Why scientists study the planets

- To test ideas on how our Earth works by applying them to other planets.
- To better understand the laws of nature under conditions that cannot be found on our Earth.
- To discover how planets form and evolve.
- To discover how life began in the solar system.

What the people of Tucson gain from scientists studying the planets

- Inspiration - Images and ideas from exploration of the solar system have revolutionized our understanding of humanity's place in the universe and of the fragility of our Earth.
- Educational stimulus - The most exciting thing your children have learnt in school recently probably comes from space exploration. See the table for some examples.
- Value for money - Only $ 1 of your weekly taxes pays for the Space Shuttle, the Space Station, planetary exploration, and all the rest of NASA's work.

Where is Mars right now?

- A small piece of Mars is on public display less than a thousand feet away in Flandrau Planetarium. It was blasted off Mars in a meteorite impact and landed on the Earth.
- Tucson meteorite dealer Robert Haag owns the largest such piece of Mars on Earth. It's as big as a football and weighs six pounds. It's worth a fortune and I almost dropped it.
- Right now, Mars is 150 million miles away. It is about 30^{o} above the horizon and 30^{o} east of south. This direction is roughly where the Sun was four hours ago. The Sun's light is too bright for you to see Mars during the day.

Different ways to explore Mars

- Look at pictures of its surface to understand its geologic history.
- Chemically analyze soil samples to understand its composition.
- Study its atmosphere to understand its weather and climate.
- Bring back samples to Earth for more detailed study.
- Mars is too large for one graduate student to study all of it. I have been studying the Martian upper atmosphere.

What is the Martian upper atmosphere like?

- It is very different to the atmosphere you are breathing right now - colder, less dense, and made of different gases.
- It is almost 300 ^{o}F colder than Tucson's atmosphere.
- It is a billion times less dense than Tucson's atmosphere.
- It is almost pure carbon dioxide - the gas that makes your Coke fizz and bubble - instead of the mixture of nitrogen and oxygen than makes up Tucson's atmosphere.
- You wouldn't be able to breathe it and survive.

Mars Global Surveyor (MGS)

- This spacecraft spent 18 months studying the upper atmosphere of Mars before turning to its main mission, the study of surface features and magnetic and gravitational fields.
- Pictures of the Martian surface, taken with unprecedented detail, reveal sand dunes, boulders, and stream channels.
- Unexpectedly strong features in the Martian magnetic field suggest that Mars once had plate tectonics like our Earth does today, with moving continents and earthquakes.
- Mapping the shape of Mars, its mountains and valleys, and its gravitational field allows Martian geologic history to be better understood.

Studying the Martian upper atmosphere with MGS

- As the Mars Global Surveyor spacecraft passed through the Martian upper atmosphere, it was slowed down due to friction between the spacecraft and the atmosphere. This same process slows down the Space Shuttle as it re-enters Earth's atmosphere.
- The acceleration of the spacecraft was measured and then used to calculate the density of the atmosphere. This can then be used to calculate the temperature and pressure in the atmosphere as well.
- So we know the atmospheric density, pressure and temperature wherever and whenever the spacecraft passed through the atmosphere.

Exactly what atmospheric information has MGS supplied?

- Mars Global Surveyor's data will let us study the pressure, density, and temperature of the Martian upper atmosphere between an altitude of 60 and 100 miles over nearly every latitude and longitude. The data cover nearly all Martian seasons and a few, widely-spaced times of day.
- We will be able to study how the atmosphere is affected by the seasons, by the underlying mountains and valleys, by the time of day, and how the lower atmosphere influences the upper atmosphere.

What happened to Mars Climate Orbiter?

- Another spacecraft, Mars Climate Orbiter, should be orbiting Mars at the moment. I had hoped to be able to show some brand new data, less than a day old, from this spacecraft today but, as you may have seen on TV or read in the newspapers, it was destroyed about a month ago as it approached Mars.
- A mix-up between two groups of engineers led to the spacecraft flying too close to Mars, at such low altitudes that it was burnt up in the atmosphere like a meteor.
- One team was using feet and inches, the other metres, and neither converted their measurements as they discussed them. This elementary mistake cost $ 125m.

