Salient Martian Features

- $R_{\text{Mars}} = 3396 \text{ km} \ (R_{\text{Earth}} = 6378 \text{ km})$
  - Higher surface area to mass ratio
  - More efficient cooling
  - Lower internal heat flow, less volcanism
  - No plate tectonics

- Atmospheric Composition
  - 95% CO$_2$ (same as Venus)
  - Pressure = 0.006 bar (Earth = 1, Venus = 89)

- $T_{\text{Surface}} \rightarrow$ hey, it's cold!
  - Mean solar constant $\rightarrow$ 0.431 (Earth = 1)
  - Summer $\rightarrow$ $T \sim 273K$ (max)
  - Winter (polar) $\rightarrow$ $T \sim 150K$ $\rightarrow$ ground is permanently frozen to 1 km
## Soil Composition

<table>
<thead>
<tr>
<th>Element</th>
<th>Soil</th>
<th>Dust A</th>
<th>Dust B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>0.035(2)</td>
<td>0.20(1)</td>
<td>0.116(5)</td>
</tr>
<tr>
<td>Mg</td>
<td>0.172(4)</td>
<td>0.53(2)</td>
<td>0.348(9)</td>
</tr>
<tr>
<td>Al*</td>
<td>0.266(5)</td>
<td>4.7(4)</td>
<td>13.1(9)</td>
</tr>
<tr>
<td>Si</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>P</td>
<td>0.027(2)</td>
<td>0.040(6)</td>
<td>0.037(3)</td>
</tr>
<tr>
<td>S</td>
<td>0.088(3)</td>
<td>0.109(7)</td>
<td>0.114(5)</td>
</tr>
<tr>
<td>Cl</td>
<td>0.021(1)</td>
<td>0.032(5)</td>
<td>0.037(3)</td>
</tr>
<tr>
<td>K</td>
<td>0.012(1)</td>
<td>0.013(4)</td>
<td>0.012(2)</td>
</tr>
<tr>
<td>Ca</td>
<td>0.094(3)</td>
<td>0.062(6)</td>
<td>0.071(4)</td>
</tr>
<tr>
<td>Ti</td>
<td>0.009(1)</td>
<td>0.009(4)</td>
<td>0.009(2)</td>
</tr>
<tr>
<td>Fe</td>
<td>0.355(5)</td>
<td>0.083(7)</td>
<td>0.100(5)</td>
</tr>
</tbody>
</table>

Areas of element peaks in APX spectra of soil (Spirit sol 14), and of dust on the capture magnet on the two rovers: A (Spirit sol 150) and B (Opportunity sol 168). The error on the last digit is given in parentheses. In each spectrum, the areas are normalized relative to Si.

* The aluminium signal is mainly due to the high-purity aluminium plate on the magnet (below the dust).
Mars Missions

- **Current Missions**
  - Spirit and Opportunity (rovers)
  - 2001 Mars Odyssey (orbiter)
  - Mars Global Surveyor (orbiter)
  - Mars Express (polar orbit)
  - Mars Reconnaissance Orbiter (just launched)

- **Planned**
  - Phoenix
  - Mars Science Laboratory

- **Past**
  - Mariner flybys/orbiters
  - Viking landers
  - Pathfinder
NASA Mars Missions -- Goals

- Determine whether life ever arose on Mars
- Characterize the Climate of Mars
- Characterize the Geology of Mars
- Prepare for Human Exploration
Where to land?

- Equatorial $\rightarrow$ maximum solar radiation
- Low elevation $\rightarrow$ maximum atmosphere to slow descent, low shear
- Relatively flat to preserve airbag
- Radar-reflective, hard surface for rovers
Where to land?

- Parachute to slow descent, followed by bouncing airbag....
Gusev Crater
Spirit Landing Site
Golombek et al 2005 Nature 436 44

- Nice and flat....
Opportunity landing site – and some space junk
Rock size distribution on landing sites
Surface Composition
Bibring et al. 2005 Science 307 1576

- **Ices/Frosts**
  - $\text{CO}_2$ veneers over polar ice caps
  - $\text{H}_2\text{O}$ ice w/ dust

- **Hydrated Minerals/Ferric Oxides**
  - Significant presence — detected via 3µm feature
  - Primarily in older craters (younger craters lack hydrated minerals)

- **Igneous Rocks**
  - Standard olivines
Water on Mars

- Canals?
- Background $\rightarrow$ origin of $\text{H}_2\text{O}$ on Earth
  - Outgassing via internal processes $\rightarrow$ volcanic
    - Formation via accretion of hydrated protoplanetary material
  - External origin via hydrated impactors (comets?)
- Maintaining liquid $\text{H}_2\text{O}$ on surface....
  - Temperature
    - Liquid $\text{H}_2\text{O}$ unstable at $150 \text{ K} < T < 220 \text{ K}$
    - But ice on stable at poles
  - Pressure
    - Sublimation of polar ice $\rightarrow$ atmospheric pressure insufficient to maintain water in atmosphere
    - Dissociation of $\text{H}_2\text{O}$, loss of $\text{H}$

- Current conditions not favorable for liquid $\text{H}_2\text{O}$ on Martian surface or significant $\text{H}_2\text{O}$ in atmosphere
- But.....
Water on Mars

- Polar Ice Caps
- Mariner 9 (1972) → images of obvious channels that look like river beds → major amounts of surface water in past
- Atmospheric chemistry
  - Trace $\text{H}_2\text{O}$ content via outgassed volatiles
  - 80-160m of water outgassed

North Polar Ice Cap in summer
Water on Mars

- Water channels
  - Outflow channels
    - Catastrophic floods ($10^8$ m$^3$ s$^{-1}$ vs $10^4$ m$^3$ s$^{-1}$)
    - “sudden” appearance
    - Volcanism, internal pressure, ???
  - Valley networks
    - Look like river systems
    - Groundwater
  - Fretted channels
- Remote sensing/imaging
Possible water flow as seen by Global Surveyor.
Gusev Crater
Haskin et al 2005 Nature 436 66

- Gusev plain → an old lake bed?
- Primarily igneous rock (olivine basalt)
  - Veins/plugs → aqueous solutions plausible
  - Composition measured via near-IR spectrometer
Gusev crater
Haskin et al 2005

Note inclusions – need water to form
Veins/plugs $\rightarrow$ aqueous solutions plausible

Composition measured via near-IR spectrometer

Various geochemical effects of aqueous solutions
- E.g. ratio of $\text{Al}_2\text{O}_3$ vs $\text{SO}_3$
- Increased ratio of salts, oxidation of $\text{Fe}^{2+}$

Conclusions: running water, but no pools/oceans

Inverse correlation – mixing with evaporative component with high S content
Gusev Crater
Haskin et al 2005 Nature 436 66

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Frozen Equatorial Sea?
Murray et al. 2005 Nature 434 352

- What are these cracked “plates”? Lava? The authors think not…
- Edges much younger than rest of plate – lava doesn’t do this
- Crater density suggests age ~ 5Myr
- Resemblance of plates to pack-ice in Arctic
a. Mars 13.7m resolution  
b. Antarctica  
c. Martian ice raft?
But is there water there now?

Diagram showing possible fossil water flow from subsurface source. Images from Global Surveyor. See handout.
Phobos & Deimos

- Low inclination, equatorial orbits