equipped with a manually removable external gas tight cover, that allows for a dry N_2 purge until launch and will be pre-baked in UHV and purged with dry N_2 prior to delivery.

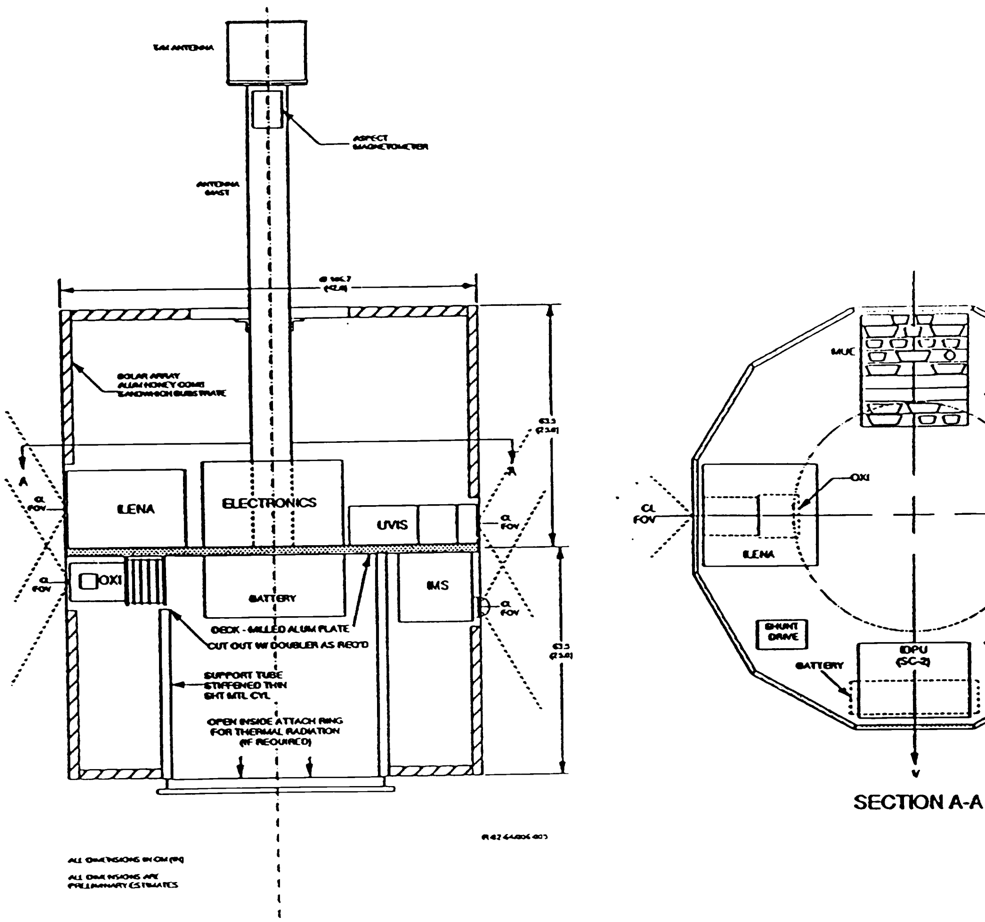

Fig. 4.1 HI-LITE Spacecraft Configuration showing instrument and spacecraft sub-system mounting.

