Mars Laser Communication Demonstration

MLCD

AFRL Optical Ground Stations For MTO Lasercom Demo

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Mars Telecommunications Orbiter (MTO)

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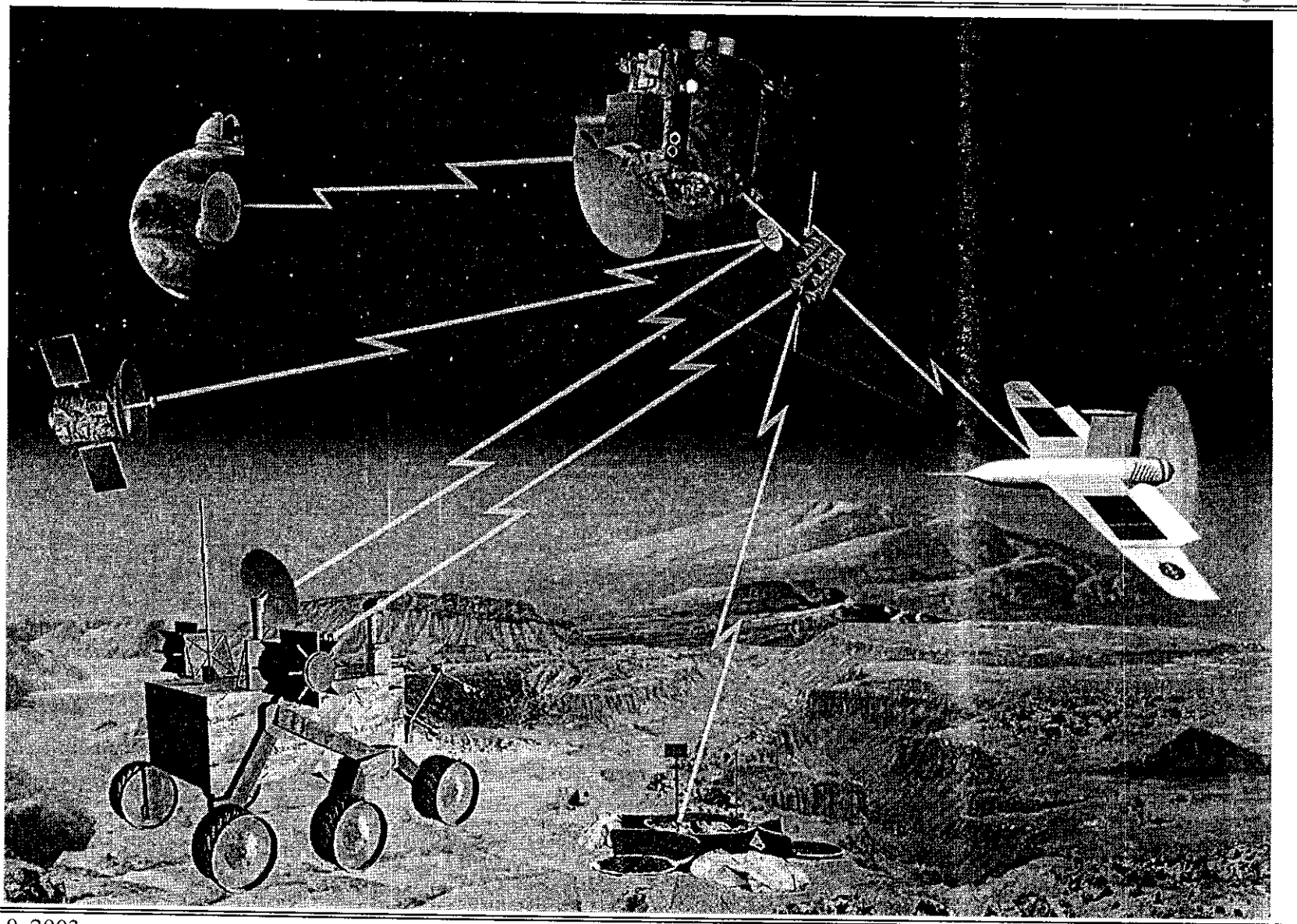
Mars Laser Communication Demonstration

