

MULTISPECTRAL LINEAR ARRAY (MLA)

SCIENCE AND TECHNOLOGY PROGRAM

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

W. L. BARNES

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ABSTRACT

This document summarizes a Goddard Space Flight Center program of science studies, and research and technology development to provide the basis for future earth observation sensors employing multispectral linear array (MLA) technology.

SCIENCE ACTIVITIES INCLUDE:

1. Science Requirements Study
2. Establishment of MLA Performance Parameters
3. Performance Modeling to Assess MLA Instrument Parameter Recommendations

CRITICAL TECHNOLOGIES BEING DEVELOPED INCLUDE:

1. Short-Wave Infrared (SWIR) Detector Arrays:
 - a. Primary Approach (HgCdTe)
 - b. Alternate Approach (monolithic Schottky barrier)
2. Visible/and Near Infrared Detector Arrays
3. Passive cryogenic coolers

SUPPORTING ACTIVITIES INCLUDE:

1. Test and Field Instrument Development
2. Focal Plane Research and Assessment Laboratory
3. System Simulation Laboratory
4. Calibration Sources and Techniques
5. Optics
6. Thermal Infrared Arrays (TIRA)

INTRODUCTION

This document summarizes a set of science studies, and research and technology developments which will provide the basis for future land observing research mission sensor systems utilizing multispectral linear array (MLA) technology. These sensors will support important research in agriculture, forestry, geology, water resource analysis, urban management, and environmental assessment. MLA technology provides the potential for significant advances in performance beyond the Thematic Mapper. An MLA sensor can provide very high spatial and spectral resolution data, improved mapping, multispectral stereoscopic data, and capability for multi-altitude operations.

An MLA sensor will be developed in the near future for a land observing remote sensing research program. Science studies are being initiated to establish objectives for the land observing research mission and to convert these scientific objectives to a set of required MLA sensor parameters. A technology development program in selected areas is being generated to permit the sensor to be brought to fruition with reasonable technical risk to the mission objectives. Finally, a laboratory and field research program is being conducted to provide a base of expertise at GSFC in the reduction and analysis of MLA sensor data and in the complexities of detector array technology.

This program is managed by the Earth Observation Systems Division of the Goddard Space Flight Center. Major supporting roles are provided by other divisions within the Applications Directorate, by the Engineering Directorate, and the Mission and Data Operations Directorate.

Objectives:

1. Perform studies to provide an improved science basis for earth resource applications of a future MLA type sensor.
2. Develop and demonstrate focal plane array technology for the visible near infrared, shortwave infrared, and thermal infrared spectral regions.
3. Design and fabricate field test instruments, conduct evaluation tests and provide data for scientific assessment.
4. Perform engineering studies in technical areas critical to MLA instrument development.

Justification

An MLA sensor operating in the pushbroom scan mode can meet difficult research requirements. A pushbroom mode sensor provides:

- a. Long dwell times which permit high spatial resolution and radiometric sensitivity.
- b. Fixed detector array and optics geometry which result in improved mapping.
- c. compact optics which allow a pointable field-of-view to conduct atmospheric effects and stereographic experiments.

The key technical advancements that are necessary for a land observing research mission will be addressed by this program.

Approach

Instrument and mission requirements are being defined based on science and engineering studies. Principal technology drivers have been identified, and development activities are being initiated to assure timely availability of critical MLA technology.

An in-house capability is being developed to evaluate sensor concepts, assess advanced detector arrays, conduct field test experiments and provide a calibration capability.

Expected Results:

1. Science and engineering studies, including feasibility and risk assessments, will be provided for use in defining experimental and technological objectives for MLA sensors.
2. Visible, NIR, SWIR and thermal IR focal plane arrays for MLA type sensors will be developed, tested and evaluated.
3. Data from airborne field test instruments will be used to develop and test science algorithms.
4. Studies in other technology areas critical to MLA development will assess the state-of-the-art, identify required technology developments, and provide potential design solutions. These studies will include:
 - a. passive cryogenic coolers.
 - b. wide-field-of-view, broad spectral range optics.
 - c. narrow-band stripe interference filters deposited on silicon detector arrays.
 - d. dichroic beam splitting techniques.
 - e. calibration techniques.

A Focal Plane Research and Assessment Laboratory as well as a System Simulation Laboratory will be completed. Advanced detector arrays will be evaluated and end-to-end hardware/software MLA instrument simulations will be conducted

1.0 SCIENCE ACTIVITIES

Science support for the MLA development program is focused on three areas:

- (a) further the basic science of remote sensing,
- (b) establish the initial scientific basis for selection of performance parameters for a land observing research mission, and
- (c) establish relationships and trade offs between experimental sensor/system/mission alternatives.

1.1 SCIENCE REQUIREMENTS

The design of an optimum land observing research mission requires a thorough understanding of the current state-of-the-art in remote sensing, and of the additional capabilities offered by available new and developing techniques (e.g., MLA). A thorough review of available documentation and associated R&D activities is therefore being performed to provide a basis for the mission design.

A Multispectral Imaging Science Working Group has been established, with representation from NASA centers, other federal agencies, universities and not-for-profit industry. This working group will provide in-depth review and analysis of current remote sensing techniques. Potential future research and experimental approaches for the detection, identification, and measurement of renewable and nonrenewable resources will be examined using new technologies as required. These efforts will be directed toward definition and prioritization of experimental objectives for the proposed land observing research mission.

1.2 PERFORMANCE PARAMETERS

The short term science goal is the establishment of the scientific justification for a land observing research mission payload. Initial efforts have concentrated on identifying instrument parameters, and performing critical research activities where definitive parameter selection is not yet supportable. This research will build on present knowledge and will include field experiments as appropriate. The schedule of this activity will be coordinated with the mission schedule and will provide the latter with the necessary inputs. Major instrument parameters being considered are:

- SPECTRAL:** Band location and width, spectral band information content and redundancy.
- SPATIAL:** Instantaneous field-of-view (IFOV), sampling rate, registration, textural information, mixed resolution utility.
- TEMPORAL:** Revisit frequency, illumination conditions, global coverage.
- RADIOMETRIC:** Calibration, atmospheric correction, adjacency effects, quantization, polarization.
- OFF-NADIR:** Bi-directional reflectance, atmospheric correction, ground resolution and registration, height resolution, and base-to-height ratio (stereo)

The interrelationships and tradeoffs between these parameters are also being studied.

1.3 PERFORMANCE MODELLING

Preliminary identification of the performance parameters will allow work to start on the definition of parameter extraction algorithms. These algorithms will form the basis for performance modelling and simulation. The work will begin on existing image analysis/geographic information facilities while other alternatives, for instance, the Landsat Assessment System, will be examined for suitability for use in the future. Integration of target emission/reflectance models, atmospheric path models, sensor/system/mission performance parameters, accuracy and position requirements, classification techniques, and test data bases will allow trade-off analyses to be conducted using the experimental objectives and the payload and mission alternatives. Results will be used to define further research activities and field experiments. Performance modeling will allow verification of the initial instrument/payload parameters and the refinement of the system and mission capabilities. This activity will be coupled with that of the System Simulation Laboratory in the Engineering Directorate, to provide an overall sensor/science/requirements modeling capability in support of the land observing research mission. It is anticipated that the land observing research mission will be a very flexible/versatile tool for numerous remote sensing applications. These simulation activities will hence eventually provide the capability for assessing the feasibility of new experiments prior to the implementation on future missions.