SPACECRAFT COMPONENTS	NOMINAL INSTRUMENT WEIGHT (KG)	WEIGHT MARGIN (PERCENT)	INSTRUMENT WEIGHT (KG) WITH MARGIN	NOMINAL OPERATING POWER (W)	ORBIT DUTY CYCLE (139 MIN ORBIT)	ORBIT AVERAGE POWER (W)	POWER MARGIN (PERCENT)	ORBIT AVERAGE POWER (W) WITH MARGIN	NOTES
SCIENCE INSTRUMENTS									
OXYGEN ION IMAGER	4.60	15.00%	5.18	7.60	0.285	2.166	20.00%	2.599	1, 2
UV IMAGING SPECTROMETER	9.00	15.00%	10.35	5.00	0.285	1.425	20.00%	1.710	1, 2
IMAGER OF LOW ENERGY NEUTRAL ATOMS	8.00	20.00%	9.60	6.00	0.285	1.710	25.00%	2.138	2, 3
ION MASS SPECTROMETER	2.50	15.00%	2.88	3.50	0.285	.998	20.00%	1.197	1, 2
SC-4 SPACECRAFT COMPUTER (IDPU)	2.40	15.00%	2.76	10.00	1.000	10.000	20.00%	12.000	4, 5
INSTRUMENT WEIGHT	26.40								
INSTRUMENT WEIGHT WITH MARGIN			30.78						
INSTRUMENT POWER						16.30			
INSTRUMENT POWER WITH MARGIN								19.64	
SPACECRAFT BUS COMPONENTS									
PRIMARY STRUCTURE	12.93	15.00%	14.87	N/A	N/A	N/A	N/A	N/A	6
BRACKETS AND FASTENERS	4.50	15.00%	5.18	N/A	N/A	N/A	N/A	N/A	7
LAUNCH VEHICLE INTERFACE	0.82	15.00%	0.94	N/A	N/A	N/A	N/A	N/A	6
SOLAR ARRAY	25.00	15.00%	28.75	N/A	N/A	N/A	N/A	N/A	7
SHUNT ASSEMBLIES & ARRAY HARNESS	1.40	15.00%	1.61	N/A	N/A	N/A	N/A	N/A	6
BATTERY	11.30	15.00%	13.00	N/A	N/A	N/A	N/A	N/A	7
HARNESS	11.30	15.00%	13.00	N/A	N/A	N/A	N/A	N/A	7
SPACECRAFT UMBILICAL ASSEMBLIES	0.45	15.00%	0.52	N/A	N/A	N/A	N/A	N/A	6
HEATERS	N/A	N/A	N/A	5.00	1.000	5.000	20.00%	6.000	6
BATTERY RADIATOR	1.40	15.00%	1.61	N/A	N/A	N/A	N/A	N/A	7
TRANSPONDER HEAT SINK	1.10	15.00%	1.27	N/A	N/A	N/A	N/A	N/A	7
THERMAL BLANKETS	2.30	15.00%	2.65	N/A	N/A	N/A	N/A	N/A	7
MISSION UNIQUE ELECTRONICS	15.00	15.00%	17.25	14.00	1.000	14.000	20.00%	16.800	7
SHUNT DRIVERS	2.30	15.00%	2.65	0.50	1.000	.500	20.00%	.600	7
SOLID STATE MEMORY CARD	0.90	15.00%	1.04	0.50	1.000	.500	20.00%	.600	7
TRANSPONDER (STANDBY)	4.10	15.00%	4.71	4.50	0.928	4.176	20.00%	5.011	7, 8
TRANSPONDER (XMITTING)	N/A	N/A	N/A	33.00	0.072	2.376	20.00%	2.851	7, 8
ELECTROMAGNETIC TORQUER 1	3.20	15.00%	3.68	5.00	0.072	.360	20.00%	.432	7, 8
ELECTROMAGNETIC TORQUER 2	3.20	15.00%	3.68	5.00	0.072	.360	20.00%	.432	7, 8
SPINNING SUN SENSOR	0.84	15.00%	0.97	0.50	1.000	.500	20.00%	.600	7
HORIZON CROSSING SENSOR	0.73	15.00%	0.84	0.70	1.000	.700	20.00%	.840	7
3-AXIS MAGNETOMETER	0.14	15.00%	0.16	0.50	1.000	.500	20.00%	.600	7
SPACECRAFT BUS WEIGHT	102.91								
SPACECRAFT BUS WEIGHT WITH MARGIN			118.35						
SPACECRAFT BUS POWER						28.97			
SPACECRAFT BUS POWER WITH MARGIN								34.77	
TOTAL HI-LITE WEIGHT WITH MARGIN			149.11						
TOTAL HI-LITE POWER WITH MARGIN								54.41	

