February 6, 1996

Subject: Final Report for CRADA No. TSB-843-94

Dear Dr. Albert:

As you know, the Cooperative Research and Development Agreement, CRADA No. TSB-843-94, between your company and the Lawrence Livermore National Laboratory (LLNL) is in the close-out phase. To complete this phase, Dr. Alan Bennett, Director of Industrial Partnership and Commercialization, and I would appreciate if you would sign the attached CRADA Final report and return it in the enclosed self-addressed envelope at your earliest convenience.

The Final report is the DOE official record of this cooperative research project and your concurrence is required. The main body of the report summarizes the project scope, project milestones, highlights any unresolved problems encountered during the project and includes a summary of the financial information. As per your request during our telephone conversation yesterday, LLNL will store the equipment associated with the CRADA until you let us know what you want done with it. If we do not hear from you by April 1, 1996, we will ship it to you. In addition, the report contains an attachment, the Project Accomplishments Summary, which will be part of the Department of Energy database system and is likely to receive wide distribution both within and outside of DOE.

Please review and sign the attached Final report. If for any reasons you don’t concur with or you wish to modify any of the information reported, please feel free to contact LLNL Principal Investigator, Ken Dolan, to resolve any outstanding issues. In the meantime, feel free to contact Alan at (510)423-3330, or me at (510)422-7782 if you have any questions or comments.

We greatly appreciate your assistance.

Sincerely,

Linda Ault
Small Business Program Manager
Industrial Partnership & Commercialization

Copies to:
Small Business Office CRADA File
Ken Dolan, L-333
Jens Mahler, L-123
Bart McDermott, L-795
Hallie Gibson, L-12
Susan Springer, L-795
Jeff Williams, L-332

Enclosures:
Final Report (w/attachment)
Self-addressed Envelope

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DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
A. Parties

The project is a relationship between the Lawrence Livermore National Laboratory (LLNL) and Digiray Corporation:

- University of California
- Lawrence Livermore National Laboratory
- 7000 East Avenue, L-333
- Livermore, CA 94550

- Digiray Corporation
- 2239 Omega Road
- San Ramon, CA 94583

B. Project Scope

Description: The purpose of this CRADA was to assist Digiray Corporation in the development and evaluation of a Transportable Reverse Geometry X-Ray (RGX-T) cart for aircraft inspection.

Scope: LLNL was to provide a review of the RGX-T engineering drawing package supplied by Digiray, suggest and incorporate design modifications, fabricate, assemble and provide performance evaluation testing of the RGX-T prototype. Major deliverables were (a) engineering design analysis and evaluation, (b) cart prototype hardware, and (c) performance evaluation.

Schedule: Procurement and technical delays extended the project twelve months past the original four month project duration estimate.

Deliverables:

A) Prototype Hardware

The cart prototype hardware is complete. The engineering design analysis and evaluation has revealed both functional and component failure issues.

B) Final Report

The final report is complete.

C. Technical

LLNL reviewed engineering drawings of the RGX-T prototype provided by Digiray, performed an engineering design analysis and evaluation, suggested and incorporated modifications to improve design safety factors, fabricated and assembled the prototype system, and evaluated the motion and positioning capabilities of the assembled system. The RGX-T provides a limited set of positioning orientations for the Digiray x-ray tube head that do not meet the overall Digiray requirements for aircraft inspection. In addition, mechanical stability concerns remain for positioning the tube head with the mechanical arm and for rolling the assembly with arbitrary orientation of the mechanical arm.
D. Partner Contribution
Digiray provided an original engineering drawing package used as the basis for the engineering design analysis and evaluation, fabrication, loan of equipment, consultation and review time to consider modifications to the design, and time and materials for fabrication of selected components.

E. Financial ($K)

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F. Documents/Reference List
None.

G. Property and Proprietary Information:

1) Property - The cart assembly prototype, including selected components fabricated by Digiray Corporation (which Mr. Richard Albert, President of Digiray Corporation, says belongs to NASA) is being stored at LLNL until April 1, 1996 pending disposition instructions from Mr. Albert. If no instructions are received, the prototype will be returned to Digiray.

2) Proprietary Information – Design plans were returned.

3) No Subject Inventions were generated as a result of this CRADA.
H. Acknowledgment
Participant's signature of the final report indicates the following:

1) The Participant has reviewed the final report and concurs with the statements made therein.