2.0 TECHNOLOGY DEVELOPMENT

Emphasis is being placed in two areas: (1) high priority development of technologies critical to MLA sensor development; and (2) engineering studies and hardware development in related important technical areas.

2.1 CRITICAL TECHNOLOGIES

2.1.1 SWIR Focal Plane (1.0-2.4 micrometers)

The preferred configuration consists of photovoltaic HgCdTe detector arrays coupled to a silicon multiplexer. Key Parameters:

- (1) Spectral region 1.0-2.4 μm ;
- (2) pitch-30 micrometer;
- (3) number of detectors - 6200;
- (4) temperature - 130K (nominal);
- (5) sensitivity - $NE_{\rho} = 0.5\%$ (for scene reflectivity of 50%)

Items to be developed: Detector material, module (100 to 500 detectors), 5 module Test Assembly and a 6200 element Focal Plane Assembly. Proposals have been submitted to GSFC.

Two contractors will be chosen to conduct parallel 42-month development efforts. Anticipated starting time is early CY 1983.

The programs will involve two phases and will include the following: Phase I --Study followed by material, module and Test Assembly development. The Test Assembly will incorporate five modules. Phase 2 - a fully populated Focal Plane Assembly of 6200 detectors will be developed.

The modules, Test Assembly, and Focal Plane Assembly will also be delivered to GSFC for in-house test and evaluation

2.1.2 Alternate SWIR Array (1.0-2.4 μm)

Because of the importance of the SWIR spectral bands to a future MLA sensor, an alternate array technique will also be developed. Proposals have been submitted to GSFC to develop a monolithic PdSi Schottky barrier diode array. Key parameters are the same as stated in 2.1.1, except that the nominal operating temperature is 110K and the 6200 element Focal Plane Assembly will not be provided.

The proposed 24-month program will design, develop, test, and evaluate monolithic Schottky barrier SWIR chips and a 5-module Test Assembly

2.1.3 VIS/NIR Array (0.4-1.0 μm)

Although VIS/NIR arrays are not considered a technological problem for the MLA, there are very few off-the-shelf devices to choose from, and

those that are available have not been optimized to meet MLA requirements. The purpose of this activity is to develop a VIS/NIR integrated silicon circuit (chip) optimized for an MLA sensor. The chip would be available in time for incorporation into an MLA sensor. Proposals have been received and are being evaluated.

The proposed 24-month program is to design, develop, test and evaluate a VIS/NIR chip with 4 parallel arrays each having an interference filter in close proximity and a 5-chip Evaluation Focal Plane.

2.1.4 Passive Cryogenic Cooler Study

The SWIR detectors will require cooling in the 110 to 190K temperature range, with thermal loads on the order of 1.0 watt. A passive cooler of this capacity is substantially larger than those NASA has flown to date. The potential development risks and problems associated with such a cooler need are being addressed in a detailed study. The study is a 9-month effort to size a passive cooler for an MLA sensor and to fabricate a breadboard heat transfer device.

3.0 SUPPORTING ACTIVITIES

3.1 TEST/FIELD INSTRUMENT DEVELOPMENT

In order to assess technology capability, evaluate radiometric properties and examine calibration and information extraction techniques, pushbroom type airborne sensors will be developed and flown. The first of the GSFC radiometers was flown in CY1979. Sensors near completion include an advanced visible sensor and a short wave infrared sensor. Sensors planned for the FY1983 through FY1985 time period will utilize area SWIR and VIS/NIR arrays in an imaging spectrometer mode to provide multispectral data for algorithm development. The main effort will be to develop an airborne MLA Experiment Simulator. Sensor definition is underway. The aircraft sensors are built in-house. These include:

- (a) LAPR-I (3 VIS/NIR channels);
- (b) LAPR-II (4 VIS/NIR bands with selectable spectral channels);
- (c) SWIR/LAPR (1 band, 1 - 3 micrometers);
- (d) MLA Experiment Simulator.

Laboratory instrument developments include both SWIR and TIR pushbroom array sensors. The laboratory instruments include the following:

1. 9-element HgCdTe array, TIR imager (10 - 12 micrometers)
2. 90-element HgCdTe array, TIR imager
3. 64-element PbS, SWIR imager

Each of the laboratory sensors is complete. They are being used in several in-house studies.

3.2 FOCAL PLANE RESEARCH AND ASSESSMENT LABORATORY

The purpose of this laboratory is to perform science and engineering studies to validate characteristics of detectors and detector arrays, post-amplifiers, multiplexers, etc. during the device research and development phase, and to evaluate modules and arrays operating in the visible, NIR, SWIR, and TIR spectral regions.

Emphasis will be placed on achieving accurate measurements of detector radiometric properties, stability, sensitivity, spectral and temporal response. This laboratory is required to provide an independent assessment of MLA detector performance.

3.3 SYSTEM SIMULATION LABORATORY

The purpose of this laboratory is to perform end-to-end hardware/software simulations to support MLA flight and/or ground system trade-off, optimization and evaluation studies. The simulation activity will concentrate on the electro-optical signal processing chain and will provide a capability for technology development, assessment, and evaluation of critical subsystem elements in a "system" environment. The MLA focal planes and optical breadboards as well as signal processing breadboards developed in the technology program will be utilized in the simulations. This laboratory will: provide MLA "hands-on" experience; provide capability for independent testing, assessment and validation of instruments and subsystems; lead to realistic instrument specifications; and lead to improved techniques for synthesizing and evaluating focal plane assemblies, signal processing electronics, wide field of view optics, spectral separation concepts, and high data rate information handling systems.

3.4 CALIBRATION SOURCES AND TECHNIQUES

The MLA requirement for high radiometric accuracy (+5% absolute and +1% relative between spectral bands) requires frequent on-orbit calibration of detectors using sources of high stability. High quality sources for ground calibration traceable to NBS are also required. GSFC has traditionally provided ground sources to calibrate earth viewing sensors, and this capability is being extended to support the MLA requirements.

3.5 OPTICS

A requirement generated by the need for MLA type sensors is for wide field collecting optics (up to 15° FOV) that are achromatic over the spectral region from 0.4 to 2.5 micrometers. An in-house capability to design and analyze complex optical systems has been developed over several years and a variety of sophisticated computer programs are available (ACCOS-V, GENOPTICS, CODE V). These are being used to examine potential

optical systems for MLA sensors. Extensive work has already been done which indicates that an all reflective Swarzschild is one desirable candidate. However, other optical forms need to be examined and optimization studies performed. A breadboard optical system of one or more of these designs will be fabricated and tested.

