Oil and natural gas on Mars

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Outline of Talk

- Oil and natural gas on Earth and Mars
- Instrumentation
  - Ground Penetrating Radar
  - Trace Gas (Methane) Detectors
    - Point Detectors
    - Open Path Detectors
    - Remote Sensors

Oil and natural gas

- *Finding past life - even present life - on Mars may be quite difficult.*
- *Need for a biomarker or biomarkers that will be widespread, easy to find and easy to identify.*
- *Ideally, need to be able to detect biomarker at a distance. Cannot visit every square meter of Mars.*

Oil and natural gas

- Conventional theory holds that oil, coal, natural gas, and other subsurface hydrocarbons are derived from past life on Earth.
- Far more carbon is stored in oil, gas, and other subsurface hydrocarbons than in surface life.

Oil and natural gas

- *Nearly all oil and coal contains molecules of biological origin - especially hopanoids, phytane, and sterane.*
- *Biological origin of hopanoids, phytane, and sterane is almost universally accepted.*
- *Sedimentary source rocks associated with natural gas contain the same molecules and kerogen.*

Oil and natural gas

- *Oil, coal, and natural gas are usually attributed to pressure cooking of biological debris over millions of years.*
- *Hopanoids derive from prokaryotes, simple single-celled organisms, not plants or animals.*
- *Oil is now attributed to simple organisms in rivers and seas, not plants and animals.*

Oil and natural gas

- An ancient wet and warm Mars may have supported oceans, lakes, or rivers teeming with microorganisms.
- Conditions for formation of oil, coal, or natural gas may have occurred on ancient Mars.
- Time frame is 3.8 billion years ago (Noachian Mars) to 300 million years ago.

Oil and natural gas

- *An alternative theory holds that oil, coal, and natural gas are primordial.*
- *This theory almost certainly predicts large quantities of oil, coal, or natural gas on Mars.*
- *Some variants (e.g. Thomas Gold) propose that life originated in the primordial subsurface hydrocarbons.*

Oil and natural gas

- Columbia River Basalt Group SLiME ecosystem is often suggested as a model for current life on Mars.
- Natural gas was produced commercially at the Columbia River Basalt.
- SLiME proposed to produce methane
- Methane seeps from a SLiME-like Martian ecosystem seem likely.

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Instrumentation

- *How to find oil or natural gas on Mars.*
  - *Ground Penetrating Radar*
  - *Trace Gas Detectors*
    - *Point Detectors*
    - *Open Path Detectors*
    - *Remote Sensors*
      - *Scanning IR Lasers*
      - *Passive IR Imaging Arrays*

Ground Penetrating Radar

- *Hydrocarbons have a dielectric permittivity in range 2.0 to 3.0*
- *Water and water ice have dielectric permittivity in range 2.0 to 3.0*
- *Martian regolith has dielectric permittivity in range 2.0 to 3.0*
- *GPR cannot unambiguously identify oil and natural gas*

Trace Gas Detectors

- *Detect CH_4, H_20S, H_20, and other gases.*
- *Unambiguously identify methane (CH_4), Hydrogen Sulfide (H_2S), Water Vapor (H_20), and other gases.*
- *Measure the concentration of CH_4, H_2S, H_20, and other gases in the Martian atmosphere.*

Trace Gas Detectors

- *Mars has winds (6-8 meters/second) that will carry gas from seeps far downwind.*
- *The Martian atmosphere has turbulent diffusion that will spread the gas seep across the wind and vertically.*
- *Thus, even a point trace gas detector will be able to detect a methane seep at a distance.*