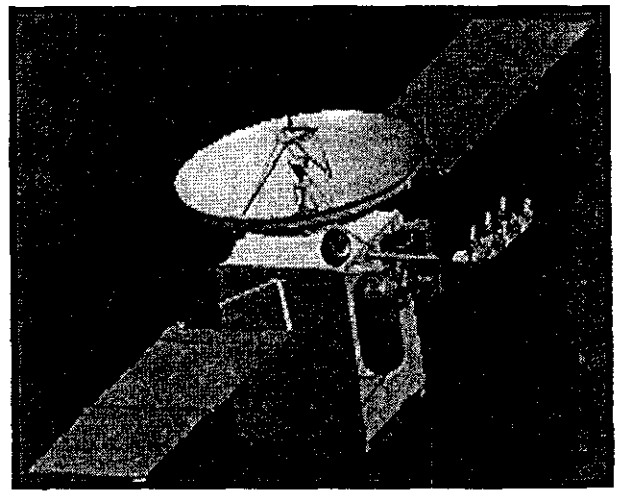


MTO Overview

MLCD Mars Laser Communication Demonstration

Salient Features

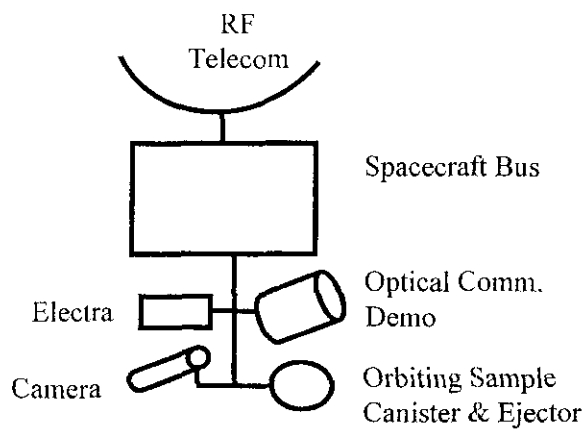
- Communications relay for MSL, Scouts and next-decade Mars surface and orbital missions
- Provide Critical Event Coverage, such as EDL or MOI
- Demonstrate deep-space Optical Comm link from Mars
- Detect and track Orbital Sample Canister
- Spacecraft to be built under a competed system contract
- Lifetime: 6 years on orbit, consumables for 4 more yrs



Current Payload

- Optical Comm Demonstration Flight Terminal
- RF Telecom (100 W X-band, 35 W Ka-band)
- Electra (UHF, X)
- OSC Finder Camera
- Orbiting Sample Canister (OSC) and Ejector
- *Optional: 100 W Ka-band telecom*
- *Optional: Other payloads under discussion w/NASA*