Another key technology item in the optics area is the problem of spectral band selection. Techniques such as dichroic beam splitting, use of narrow stripe interference filters deposited directly on the linear arrays are also being addressed.

3.6 THERMAL INFRARED ARRAYS (TIRA)

Thermal Infrared Arrays will be required for research in resource applications such as geology and/or hydrology.

A program has been underway for several years to develop Thermal Infrared Array (TIRA) technology. The major thrust has been directed towards hybrid HgCdTe structures. Up to this time, 9 element and 90 element photoconductive array imagers have been fabricated and successfully tested.

The present thrust of the program is the development of a hybrid photovoltaic HgCdTe module capable of being assembled into large linear arrays.

A program is underway to develop the photovoltaic HgCdTe module with the Honeywell Electro-Optics Center. The study phase of the program has been completed and the fabrication phase is underway.

MULTISPECTRAL LINEAR ARRAYS FOR TERRESTRIAL REMOTE SENSING 677-27-01

OBJECTIVES:

- DEMONSTRATE REQUIRED MLA FOCAL PLANE TECHNOLOGY FOR RESOURCE OBSERVATIONS
- DEVELOP A SCIENTIFIC BASIS FOR SYSTEM PERFORMANCE CRITERIA.
- DEVELOP CRITICAL ASSOCIATED TECHNOLOGIES.



MLA SCIENCE PROGRAM

OBJECTIVE:

TO PROVIDE A SCIENTIFIC BASIS FOR THE SELECTION OF MLA SENSOR, SYSTEM AND MISSION PARAMETERS FOR FUTURE SATELLITE-BASED LAND REMOTE SENSING

APPROACH:

IN-HOUSE STUDIES AND FIELD EXPERIMENTS UTILIZING SUPPORT CONTRACTORS TO EXAMINE:

- SPATIAL PARAMETERS: IFOV, MIXED RESOLUTION, TEXTURE
- SPECTRAL PARAMETERS: LOCATION, WIDTH, SHAPE, SELECTION
- ATMOSPHERIC CORRECTION: ATTENUATION, PATH RADIANCE, ADJACENCY
- OFF-NADIR PARAMETERS: BI-DIRECTIONAL, REFLECTANCE, STEREO
- OTHER ISSUES: CALIBRATION, REGISTRATION

STATUS:

ALL ACTIVITIES UNDERWAY

PRELIMINARY RESULTS AVAILABLE FROM SPATIAL, SPECTRAL, OFF-NADIR



HYBRID SWIR TECHNOLOGY DEVELOPMENT

OBJECTIVE:

TO DEVELOP AND DEMONSTRATE A SWIR FOCAL PLANE DETECTOR/
MULTIPLEXER ARRAY.

APPROACH:

- TWO PARALLEL 42-MONTH CONTRACTS TO DEVELOP A HYBRID HgCdTe DEVICE.
- PHASE I—DEVELOP 256-ELEMENT MODULE AND 5-MODULE TEST ASSEMBLY.
- PHASE II—DESIGN, FABRICATE AND TEST 6200-ELEMENT FOCAL PLANE ASSEMBLY.

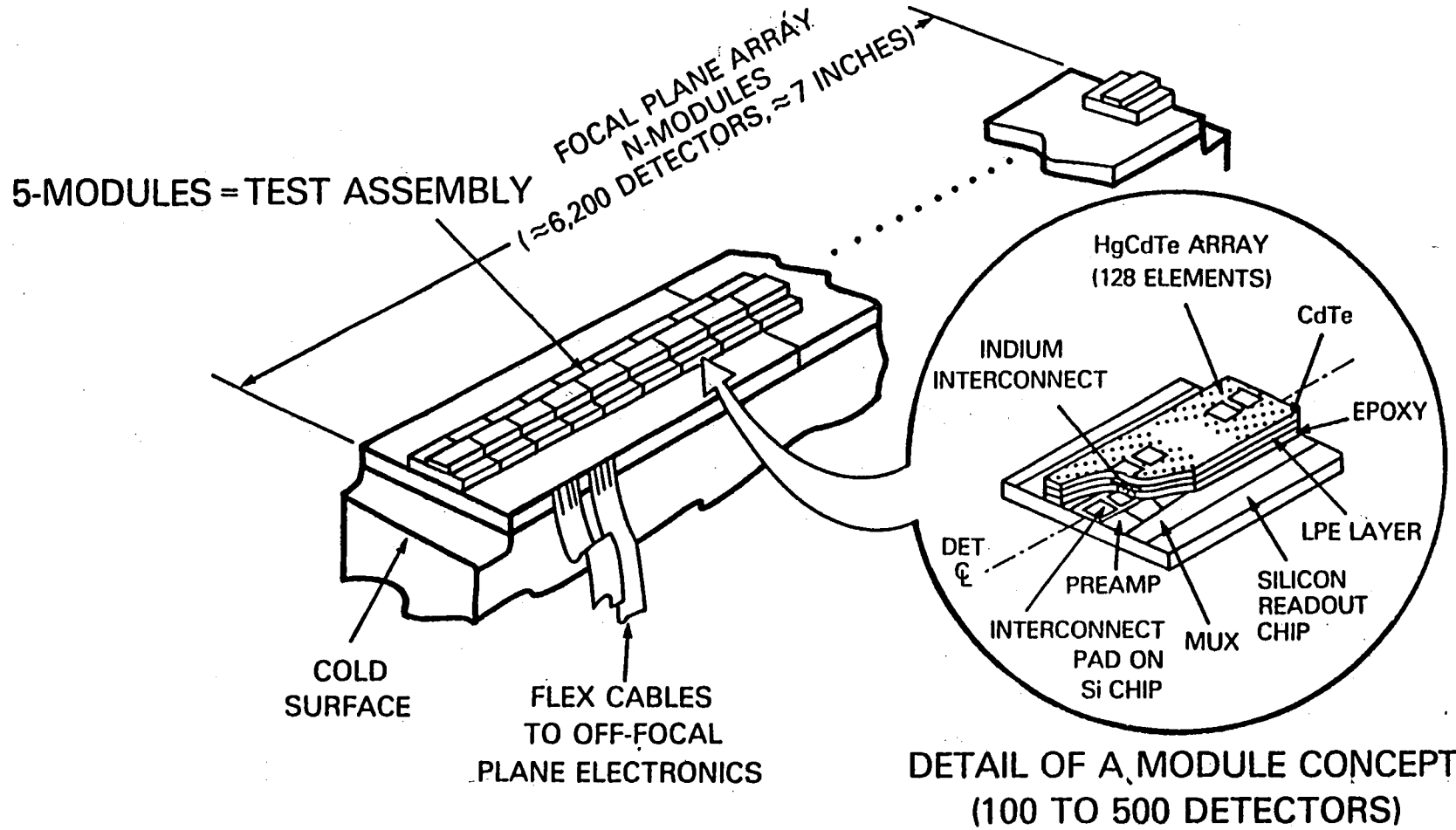
STATUS:

- PROCUREMENT PACKAGE COMPLETE.
- RFP RELEASE 2/82.
- CONTRACTS 1/83.



