IMAGE SCIENCE TEAM

PRESENTED BY: KEN ANDO
RECOMMENDATIONS (TENTATIVE)

- There is a pressing need for a airborne spectrometer class instrument for fundamental research in the new domain (for remote sensing) of high spectral and spatial resolution. One or more aircraft sensor developments should be initiated as part of an overall aircraft measurement research program.

- Develop and fabricate portable field instruments, conduct supportive tests, and provide data for research.

- Continue science studies to converge the sensor design and provide an improved science basis and rationale for MLA type systems.

- Develop specific mission scenarios with further inputs from the discipline panel as part of the follow-on to the MSWIG effort.

- Foster an involvement of a broader cross section of the remote sensing community including universities to develop a constituency and advocacy group for this technology.

- Continue on-going engineering and critical developments in areas such as wide field optics, focal planes, and spectral filter techniques.

- Develop a better understanding of the trades and interactions between the ground and space segment for strawman scenarios.
GSFC MLA PROGRAM ELEMENTS

0 TECHNOLOGY DEVELOPMENT
- SHORTWAVE INFRARED (SWIR) HYBRID (HGCDET) DECTOR ARRAYS
  (2 CONTRACTS - $4.5M EACH)
- MONOLITHIC SWIR DETECTOR ARRAYS ($950K)
- VISIBLE/NEAR INFRARED DETECTOR ARRAYS ($950K)
- DEPOSITION OF SPECTRAL FILTERS ON DETECTOR ARRAYS ($100K)
- PASSIVE COOLERS ($100K)
- SPECTRAL BEAM SPLITTERS ($45K)

0 INSTRUMENT/MISSION DESIGN STUDIES
- INSTRUMENT DEFINITION STUDIES (4 CONTRACTS, $450K EACH)
- END-TO-END SYSTEM STUDIES (4 CONTRACTS, $250K EACH)

0 SUPPORTING SCIENCE
- SENSOR PARAMETER ANALYSIS
- PERFORMANCE MODELING

0 IN-HOUSE CAPABILITY UPGRADE
- SENSOR CONCEPT EVALUATION
- DETECTOR ASSESSMENT LABORATORY
- CALIBRATION SOURCE DEVELOPMENT
- FIELD EXPERIMENTS
<table>
<thead>
<tr>
<th>INSTRUMENTS FLOWN</th>
<th>INSTRUMENTS UNDER DEVELOPMENT</th>
<th>INSTRUMENT CONCEPTS</th>
<th>AIRCRAFT INSTRUMENTS</th>
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<tbody>
<tr>
<td>MSS - Multi-spectral</td>
<td>TM - Thematic Mapper</td>
<td>MLA - Multi-spectral</td>
<td>AIS - Airborne Imaging</td>
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<tr>
<td>Scanner System</td>
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<td>Linear Array</td>
<td>Spectrometer</td>
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<td>SMIRR - Shuttle</td>
<td>SPOT - HRV - Systeme</td>
<td>SHSU - Shuttle</td>
<td>AVIRIS - Advanced</td>
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<tr>
<td>Multi-spectral</td>
<td>Probatoire d'Osservatation</td>
<td>Imaging Spectro-</td>
<td>Visual and Infrared</td>
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<td>Radiometer (Shuttle</td>
<td>De La Terre (1984)</td>
<td>meter (A: 1987-)</td>
<td>Imaging Spectrometer</td>
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<tr>
<td>GSO-2)</td>
<td></td>
<td>(B: 1987-)</td>
<td>(1995)</td>
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<tr>
<td>MESSR - Multi-spectral</td>
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<td>ISFF - Imaging</td>
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<tr>
<td>Electronic Self-Scan-</td>
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<td>Spectrometer Free-</td>
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<tr>
<td>ing Radiometer</td>
<td></td>
<td>Flyer (1990-)</td>
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<td>(1985)</td>
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<td>VTIIR - Visible and</td>
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<tr>
<td>Thermal Infrared</td>
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<td>Radiometer (1985)</td>
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<td>SMIRR - Shuttle</td>
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<tr>
<td>Multi-spectral Infrared</td>
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<tr>
<td>Radiometer (II: 1885-)</td>
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A CONCEPT HYBRID SWIR ARRAY

5-MODULES = TEST ASSEMBLY
(≈6,200 DETECTORS, ≈7 INCHES)

FLEX CABLES TO OFF-FOCAL PLANE ELECTRONICS

COLD SURFACE

FOCAL PLANE ARRAY
N-MODULES

HgCdTe ARRAY
(128 ELEMENTS)