Payload Options



MTO Return Links

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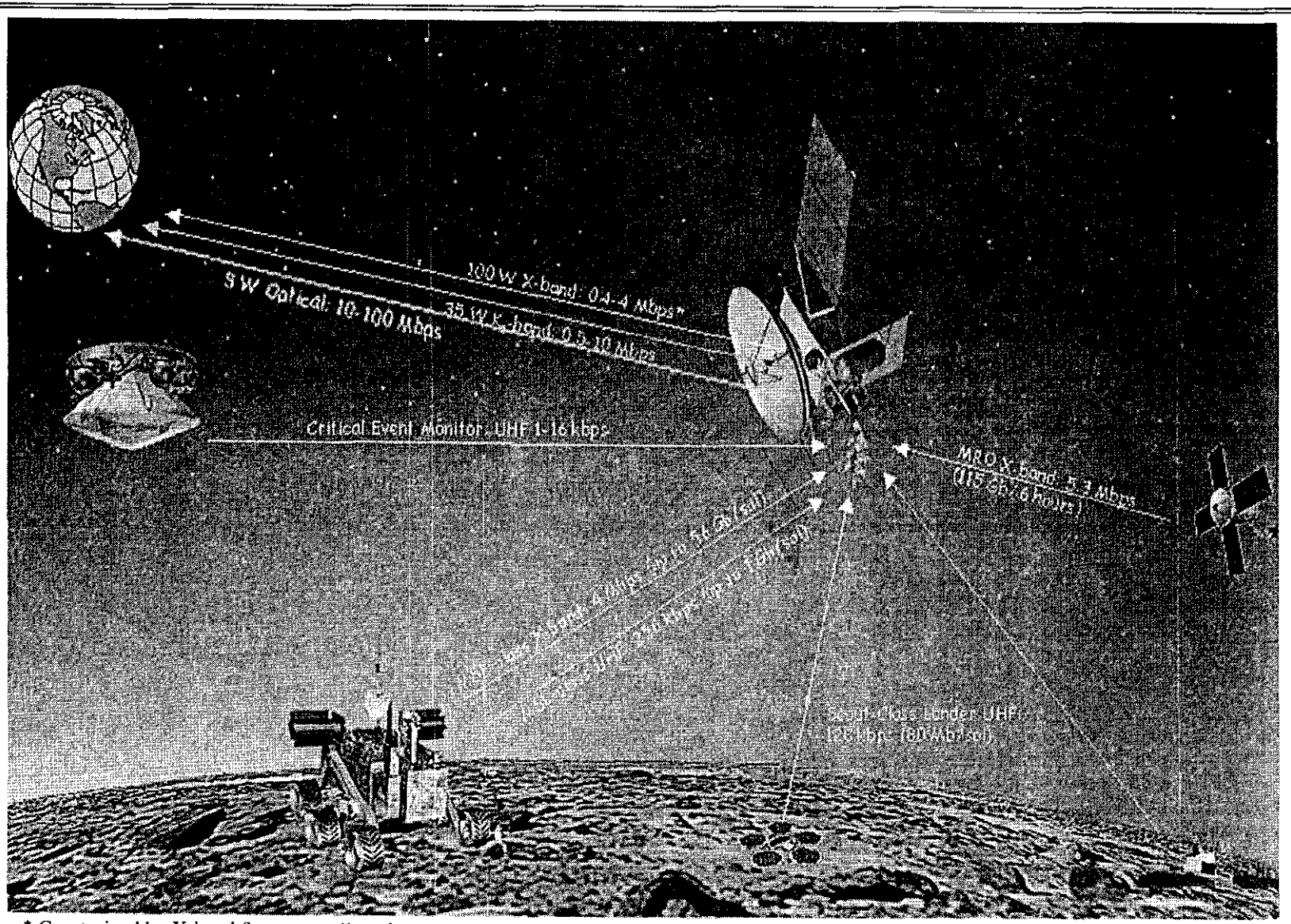

* Constrained by X-band frequency allocation

MLCD Overview

Mars Laser Communication Demonstration

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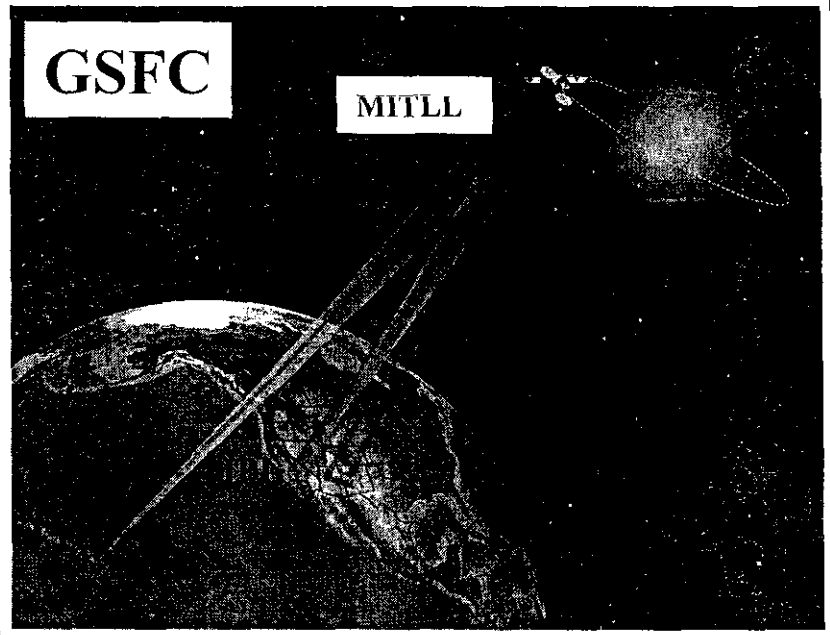
Salient Features

- Demonstrate deep-space Optical Communication link from Mars
- Project Management by GSFC, Flight Terminal implemented by MIT LL, and Ground Network implemented by JPL
- Flight Terminal will be a payload on MTO S/C
- Ground Terminals will use existing telescope facility in the current plan
  - Palomar Mountain 5 meter will be used for primary down-link
  - Table Mountain 1 meter OCTL will be used as primary up-link beacon
  - Other telescopes/configurations trade offs under consideration
- Implementation Phase C/D to start in FY '05
- Operational Date: October 2009
- Demonstration Lifetime Period: 2 years, Extended life time TBD yrs



