

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 (HGCDTE) DETECTOR ARRAYS (2 CONTRACTS - \$4.5M EACH)
  - MONOLITHIC SWIR DETECTOR ARRAYS (\$950K)
  - VISIBLE/NEAR INFRARED DETECTOR ARRAYS (\$950K)
  - DESPOSITION 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

# LAND REMOTE SENSING SYSTEM INDEX

## INSTRUMENTS FLOWN

**MSS** - MULTI-SPECTRAL SCANNER SYSTEM (LANDSAT 1-3)

**SMIR** - SHUTTLE MULTI-SPECTRAL RADIOMETER (SHUTTLE OSTA-2)

## INSTRUMENTS UNDER DEVELOPMENT

**TM** - THEMATIC MAPPER (1982)

**SPOT** - HRV - SYSTEME PROBATOIRE D'OBSERVATION DE LA TERRE (1984)

**MESSR** - MULTI-SPECTRAL ELECTRONIC SELF-SCANNING RADIO-METER (1985)

**VTIR** - VISIBLE AND THERMAL INFRARED RADIOMETER (1985)

## INSTRUMENT CONCEPTS

**MLA** - MULTI-SPECTRAL LINEAR ARRAY (1987-)

**SH** - SHUTTLE IMAGING SPECTROMETER (A: 1987-) (B: 1989-)

**ISFF** - IMAGING SPECTROMETER FREE-FLYER (1980-)

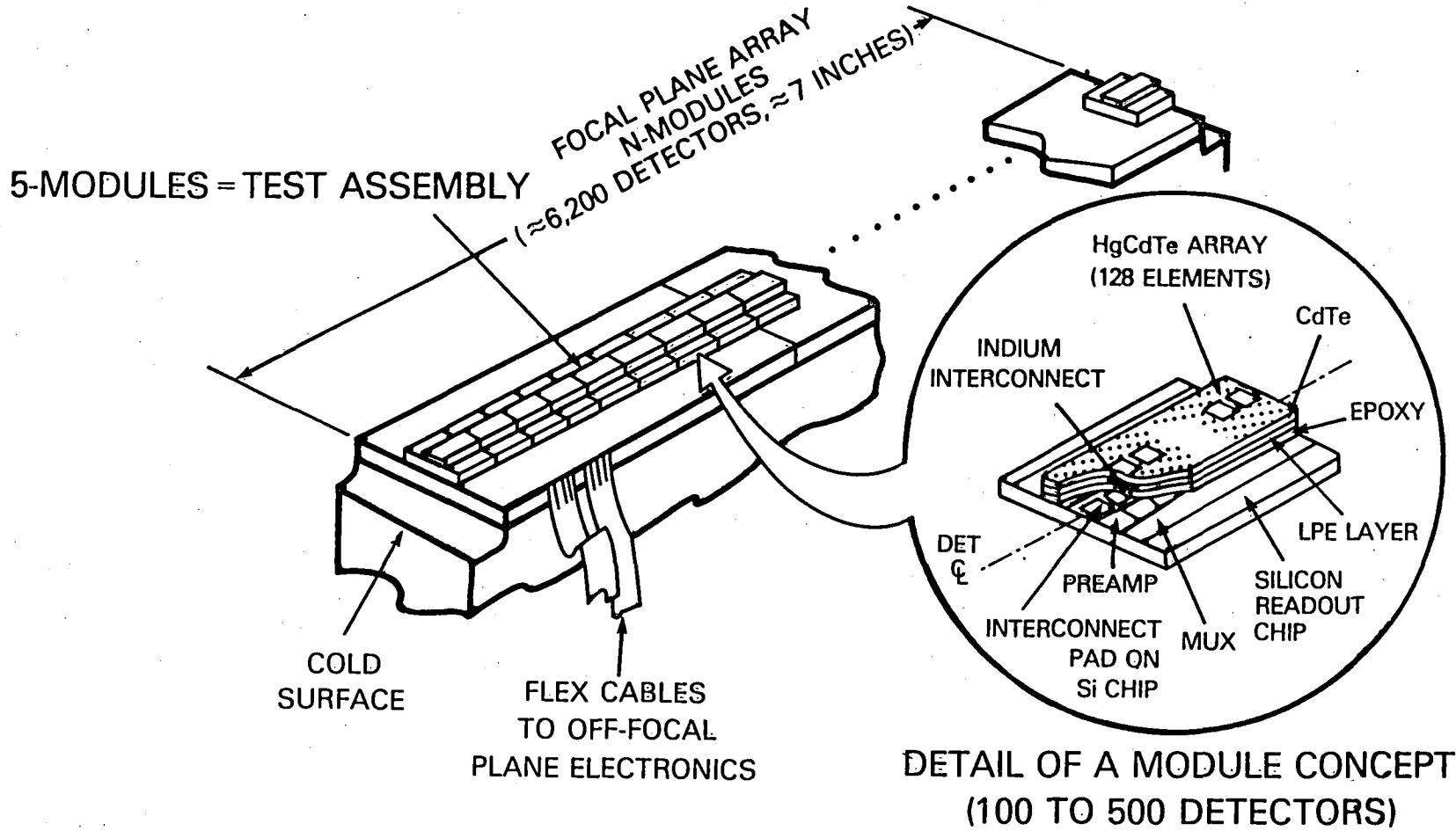
**SMIR** - SHUTTLE MULTI-SPECTRAL INFRARED RADIO-METER (II: 1985-) (III: 1987-)

