**JUpiter MagnetosPheric boundary ExploreR (JUMPER).** R. W. Ebert¹ F. Allegri²,³, F. Bagenal¹, C. Beebe¹, M. I. Desai¹,², D. George¹, J. Hanley¹, N. Murphy⁴, and A Wolf⁴, ¹Southwest Research Institute, 6220 Culebra Rd., San Antonio, TX USA 78238 (rebert@swri.edu) ²University of Texas at San Antonio, One UTSA Circle, San Antonio, TX USA 78249 ³Laboratory for Atmospheric and Space Physics, University of Colorado, 1234 Innovation Dr, Boulder Colorado, USA 80303 ⁴Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena California, USA 91109.

**Mission Summary:** We present the JUpiter MagnetosPheric boundary ExploreR, JUMPER, a Jupiter orbiting SmallSat mission concept to explore the planet’s magnetospheric boundaries and image its energetic neutral atom (ENA) emissions. JUMPER’s science objectives focus on how the solar wind interacts with Jupiter’s magnetosphere and the contribution of ENAs to mass loss from the jovian space environment. These objectives will be met with a science payload consisting of two ion sensors, a magnetometer, and an ENA imager. Measurements from these instruments will complement simultaneous observations of Jupiter’s magnetosphere from a primary spacecraft (e.g. Europa Multiple Flyby Mission, Jupiter Icy moons Explorer, Io Observer, etc.), providing a multi-point platform from which to study the dynamics of this system. The science objectives, which have yet to be addressed by any other Jupiter mission, are responsive to the NASA Planetary Science Division (PSD) science goal – Advance the understanding of how the chemical and physical processes in our solar system operate, interact, and evolve – as defined in NASA’s 2014 Science Plan.

JUMPER’s science objectives drive several top-level requirements on mission design. The most important is an orbit that includes several passes through Jupiter’s bow shock and magnetopause on the dayside of Jupiter. Mission design is also constrained by the necessity to ride share on a primary vehicle, at least until after Jupiter orbit insertion.

The JUMPER spacecraft design derives heritage from SmallSats developed for the Southwest Research Institute (SwRI)-led Cyclone Global Navigation Satellite System (CYGNSS) mission. It consists of an Evolved Expendable Launch Vehicle Secondary Payload Adapter (ESPA) compatible frame supporting four double-deployed solar array panels, ESPA ring interconnections, four science instruments, and a radiation vault to house the spacecraft avionics and payload subsystem electronics. JUMPER will use its peri-Jovian periods to transmit data to the primary spacecraft and execute ranging activities. It will de-orbit into Jupiter at end of mission.

While the JUMPER mission focuses on Jupiter, this concept can be applied, with modifications, to any planetary system, preferably one where there’s an interaction between the solar wind and the planet’s intrinsic or induced magnetic field.

**Mission Science:** JUMPER addresses open questions related to (i) how the solar wind couples to the jovian magnetosphere and (ii) influences magnetospheric dynamics, and (iii) how energetic neutral atoms contribute to mass loss from Jupiter’s magnetosphere. These questions are addressed through the following science objectives:

**Objective 1) Characterize the solar wind upstream of Jupiter’s magnetosphere and provide context for studying magnetospheric dynamics by a primary spacecraft.** One of the more hotly debated questions related to Jupiter is to what extent does the solar wind influence its magnetosphere? While the dynamics of the magnetosphere are largely driven by the planet’s 10-hour rotation period, the contribution from the solar wind is not well understood. Magnetospheric processes with evidence of solar wind influence include the motion of Jupiter’s bow shock and magnetopause [1], the opening and closing of magnetic flux in the outer magnetosphere [2, 3], the transport of mass, energy, and momentum into the magnetosphere [4], variations in ultraviolet (UV) auroral emissions and morphology [5], auroral radio emission enhancements [6,7] and current sheet asymmetries in the magnetotail [8]. While the solar wind and interplanetary magnetic field (IMF) at Jupiter’s orbital distance have been studied in detail [9, 10], our lack of understanding stems from, in part, the absence of a solar wind monitor upstream of Jupiter when the magnetosphere was being observed.

