Very Low Bitrate Video for Mars Missions

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- Video system design for Mars Airplane
- MPEG-1 and MPEG-2 Software Decoders (Windows, Unix, and Macintosh)
- Still and digital video quality metrics
- Perceptual optimization of JPEG compression
- Mars exploration/origin of life

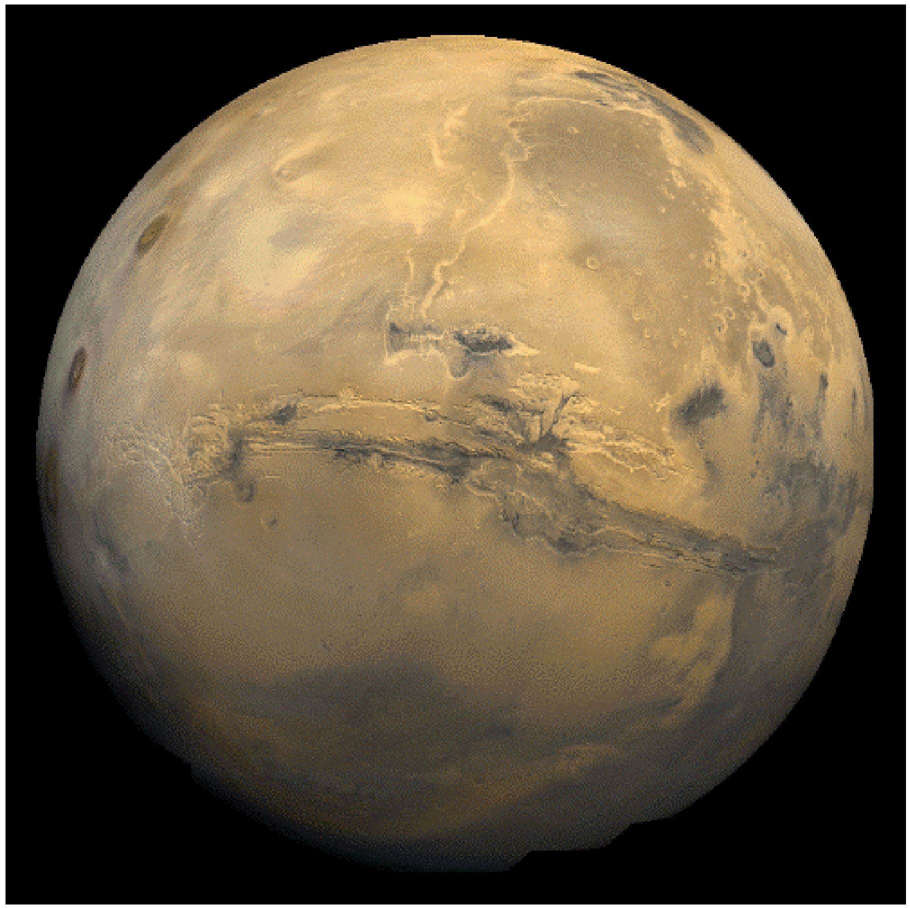
Outline of Talk

- Why Video for Mars Missions
- Obstacles to Video for Mars Missions
- How to overcome the obstacles
- Very Low Bitrate Video
- Conclusions