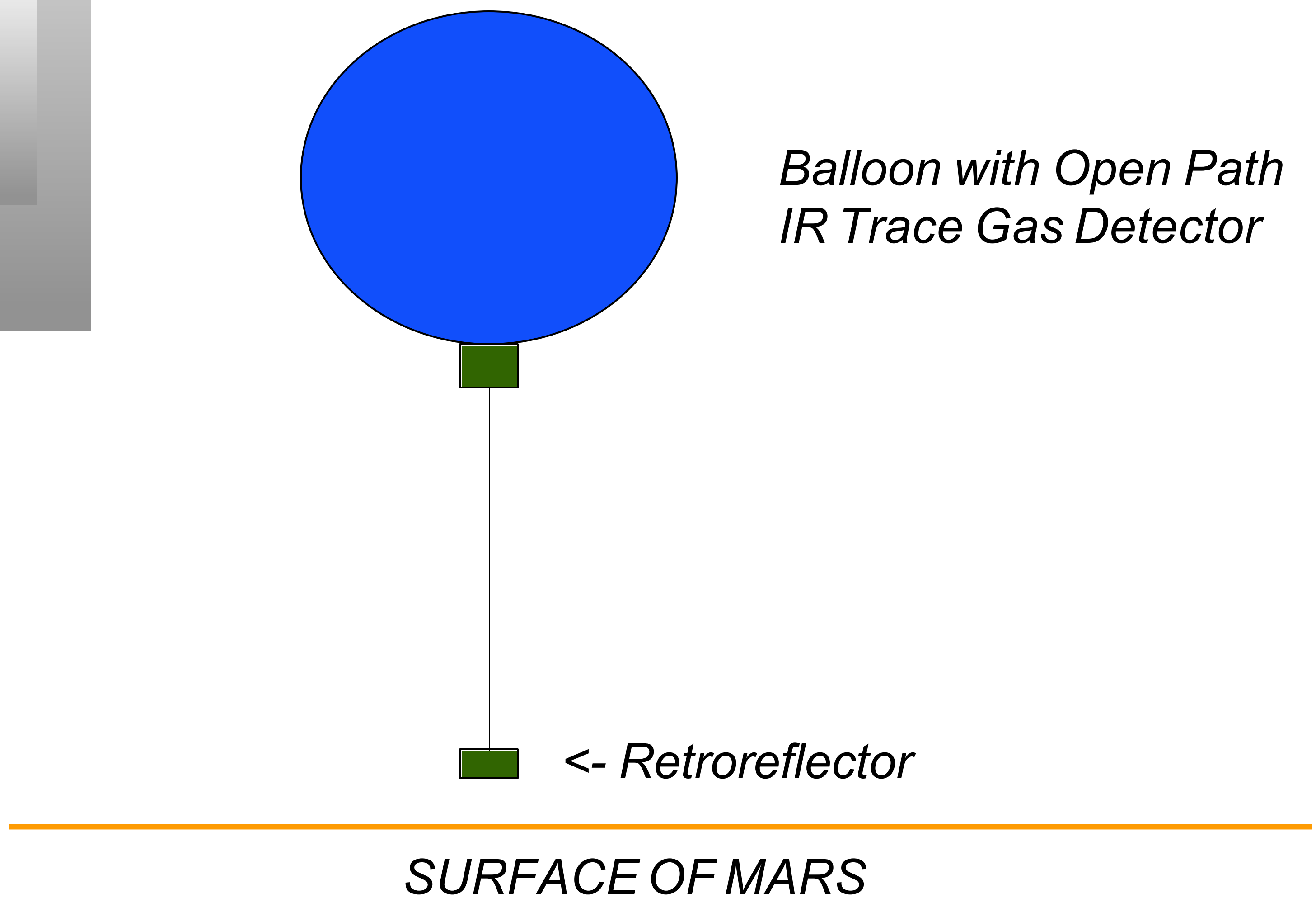
Mobile Probes

- *Mobile probes can carry trace gas detectors and locate gas seeps of any origin.*
- *High Speed Rovers (1 meter per second)*
- *Balloons (1-10 meters/second)*
- *Airplanes (10-100 meters/second)*

