EARTH OBSERVING SYSTEM
MICROWAVE LIMB SOUNDER:
A VIEW FROM THE FRONT

PRESENTED AT THE
SECOND INTERNATIONAL CONFERENCE ON SPACE THZ TECHNOLOGY

CALIFORNIA INSTITUTE OF TECHNOLOGY
JET PROPULSION LABORATORY
PASADENA, CALIFORNIA

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BY
PETER H. SIEGEL
EOS GOALS

1. LONG TERM RELIABLE MEASUREMENTS OF GEOPHYSICAL & BIOLOGICAL VARIABLES SO THAT GLOBAL, REGIONAL & LOCAL CHANGES CAN BE DOCUMENTED OVER A 15 YEAR PERIOD

2. IDENTIFICATION OF THE MOST IMPORTANT PROCESSES IN EARTH SYSTEM SCIENCE

3. IMPROVEMENTS IN PREDICTIVE MODELS OF THE EARTH'S DYNAMIC PROCESSES
# EO Investigations

1. INTERDISCIPLINARY INVESTIGATIONS  
   Climatology, Earth Resources, Biological Monitors

2. SPECIFIC SCIENCE INSTRUMENTS  
   Imaging, Atmospheric Chemistry, Radiance

3. FACILITY INSTRUMENTS  
   Wind speed & direction, temperature, humidity, cloud cover, IR imaging

<table>
<thead>
<tr>
<th>Surface Imagers</th>
<th>Stratospheric Chemistry</th>
<th>Tropospheric Chemistry</th>
<th>Solar-Terrestrial Interactions</th>
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<td>CERES</td>
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<td>SOLAR IRRADIANCE</td>
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<td>Tropospheric Sounders</td>
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<td>EOS SAR</td>
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CURRENT EOS PLATFORM STATISTICS AS OF 2/91

LAUNCH DATES: EOS-A 12/98  EOS-B 6/01
                12/03           6/06
                12/08           6/11

LAUNCH VEHICLE: TITAN IV

ORBIT: SUN SYNCHRONOUS-705KM 98.2 DEG INCL.

MASS=3500kg  POWER=3200W  DATA RATE=30 Mb/sec
                        2,600 Gb/day

PAYLOADS: EOS-A  11 INSTRUMENTS
          AIRS/AMSU-ASTER-CERES-EOSP-HIRLDS-LIS
          MIMR-MISR-MODIS-MOPITT-STIK SCAT

          EOS-B  14 INSTRUMENTS PLUS EOS-SAR
          SOLSTICE-HIRLDS-MLS-SAFIRE-SAGE-SWIRLS
          TES-LAWS-ALT-GLRS-GGI-GOS-IPEI-XIE

TOTAL COST: 30 BILLION OVER 20 YEARS
            2-3 BILLION/PLATFORM (6 TOTAL) PLUS SCIENCE
APPROXIMATE
SPACECRAFT COMPARISON

NIMBUS-7
1,021 KG
1.6 M DIAMETER
3.6 M HIGH
303 KG PAYLOAD
(1978)

ERBS
2,225 KG
1.6 M DIAMETER
3.8 M HIGH
100 KG PAYLOAD
(1984)

LANDSAT
1,727 KG
2.2 M DIAMETER
5.6 M HIGH
318 KG PAYLOAD
(1984)

ATN
1,909 KG
1.9 M DIAMETER
4.2 M HIGH
381 KG PAYLOAD

UARS
6,736 KG
4.3 M DIAMETER
9.8 M HIGH
2,283 KG PAYLOAD
(EARLY 1990'S)

EOS-CONCEPT
12,210 KG
4.3 M DIAMETER
12 M HIGH
3,500 KG PAYLOAD
Figure 5. EOS-A and EOS-B Platforms
Eos Microwave Limb Sounder (MLS)

Studying Stratospheric Ozone Chemistry with Submillimeter Waves

DAY/NIGHT COVERAGE

<table>
<thead>
<tr>
<th>Individual profiles</th>
<th>Daily sonar means</th>
<th>Monthly sonar means</th>
<th>Special situations</th>
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<tbody>
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</table>