A CONCEPT HYBRID SWIR ARRAY

66



SWIR FPA

KEY CHARACTERISTICS

- SPECTRAL REGION 1.1 TO 2.4 μM
 - BANDS 1.2, 1.6, 2.2 μM , <10% BW
 - DETECTOR SIZE 30 μM PITCH
 - ARRAY \approx 6200 DETECTORS
 - BLEMISHES LESS THAN 1%, INCLUDING BUTTS
 - SIGNAL-TO-NOISE 100 P-P/RMS AT WORKING LEVEL IRRAD
 - STABLE LESS THAN 1% DRIFT IN 25 SEC
 - UNIFORM LESS THAN 10% STANDARD DEVIATION
 - MULTIPLEXING FIRST LEVEL ON FOCAL PLANE
 - OPERATING TEMPERATURE 130K OR WARMER
 - HEAT LOAD 40 μW PER DETECTOR
-
- RELIABLE
 - TESTABLE
 - REPAIRABLE
 - AFFORDABLE
 - TIMELY



MONOLITHIC SWIR TECHNOLOGY DEVELOPMENT

OBJECTIVE:

TO DEVELOP AND DEMONSTRATE A MONOLITHIC SCHOTTKY BARRIER
DETECTOR/MULTIPLEXER MODULE AS A BACK-UP TO THE HgCdTe
DEVELOPMENT.

APPROACH:

- 24-MONTH CONTRACT TO DEVELOP AND TEST PdSi/Si MONOLITHIC
DEVICE.
- DEVELOP MODULES AND 5-MODULE TEST ASSEMBLY.

STATUS:

- RFP RELEASE..... 11/81.
- PROPOSALS DUE..... 2/2/82.
- CONTRACT AWARD..... 7/82.



VIS/NIR DETECTOR ARRAYS

OBJECTIVE:

DEVELOP A VIS/NIR DETECTOR ARRAY DEVICE THAT WILL SERVE AS THE BASIC UNIT FOR A MLA FOCAL PLANE.

APPROACH:

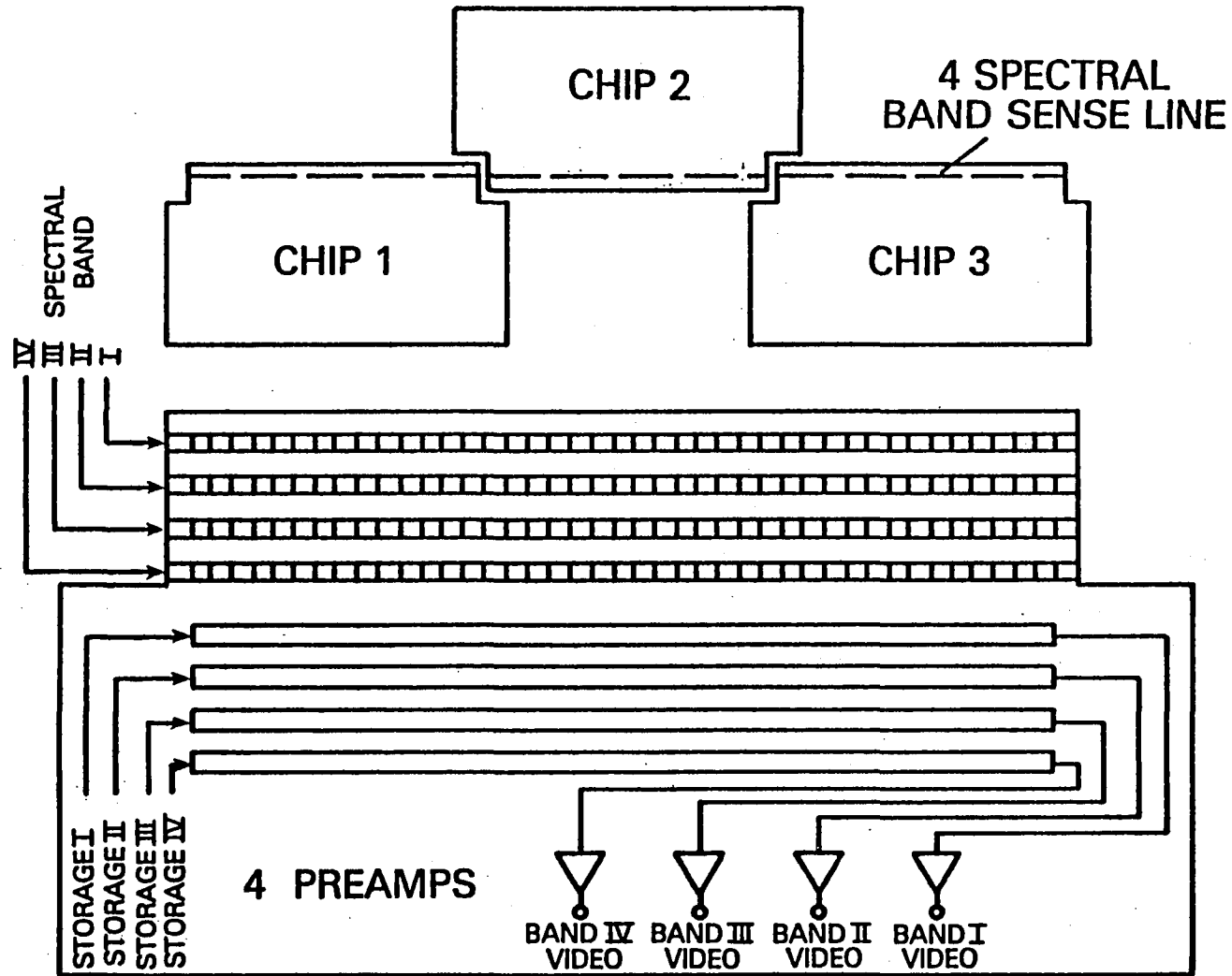
- 24-MONTH CONTRACT TO DEVELOP A SILICON DETECTOR ARRAY DEVICE.
- EACH CHIP—FOUR 1024-ELEMENT DETECTOR ARRAYS, FOUR SPECTRAL FILTERS AND ASSOCIATED ELECTRONICS.
- DEMONSTRATE BUTTABILITY.