Mars Rover

NOMAD PROTOTYPE

Mars Balloon



Mars Balloon

JPL MARS BALLOON DEPLOYMENT

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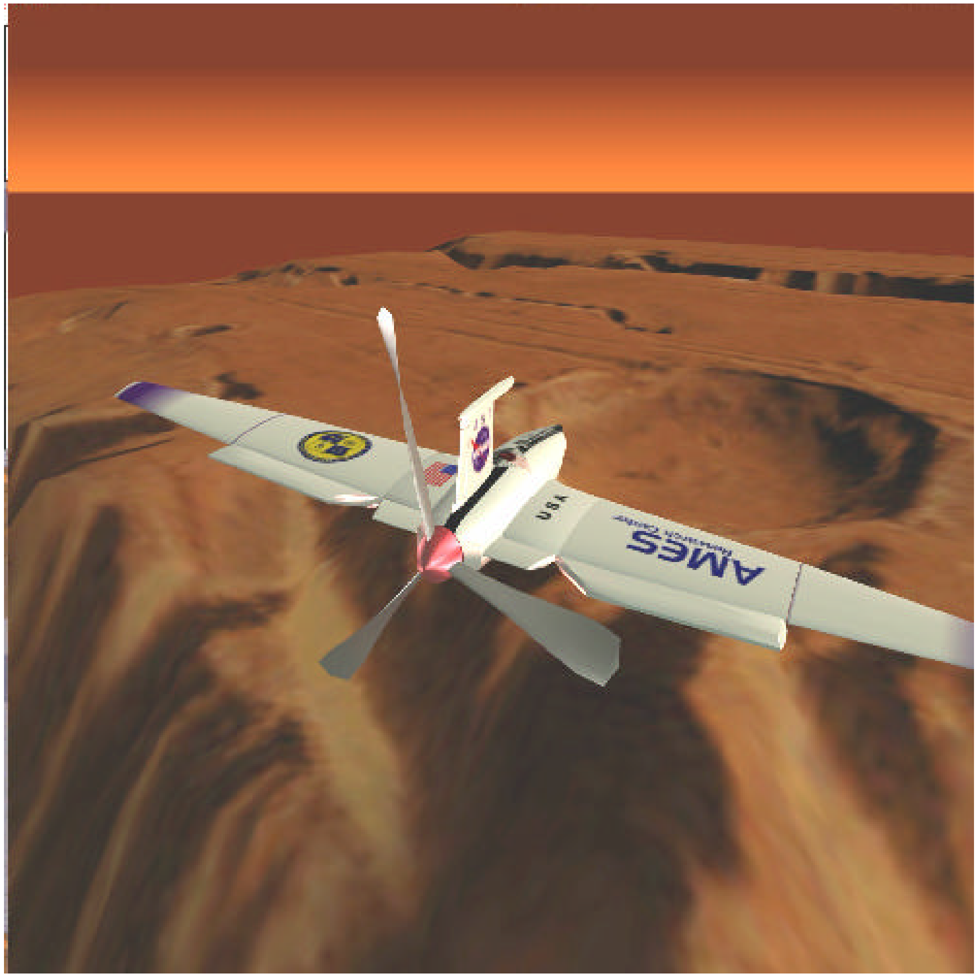
Mars Airplane



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Mobile Probes

- Usually have a science payload of 15-30 KG
- Usually have a few hundred watts of total power (e.g. 200 Watts)
- Usually have a science payload volume of order 100 cm by 100 cm by 100 cm (1,000,000 cm^3) or less

Gas Seeps on Mars

- 0.34 KG/sec emission rate
- Gaussian Plume Model
- Distances in Meters
- Gas Concentration in Parts Per Billion of Earth Atmosphere at Standard Temperature and Pressure (STP)
- 1 PPB Earth = 1×10^{-9} KG/m^3

Gas Seeps on Mars

- Wind velocity of 8 meters per second
- S_Y (Across Wind) = 0.04 x
- S_z (Vertical) = 0.04 x
- x is distance down wind.
- This is a naive extrapolation of Earth Gaussian Plume Models to Mars.