Demonstration objective

- Down-Link rate of at least 10 Mbps with a goal of 30 Mbps at 10E-6 BER from Mars, with an absolute minimum of 1 Mbps
- Forward-Link of at least 10 bps at 10E-6 BER to Mars
- Measure and characterize the system performance over a variety of conditions during cruise and over ½ Mars year on orbit
- Characterize system performance near the Sun such that the maximum outage due to solar exclusion is less than 30 days
- Demonstrate weather mitigation techniques
- Demonstrate handover strategy techniques

Why Existing Telescopes?

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- Difficult to justify building a permanent ground infrastructure for first demo
  - Lots still to learn
  - The Road Map may ultimately have receiver network in space
  - Trade off between RF versus Optical, on-going
- Project is looking at variety of ways to satisfy requirements for ground network
  - Existing
    - Variety of sizes but would really like the largest aperture possible
    - Operation in daytime and close to the sun will be a plus
    - Demonstrates mitigation of weather outage with multiple sites
  - New
    - Large single aperture specifically designed to meet requirements
    - Arrays of smaller apertures specifically designed to meet requirements
- Assumption is that existing telescopes will be cost effective
  - Existing infrastructure
    - Roads & facilities
    - No need for environmental paperwork
  - Mitigation of Schedule Risk
- Telescope/facility upgrades will have added long-term benefit to astronomical community

Baseline Ground Stations for Demo

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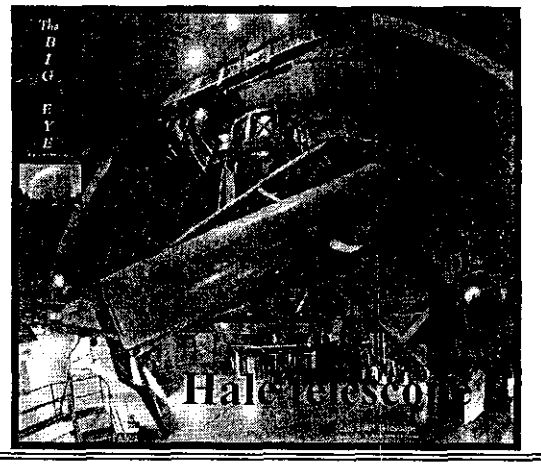
- Uplink Station
  - JPL 1-m telescope in Optical Communications Telescope Lab (OCTL) located at 2.2-km altitude, Wrightwood CA. Telescope has:
    - Coude focus to allow high power laser beam transmission
    - Baffles to shield primary mirror and special secondary spider supports to allow pointing to within 10 degrees of sun
- Downlink Station
  - 5-m Hale telescope located at 1.7 km high Mt. Palomar San Diego CA. Telescope has:
    - Cassegrain and prime foci
    - Adaptive optics system at Cassegrain focus
    - Large dome structure provides shielding for primary mirror up to 13 degrees sun angle