What do all these graphs show?

- The graph on the top row shows how the atmosphere is affected by the seasons.
- The graph on the second row shows how the atmosphere is affected by the mountains and valleys beneath it.
- The colourful graph on the third row shows Martian topography, with high regions in red and low ones in blue.
- The graph on the bottom row shows how the atmosphere at the same place and time of day changes from day to day.

What do the wiggles mean?

- The wiggles are caused by surface winds rushing around mountains and through valleys. The effects of this motion travel all the way up through the atmosphere, where we see them as wiggles
- We are only just beginning to study the wiggles, but hope that we will be able to tell what the lower atmosphere is like from its effect on the wiggles.
- Then this technique will tell us about all altitudes in the atmosphere, making it very powerful.
- Then we will be able to study how the winds blow on Mars in better detail than ever before, which will help scientists understand how the Martian atmosphere works.

Are the tops of the wiggles above mountains?

- When we first saw these wiggles we thought that we might be seeing high densities above mountains and low densities above valleys.
- Unfortunately it's not that simple. These wiggles were seen at a latitude of 20^{o}N. Compare the wiggles with the brightly coloured topography on the right. Can you see red mountains and blue valleys in the right places for this explanation to be correct? We couldn't.
- Many of the low-lying blue regions are actually craters, like Meteor Crater near Flagstaff, and not valleys.

What have we learned from this?

- We have a much better understanding of how the Martian upper atmosphere works.
- This will lead to improved understanding of the whole Martian atmosphere and climate.
- This knowledge can then be applied to our Earth, with all the benefits that improved understanding of the weather and climate can bring.
- There are still many unexplained features in the data, such as the large day to day variation in density. Who knows what we will discover investigating these…?
- The value to Tucson of my work alone is not huge. Taken with the rest of planetary exploration, some of the benefits are detailed on the next panel.

What else is the U of A doing to explore Mars?

- Prof McEwen and his team are analyzing the great pictures taken by Mars Global Surveyor.
- Prof Smith and his team built the camera that landed on Mars with the Sojourner Rover in 1996. Their next camera lands on Mars on December 3rd on the Mars Polar Lander.
- Prof Boynton and his team will also be busy on December 3rd, looking for water in the Martian soil using Mars Polar Lander.
- Finally, Dr Lorenz is involved with the Deep Space 2 mission to investigate sub-surface structure on Mars, also landing on December 3rd.

What next?

- The work presented here is only preliminary. Scientists working with this data used it to guide MGS safely into orbit around Mars and have only begun trying to understand it.
- The wiggles are a real mystery. We need to understand how and why the Martian upper atmosphere can double its density, apparently in response to the surface far below.
- Day to day variations, or weather, have never been directly measured in the upper atmosphere before. This is a brand new field of research.
- Lots of spacecraft will make similar measurements when they arrive at Mars in the next decade, telling us about changes from year to year. This is only the beginning.

Is all this good for Tucson?

- The U of A's Planetary Sciences department "constitutes the best and most distinguished research and teaching department in this discipline in the world."
- [Report of a visiting committee, 1997]
- That's better than Harvard, MIT, Caltech, or any Pac-10 school.
- The department brings $$$ into Tucson every year from federal grants, many times greater than its state funding.

What Tucson gets from planetary exploration

- You are home to the best Planetary Sciences department in the world - better than Harvard, MIT, Caltech, any Pac-10 school, or anything in Europe, Africa, or Asia.
- The department has an economic impact on Tucson of over $ 40m, money that is spent in your businesses and industries.
- Being the best brings recognition from many politicians, including the President, who personally presented Prof Smith with an award for his incredible pictures from the Mars Pathfinder mission two years ago.