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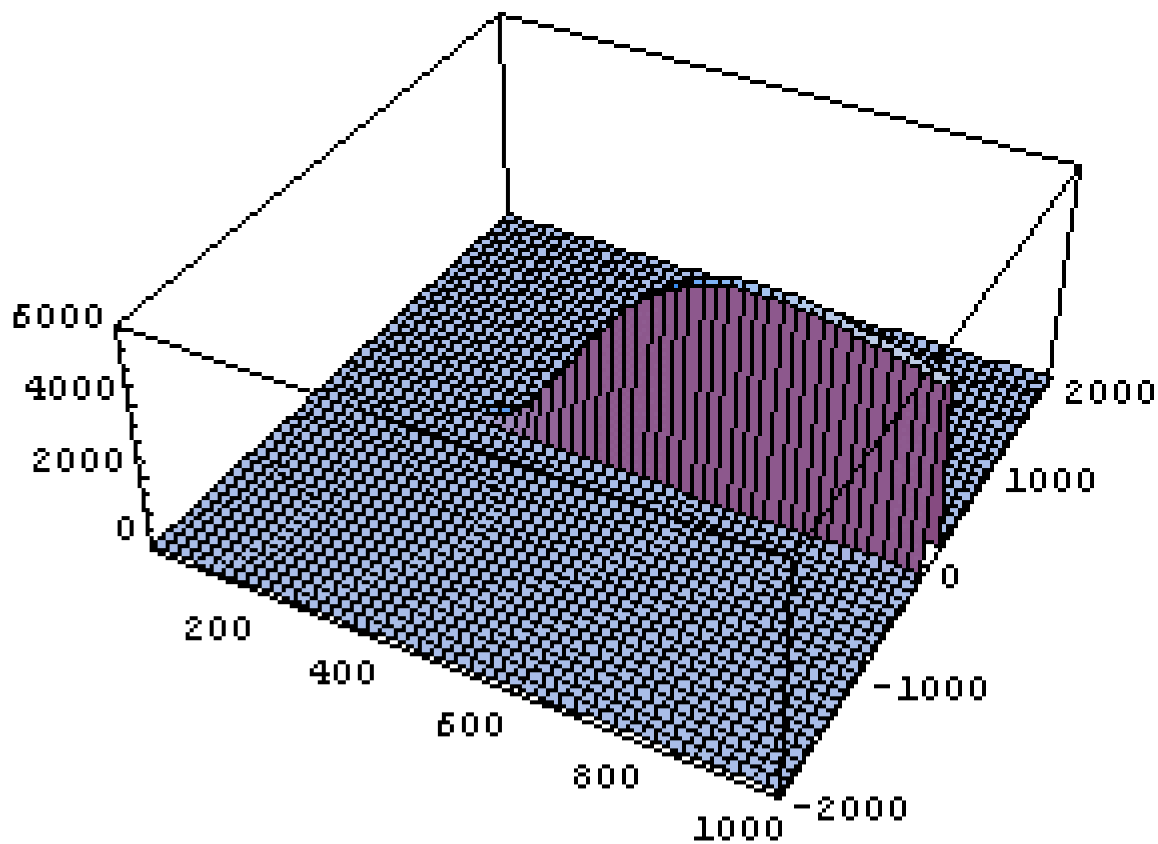