AMOS and SOR Ground Sites

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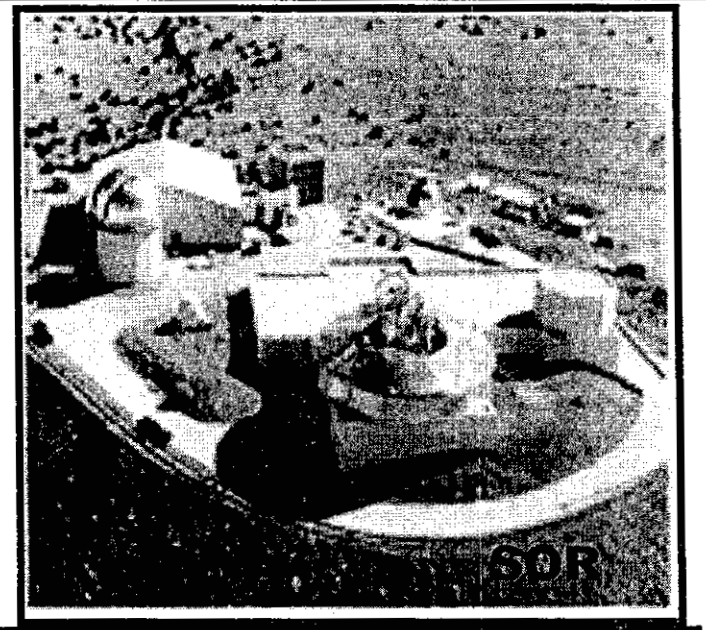
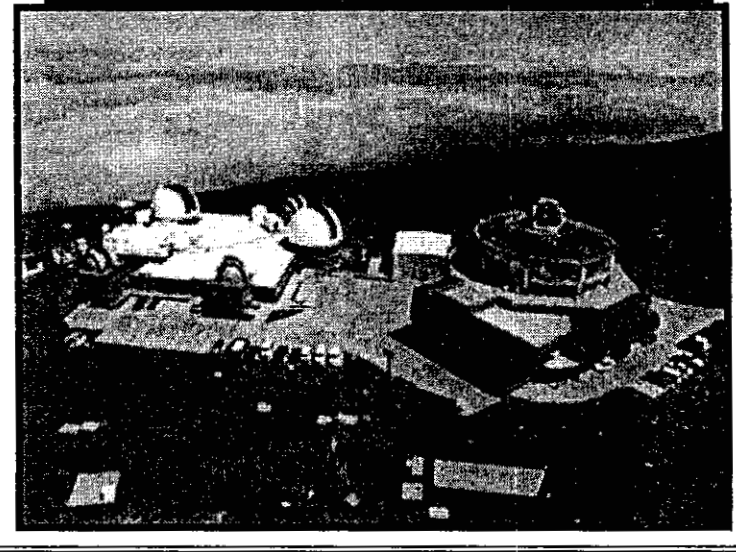
- Stations can support key MCLD objectives
  1. *Down-Link rate of at least 10 Mbps with a goal of 30 Mbps at 10E-6 BER from Mars, with an absolute minimum of 1 Mbps*
  2. *Demonstrate weather mitigation techniques*
  3. *Demonstrate handover strategy techniques*
  4. *Forward-Link of at least 10 bps at 10E-6 BER to Mars*
  5. *Measure and characterize the system performance*
     - *Over a variety of conditions during cruise*
- SOR and AMOS ground stations
  - 3-m class receiving apertures (SOR => 3.5-m AEOS => 3.67-m)
  - 1- meter class transmitters
  - On-site atmospheric measurement systems
  - Adaptive optics capabilities
    - Improves daytime reception SNR
- Stations provide site diversity to mitigate outages from:
  - Cloud cover
  - Predictive avoidance





Cruise Phase Demo

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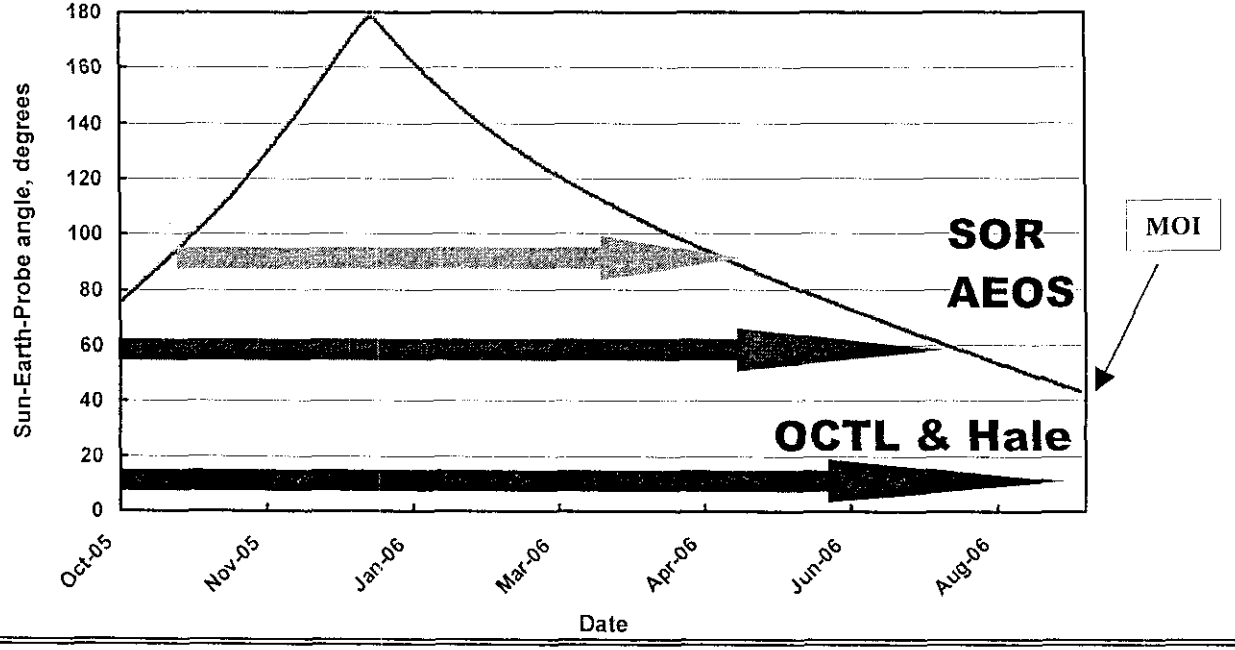
- Cruise phase demo allows early check out of spacecraft and ground terminals
- Under facilities-specified minimum operating SEP angles
  - OCTL, Palomar can support demo from early cruise to Mars Orbit insertion
    - Estimated minimum SEP operational angles are 10 & 13 degrees, respectively
  - AEOS can support demo from Launch to L+281
    - Estimated minimum SEP operational angle is 60 degrees
  - SOR can demo support from L+16 to L+209
    - Estimated minimum SEP angle 90 degrees