INDIUM INTERCONNECT

CdTe

EPOXY

DET

PREAMP

LPE LAYER

INTERCONNECT PAD ON SI CHIP

MUX

SILICON READOUT CHIP

DETAIL OF A MODULE CONCEPT
(100 TO 500 DETECTORS)
PRIMARY SWIR FPA DEVELOPMENT

OBJECTIVE:
0 DEVELOP A HgCdTe FOCAL PLANE FOR IMAGING IN THE 1-2.5 μM SWIR BAND

APPROACH:
0 42-MONTH TWO-PHASE DEVELOPMENT EFFORT
0 TWO CONTRACTS FOR PARALLEL 42-MONTH EFFORTS
0 $5M PER CONTRACT

STATUS:
0 PROPOSALS FROM SBRC, HONEYWELL, AND ROCKWELL IN EVALUATION
0 DUAL AWARDS, CONTRACT STARTS IN EARLY 1983
# Instrument Requirements

## Radiometric

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<tr>
<th>Band</th>
<th>Largest Fov M</th>
<th>Snr</th>
<th>Min</th>
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<tr>
<td>V</td>
<td>0.55-0.56</td>
<td>15</td>
<td>73</td>
</tr>
<tr>
<td>2</td>
<td>0.56-0.66</td>
<td>15</td>
<td>49</td>
</tr>
<tr>
<td>3</td>
<td>0.65-0.89</td>
<td>15</td>
<td>26</td>
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<tr>
<td>4</td>
<td>0.76-1.30</td>
<td>15</td>
<td>68</td>
</tr>
<tr>
<td>5</td>
<td>1.35-1.75</td>
<td>50</td>
<td>57</td>
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<tr>
<td>6</td>
<td>1.08-2.45</td>
<td>30</td>
<td>74</td>
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</table>

- **Nominal Altitude**
  - 10/20M Option
- **Calibration**
  - Absolute End to End Relative Band to Band Within Band
  - 5%
  - 1%
  - 0.5%

## Mission

- **Orbital Altitudes**
  - 70 Ekm (Nominal)
  - 70/283 Ekm (Alternative)
- **Orbital Inclination**
  - Sun Synchronization
- **Equator Crossing**
  - 5:30 0:30 pm
- **Coverage**
  - 185 km at 705 km 15°
- **Stereo Mode**
  - 0.2E In Track
- **Missed Scene Mode**
  - 30 Cross Track
- **Life**
  - 7 Year (85% Probability)
- **Data Links**
  - Two 60 MBPS to DRS
  - One 400 MBPS Direct
- **Shuttle Launch**

## Registration

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<tr>
<th>Pixels, Max</th>
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<tr>
<td>200</td>
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<tr>
<td>0.1</td>
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<tr>
<td>1.3</td>
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<tr>
<td>0.2</td>
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</table>

## Pointing Accuracy

- Precision: 0.1
- Sensitivity: 0.001

## Polarization Sensitivity

- 7%

## MTF

- NYQ
  - 30%
<table>
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<tr>
<th>NAME/COUNTRY</th>
<th>LAUNCH DATE</th>
<th>GENERAL DESCRIPTION</th>
<th>RESOLUTION (M)</th>
<th>STATUS</th>
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<tbody>
<tr>
<td>SPOT/FRANCE</td>
<td>MAY 1984 (ARIANE)</td>
<td>3 SPECTRAL BANDS, 61 Panchromatic Band, 60KM swath, SIDE-LOOKING STEREO CAPABILITY, 2 TAPE RECORDERS</td>
<td>20 MULTISPECTRAL, 10 PANCHROMATIC</td>
<td>ENGINEERING MODEL IN TEST DATA COMMERCIALIZATION PLANNED BY CONSORTIUM $500 TO $1,000/DIGITAL SCENE SPOT 2 (1986), SPOT 3 (1989), AND SPOT 4 (1992) PLANNED TO ASSURE DATA CONTINUITY-SPOT 3 &amp; 4 MAY ALSO CARRY SAR</td>
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<tr>
<td>MOPS/GERMANY</td>
<td>1982 (SHUTTLE), 1983 (SPACELAB)</td>
<td>2 SPECTRAL BANDS, 140KM swath, OPTICALLY BUTTED RETICON ARRAYS, DIRECT CONTOUR MAPS VIA STEREO VIEWING</td>
<td>20</td>
<td>IN DEVELOPMENT FOR 1982 SHUTTLE AND SPACELAB EXPERIMENT</td>
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<tr>
<td>ERS-1/JAPAN</td>
<td>1987</td>
<td>SAR, VIB/IR SENSOR, EARTH RESOURCES/GEODETICAL OBSERVATIONS</td>
<td>50-500M</td>
<td>MITI/NASDA DEFINITION PHASE</td>
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<td>MOS-1/JAPAN</td>
<td>1989 (DELTA/N2) SECOND STAGE</td>
<td>OCEAN COLOR AND TEMPERATURE MONITOR WITH VISIBLE PUSHPBROOM SCANNER, THERMAL INFRARED AND MICROWAVE RADIO-METERS, MARINE AND LAND OBSERVATIONS</td>
<td>50</td>
<td>IN DEVELOPMENT</td>
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<tr>
<td>AERS-1/ESA</td>
<td></td>
<td>LAND OBSERVING MLA INSTRUMENT, VISIBLE, NIR &amp; SWIR CAPABILITY, C-BAND SAR</td>
<td></td>
<td>UNDER STUDY</td>
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</table>
"RESOLUTION" (1 FOV) AND FIELD OF VIEW
OF THE SENSORS