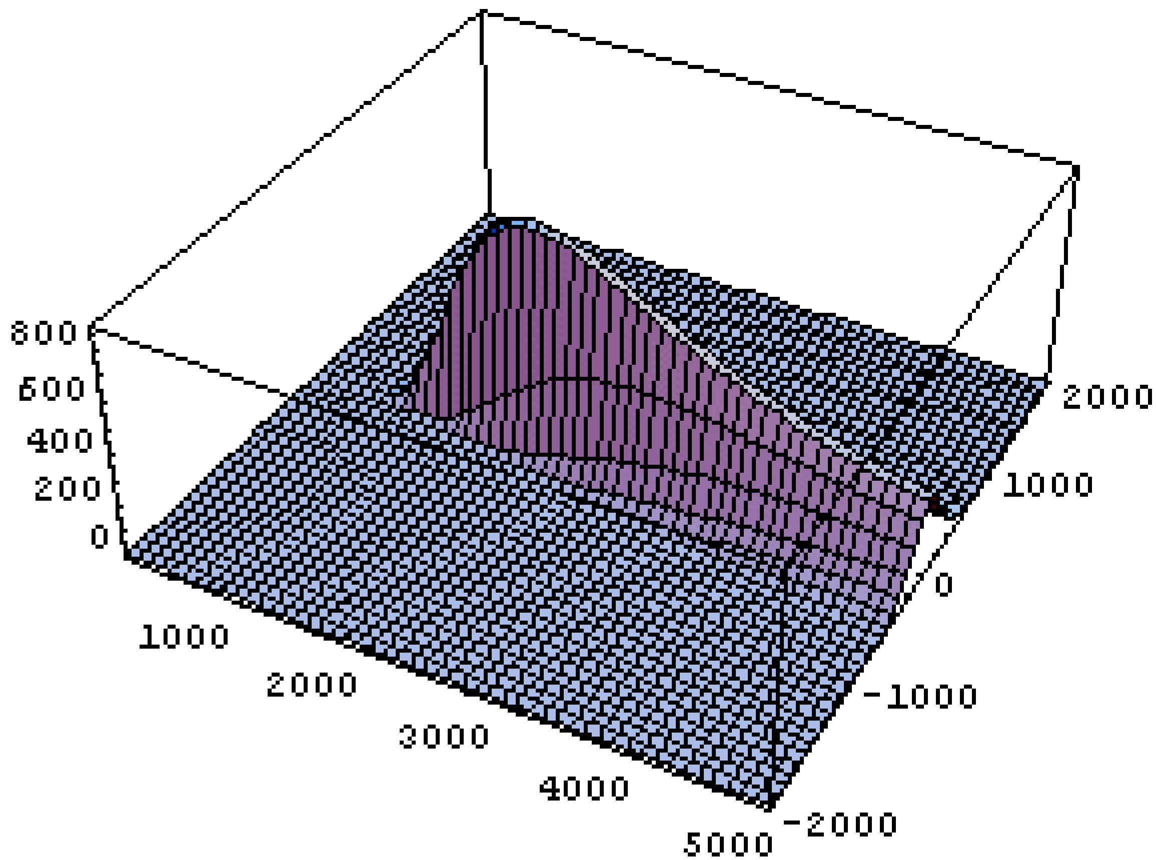
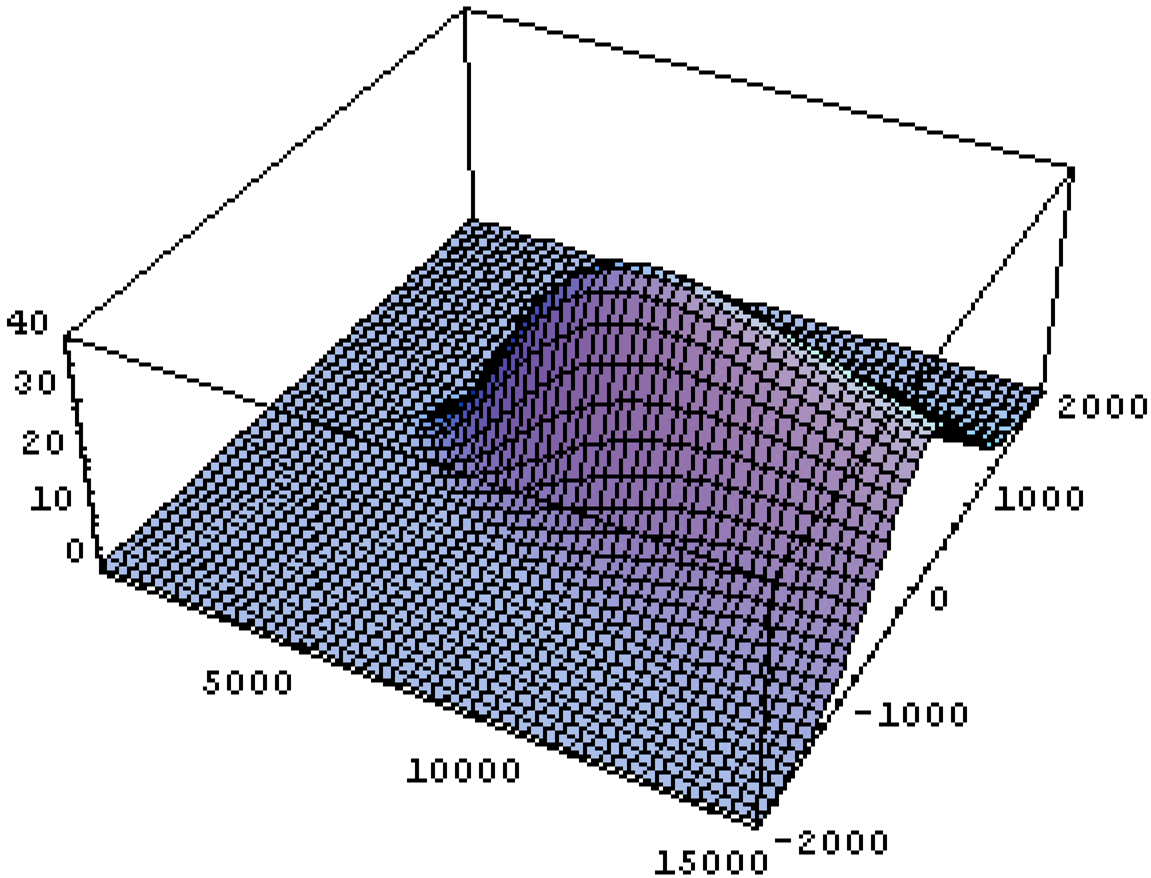
Gas at 1 Meter (Rover)