Three Site Network for Cloud Cover Mitigation

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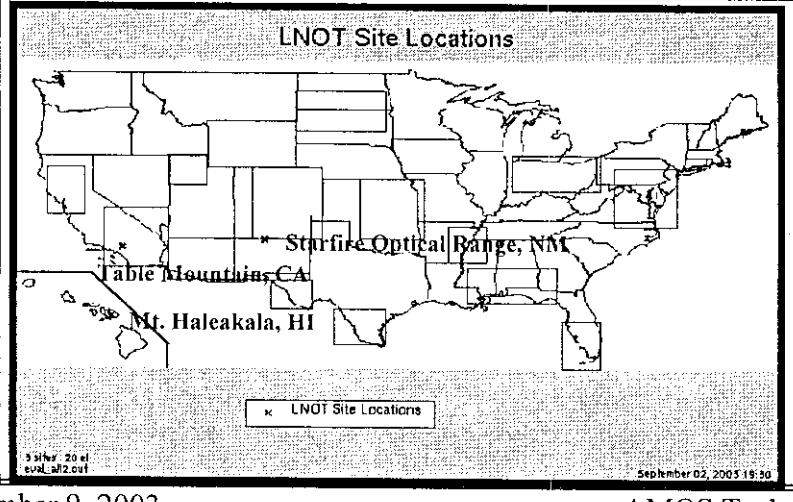
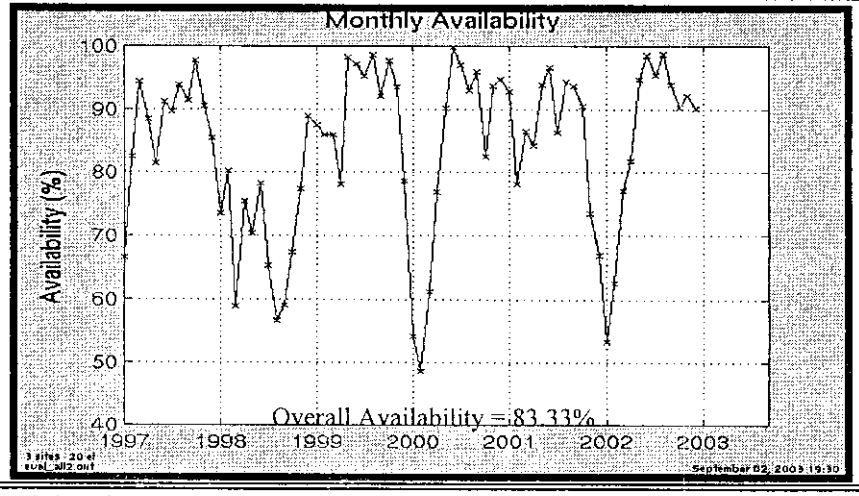
- Demonstration opportunities are scheduled in advance and coordinated with other spacecraft events. Unplanned outages impact demonstration
- Reviewed six-years of cloud cover data for AFRL and TMF ground sites
- Single site availabilities are:
  - Mt. Haleakala => 42.47%
  - Table Mountain => 60.1%
  - SOR => 48.96%
- Three-station network data shows that, on average, one of the stations is available at least 83.3% of the time
  - Average availability weighted by adverse years('98 '00, '02)
    - Availability is below 80% for 23 months