## AIRCRAFT INSTRUMENTS

**AIS** - AIRBORNE IMAGING SPECTROMETER (1982)

**AVIRIS** - ADVANCED VISUAL AND INFRARED IMAGING SPECTROMETER (1985)

# A CONCEPT HYBRID SWIR ARRAY



## PRIMARY SWIR FPA DEVELOPMENT

### OBJECTIVE:

- o DEVELOP A HgCdTe FOCAL PLANE FOR IMAGING IN THE 1-2.5  $\mu$ M SWIR BAND

### APPROACH:

- o 42-MONTH TWO-PHASE DEVELOPMENT EFFORT
- o TWO CONTRACTS FOR PARALLEL 42-MONTH EFFORTS
- o ~\$5M PER CONTRACT

### STATUS:

- o PROPOSALS FROM SBRC, HONEYWELL, AND ROCKWELL IN EVALUATION
- o DUAL AWARDS, CONTRACT STARTS IN EARLY 1983

# INSTRUMENT REQUIREMENTS

## • RADIOMETRIC

BAND	WAVELENGTH RANGE (μm)	LARGEST FOV (M)	MIN SNR
2	0.56-0.60	15	149
3	0.63-0.69	15	126
4	0.76-0.90	15	168
5	1.55-1.75	30	54
6	2.08-2.35	30	77

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### • \*NOMINAL ALTITUDE

10/20M OPTION

### • CALIBRATION

ABSOLUTE END TO END  
RELATIVE BAND TO BAND  
WITHIN BAND

5%  
1%  
0.5%

### • REGISTRATION

SEPARATION BAND TO BAND  
(POSITION KNOWLEDGE)  
ARRAY LENGTH  
BAND PARALLELISM

### PIXELS, MAX

20.0  
0.1  
+3.0  
+0.2

### • POINTING ACCURACY

PRECISION

±0.1  
±0.01

### • POLARIZATION SENSITIVITY

1%

### • MTF (NYQ)

30%

## • MISSION

### ORBITAL ALTITUDES

705 KM (NOMINAL)

470-285 KM

(ALTERNATIVE)

### ORBITAL INCLINATION

SUN SYNCHRONISM

### EQUATOR CROSSING

9:30 TO 30 P.M.

### COVERAGE

185 KM AT 705 KM, 15°

### STEREO MODE

10-20 IN TRACK

### MISSED SCENE MODE

30 CROSS TRACK

### LIFE

5 YEAR (85%

PROBABILITY)