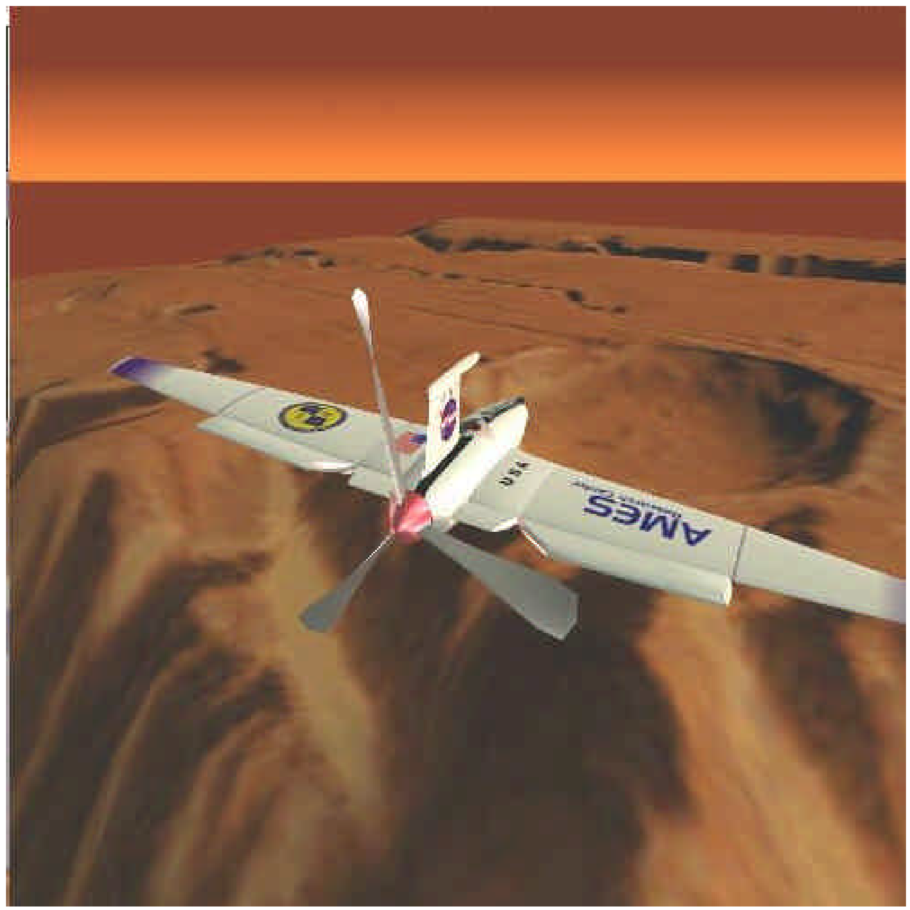
Televising Mars Missions

- Build and maintain public support
- Video from mobile probes – airplanes, balloons, and rovers – will be dramatic!
- Airplane in Valles Marineris (NASA Year 2000 Budget Proposal)
- Major source of revenue for a private mission

Televising Mars Missions



Televising Mars Missions



Televising Mars Missions

- Life detection
- Unambiguous detection of life has proven difficult (Viking Labeled Release, microfossils in meteorites)
- Directly observe microorganisms reproducing under a microscope
- Directly observe motion by microbes

Televising Mars Missions

- Failure analysis and prevention
- Video of landing, e.g. Mars Polar Lander
- Video of final approach, e.g. Mars Climate Orbiter
- Visual inspection of probe during long journey from Earth

Televising Mars Missions

- Mobile probes such as airplanes, balloons, or high-speed rovers will benefit from video.
- Video provides multiple successive overlapping images for better interpretation of ambiguous surface features.

Televising Mars Missions

- Detection and study of releases of subsurface water.
- Geysers, hot springs, or eruptions of water from collapsing crater or mountain walls.
- Evidence of recent groundwater seepage (Malin and Edgett)

Televising Mars Missions

- Seepage of gases or fluids at the Martian surface.
- Methane or other gases from subsurface life.
- Columbia River Basalt Group SLiME produces large amounts of methane (natural gas)

Televising Mars Missions

- Oil or natural gas on Mars?
- Seepage of methane, natural gas, or oil is possible.
- Trace gas detectors are best but video may assist especially for eruptions or bubbling activity.

Televising Mars Missions

- Known past volcanic activity on Mars
- Is there current activity?
- Video can directly observe eruptions or other volcanic or seismic activity.

Televising Mars Missions

- Many gases of interest, such as methane or hydrogen sulfide, and some liquids are transparent to visible light.
- Gases or liquids from beneath the surface will probably be warmer than the surface, especially volcanic gases.
- Infrared video may easily detect seepage, eruptions, or active volcanism.

Televising Mars Missions

- Video for atmospheric phenomena such as dust storms, dust devils, snow, lightning, and so forth.
- Still images have problems detecting or studying many transient atmospheric phenomena.

Televising Mars Missions

- Animals seem unlikely
- Video will be better able to detect animals, especially if camouflaged or quite small.
- Unexpected discoveries. New physical phenomena. Functioning mobile probes from extraterrestrial civilizations.

Televising Mars Missions

- COTS MPEG-1 or MPEG-2 Components
- 800 cm^3
- 2 KG
- 20 Watts (probably less than 6.5 Watts)
- 1 Megabit/second for MPEG-1 SIF
- Bit Error Rate: 10^{-6}

Televising Mars Missions

- 352 by 240 pixels
- Frame rate of 30 fps (NTSC video)
- Peak Signal to Noise Ratio: 30 dB
- Subjective quality comparable to a VHS analog video tape

Televising Mars Missions

- Bit rate requirements are substantial
- Minimum of about 1 Megabit/second for VHS quality video
- 6-8 Megabits/second for Broadcast or Studio Quality Video (DVD Video)
- Current Mars to Earth is less than 100 Kilobits/second with line of sight.