NOTES :-
1. INSTRUMENT PREVIOUSLY FLOWN ON SOUNDING ROCKET.
2. INSTRUMENT ACTIVE FOR APPROXIMATELY 39.6 MINUTES PER ORBIT.
3. INSTRUMENT IS A NEW DEVELOPMENT.
4. IN-PRODUCTION INSTRUMENT.
5. INSTRUMENT ACTIVE FOR THE WHOLE ORBIT.
6. STD NASA SMALL EXPLORER SPACECRAFT SYSTEM DESIGN MODIFIED FOR HI-LITE.
7. STD NASA SMALL EXPLORER SPACECRAFT SYSTEM DESIGN.
8. ESTIMATED MAXIMUM ACTIVE TIME OF 10 MINUTES PER ORBIT.
9. POWER CALCULATIONS BASED ON ORBIT OF 250KM PERIGEE AND 4600KM APOGEE.

Table 4.1 Mass and power allowences for the HI-LITE instruments and spacecraft sub-systems.

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4.2 Orbit, Spin Rate, and Pointing Requirements

To obtain good viewing geometry a high-inclination orbit is preferred. However, this has two disadvantages for the HI-LITE mission. Firstly, for the mass of HI-LITE a polar orbit would severly reduce the apogee due to the restricted capabilities of the Pegasus launch vehicle. Too low an apogee would give poor viewing geometry. Secondly, precession would move apogee rapidly to low-latitude again rendering a poor viewing geometry. A 65° inclination orbit allows a high apogee orbit plus a slow precession of the apogee over the northern polar region. Thus, for a one year mission the apogee will always be over high-latitudes. Orbit analysis shows that even for a 65° inclination orbit the viewing geometry is favorable for the imaging instruments over most orbits. In addition, about 3-4 times per day the spacecraft will pass through the high-latitude cusp/cleft region thus allowing the PIMS to obtain measurements in this region. This orbit also gives full local time coverage within a year duration mission. This allows for the imaging instruments to obtain views of the high-latitude magnetosphere from all directions..The total mass to orbit of the HI-LITE spacecraft dictates the apogee for a 65° inclination orbit. For 151.26 kg with a perigee of 250 km the nominal apogee achievable by the standard Pegasus launcher is 4600 km. This is acceptable for imaging purposes. The spin rate of the spacecraft is driven by the need for reasonably fast in-situ ion mass measurements yet slow enough for the imaging instruments to be able to adequately build-up images. A rate of 1 rpm meets these criteria and a moment-of-inertia calculation shows the HI-LITE spacecraft configurationto be acceptable. The imaging instruments require a pointing accuracy of about 0.5°. However, pointing knowledge, for analysis purposes, is required to 0.25°. These accuracies are easily obtainable with the standard SMEX avionics.

4.3 Commands and Telemetry

Commanding of the HI-LITE instruments will be required on contact periods with Wallops Island Flight Facility (WFF). Typically this will be 2-5 passes per day . The number of commands sent to each instrument will generally be small except in the initial checkout phase. The total downlink required is about 6 Mbits per orbit. At maximum the IDPU will be required to store up to 6 orbits of data. Thus a maximum of 40 Mbits of data will need to be downlinked in a 10 minute contact period with WFF. This is well within the maximum possible downlink rate and considerably less than required by FAST.