### DATA LINKS

200-150 MBPS TO

EDRS

DIRECT (100 MBPS DIRECT

### SHUTTLE LAUNCH

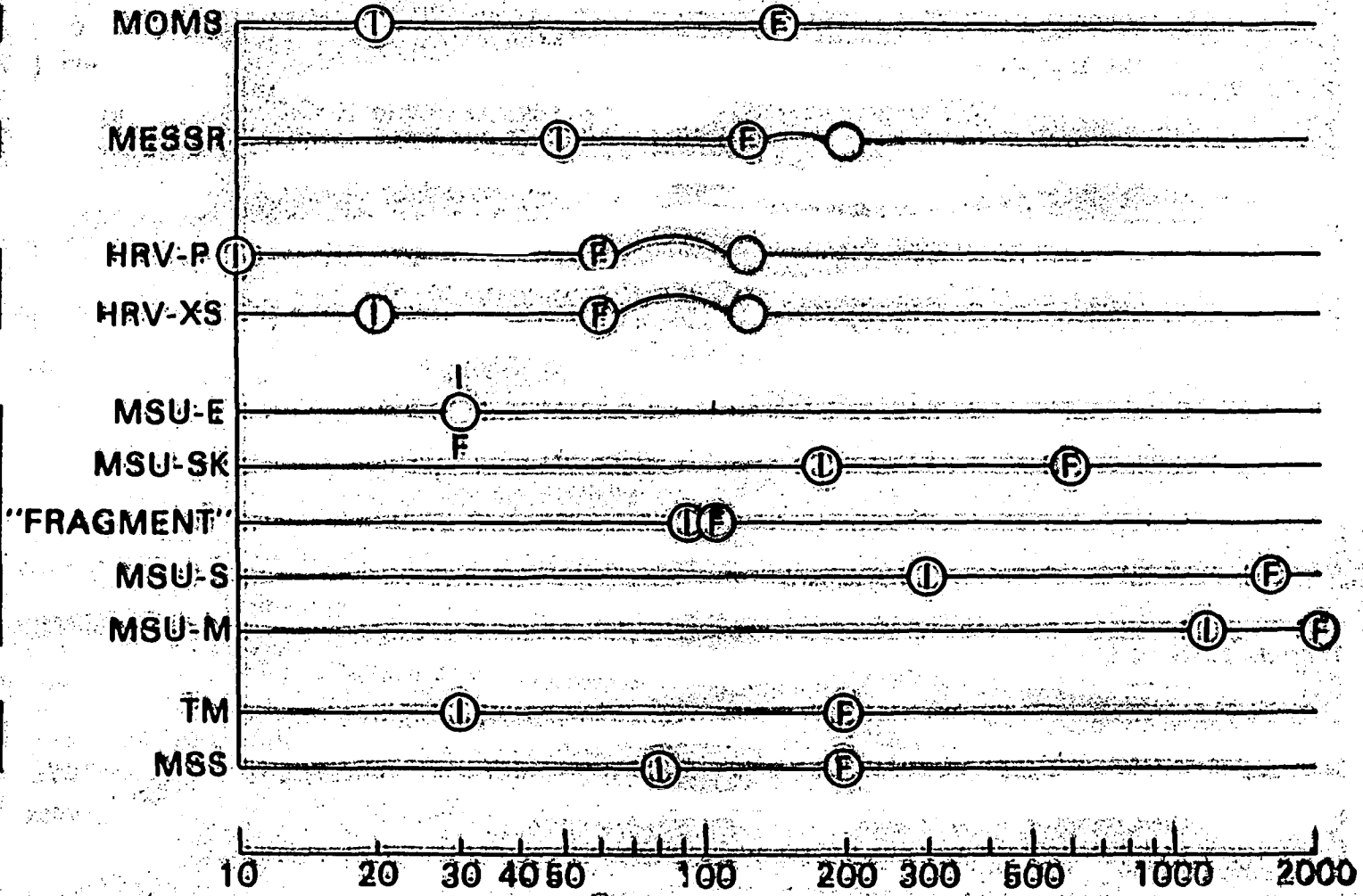
FOREIGN LAND OBSERVING SYSTEMS

<u>NAME/COUNTRY</u>	<u>LAUNCH DATE</u>	<u>GENERAL DESCRIPTION</u>	<u>RESOLUTION (M)</u>	<u>STATUS</u>
SPOT/FRANCE	MAY 1984 (ARIANE)	3 SPECTRAL BANDS & 1 PANCHROMATIC BAND; 60KM SWATH, SIDE-LOOKING STEREO CAPABILITY; 2 TAPE RECORDERS	20 MULTISPECTRAL 10 PANCHROMATIC	ENGINEERING MODEL IN TEST DATA COMMERCIAL- IZATION 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 & 4 MAY ALSO CARRY SAR
MOMS/GERMANY	1982 (SHUTTLE) 1983 (SPACELAB)	2 SPECTRAL BANDS, 140KM SWATH OPTICALLY BUTTED RETICON ARRAYS DIRECT CONTOUR MAPS VIA STEREO VIEWING	20	IN DEVELOPMENT FOR 1982 SHUTTLE AND SPACELAB EXPERIMENT
ERS-1/JAPAN	1987	SAR, VIS/IR SENSOR, EARTH RESOURCES/ GEOLOGICAL OBSER- VATIONS	20-50M ?	MITI/NASDA DEFINITION PHASE
MOS-1/JAPAN	1985 (BELTA/N2) SECOND STAGE	OCEAN COLOR AND TEMPERATURE MONITOR WITH VISIBLE PUSHBROOM SCANNER, THERMAL INFRARED AND MICROWAVE RADIO- METERS, MARINE AND LAND OBSERVATIONS	50	IN DEVELOPMENT
AERS-1/ESA		LAND OBSERVING MLA INSTRUMENT, VISIBLE, NIR & SWIR CAPABILITY, C-BAND SAR		UNDER STUDY