STATUS:

- PROPOSALS DUE 2/8/81
- CONTRACT AWARD 7/82

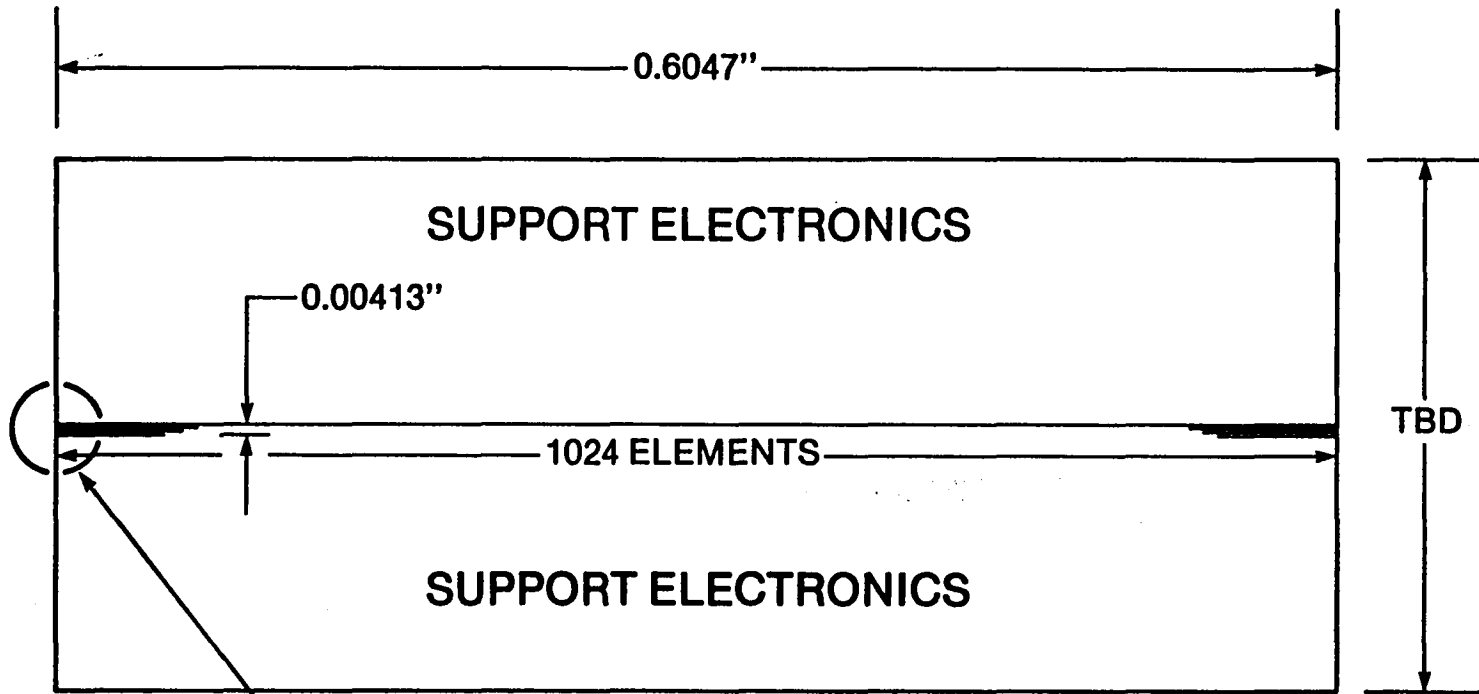


CONCEPTUAL VIS/NIR DETECTOR ARRAY



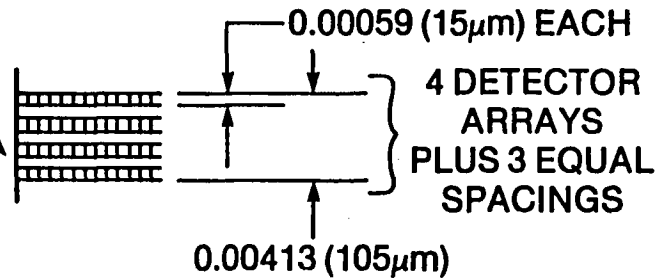
4 SPECTRAL BANDS PER CHIP WITH SPECTRAL FILTERS
 1024 ELEMENTS PER BAND (NOMINAL)
 DETECTOR SPACING 15 μm
 < 2 MISSING ELEMENTS/BUTT JOINT

VIS/NIR DEVICE LAYOUT



103

DEVICE:
 1024 DETECTOR
 ELEMENTS/ARRAY
 4 ARRAYS/DEVICE
 4096 ELEMENTS/DEVICE



FOCAL PLANE:
 12 DEVICES LONG (7.256")
 12,288 ELEMENTS/ARRAY
 49,152 ELEMENTS/
 FOCAL PLANE

OPTICS DESIGN AND FABRICATION

OBJECTIVE:

DESIGN, FABRICATE AND TEST CRITICAL OPTICAL COMPONENTS REQUIRED FOR MLA SENSOR.

APPROACH:

- NINE-MONTH \$100K STRIPE FILTER DEVELOPMENT AND EVALUATION.
- FOUR-MONTH \$45K STUDY OF MLA DICHROIC BEAM-SPLITTERS.
- IN-HOUSE ASSESSMENT OF IDS OPTICAL SYSTEM DESIGNS AND DEVELOPMENT OF GSFC DESIGN.

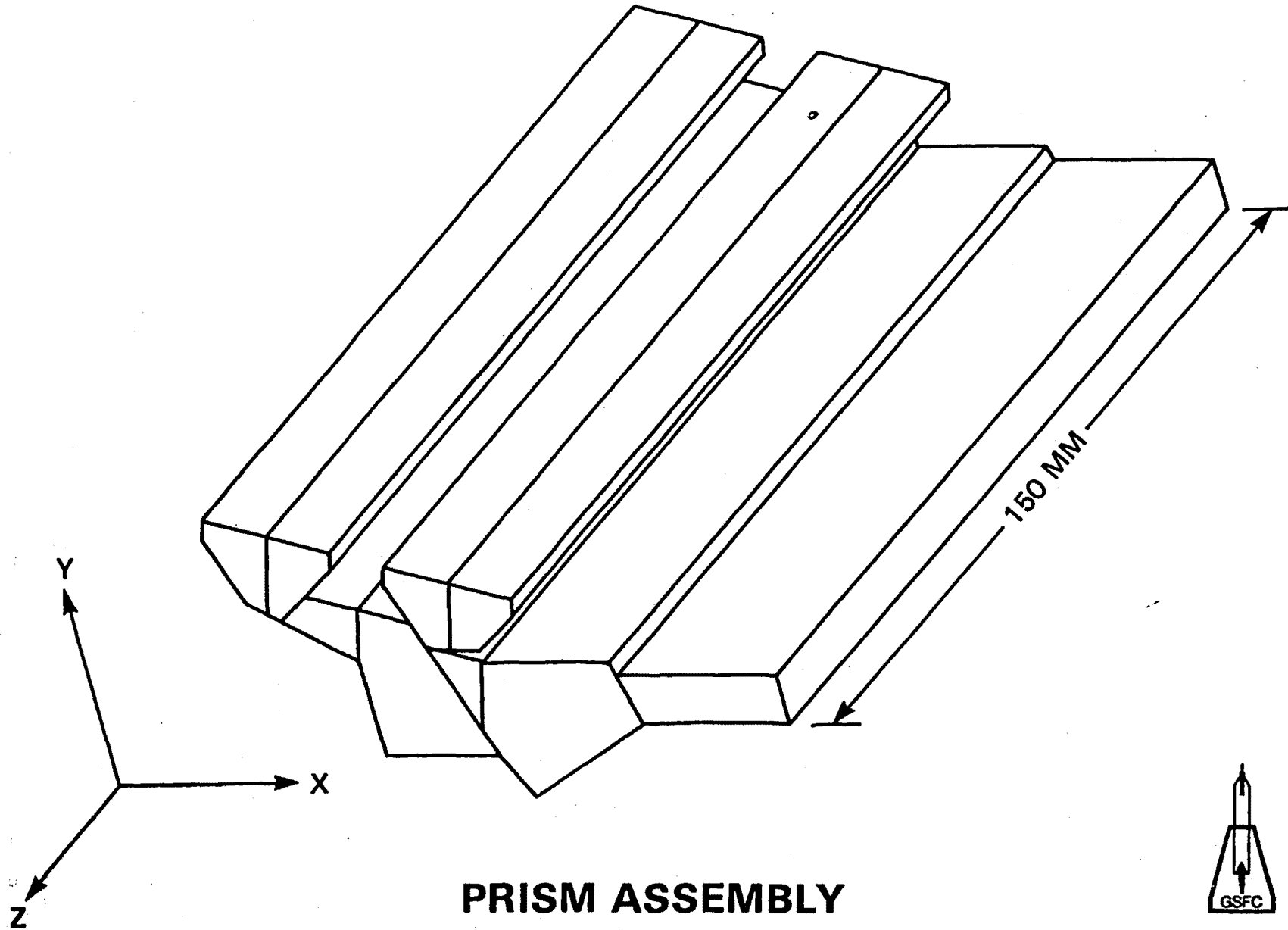
STATUS:

- STRIPE FILTER CONTRACT/WESTINGHOUSE COMPLETE 2/82
- DICHROIC FILTER STUDY/PERKIN-ELMER COMPLETE 9/81



MLA BEAMSPLITTER DESIGN STUDY

106

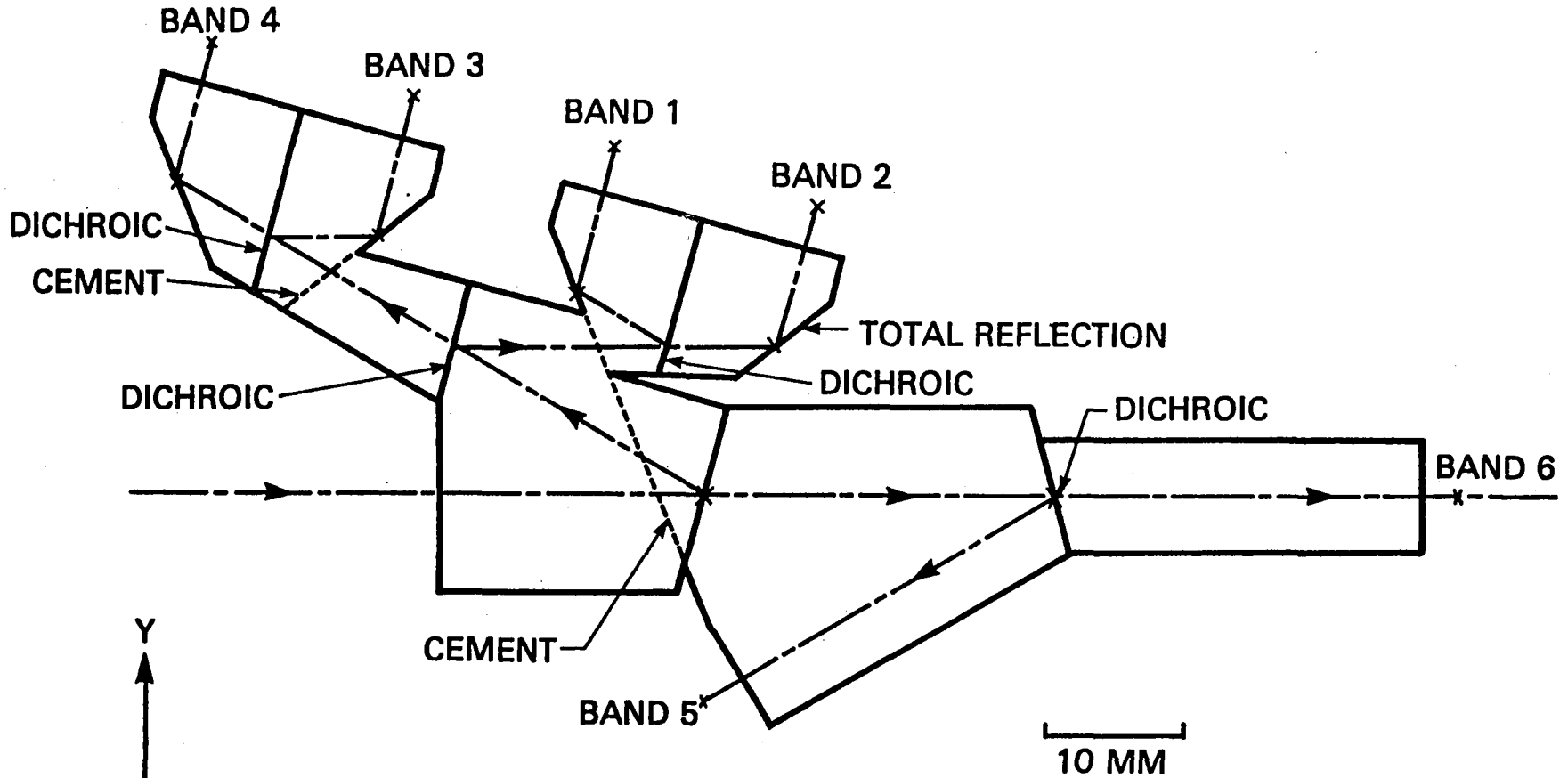


PRISM ASSEMBLY



MLA BEAMSPLITTER DESIGN STUDY

107



**PRISM ASSEMBLY
CROSS SECTION**



PASSIVE COOLER DESIGN

OBJECTIVE:

DEVELOP A DETAILED DESIGN FOR A PASSIVE RADIATIVE COOLER THAT WILL FULFILL THE REQUIREMENTS GENERATED BY A MLA SENSOR.