Gas at 100 Meters (Aerobot)



Gas at 500 Meters (Aerobot)



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Coverage of Mars (100 days)

Speed	Range	Coverage	Percent
1 m/sec	100 m	1,728 km^2	0.0012 %
100 m/s	100 m	17,280	0.12 %
100 m/s	1,000 m	1,728,000	1.2 %
100 m/s	10,000 m	17,280,000	12.0 %

Gas Seeps

- *Probes should travel as close to perpendicular to the Martian wind direction as possible to achieve maximum coverage of the Martian surface.*
- *Probes should travel as close to the Martian surface as possible to maximize the likelihood of seep detection and the detection range to a seep.*

Infrared (IR) Gas Detectors

Sensor	Size	Weight	Power	MDC	Time
DFG	45 cm by 45 cm by 12 cm	25 KG	60 W	23 ppb	2.1 sec
Rosemount	22 cm by 48 cm by 48 cm	25 KG	150 W	1 ppm	0.5 – 20 sec
ALIAS	200 cm by 50 cm by 50 cm	72 KG	400 W	50 pptv	10-30 sec

Mass Spectrometers (MS)

Sensor	Size	Weight	Power	MDC	Time
ESS	53 cm by 45 cm by 23 cm	26 KG	170 W	2 ppb	100 msec
Viking GCMS	less than 100 cm by 100 cm by 100 cm	much less than 600 KG	much less than 140 W	10-50 ppm	At least 10.24 seconds
Viking SpectraTrak	35 cm by 52.5 cm by 80 cm	66 KG	1300 W	few ppm	10-15 minutes
Galileo MS	18.4 cm (D) by 37 cm (L)	13.2 KG	13 W + 12 W	10 ppmv H_2O	75 seconds

Current Trace Gas Detectors

- *Are point or open path detectors.*
- *In principle, scanning IR laser detectors (active sensors) and passive IR imaging arrays (passive sensors) are possible.*
- *Scanning IR detectors and passive IR imaging arrays can detect gas plumes at a distance without relying on dispersion in the atmosphere.*

Current Trace Gas Detectors

- *Too big, too heavy, too high power, too insensitive, or too slow for detecting gas seeps from mobile probes on Mars.*
- *Pretty close to needed parameters*
- *"Faster, better, cheaper" mass spectrometers and infrared detectors are being developed. Probably can be developed to meet mission needs.*