What Tucson gets from planetary exploration

- Planetary exploration has been at the forefront of discoveries about how our Earth's ecosystem works, and what might happen to it if it is abused.
- Ideas about the greenhouse effect, the ozone hole, and possible catastrophic meteorite impact were first created by scientists studying other planets.
- Pictures of our blue-green Earth, girdled with white clouds, isolated and alone in space, that inspired so much support for conservation and enviromental awareness, can only be obtained by exploration beyond our planet.

What Tucson gets from planetary exploration

- Many Americans feel great pride in their country's achievements in planetary exploration. No other country can explore the outer solar system or send people to the Moon. These technological successes stimulate and are made possible by American businesses and industries.
- The many outreach programs run by the U of A's Planetary Sciences department show teachers and school children the inside story of how we explore the planets.
- Whether successful or not, the search for life on Mars and beyond will profoundly affect our understanding of our place in the universe.

Acknowledgements

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- Thanks to the MGS Accelerometer team, led by Gerry Keating, for sharing all this lovely new data with me.

Further Information About...

- The Solar System - http://sse.jpl.nasa,gov
- Mars exploration - http://mars.jpl.nasa.gov, http://nssdc.gsfc.nasa.gov/planetary/planets/marspage.html
- Pictures of the solar system - http://photojournal.jpl.nasa.gov
- Or ask at your local library…
- The U of A's Planetary Sciences department - phone Joan Weinberg, 621-2828, or go to http://www.lpl.arizona.edu

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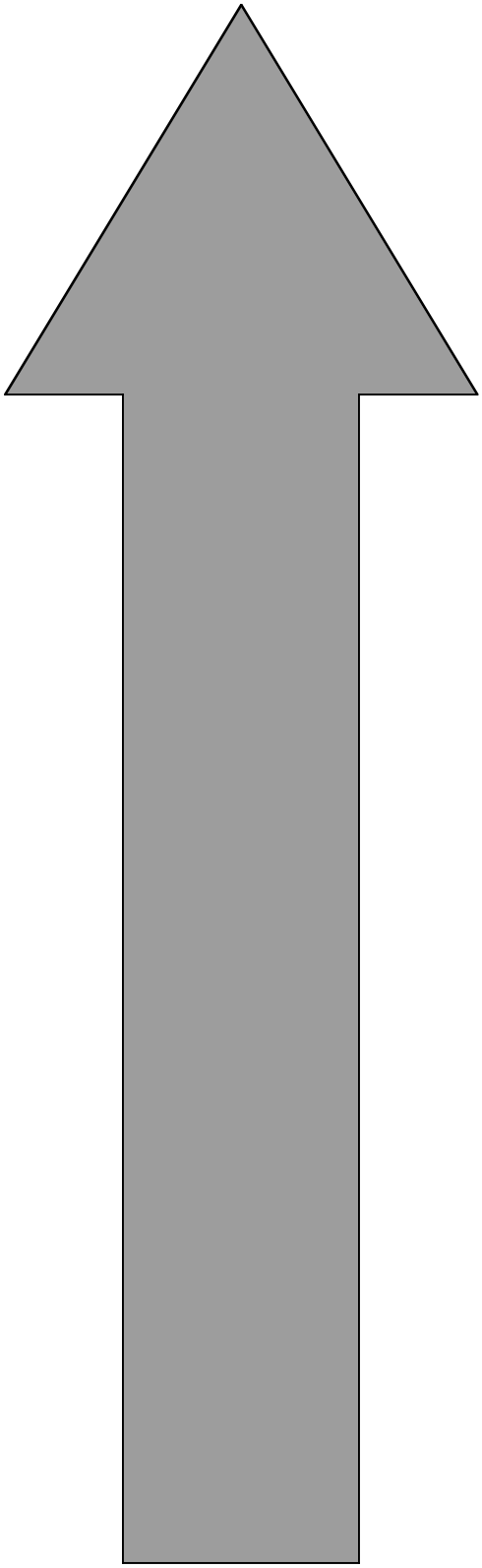

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Mars
How to Explore Mars
Results from my exploration of Mars
The End

Mars

How to explore Mars

Results from my exploration of Mars

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“Exploring Mars”
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