APPROACH:

\$100K CONTRACT FOR RADIATIVE COOLER DESIGN TO MEET IDS REQUIREMENTS

REQUIREMENTS:

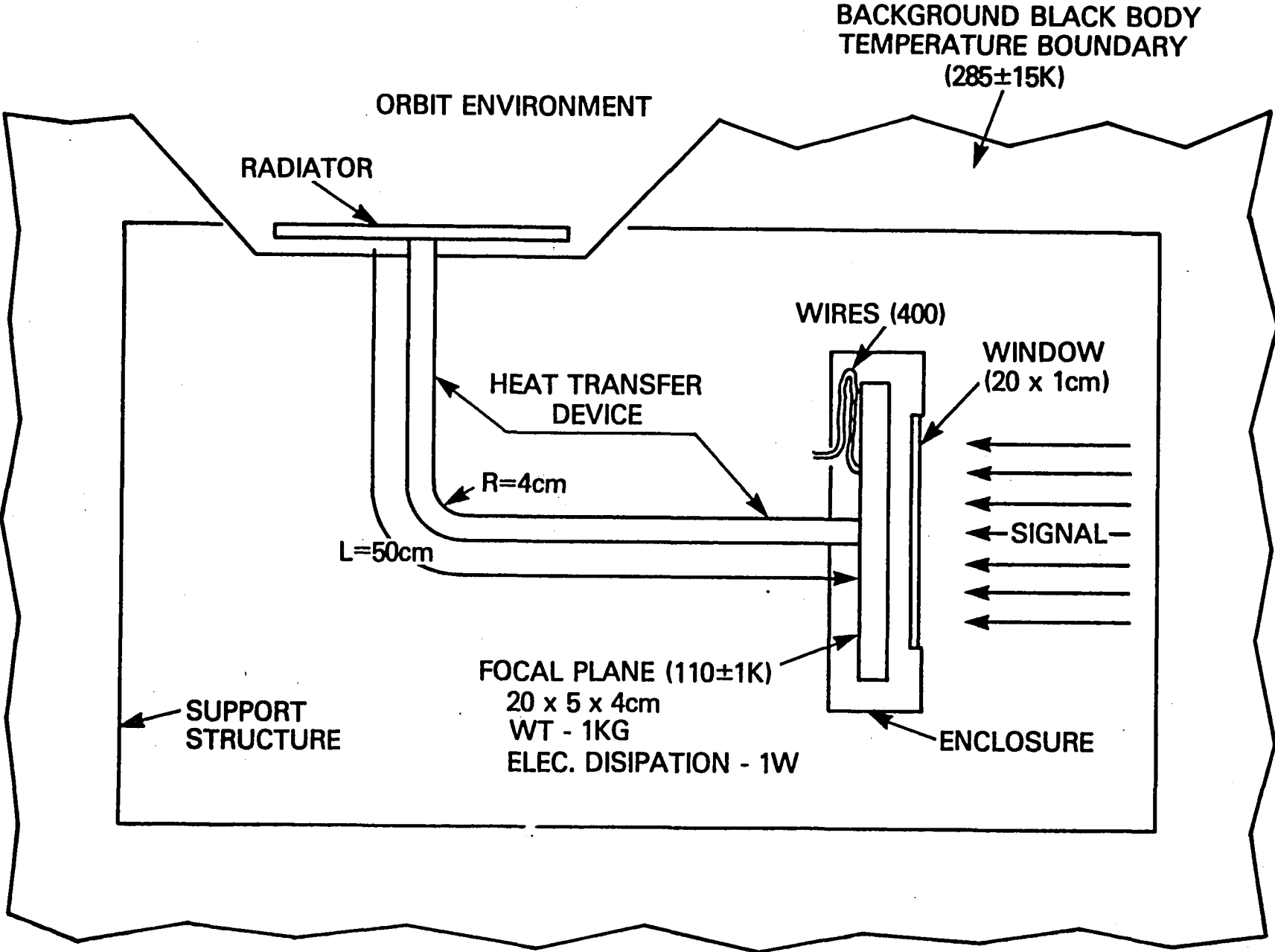
1W ELECTRICAL DISSIPATION AT 125K.
400 SIGNAL LEADS.
50 CM HEAT TRANSFER DEVICE.

STATUS:

RFP RELEASE 11/81.
CONTRACT START 1/82.



MLA COOLER STUDY



SENSOR SYSTEM SIMULATION

OBJECTIVE: EVALUATE MLA FLIGHT AND/OR GROUND SYSTEM TRADE-OFFS VIA AN END-TO-END HARDWARE/SOFTWARE SYSTEM SIMULATOR.

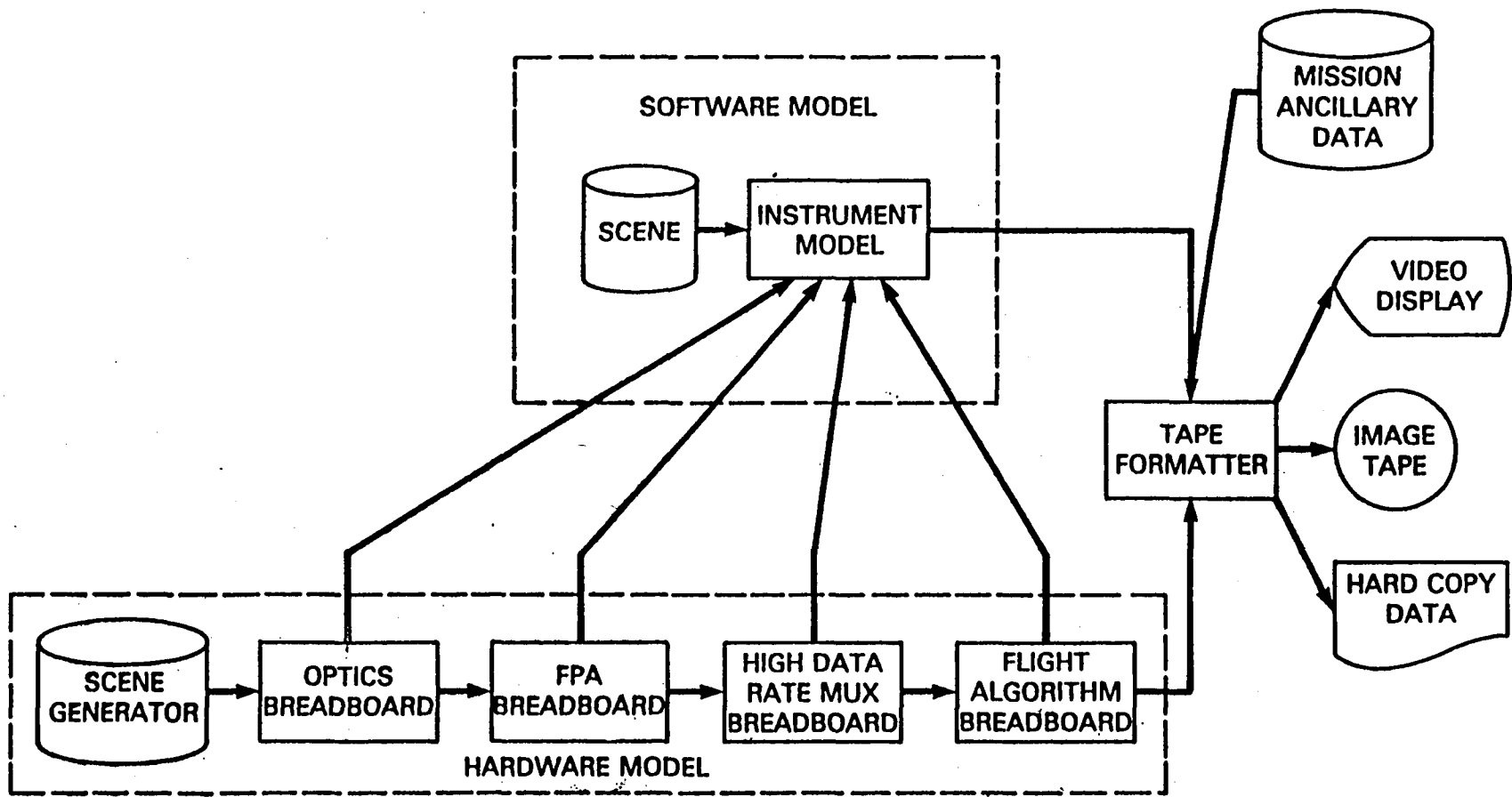
APPROACH: COMBINE OUTPUTS FROM BREADBOARD HARDWARE AND SOFTWARE SYSTEM SIMULATOR.