5. MISSION OPERATIONS AND DATA ANALYSIS

5.1 Flight Operations

The HI-LITE instruments have been designed to operate autonomously with minimal commanding. Command sequences will be time-tagged and stored in the IDPU for execution at the appropriate time. In the initial period after launch, checkout of the instruments will be required. During this phase it would be beneficial to have real-time contact with the HI-LITE spacecraft. However, after this initial period command sequences and data acquisition can be done from WFF. Very little interaction with the HI-LITE instruments is anticipated. Command sequences will be sent to the payloads operation center (POC) from the science operations center (SOC). However, instrument command sequences will be generated remotely by the lead instrument investigators and sent over the network to the SOC for integration into a HI-LITE command sequence (Figure 5.1). As an option, the HI-LITE spacecraft can be run in a campaign mode. The HI-LITE mission main operational period occurs in the northern hemisphere winter. This was chosen to coincide with the operation of the high-latitude radars (e.g. EISCAT), and all-sky cameras. This would provide a unique opportunity for collaboration between these ground-based facilities, HI-LITE, and sub-orbital rockets. For the campaign mode an extra ground station to collect real time data at the rocket launch facility would be ideal. Such a mode is planned for FAST and would be beneficial not only to HI-LITE but to the ground-based and sub-orbital communities.

5.2 Data Reduction and Analysis Plan and Facilities.

The Science Operations Center (SOC) for HI-LITE will be at GSFC. Each lead instrument institution will have a remote data analysis facility (RDAF) connected by presently available network facilities to the SOC (Figure 5.1). Since the data volume is

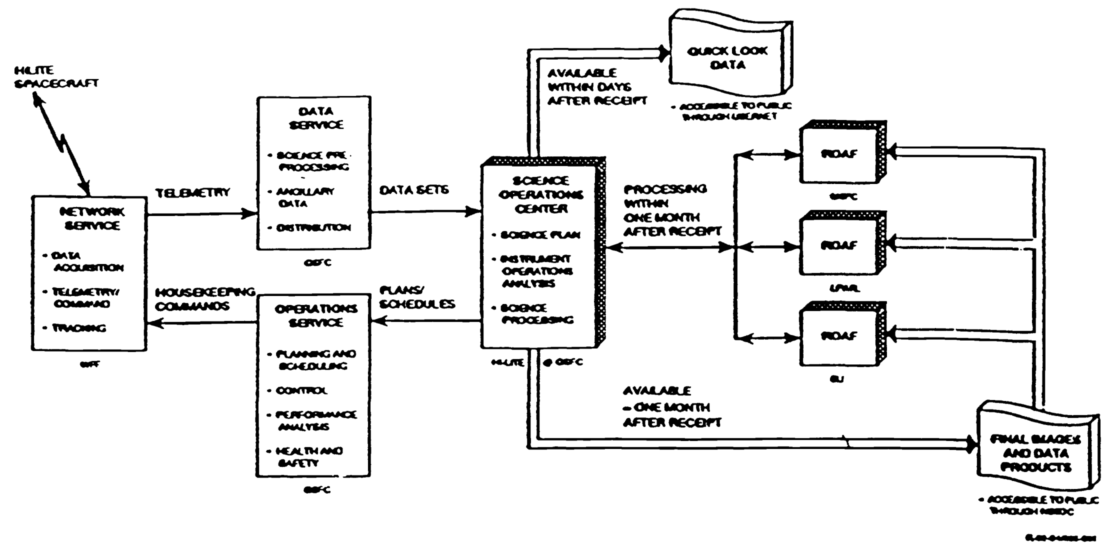

Fig. 5.1 HI-LITE on-orbit operations.

modest, the SOC and RDAF's will be workstation based. Data from the spacecraft will first go to the SOC. Here the data will undergo a basic processing that formats the data to make it readily accessible to the RDAF's. As the data are received basic images from the instruments will be generated using algorithms developed at the Co-I institutions. From these a summary quick-look dataset will be generated. The philosophy of the HI-LITE mission is to have no proprietry data, thus these data will be available over the network in as near real time as possible. These data will also be offered to educational establishments as a teaching tool. Data from all the HI-LITE instruments along with correlative data will be distributed to all the RDAF's over the network or via suitable media. At the RDAF's the data will be further processed to produce high-quality verfied images in geophysical units. A subset of these will be assembled by the Principal Investigator into a master image dataset that will be sent to NSSDC for addition to their database. It is expected that these data will be sent to NSSDC within one month of acquisition.

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