Televising Mars Missions

- Mars Communication Relay Networks
- NASA Jet Propulsion Laboratory studying
- Possible bit rates of 1-10 Megabits/second
- Solar or Nuclear Powered
- Low Mars Orbit or Mars Geosynchronous Orbit (or both)

Televising Mars Missions

- Relays are infrastructure, no immediate return on investment
- All current relays coupled to a planetary exploration probe with a camera
- High bandwidth relays can carry video cameras.
- Dust storms! Global Circulation Models

Televising Mars Missions

- Other obstacles
- Vibration and jitter on mobile probes may interfere with efficient digital video compression
- Multipath interference in canyons such as Valles Marineris

Televising Mars Missions

- Radiation Hardening
- 10-20 Krad Total Ionizing Dose (TID)
- Shielding fine for TID
- Reset software for Single Event Upsets
- Single Event Latchup (SEL) may force radiation hardened video processing

Televising Mars Missions

- Rad hard CMOS processes have achieved system clock speeds and levels of integration needed for single or few chip MPEG-1 or MPEG-2 Video Encoders
- Honeywell RICMOS-V, UTMC UT 0.6 Micron CRH RadHard Gate Array, Lockheed 5M, Lockheed RAD-LITE, Sandia CMOS6R

Televising Mars Missions

- Mars Networks take a long time to build
- 24/7 Real-Time Network
- Three (3) Geosynchronous Mars Orbit relays at $500 million each.
- Ten (10) Low Mars Orbit relays at $200 million each
- Total cost is at least $3.6 billion

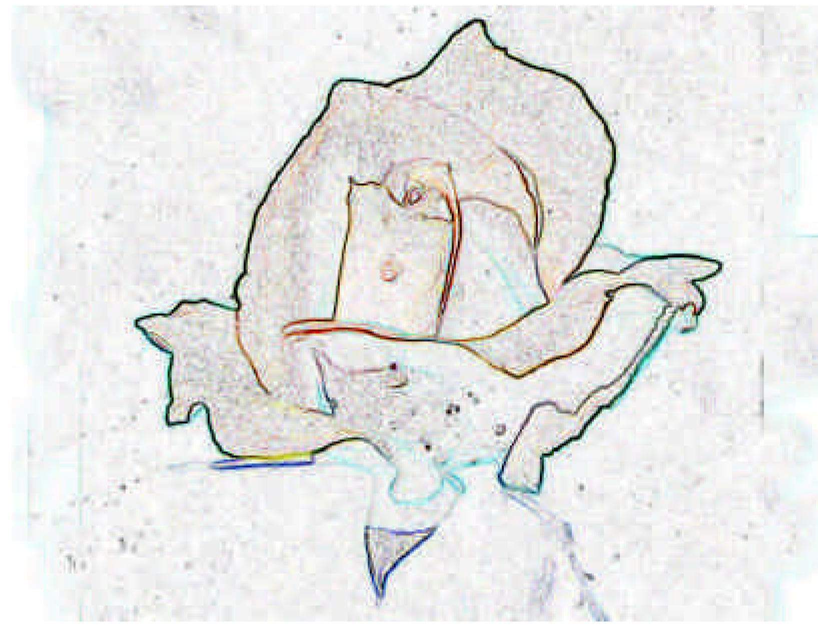
Televising Mars Missions

- Complementary approach is to develop Very Low Bitrate Video
- VHS Quality at 56 Kilobits/second
- Cost to design and fabricate a VLSI video encoder chip is $5-10 million *given a working very low bitrate video algorithm*
- Inexpensive compared to Mars Network

Very Low Bitrate Video

- Contour or object-based video coding may be able to achieve much higher levels of compression than MPEG or wavelet video.
- Contour based image coding consists of representing an image or image sequence as contours and textures filling regions delimited by the contours.

Very Low Bitrate Video



Very Low Bitrate Video

- Contour-based video coding may be able to achieve bit rates in the range of 40 – 400 Kilobits/second for VHS quality video.
- The principal obstacle to contour based video coding is the encoder that converts uncompressed bitmap images or image sequences to compressed data.
- Current edge detection and image segmentation algorithms are inadequate to properly identify and extract contours from natural images.

Very Low Bitrate Video

- While some edges are found correctly, these algorithms find spurious edges and fail to find other edges.
- Very low bit rate video compression probably requires developing methods for image segmentation, edge detection, or object detection comparable to the human visual system in accuracy.

Very Low Bitrate Video

- Edge detection and image segmentation is an unsolved problem.
- Push envelope. New idea is needed.
- Something from a field of mathematics not previously applied to computer vision, pattern recognition, and so forth?
- New mathematics?

Conclusions

- It is technically feasible to fabricate a single-chip or few chip MPEG digital video encoder using radiation hardened CMOS semiconductor processes.
- There is no fundamental obstacle to creating compact, lightweight, low power video systems for missions to Mars or other space missions.

Conclusions

- Televising Mars missions with MPEG digital video compression probably requires the establishment of a Mars communication network, a network of communication relay satellites in orbit around the planet.

Conclusions

- Contour based video coding can probably achieve bit rates of 40 to 400 Kilobits/second with subjective quality comparable to a brand new VHS videotape.

Conclusions

- Development of very low bitrate video compression may substantially reduce the time and money needed to build a Mars Network.
- Increase the number and the quality of video channels available over a Mars Network.