Paul Withers – Research Plan

My research objectives for the first two/three years after I receive my PhD are focused towards improving our understanding of the dynamics of upper atmospheres and their coupling to lower atmospheres. They will be achieved by the analysis of data from accelerometers and other instruments and by the comparison of this data to atmospheric models. By facilitating major spacecraft missions, my research objectives will also contribute to every area of planetary science. Accurate upper atmosphere weather predictions are needed to support aerobraking spacecraft and offer great ($100M+) savings over orbital insertion using rocket fuel. Accurate upper and lower atmosphere weather predictions are needed to support landers and entry probes. All spacecraft passing through an atmosphere carry accelerometers to measure the drag experienced, and my PhD has focused on the science within these essential operational measurements. In this way, atmospheric densities, pressures, temperatures, and winds can be measured with an instrument that is guaranteed to be part of the spacecraft's payload.

1 – Upper Atmospheric Winds

I have developed a novel technique to measure wind speeds from latitudinal gradients in density and applied it to Mars Global Surveyor's (MGS) accelerometer data. A preliminary validation of this technique and simple results from Mars will form the last chapter of my PhD thesis. Winds are hard to measure in an atmosphere, so this technique could enable the first direct wind measurements of several different upper atmospheres. I plan to develop this technique by a more detailed validation on atmospheric simulations and a comprehensive analysis of the MGS data. It can then be applied to accelerometer data from Mars Odyssey (2001) and Mars Reconnaissance Orbiter (2005), to orbiter neutral mass spectrometer data from Pioneer Venus Orbiter (archived), Nozomi (in flight to Mars), and Cassini (in flight to Titan and Saturn), to a low altitude Jupiter orbiter such as the proposed Jupiter Polar Orbiter with Probes, and to terrestrial data. These wind measurements and pressure and temperature profiles can then be used to constrain and develop atmospheric models. If successful, I can use this skill to join the Science Teams of forthcoming missions, which offers long-term funding and influence upon the goals and planning of future missions.

2 – Entry Accelerometer Data Analysis

During the summer of 2001, I worked in Britain with the Beagle 2 Mars Lander mission, which will launch in 2003. This was a collaboration that I initiated, without the framework of a summer internship, by proposing the basic idea to the mission leader and working with him to develop something beneficial to both of us. I developed programs that will process Beagle 2's entry accelerometer data into profiles of atmospheric density, pressure, and temperature; I have the opportunity to continue collaborating with them when the data arrives in late 2003. Temperature profiles with good vertical resolution can show, for example, thermal tides, clouds, convective regions, or the effects of aerosols. My programs will be used by this British group on similar data from Huygens. I am also an Atmosphere Science Advisor for the landing of NASA's two 2003 Mars Rovers. The near-simultaneous acquisition of three *in situ* entry profiles and extensive remote sensing from the orbiting MGS, Mars Odyssey, and Mars Express has never been available on a distant planet before. It provides a valuable opportunity to cross-calibrate the many instruments and obtain an snapshot of the martian atmosphere at both local and global scales. The Huygens entry profile will define the reference thermal structure of Titan's atmosphere, will be crucial for understanding Titan's atmosphere, and can also be compared to other atmospheric measurements from Cassini's orbital tour. This kind of analysis was led for many years by a group that has now retired, so there is an opportunity for me to establish myself as one of the leaders in this field.

3 – Martian Upper Atmosphere

The primary goal of my PhD research using MGS data was to understand factor-of-2 variations in upper atmospheric density with longitude at fixed altitude, latitude, season, and time of day. This unusual phenomenon, which is not found on Earth or Venus, greatly complicates the aerobraking of a spacecraft and was not expected prior to its discovery by MGS. It is caused by atmospheric tides traveling upwards from the surface 100 km below. The tides are affected by the state of the lower atmosphere, through which they propagate, and I will investigate whether scientifically useful information about the lower atmosphere can be extracted from the upper atmospheric measurements. This will require analysis of the MGS accelerometer data, atmospheric data from MGS's other instruments, and theoretical work. It offers many opportunities for collaboration with other scientists. If successful, it will allow the lower atmosphere to be studied routinely during the aerobraking of future missions, which can then redirect parts of their limited scientific payload to other investigations. Other investigations possible with the MGS data include the comparison between the effects of solar variability (the 28-day solar rotation and solar flares) on the atmospheres of Earth and Mars, and analysis of the effects of lower atmospheric dust storms on the upper atmosphere. This work can be extended with the Mars Odyssey accelerometer dataset (undergoing archiving) and the 2005 Mars Reconnaissance Orbiter data. This will carry a sensitive accelerometer with the potential of measuring atmospheric densities up to the exobase, which will enable investigations of current atmospheric escape processes. The Science Team for this Facility Science Instrument currently consists of only two members, so several Participating Scientists are likely to be added before launch.

These themes include investigations that are suitable for a Participating Scientist or Science Team Member proposal for upcoming flight missions, as well as the annual NASA Planetary Atmospheres, Mars Data Analysis, or forthcoming Saturn Data Analysis funding cycles, and I hope to be an established principal investigator on grants by the end of my postdoctoral contract.