# "RESOLUTION" - (I FOV) AND FIELD OF VIEW OF THE SENSORS

LANDSAT METEOR S/C  
SPOT  
MOS-1  
SPAS-01



Ⓜ = INSTANTANEOUS FIELD OF VIEW - METERS  
 Ⓜ = FIELD OF VIEW - KILLOMETERS

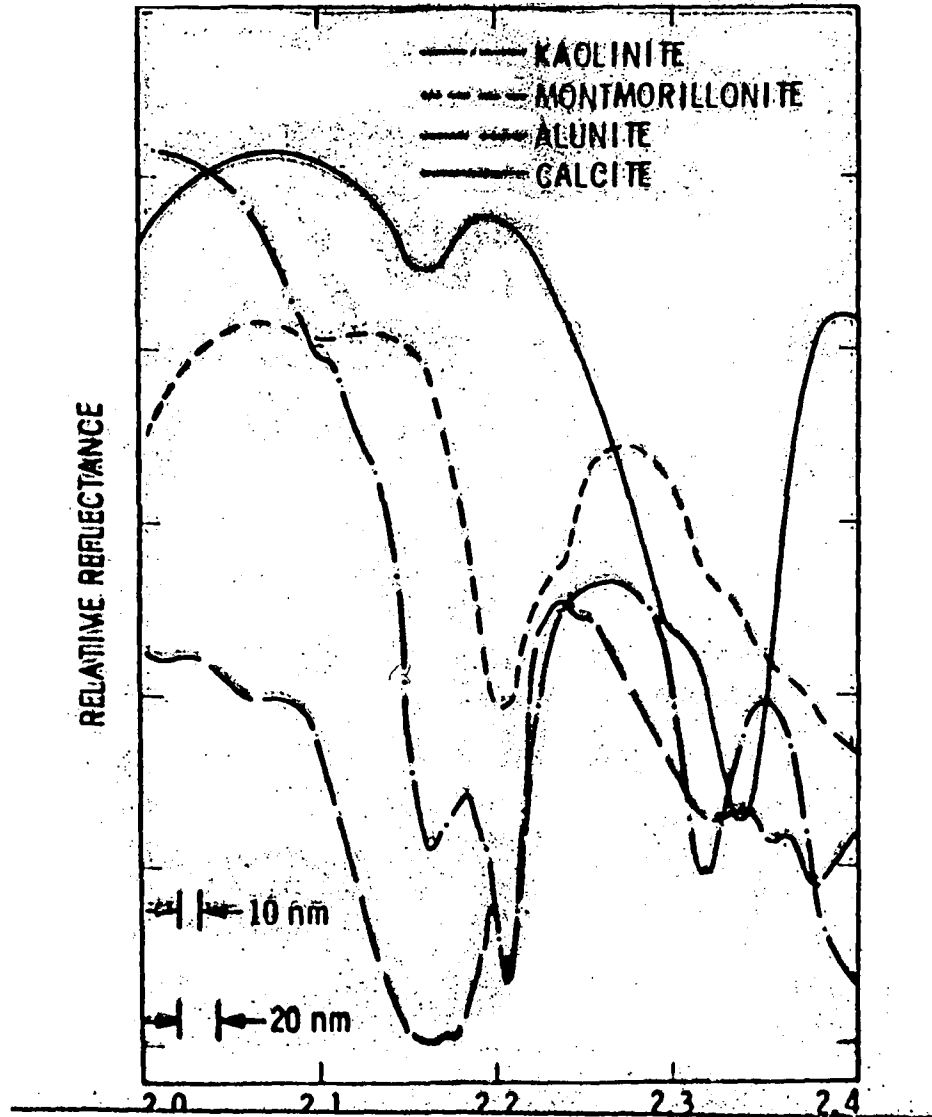
## IMAGING SCIENCE WORKSHOP

### 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





## JPL MLA PROGRAM ELEMENTS

### o 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

### o SHUTTLE/SPACE PLATFORM IMAGING SPECTROMETER (SIS)

- FUNCTIONAL DESIGN OF INSTRUMENT SYSTEM
- STS INTERFACE STUDY INCLUDING POINTING SYSTEM
- EFFECTS OF ORBIT CHARACTERISTICS ON IMAGE GEOMETRY

