Year 1

Technical Progress Report

for the

EDCCD Detector Development

for the

Constellation-X Mission

Grant # NAG5-13217

for the period

April 1, 2003 through March 31, 2005

This Report is Submitted by the

Center for Space Research
Massachusetts Institute of Technology

Principal Investigator
Dr. George R. Ricker
MIT Center for Space Research

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Preface

The original version of this project was documented in a proposal submitted on March 17, 2003. That proposal was for a two year effort with funding of $850K for the period of 4/1/03 to 3/31/04 (Year 1) and funding of $1,050K for the period of 4/1/04 to 3/31/05 (Year 2). As a result of this proposal, a grant (NAG5-13217) was issued by NASA on 4/1/03.

Although the total FY03 portion of the Year 1 funding ($525K) was allocated as part of the initial grant, the remainder of the Year 1 funding was not allocated. In the spring of 2004, an additional funding of $100K was added to the grant, resulting in a total to date of $625K. The Con-X project at GSFC has decided to consider all the funding received to-date as "Year 1" and requested that MIT submit this report to revise the Year 1 funding (from $825K to $650K) and revise the Statement of Work accordingly.

So as to maintain a reasonable level of understanding, this revision is structured on the original proposal, but, in light of the reduced funding, the SOW tasks (planned and accomplished) have been updated for this report.

Year 1 Progress Report

Statement of Work

The original proposal was for a 24-month follow-on effort to a one-year grant (NAG5-12377) received on 7/15/02. During the proposed period, work has been, and will be, performed at both the Center for Space Research on the MIT main campus in Cambridge and Lincoln Laboratory in Lexington, MA.

The status of the work planned, and accomplished, for "Year 1" is provided below.

"Year 1"

(first six months)

Lincoln Laboratory:

Original LL Tasks

1) Mask Design & Layout for Gen2 EDCCD (1K x 1K; MBE-BI EDCCD)
2) Lot#1 Fab for Gen2 EDCCD (1/2 lot)
3) Package multiguard ring test CCDs

Revised LL Tasks

1) Mask Design & Layout for Gen 1.5 EDCCD—*Completed*
2) Lot#2 Fab for Gen1 EDCCD (1/2 lot) —*Completed*
1) Package multiguard ring test CCDs—*Completed*

Explanation for differences in Proposed and Accomplished Tasks:
In order to more fully explore the parameters of thinning and back-illumination technologies, and see how they effect the low energy operation of the EDCCD, it was decided (in consultation with the ConX scientific and management team) that a more extensive evaluation of possible implantation and guard ring geometries was called for. Thus, rather than going immediately to a "full up," flight-like Gen 2 EDCCD device, as

originally proposed for Task #1, an intermediate mask and wafer design, the "Gen 1.5" EDCCD, was adopted (See Figure 1). This wafer design would accommodate a large number of experimental "device splits" which would allow us to optimize device performance in a smaller die, thus reducing the risk of lot failure. Furthermore, to assure that we had an ample number of functioning wafers for backside thinning and filter deposition experiments, we elected to fabricate a second lot of Gen 1 devices as Task #2, utilizing a wide variety of substrate materials (different wafer resistivities and dopant concentrations, achieved using materials from different wafer vendors) and field oxide thicknesses.

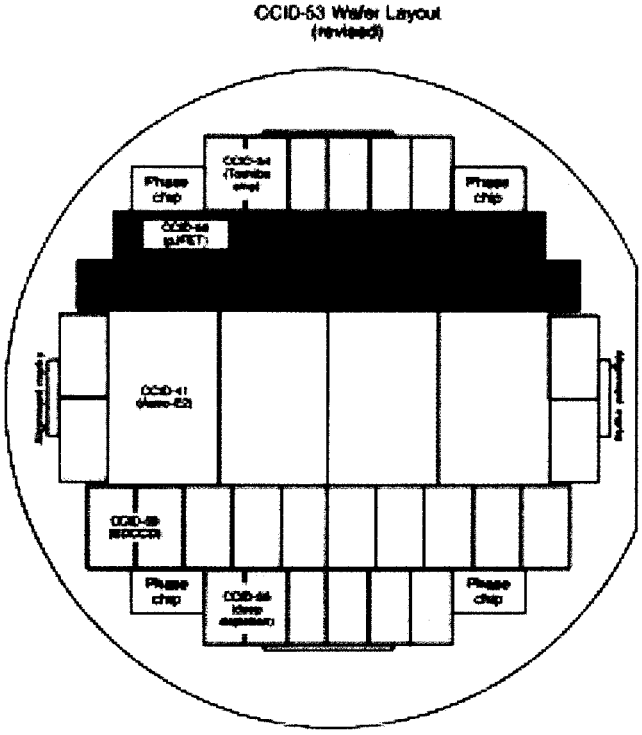

Figure 1: Wafer Layout for Gen 1.5 EDCCD

Center for Space Research:

Original CSR Tasks

1) Testing of multiguard ring CCDs
2) Relative QE measurements in 0.1-0.3 keV band for Lot 1
3) Energy resolution measurements at 0.1keV for Lot 1
4) Background rejection testing for MBE EDCCD
5) Camera concept designs
6) Focal Plane studies for in-plane and off-plane designs

Revised Tasks:

1) Testing of multi-guard ring CCDs—*Functional Tests Completed*

2) Relative QE measurements in 0.1-0.3 keV band for Lot 1 BI Device—*Completed at the MIT CCD Laboratory using a CCID41*

3) Energy resolution measurements at 0.2 keV for Lot 1 BI Device—*Completed at the MIT CCD Laboratory using a CCID41*

4) Background rejection testing for EDCCD—*Not completed*

5) Camera concept designs—*Completed*

6) Focal Plane studies for in-plane and off-plane designs—*Completed*

Explanation for differences in Proposed and Accomplished Tasks:

During the period of this effort, the drive electronics for the EDCCD was undergoing design and initial layout. Thus, event driven operation of the CCID40 was not possible. In addition, we were informed that funding for Con-X during the remainder of the grant period would be drastically curtailed. Hence, it was decided not to duplicate the work being performed by the MIT CCD Laboratory at CSR in support of the Astro-E2 effort. That effort succeeded in having several wafers from Lot 1 back-illuminated at the University of Arizona. Low energy measurements of quantum efficiency and energy resolution (Tasks #2 and #3 above) were then carried out on a back illuminated (BI) CCID41 – the Astro-E2 flight device. The results of these tests were spectacularly successful. Quantum efficiencies of ~90% at 525 eV, and ~50% at 277eV, were measured. The Con-X effort had previously established that the CCID40 functions fully in a "non EDCCD" mode, and that the front-illuminated CCID 40 and 41 provide essentially the same performance. Since the backside treatment and the parallel gate structures for the CCID40 and CCID41 devices on a given wafer are identical, the quantum efficiency measurements of the CCID41 should accurately reflect those that would be obtained from a CCID40 when it can be tested in an event-driven mode. (The CCID40 has already been tested in a conventional mode.) For the energy resolution measurements, the CCID41 results of 52eV at 277eV provide a useful limit on what can be expected for the CCID40 in event-driven mode. The background rejection testing task (#4) requires the full EDCCD electronics to complete; thus, this task is being deferred until the next development period of this research in FY04.

"Year 1"

(remaining 18 months)

Lincoln Laboratory:

Originally Proposed LL Tasks (assuming full Year 1 funding)

1) Complete Lot #1 Gen2 through back-illumination process, package several devices, and deliver to CSR.

2) Design Reduced-noise floating gate output

Revised LL Tasks (as a result of reduced Year 1 funding)

1) Complete Lot #2 Gen1 through FI, and selected wafers through back-illumination process.

2) Complete probing and yield mapping of Gen 1 Lot 2 Wafers.

3) Package two FI and two BI CCID-40 EDCCD devices from Gen 1 Lot 1.

Status of Revised LL Tasks:

Tasks 1 & 2 complete; for Task 3, two FI and one BI devices have been packaged.

Center for Space Research:

Originally Proposed CSR Tasks (assuming full Year 1 funding)

1) Functional tests and screening of Lot 2 devices

2) Absolute QE measurements in 0.1-0.3 keV band for Lot 2

3) Energy resolution measurements at 0.1keV for Lot 2

4) Focal Plane configuration for down-selected grating approach

5) Camera concept designs

6) High speed testing of Lot 2 devices

Revised CSR Tasks (as a result of reduced Year 1 funding)

1) Measure energy resolution at Oxygen K of FI CCID-40 in EDCCD mode.

2) Measure absolute quantum efficiency and energy resolution at Oxygen K of BI CCID-40 in EDCCD mode.

3) Initial modeling of radiation damage mechanisms anticipated in EDCCDs in orbit at L2.

4) Support Con-X project focal plane studies

5) Preparation and presentation of scientific papers describing EDCCD research.

6. Initiate modeling of EDCCD low energy quantum efficiency.

Status of Revised CSR Tasks:

Tasks 1 & 2 will be completed when EDCCD drive electronics are available (anticipated August 2005); Tasks 3-6 have been completed through initial phases, are continuing (Task 5), or are being revised in response to ConX Project inputs (Tasks 3 & 4).