STATUS: NEW TASK START FY82

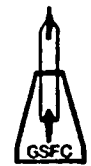


SENSOR SYSTEM SIMULATION

111



MLA END-TO-END INSTRUMENT MODEL



ASSESSMENT AND CALIBRATION LABORATORY

OBJECTIVE:

CHARACTERIZATION OF THE RADIOMETRIC, SPECTRAL AND ELECTRONIC RESPONSE OF DETECTOR ARRAY MODULES AND FOCAL PLANE ASSEMBLIES

APPROACH:

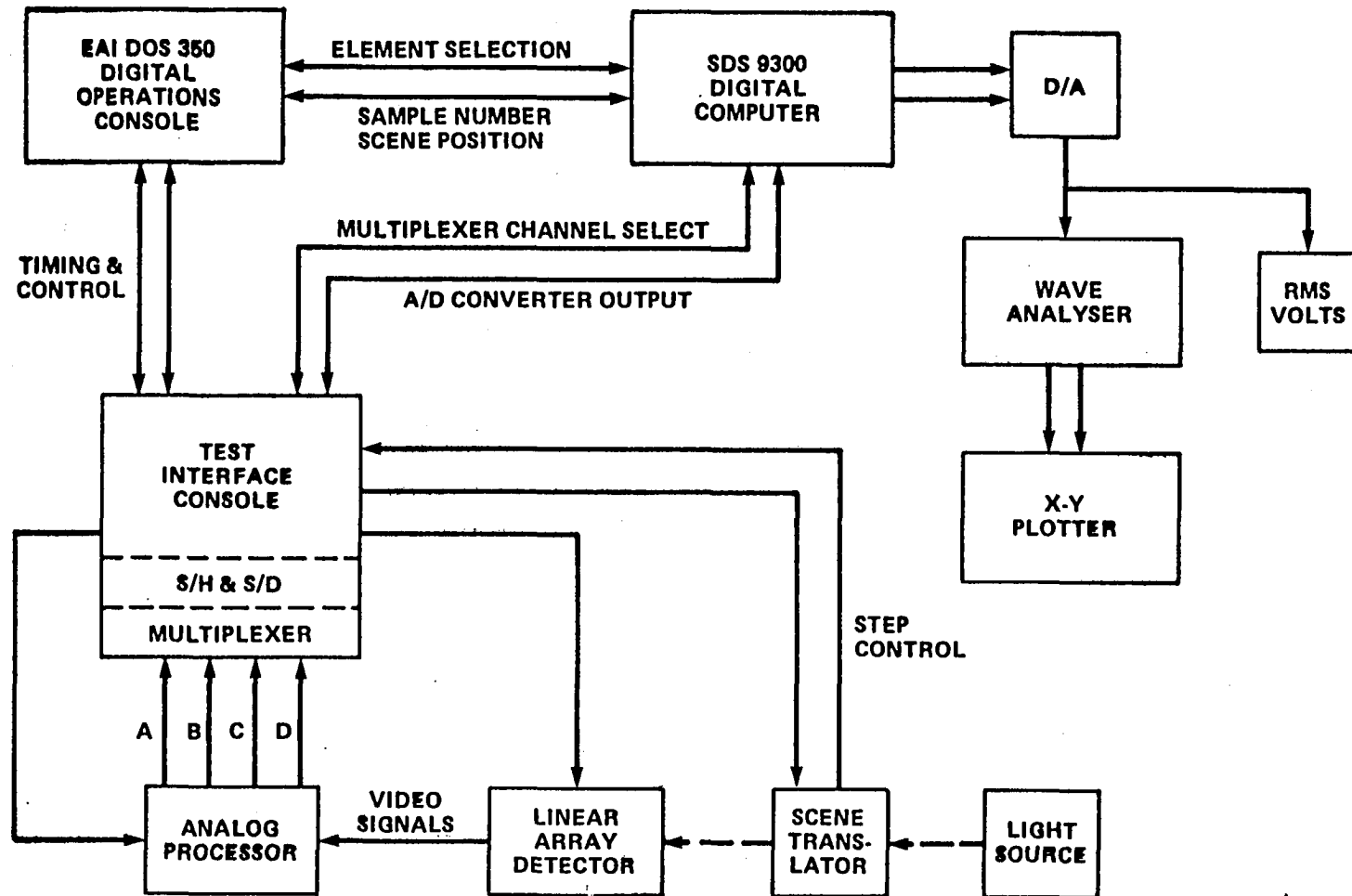
- EXPAND EXISTING FACILITY WITH VIS/NIR CAPABILITY TO SWIR AND TIR SYSTEMS.
- MEASURE ANGULAR AND SPATIAL VARIATIONS IN RADIANCE OF RADIOMETRIC CALIBRATION STANDARDS.
- IMPROVE ABSOLUTE ACCURACY OF EXISTING RADIOMETRIC STANDARDS.

STATUS:

- INTEGRATING SPHERE RADIANCE MAPPER COMPLETE.
- LABORATORY EXPANSION PLAN UNDER DEVELOPMENT.



ASSESSMENT AND CALIBRATION LABORATORY



AIRBORNE MLA SENSORS

OBJECTIVES:

- DEVELOP EXPERTISE IN THE DESIGN CALIBRATION AND TESTING OF MLA REMOTE SENSORS.
- EXAMINE TECHNIQUES TO CALIBRATE AND REMOVE SENSOR ARTIFACTS FROM MLA DATA.
- SUPPLY CALIBRATED MLA DATA TO THE SCIENTIFIC USERS.

APPROACH:

DEVELOP AIRBORNE LINEAR ARRAY PUSHBROOM RADIOMETERS (LAPR) AND ELOS SIMULATOR(S)

STATUS:

- | | | |
|------------|----------------------|--------|
| ● LAPR I | — RETIRED | — 9/81 |
| ● LAPR II | — DELIVERY | — 9/82 |
| ● ELOS/SIM | — PRELIMINARY DESIGN | — TBD |