### o AIRCRAFT EXPERIMENTAL PROGRAM

- DEVELOPMENT OF RESEARCH OBJECTIVES
- INSTRUMENT DEFINITION AND COSTING

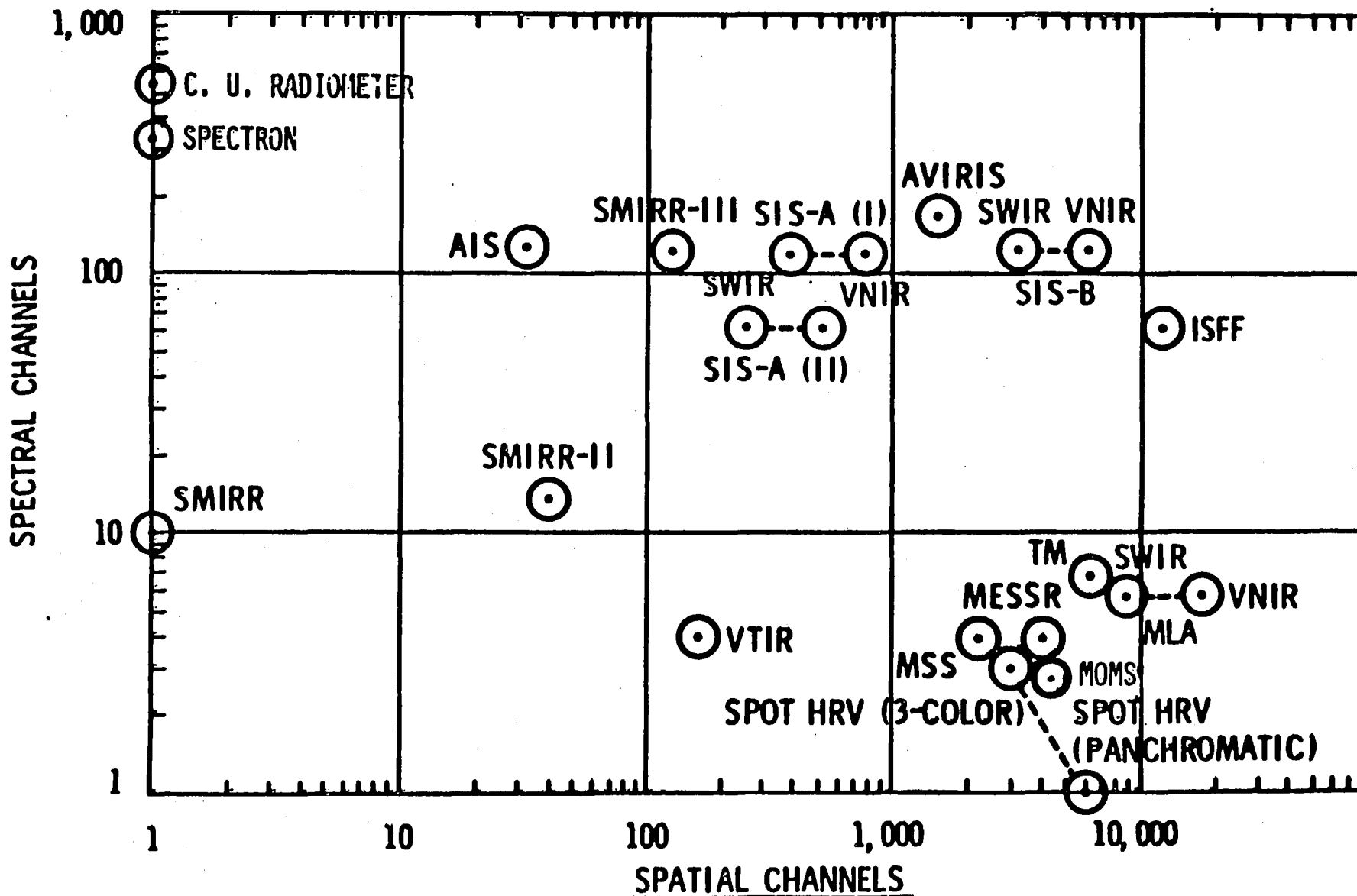
### o IS APPLICATIONS DEVELOPMENT

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

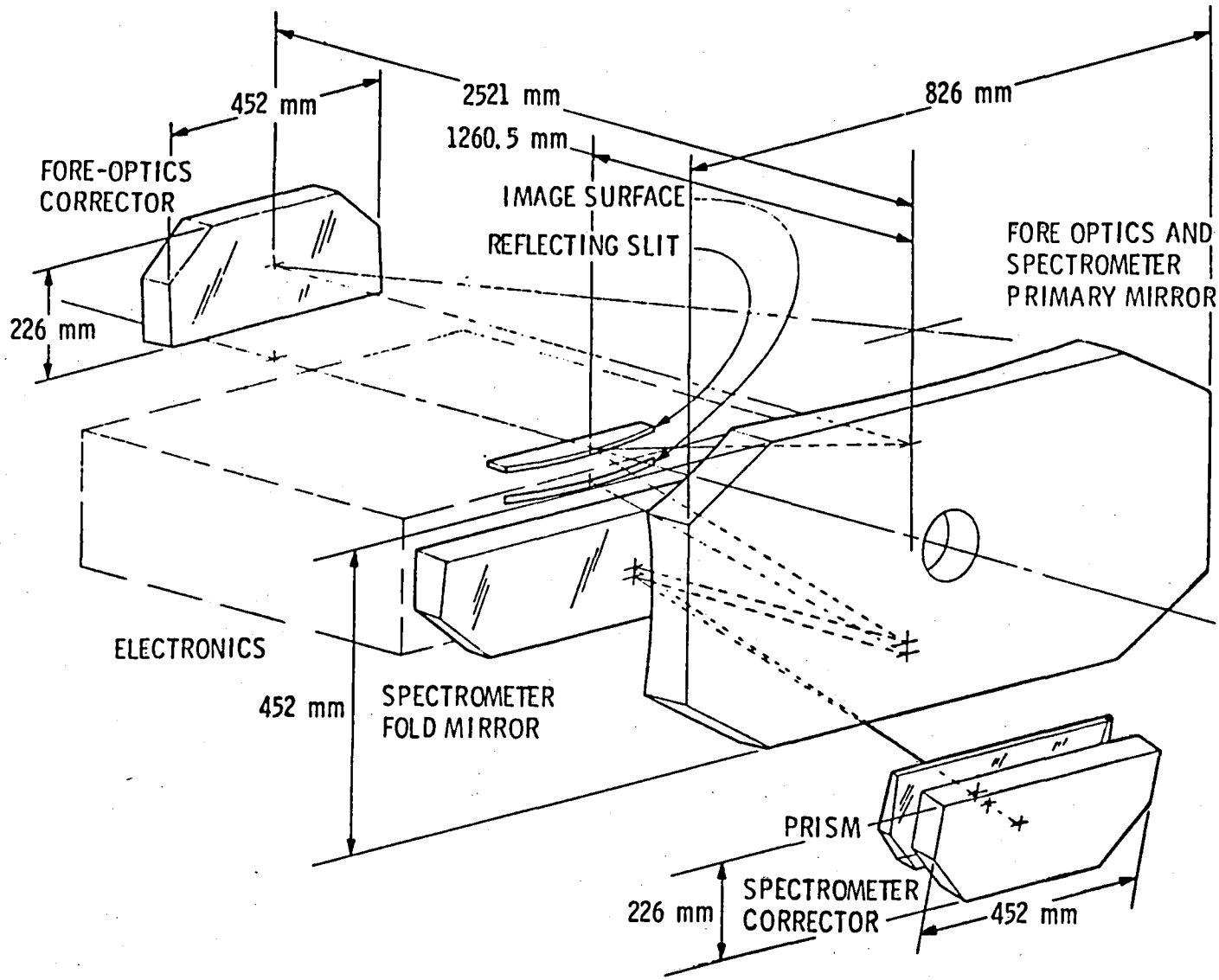
## CONCLUSIONS

- 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 VERSATIVE 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)