Laser Beam Propagation to Space

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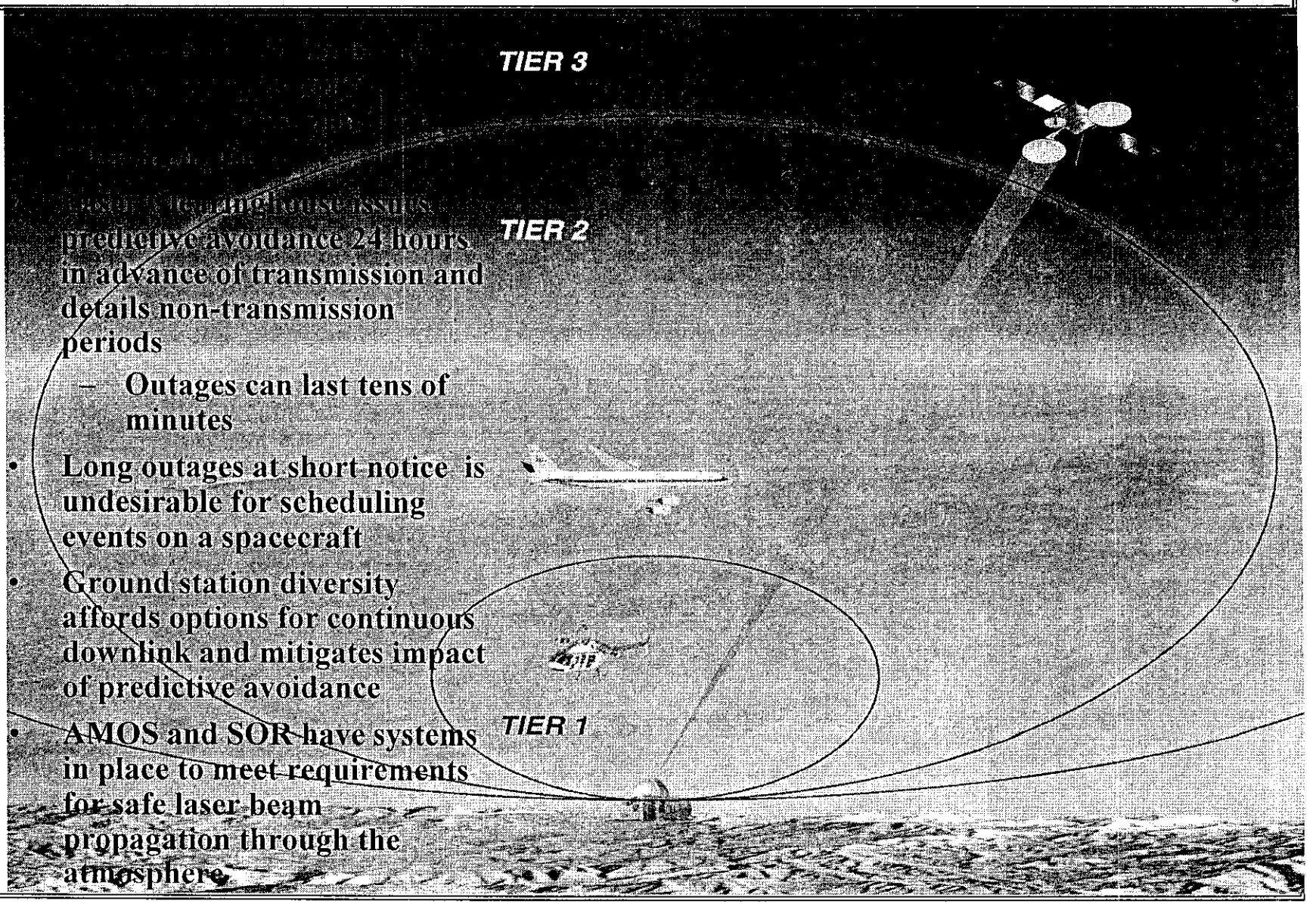
- Based on greenhouse issues predictive avoidance 24 hours in advance of transmission and details non-transmission periods
  - Outages can last tens of minutes
- Long outages at short notice is undesirable for scheduling events on a spacecraft
- Ground station diversity affords options for continuous downlink and mitigates impact of predictive avoidance
- AMOS and SOR have systems in place to meet requirements for safe laser beam propagation through the atmosphere