PASSIVE INSTRUMENT

TYPICAL PROFILES

0 km

trop
100 km

OCIO, HCl, NO Cl, OCS, H2O, HNO3, N2O

0 10 20 30 40 50 km
EOS-MLS PRIMARY OBJECTIVES

MONITOR/STUDY GLOBAL CHANGE IN STRATOSPHERE/MESOSPHERE
CRITICAL GLOBAL MONITORING OF OZONE CHEMISTRY
MONITORING OF HETEROGENEOUS CHEMISTRY PERTURBATIONS

INSTRUMENT FEATURES

HIGH SENSITIVITY, HIGH SPECTRAL RESOLUTION HETERODYNE RADIOMETERS IN MILLIMETER & SUBMILLIMETER WAVE BANDS
RADIATIVE COOLING OF DETECTORS TO 90K
COMPLETE SPECTRUM EVERY 0.6 SEC
MODULAR PACKAGING
HERITAGE FROM PRIOR & ON-GOING MLS EXPERIMENTS BALLOON, AIRCRAFT, UARS
EOS-MLS Vital Stats

Mass=450 kg
Power=650W
Cost (NAR)=320M
Data Rate=15Gb/day
Optics: Off-axis Cass. Eff. f/D=3.75
Ellipsoidal Reflector 1.6x.8m 2.5um RMS
Spectra: 48/sca, 0.64 sec int. time
Vertical Scan Rate=42 sec
Ver. FOV=1.5 arcmin=1.2Km @640GHz
Hor. FOV=2.5 deg along orbit
Front End Radiometers: 640 (2)
540 (2)
440 (2)
220 (1)
63 (1)
LIMB SOUNDING GEOMETRY

OBSERVATION POINT (ORBITAL VELOCITY OUT OF PAGE)

100 km

OBSERVATION PATH

ATMOSPHERE

EARTH
OZONE ABUNDANCE ABOVE HALLEY BAY, ANT. IN 1987

Ref.: J. Farman, New Scientist, v. 12, pp.50-54, Nov. 1987
Eos MLS Measurement Capability

HORIZONTAL COVERAGE

Figure shows one day's coverage.

- Each cross, except at pole, is independent vertical profile measurement.
Figure 2. Stratospheric ozone chemistry schematics. MLS measurements in larger type.
Eos MLS: Primary Measurement Objectives

- Individual profiles every 2.5° along great circle of suborbital path
- Daily zonal means (separate day and night): ±80° latitude with 2.5° latitude resolution
- Monthly zonal means (separate day and night): ±80° latitude with 2.5° latitude resolution
- Heterogeneous chemistry enhancements for ClO and BrO; volcanic enhancements for SO₂
Eos MLS: Additional Measurement Objectives

- Individual profiles every 2.5° along great circle of suborbital path
- Daily zonal means (separate day and night): ±80° latitude with 2.5° latitude resolution
- Monthly zonal means (separate day and night): ±80° latitude with 2.5° latitude resolution

During solar storms (magnetic variations identify areas of solar interaction where resulting chemical perturbations will be studied)
COLLABORATORS ON EOS-MLS RECEIVERS