- MOMS
- MESSR
- HRV-P
- HRV-XS
- MSU-E
- MSU-SK
- "FRAGMENT"
- MSU-S
- MSU-M
- TM
- MSS

1 = INSTANTANEOUS FIELD OF VIEW - METERS
F = FIELD OF VIEW - KILOMETERS
OBJECTIVES

SUMMARIZE THE CURRENT STATE-OF-THE-ART OF SENSOR TECHNOLOGY, IDENTIFY CRITICAL ISSUES AND PROVIDE LONG RANGE GUIDANCE FOR THE DEVELOPMENT AND TESTING OF MULTISPECTRAL IMAGING TECHNOLOGY IN SPACE.

DEFINE NEEDED TECHNOLOGY AND INFORMATION EXTRACTION EXPERIMENTS IN THE LIGHT OF THE MEASUREMENT REQUIREMENTS AND SCIENTIFIC EXPERIMENTS DEVELOPED BY THE TERRESTRIAL SCIENCE DISCIPLINE GROUPS.
Reflectance Spectra for Typical Hydrothermal Alteration Minerals
Figure 3-4. Composite geologic interpretations of Patrick Draw, Wyoming, from Landsat MSS data (left) (Roehler, 1977) and Thematic Mapper Simulator MU-GUI data (right) (Lang et al., 1981). These two interpretations shown at the same scale illustrate the difference in detail detectable with 79 m and 18 m IPGVs respectively.
JPL MLA PROGRAM ELEMENTS

- TECHNOLOGY DEVELOPMENT
  - MERCURY CADMIUM TELLURIDE HYBRID DETECTOR ARRAYS
  - INDIUM ANTIMONIDE LINEAR AND AREA ARRAYS
  - ADVANCED OPTICAL DESIGN CONCEPTS AND ANALYSIS
  - COOLER DEVELOPMENT FOR SPACE SHUTTLE APPLICATIONS
  - ADVANCED ONBOARD PROCESSING ANALYSIS AND SIMULATION

- SHUTTLE/SPACE PLATFORM IMAGING SPECTROMETER (SIS)
  - FUNCTIONAL DESIGN OF INSTRUMENT SYSTEM
  - STS INTERFACE STUDY INCLUDING POINTING SYSTEM
  - EFFECTS OF ORBIT CHARACTERISTICS ON IMAGE GEOMETRY

- AIRCRAFT EXPERIMENTAL PROGRAM
  - DEVELOPMENT OF RESEARCH OBJECTIVES
  - INSTRUMENT DEFINITION AND COSTING

- IS APPLICATIONS DEVELOPMENT
  - DISCIPLINES REQUIREMENTS FOR IS DATA
  - GROUND PROCESSING TECHNIQUES AND SYSTEM STUDY
CONCLUSIONS

- A significant technology base for solid state pushbroom sensors exists and is in the process of further evolving through substantial NASA and collateral DOD funding.

- Two different but complementary sensor approaches and the associated technologies were presented: Spaceborne and Aircraft Instruments variants under development were reviewed.

- Adaptive and fixed on-board data compression schemes applicable to an MLA spaceborne instrument are available. DPCM, which provides modest (~2.4:1) data compression ratios, is probably preferable for near term hardware implementation. Adaptive systems which provide greater compression ratios, need further study.

- 32x32 element SWIR HgCdTe hybrid devices suitable for aircraft instrument use are becoming available. Buttable, 64x64 element devices for the imaging spectrometer applications will be available in about two years.