# SELF CALIBRATED ABSOLUTE SILICON DETECTOR

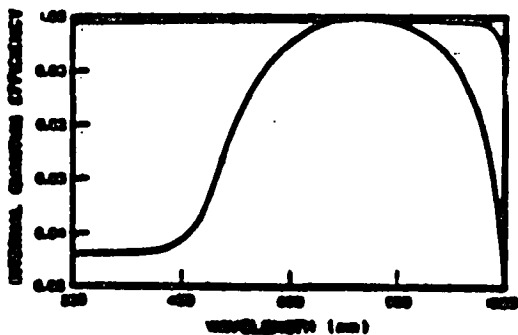


Fig. 1. Typical photodiode internal quantum efficiency without biasing (lower curve) and with biasing (upper curve), reference 9.

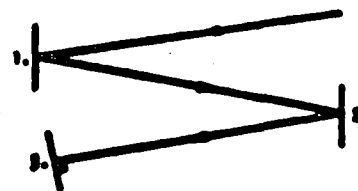


Fig. 2. A three-disk arrangement to minimize specular reflection losses.

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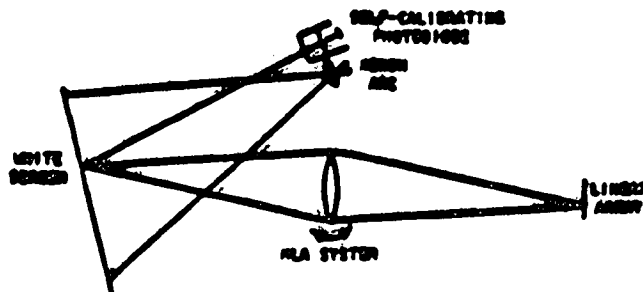


Fig. 4. The factory procedure for absolute spectroradiometric calibration.

## VIS/NIR MULTISPECTRAL CCD DEVELOPMENT

### OBJECTIVE:

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

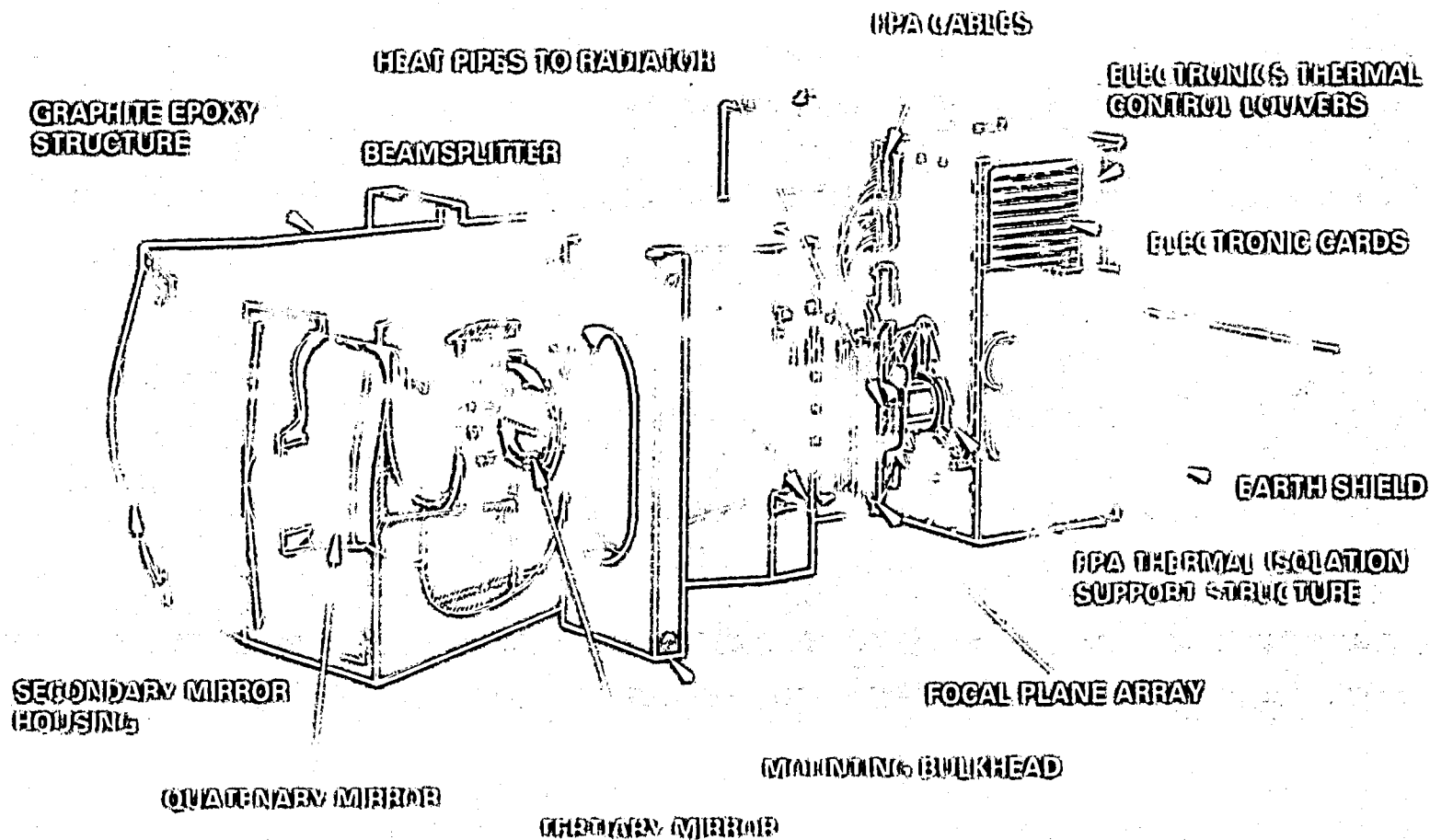
### APPROACH:

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

### STATUS:

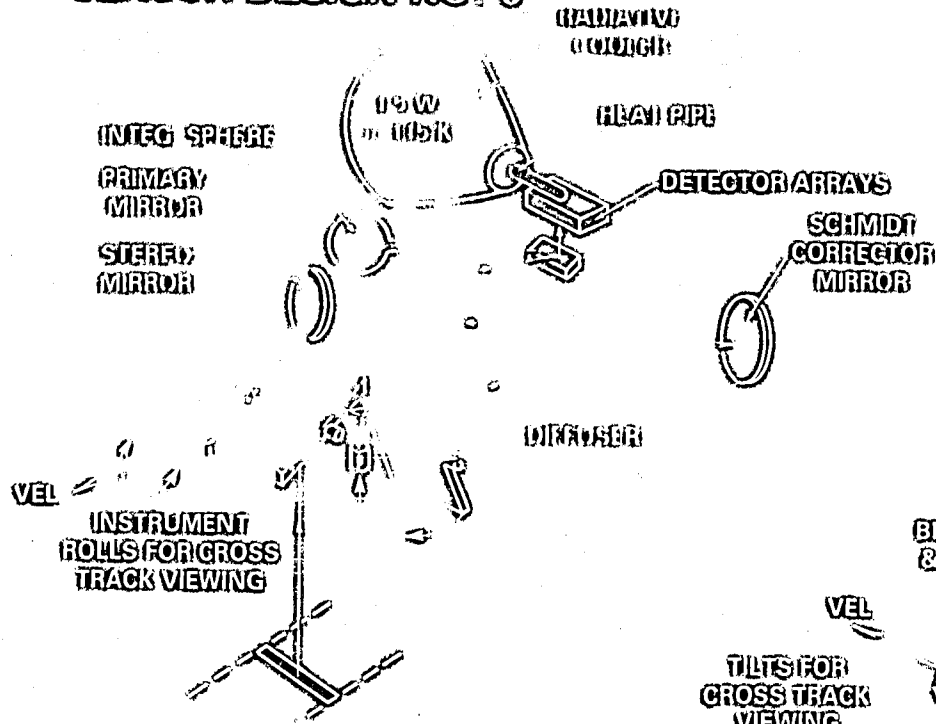
- o PROPOSALS FROM RCA, FAIRCHILD, WESTINGHOUSE AND HUGHES IN EVALUATION.
- o CONTRACTOR SELECTION AND AWARD BY AUGUST 1982.