System Requirements

- *SIZE: 1000 cm^3*
- *WEIGHT: 2 KG*
- *POWER: 20 Watts*
- *RESPONSE TIME: 1 second*
- *Minimum Detectable Concentration (MDC): 10 ppb of Earth atmosphere at STP (about 1×10^{-8} KG/m^3)*

System Requirements

- Bit Rate: 4096 bits per second
- Bit Error Rate: 10^{-5}
- Target Gases: Methane (CH_4), other hydrocarbon gases, Hydrogen Sulfide (H_2S), Water Vapor (H_2O)

Conclusion

- *The Dream: The Probe detects a gas seep at a distance.*
- *The Probe navigates to the source of the gas seep.*
- *The Probe analyzes the soil at the gas seep and finds organic molecules such as hopanoids that indicate past life or even finds present life!*

Oil and natural gas

- On Earth, most commercial oil and gas is 400 million years or younger.
- Several commercial fields are Proterozoic (Precambrian)
- Oil seeps in 1.1 billion year old rocks in U.S. mines reported.
- Oil “shows” in Australia to 1.6 billion years ago.

Oil and natural gas

- *Small amounts of oil reported preserved in “inclusions” in Archaean sandstones from several sites to 3,000 million years ago.*
- *Kerogen, presumed precursor of oil and gas, common in Precambrian rock.*
- *Kerogen reported in Isua rocks in Greenland (3.8 billion years ago)*

Oil and natural gas

- *Could oil or natural gas formed hundreds of millions or billions of years ago have survived to the present on Mars?*
- *Some studies indicate that oil can be stable under conditions of oil creation for billions of years. Conversion to natural gas requires higher temperatures than petroleum genesis.*

Oil and natural gas

- *On Earth, sedimentation and metamorphosis have been continuous. Few primordial rocks survive, e.g. Isua rocks in Greenland.*
- *Any ancient hydrocarbon deposits on Earth would have buried at great depth and pressure cooked into natural gas.*

Oil and natural gas

- *On Mars, ancient rocks, e.g. 3.8 billion years old, appear to survive near surface. An ancient oil deposit may never have been buried at sufficient depth to convert to natural gas.*
- *Martian volcanoes may have provided caprocks to prevent outgassing of gas fields.*

Oil and natural gas

- Oil is ideal biomarker because it can seep to the surface and directly contains biological molecules such as hopanoids.
- Natural gas is also a biomarker. However, it will not directly contain the biological molecules. Must seek associated sedimentary source rocks to prove biology.

Oil and natural gas

- The easiest way to look for oil, coal, and natural gas is surface seeps of natural gas, primarily methane, and oil.
- No excavation.
- No drilling.
- Methane is less than 20 parts per billion of Martian atmosphere. Methane seep will be very obvious.

Oil and natural gas

- Seeps of natural gas on Earth follow a log-normal distribution.
- Most seeps are small.
- Some seeps are large. These seeps dominate.
- Coal Oil Point at Santa Barbara is an example of a large seep (roughly 0.34 KG/second of Methane)

Oil and natural gas

- *On Mars, would try to find a large seep.*
- *A large seep will be easiest to detect.*
- *A large seep will probably represent a large subsurface source of gas near the surface.*
- *May find hopanoids or other biomarkers in the soil at the seep. Even oil on surface may be possible.*

Under Development

Sensor	Size	Weight	Power	MDC	Time
TinyTOF	30 cm by 15 cm by 15 cm	5 KG	50 Watts	?	?
JPL (Sinha et al)	?	1 KG	2 Watts	?	?
JPL (Chutjian et al)	10 cm by 15 cm by 20 cm	1.1 KG	?	?	?
Cassini-Huygens	?	?	?	10 ppb	?

Under Development

- Small solid-state Fourier Transform Infrared Spectrometer (FTIR), less than 2 cm^3,reported.
- Small solid state gas chromatograph prototype, less than 2 cm^3, reported.
- Further miniaturization of suitcase sized IR prototypes (DFG) are possible.