Summary

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- We have described the MTO project and the MTO lasercom demonstration
- Results for an analysis of six-years of cloud cover data show that site diversity using AMOS and SOR facilities affords a significant increase in link availability and mitigates cloud coverage outages
- SOR and AMOS have transmitted lasers into space. are experienced in coordinating laser transmissions with the appropriate regulatory government agencies
- Ground station site diversity will mitigate impact of Laser Clearinghouse imposed predictive avoidance outages on demonstration
- We are continuing to explore how these and other ground stations could support the MLCD

On-orbit Demo

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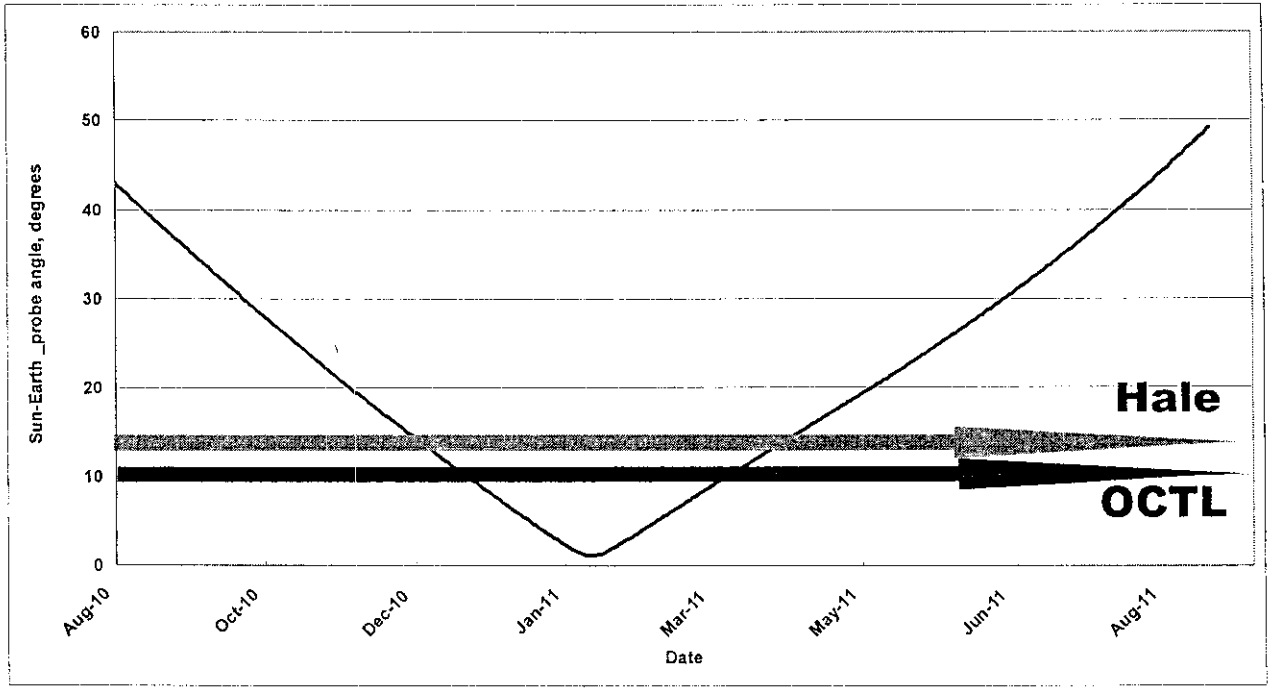
- Goal of ½ Mars on-orbit continuous support met in part by primary ground stations
  - Outage at TMF => 88 of 365 days; SEP<10 degrees
  - Outage at Palomar =>114 of 365 days; SEP<13 degrees
- Minimum SEP angle limitation of AFRL stations preclude participation in on-orbit phase of demo