# MLA INSTRUMENT WITHOUT COVERS AND STEREO MODULE

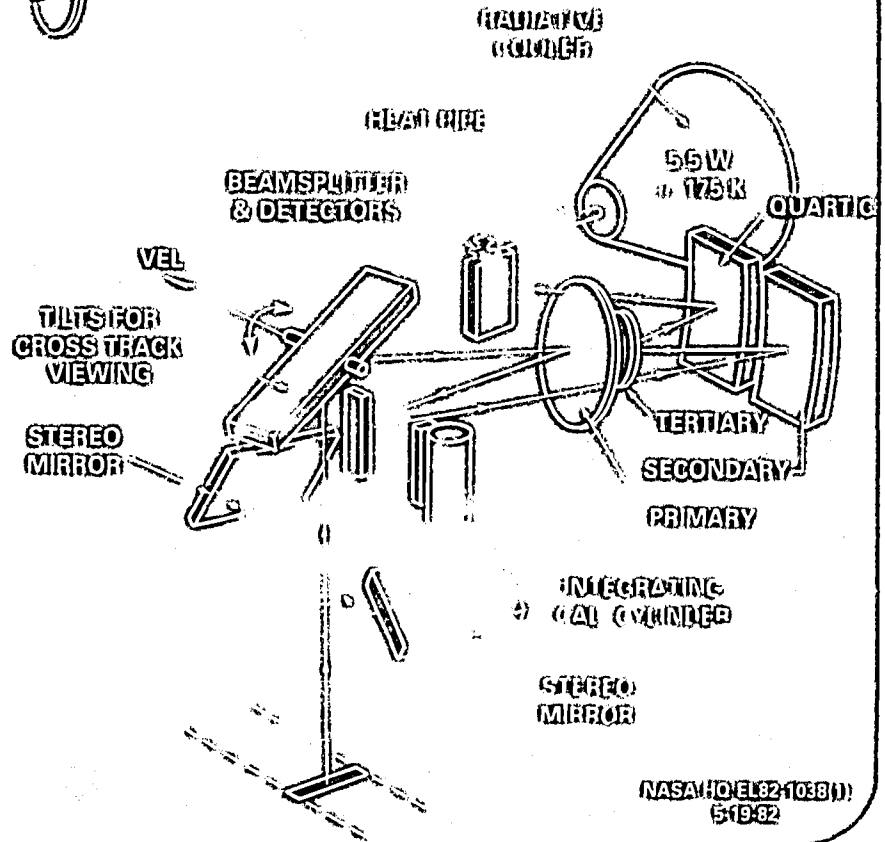


NASA/DOD/EEB (COST) 5192

### SENSOR DESIGN NO. 3

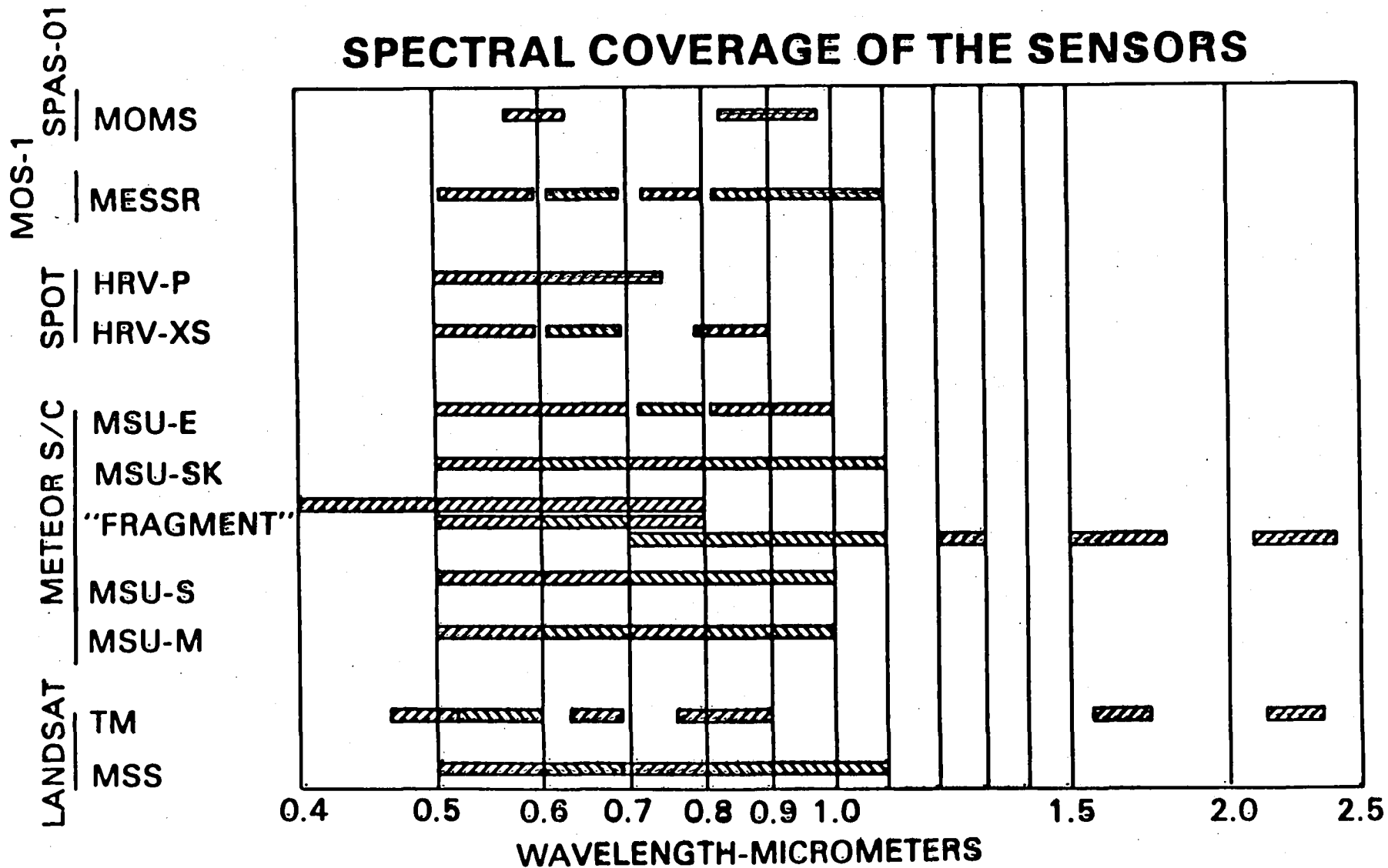


### SENSOR DESIGN NO. 4



NASA/HO/EI/32-1038(1)  
 5-19-82

# SPECTRAL COVERAGE OF THE SENSORS



## 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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**PRINCETON UNIVERSITY**

# SCHEDULE OF PAST AND PROPOSED FLIGHTS

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