JUMPER will address this topic by placing a SmallSat into orbit around Jupiter with an apoJove beyond the nominal position of Jupiter’s bow shock. JUMPER will measure the solar wind ions and IMF upstream of Jupiter’s magnetosphere to complement simultaneous observations of the magnetosphere and/or aurora from a primary spacecraft. These simultaneous observations will be key to obtaining a more complete understanding of the physics governing this system.

**Objective 2) Investigate the modes of solar wind coupling (e.g. magnetic reconnection, Kelvin-Helmholtz waves) along Jupiter’s dayside magnetopause.** Another important open topic is how the solar wind interacts with Jupiter’s magnetopause. This has important implications for outer magnetosphere dynamics, especially the transport of mass, energy, and momentum into the magnetosphere and the circulation of open magnetic flux. The two primary modes of interaction are thought
to be magnetic reconnection [11] and shear-flow driven instabilities [4]. Evidence of magnetic reconnection has been limited to a few magnetopause crossings with signatures observed primarily in the magnetic field observations [12, 13] and more recently in the form of accelerated ions flows [14]. Evidence of wave activity at Jupiter’s magnetopause, such has the Kelvin-Helmholtz instability, is essentially non-existent. Our lack of knowledge on the processes operating at Jupiter’s magnetopause is primarily due to the limited number of spacecraft observations taken over a limited spatial extent [15].

JUMPER will help address this key question by measuring the ion velocity distributions and flows and the magnetic field in the vicinity Jupiter’s dayside magnetopause to look for signatures of these processes. JUMPER’s orbit places the spacecraft in a favorable location to cross the magnetopause multiple times as it drifts along Jupiter’s dayside magnetosphere.

**Objective 3) Determine the flux, energy spectra, and spatial distribution of energetic neutral atoms escaping from Jupiter’s magnetosphere.** Jupiter’s moon Io provides a 1-2 ton/s source of neutral material to the jovian magnetosphere that is redistributed into a neutral cloud around the moon’s orbit and is ultimately lost from the system. As these neutrals become ionized to form the Io plasma torus, an estimated 1/3 of the ions are transported outward to Jupiter’s plasma sheet while 1/3 – 1/2 of them are expected to escape as fast neutrals [16]. These fast neutrals are produced from two sources: (i) charge exchange between inward-diffusing energetic (> 10 keV/nucleon) ions and the extended H₂ neutral cloud near Europa’s orbit and (ii) charge exchange between the < 1 keV ions in the Io’s plasma torus and Io’s neutral cloud. The estimate loss rate for these fast or energetic neutral atoms (ENAs) is ~ 0.3 – 1.7 tons/s [16] although direct measurement of these particles are needed to verify these values. One approach is to remotely measure the distribution of ENAs emitted from the magnetosphere. Unfortunately, only a very limited number of ENA observations from Jupiter’s magnetosphere have been made [17] and none at energies below 10 keV.

JUMPER will address this topic by remotely measuring the flux, energy spectra, and spatial distribution of ~0.5 – 10 keV ENAs from a vantage point on the dayside of Jupiter’s outer magnetosphere. These measurements, coupled with physical chemistry [18] and neutral transport [19, 20] models, will provide new insight on the physical processes that produce the fast neutrals in Jupiter’s inner magnetosphere and help constraint their contribution to the mass budget of Jupiter’s magnetosphere.

**Mission Design**

The most important mission design requirement for JUMPER is an orbit that includes several passes through Jupiter’s bow shock and magnetopause on the dayside of Jupiter. Our baseline concept is a 1 year mission with six orbits, each having an apojove a distance of ~140 Rₖ. The baseline spacecraft design consists of an ESPA compatible frame supporting four double-deployed solar array panels, ESPA ring interconnections, and four science instruments positioned to accommodate their field-of-views (FOVs). Embedded within the frame is an electronics vault that will house a majority of the electronics for the spacecraft payload and payload subsystems. The nominal flight system consists of 5 subsystems: 1) Command and Data Handling (C&DH), 2) Electrical Power System (EPS), 3) Communication and Data System (CDS), 4) Attitude Determination and Control System (ADCS), and 5) Orbital Propulsion System (PROP).

The baseline JUMPER payload will carry two ion sensors, a magnetometer, and an ENA sensor. This nominal payload will be based on high heritage instruments that can be or have been scaled to fit the SmallSat envelope while providing the high quality ion, magnetic field and ENA measurements needed to address the JUMPER science objectives.

**References**