To: Dr Walter Gilbert
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Society of Fellows
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From: Paul Withers
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Dear Dr Gilbert,

Thank you for your letter inviting me to submit an application package for a Junior Fellowship in the Society of Fellows. I enclose:

Data sheet (1 page)
Proposal (2 pages)
Transcript from the University of Arizona (in envelope)
Transcript from Cambridge University (1 page) (see below)
Curriculum Vitae (3 pages)
Reprint of Withers, Lorenz, and Neumann, *Comparison of Viking Lander Descent Data and MOLA Topography Reveals Kilometer-Scale Offset in Mars Atmosphere Profiles*, Icarus, **159,** 259-261 (2002)
Reprint of Withers and Neumann, *Enigmatic Northern Plains of Mars,* Nature, **410,** 651 (2001)
Reprint of Withers, *Meteor storm evidence against the recent formation of lunar crater Giordano Bruno,* Meteoritics and Planetary Science, **36**, 525-529 (2001)
Reprint of Nockolds and Withers, *Comment and Reply,* Meteoritics and Planetary Science, **37**, 465-466 (2001) (see below)
Manuscript of Withers, Bougher, and Keating, *The Effect of Topographically-controlled Thermal Tides in the Martian Upper Atmosphere as seen by the MGS Accelerometer,* in preparation for submission to Icarus (87 pages) (see below)

Cambridge University does not produce transcripts in the manner of an American University. Examinations covered multiple classes, not individual ones. Roughly speaking, a grade of 67% is required for a "First Class" or A grade. There are no general education requirements, so students take only classes related to their major. If there are any questions about this, I can provide contact information for staff at Cambridge University.

The *Comment and Reply* is included because I feel it would be unethical to omit the peer-reviewed response to my work, not because it is my best work.

As discussed in my research proposal, I have included a lengthy unpublished manuscript on a comprehensive project to complement my short reprints on scattered subjects.

Paul Withers

Abstract on data sheet (rest of sheet is just address details)

My research objectives are directed towards improving our understanding of planetary atmospheres and enabling other investigations in planetary science. I plan to develop a new technique for measuring winds and apply it to several upper atmospheres. Winds are important for climate, yet difficult to measure with current techniques. I plan to study the weather of upper atmospheres to understand how they work. More accurate weather predictions for spacecraft that fly through these dangerous regions will save millions of dollars on operational costs that can be redirected to the mission's scientific goals. I plan to relate knowledge of the weather experienced by spacecraft in the upper atmosphere to weather in the lower atmosphere. Scientifically useful results about the lower atmosphere can then be obtained without needing to devote the limited scientific payload of the spacecraft to that task. I am currently involved with three Mars landers. I plan to use their brief atmospheric entry to measure how temperature changes with altitude. The analysis of this kind of measurement is common to many spacecraft; it was led for many years by a group that has recently retired. This is an opportunity for me to replace them.

Paul Withers – Research Plan

My research objectives for the first three years after I receive my PhD are directed towards improving our understanding of planetary atmospheres. They will be achieved by the analysis of data from accelerometers and other instruments and by the comparison of these data to atmospheric models. By facilitating major spacecraft missions, my research objectives will also contribute to every area of planetary science. If a planet's weather is predictable enough that a spacecraft can use atmospheric drag rather than rocket fuel to slow down, then great ($100M+) savings are possible. Improved predictions lead to greater savings and allow more sophisticated spacecraft to be launched. This technique, called aerobraking, was used by the Mars Global Surveyor (MGS) spacecraft a few years ago. An onboard accelerometer measured the drag on MGS as it passed repeatedly through the atmosphere. Studying changes in the density, pressure, and temperature of the martian upper atmosphere using these drag data forms the majority of my PhD thesis.

Changes in pressure with latitude are affected by winds. I have developed a novel technique to calculate wind speeds from these drag 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. Once developed, it can be used to analyze existing data from Venus, data from Titan (our solar system's only atmosphere-bearing moon) in 2004, and data from a Mars orbiter in 2005. There are also plans to send a low-altitude orbiter to Jupiter that could make suitable measurements. Once this technique is validated, my expertise would be useful to the designers of such missions. I have observed that scientists who become involved in the early planning stages of spacecraft missions are usually the most successful at attracting funding, maintaining broad and current research interests, setting the goals of spacecraft missions, and acting as leaders for the scientific community.

As my publication record shows, I am experienced at working independently, collaborating with diverse groups, and initiating innovative research topics. As my currently published work consists mainly of unrelated short papers, I have included in this application a lengthy manuscript on my work with the MGS data to show that I am also able to tackle long-term, comprehensive projects. Planetary science is inherently interdisciplinary, with chemists working with engineers and physicists with biologists, and I expect conversations with the other scientists and engineers in the Society of Fellows to be very useful to me as I pursue my research ideas and react to unexpected results. The gap between the arts and sciences can be hard to bridge, but I collaborated with a medieval historian and several experts on medieval Latin during my project on lunar crater Giordano Bruno. I have been free to pursue diverse projects for my PhD and ideas from one of them have often rescued an unrelated, struggling project or initiated a new project. That freedom has helped my research and, having already shown the ability to develop and attain exciting research goals without narrow supervision, I want to keep that freedom in the stimulating environment of the Society of Fellows.

The primary goal of my PhD research using the 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. Atmospheric tides, traveling upwards and caused by deviations of the planetary surface (100 km below) from a smooth sphere, are the likely cause, but accurate predictions about these extreme variations have not yet been made. The variations are controlled by solar heating and the state of the lower atmosphere. Since the drag data in the upper atmosphere, which are an operational necessity, depend on the state of the lower atmosphere, I will investigate whether scientifically useful information about the lower atmosphere can be extracted from them. This will require analysis of the MGS drag data, weather 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.

The next aerobraking spacecraft will be Mars Reconnaissance Orbiter and there will be an opportunity for scientists to join its Science Team before its 2005 launch. I will try to do so because this offers me rapid access to the data, invaluable involvement in mission operations, and funding for students or colleagues. I want to make weather predictions for its aerobraking, then test them. This cycle of prediction and observation will improve our understanding of upper atmospheres.

A lander descending through a planetary atmosphere experiences drag in much the same way as an orbiter passing through the upper atmosphere, and the techniques used to analyze the data are very similar. Atmospheric densities, pressures, and temperatures calculated from a lander's drag data are our best information on that atmosphere's vertical structure, and they can reveal thermal tides, clouds, convective regions, or the effects of aerosols. I spent the summer of 2001 working in Britain with the Beagle 2 Mars Lander mission. 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 designed the programs that the British group will use to analyze their drag data; I have the opportunity to continue collaborating with them when the data arrives in late 2003. My programs will be also used by this British group on similar data from the Huygens probe, which reaches Titan in early 2005. Due to this experience, I have recently been selected as an Atmosphere Science Advisor for the landing of NASA's next two Mars landers in early 2004. I am the youngest advisor and the only one from outside NASA. Both those roles offer me active involvement in spacecraft missions in the first years after receiving my PhD, though without significant funding. It is rare for young scientists to be involved in this way in their own right. As a Junior Fellow, I would be able to take full advantage of these opportunities. 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. As drag measurements are essential to the safe operation of any spacecraft that passes through an atmosphere, unlike the rest of the scientific instruments, I am confident that there will be opportunities for me in the future flights of planetary exploration.