- The Integral Filter Multispectral Linear Array approach appears to be the most direct and promising focal plane approach for an MLA instrument.

- The linear array SWIR HgCdTe module developments should yield devices in about two years. PD-Si Schottky barrier linear arrays are promising as a near term low cost alternative. Collateral DOD developments will provide significant support in this area.

- Self-calibrating absolute silicon detectors could be the basis for a significant improvement in our on-board instrument calibration accuracy.

- Imaging spectrometer type instrument required for acquisition of calibrated narrow band spectra. A wide range of options exist.

- A spectrally and spatially versatile instrument needed to address the diverse research requirements expressed by the discipline panels. Key technological drivers results from the geology and cartographic requirements.
COMPARISON OF MULTISPECTRAL SENSORS
FOR REMOTE SENSING
(FIELD, AIRCRAFT AND SPACE)
SHUTTLE IMAGING SPECTROMETER (SIS)

FORE-OPTICS CORRECTOR

226 mm

452 mm

FORE-OPTICS AND SPECTROMETER PRIMARY MIRROR

2521 mm

1260.5 mm

IMAGE SURFACE

REFLECTING SLIT

226 mm

452 mm

PRISM

SPECTROMETER CORRECTOR

452 mm

SPECTROMETER FOLD MIRROR

FOLD MIRROR

ELECTRONICS
SELF CALIBRATED ABSOLUTE SILICON DETECTOR

Fig. 1. Typical photomultiplier internal quantum efficiency without blinding (lower curve) and with blinding (upper curve), reference 4.

Fig. 2. A three-slide arrangement to minimize specular reflection losses.

Fig. 4. The factory procedure for absolute neutron photometric calibration.
VIS/NIR MULTISPECTRAL CCD DEVELOPMENT

OBJECTIVE:
- DEVELOP A VIS/NIR CCD ARRAY THAT WILL SERVE AS THE BASIC UNIT FOR AN MLA FOCAL PLANE.

APPROACH:
- 24-MONTH $1.2M CONTRACT TO DEVELOP AND VALIDATE APPROACH.
- CCD DESIGN: FOUR 1024-ELEMENT LINEAR ARRAYS WITH INTEGRAL BANDPASS FILTERS ON A MONOLITHIC STRUCTURE.
- DESIGN, FABRICATE AND TEST FIVE MODULE FOCAL PLANE.

STATUS:
- PROPOSALS FROM RCA, FAIRCHILD, WESTINGHOUSE AND HUGHES IN EVALUATION.
- CONTRACTOR SELECTION AND AWARD BY AUGUST 1982.
MLA INSTRUMENT WITHOUT COVERS
AND STEREO MODULE

- Graphite Epoxy Structure
- Heat Pipes to Radiator
- Beam splitter
- IPA Cables
- Electrical & Thermal Control Covers
- Electronic Cards
- Earth Shield
- IPA Thermal Isolation Support Structure
- Focal Plane Array
- Secondary Mirror Housing
- Quadrinary Mirror
- Primary Mirror
SPECTRAL COVERAGE OF THE SENSORS

- MOS-1
  - SPAS-01
  - MOMS
  - MESSR
- SPOT
  - HRV-P
  - HRV-XS
- METEOR S/C
  - MSU-E
  - MSU-SK
  - "FRAGMENT"
- LANDSAT
  - MSU-S
  - MSU-M
  - TM
  - MSS

WAVELENGTH-MICROMETERS
IMAGING SCIENCE WORKSHOP
AGENDA

NON-NASA SENSOR
MAPSAT
MLA SENSOR CONCEPTS
SENSOR TRADEOFF ISSUES
VISIBLE/IR SENSOR REVIEW
GSFC SUPPORTING TECHNOLOGY PROGRAMS
IMAGING SPECTROMETER
IR AREA ARRAY STATUS
CALIBRATION OVERVIEW
AIRCRAFT DATA PROGRAMS

ON-BOARD DATA PROCESSING

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A. MIKA (SBRC)
J. LOWRANCE (PRINCETON)
W. BARNES (GSFC)
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JOHN LOWRANCE

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UNIVERSITY OF HAWAII
LOCKHEED RESEARCH LABS
JET PROPULSION LABORATORY
GODDARD SPACE FLIGHT CENTER
PRINCETON UNIVERSITY
SCHEDULE OF PAST AND PROPOSED FLIGHTS

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<td>LANDSAT 1, 2, 3 (MSS)</td>
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<tr>
<td>MOS-1 (MESSR)</td>
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- LANDSAT 1: Launched in 6/72