JPL: P.H. SIEGEL, I. MEHDI, R.J. DENGLER, J. OSWALD
ALL ASPECTS

RAL: B. MADDISON, B. ELLISON, D. MATHESON, M. OLDFIELD
440 & 63 GHZ RADIOMETERS

UVA: T. CROWE, W. BISHOP
SCHOTTKY BARRIER MIXER & MULTIPLIER DIODES

MARTIN MARIETTA: S. WEINREB
BROAD BAND AMPLIFIERS & INTEGRATED MIXERS

UNIV. OF MASS.: N. ERICKSON
HIGH POWER FREQUENCY MULTIPLIERS

ADDITIONAL UNCOMMITTED COLLABORATORS

JPL: J. BAUTISTA AMPLIFIERS
     B.A. WILSON PLANAR SCHOTTKY DIODES

NRAO: M. POSPIESZALSKI
AMPLIFIERS

UMICH: J. EAST
SOLID STATE DEVICES: MIXER/MULTIPLIER/OSCILLATOR DIODES
<table>
<thead>
<tr>
<th>Radiometer Frequency Phys. Temp</th>
<th>Mixer Type</th>
<th>Local Osc. Freq (GHz) Multiple Gunn (GHz)</th>
<th>IF Amp Band (GHz)</th>
<th>TIF (K)</th>
<th>TRCVR (SSB)</th>
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<td>640 GHz 90K</td>
<td>SHP</td>
<td>642.85/2</td>
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<td>14.0–21.5</td>
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<td>6400</td>
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<td>540 GHz 90K</td>
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<td>15.0–22.0</td>
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<td>440 GHz Ambient</td>
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<td>.09–.54</td>
<td>50</td>
<td>1200</td>
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<td>63 GHz Ambient</td>
<td>BAL.MXR</td>
<td>63.283</td>
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**Backend:** 32 Acousto-Optic Spectrometers; Bandwidth=1 GHz, Res.=1 MHz  
14 Digital Autocorrelators Bandwidth=4 MHz, Res.=100 KHz
Challenges for Eos-MLS Submillimeter-Wave Radiometry

1. Elimination of the whisker-contacted diode in both the mixer and LO source to improve reliability & ease fabrication

2. Design of a state-of-the-art coolable broadband fixed tuned subharmonically pumped mixer mount using planar diodes to simplify LO generation & injection

3. Design of a high power fix tuned waveguide multiplier using a series array of planar diodes to produce 5-10mW of power at 320 GHz

4. Design of multi-octave bandwidth low noise coolable HEMT amplifiers which can be matched to the SHP mixers over the full IF band
Eos-MLS Radiometer Plans & Progress I.

1. MIXER DEVELOPMENT
   • SHP Mixer Mount designed, modelled & characterized at 8 GHz
   • 200 GHz blocks completed, measurements to begin 3/91
   • 640 GHz mount in construction

2. MIXER ANALYSIS
   • Obtain a better understanding of mixer performance at cryogenic temperatures through improved diode equiv. circuit
   • Perform two diode mixer analysis using measured embedding impedances and improved diode equiv. circuit
   • Compare single & two-diode SHP mixer performance

3. PLANAR DIODE DEVELOPMENT
   • Explore planarization & substrate removal techniques on UVA air bridge diodes to reduce parasitics
   • Decrease microstrip loss & increase microstrip bandwidth
   • Lift-off & 'Etch back' techniques to replace GaAs substrate with quartz both successful with individual devices, integ. with remaining mixer circuitry expected 6/91
   • Effect of composite GaAs/quartz substrate on mixer filter structures studied & characterized
   • New diode structures & materials being studied at UMICH & UVA
   • Fully integrated mixer being developed at Martin Marietta
Eos-MLS RADIOMETER PLANS & PROGRESS II.

4. HIGH POWER PLANAR MULTIPLIER DEVELOPMENT
   UVA PLANAR VARACTOR DIODE DEVELOPMENT UNDERWAY
   MULTI-DIODE MULTIPLIER BLOCK DESIGN TO BEGIN 6/91 AT UMASS

5. AMPLIFIER DEVELOPMENT
   BROADBAND INTEGRATED AMP UNDER DEVELOPMENT AT MARTIN MARIETTA
   OCTAVE BAND HEMT AMPLIFIERS UNDER DEVELOPMENT AT JPL/NRAO
   UNDER SEPARATE IN HOUSE PROGRAMS

6. RADIATIONAL COOLER DEVELOPMENT
   80K RADIATIONAL COOLERS BEING DEVELOPED AT SBRC
   JPL COOLER DEVELOPMENT EFFORT TO BEGIN IN 92
## MIXER PERFORMANCE VS. TYPE AND FREQUENCY

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<tr>
<th>freq</th>
<th>Whisker Contact</th>
<th>Planar</th>
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<td></td>
<td>FM</td>
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<tr>
<td></td>
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<td>Tm</td>
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<tr>
<td>100</td>
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<tr>
<td>650</td>
<td>5200</td>
<td>12.0</td>
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All results are for waveguide mounts at T=300K and $\nu_f<2$ GHz. Tm and Ldb are SSB noise and loss, $P_L$ is required LO in mW.

References:
3. Erickson, private comm. April 1990
4. Erickson, 1st Int. Conf. on Space THz Tech, U.Mich, Mar.5,1990
6. Carlson,McMaster, Int.Conf. on IR&MM Waves, 1979, pp.82-3
9. Garfield, private comm. UVa, April 1990
10. Archer, MTT-30, Jan 1990, pp.15-22