2) The Participant agrees that any modifications or changes from the initial proposal were discussed and agreed to during the term of the project.

3) The Participant certifies that all reports, inventions disclosures and patent applications attributable to the project are completed or are in process and a list is attached to this report.

Richard Albert  Date  Kenneth W. Dolan  Date
President, Digiray Corporation  LLNL Principal Investigator

Attachment I – Accomplishments Summary
A. Parties

The project is a relationship between the Lawrence Livermore National Laboratory (LLNL) and Digiray Corporation.

University of California
Lawrence Livermore National Laboratory
7000 East Avenue, L-333
Livermore, CA 94550

Digiray Corporation
2239 Omega Road
San Ramon, CA 94583

B. Background

Digiray markets cabinet based Reverse Geometry X-ray systems but does not have a field portable product suitable for aircraft inspection. LLNL has expertise in engineering analysis, prototype fabrication, and special facilities and test items for evaluation of the operational capabilities for a field portable x-ray imaging systems.

C. Description

Purpose: The purpose of this CRADA was to assist Digiray Corporation in building, testing, and evaluating of a Transportable Reverse Geometry X-Ray (RGX-T) Cart Prototype for aircraft inspection.

Scope: LLNL was to provide a review of the RGX-T engineering drawing package supplied by Digiray, suggest and incorporate modifications, fabricate, assemble and test the RGX-T prototype.

Accomplishments:

(1) Digiray's engineering drawings were evaluated relative to LLNL engineering design standards. Modifications to the design were suggested as a result of this evaluation and incorporated in component fabrication and assembly. These included addition of extension feet on the cart base to provide stability and prevent tipping with the mechanical arm extended at certain orientations, incorporation of structural members with larger cross sections and/or higher strength materials to provide additional stiffness and improve safety factors, incorporation of higher strength bolts, and replacement of bearings with bushings to improve static load capacity. LLNL's modifications to engineering drawings were specifically to address functionality issues and design features. LLNL's modifications were verbally reviewed and approved by Digiray.

(2) Components were fabricated based on the engineering drawings with modifications as noted above. Components supplied by Digiray, principally the extendible boom, tube head mounting frame, and equipment rack were adapted to the modified assembly. The weight of the tube head mounting frame was reduced by removal of material to reduce loading on the mechanical arm. Threaded rod turnbuckles were substituted for electronic actuators in the
assembly to evaluate mechanical arm motion prior to decision point for actuator procurement by Digiray.

(3) Manual rolling motion of the cart was found to be satisfactory with the mechanical arm in a transport (non-extended) position. A potential tipping of assembly during rolling motion with mechanical arm extended at arbitrary tilt and rotation, with tube head also at arbitrary tilt and rotation was not resolved. Administrative restrictions would most likely be required to restrict rolling speed and orientation and extension of mechanical arm and orientation of tube head based on configuration of extension feet and allowed locations for applied force when moving cart. A procedure should be written or a table devised showing in what configurations the cart will tip. The sequence of part removal for servicing is important. The case of suddenly hitting a ridge in the pavement and jolting the cart has not been analyzed but could produce deceleration high enough to initiate cart overturn.

(4) The mechanical arm provides a limited set of motions not fully covering the range required by Digiray. In addition the extendible boom presents functional and safety concerns. The boom is not as stiff as desired for the function of positioning the tube head for an x-ray exposure, and for moving the entire assembly to the next exposure location with minimal repositioning of the mechanical arm.

(5) The boom is subject to twist with tube head at some orientations because of the open beam components used in boom fabrication and mechanical slide design for boom extension. In bending about their stronger axis, stresses in the extension arm channels are not a safety concern; however, in some configurations the channels see bending about their weaker axis as well. The open channel design is a poor choice for the torsional loading that arises when the head is offset to one side. When the angle of elevation deviated from 0° (no longer parallel to ground) the loading on these channels is a combination of bending and torsion which causes large deformations (as much as 7° twist). There is not a single well defined “worst case” configuration; some configurations give rise to combined stress states. The combined loading needs to be analyzed more fully.

(6) When running the cart through its range of motions, some permanent set occurred in the vertical leg assembly. The analysis needs to be explored more thoroughly for extension arm configurations other than fully extended and parallel to the ground. The drive angle of the piston for raising and lowering the head assembly is related to the reaction stresses in the vertical legs.

(7) The turnbuckles that were used to simulate motion prior to planned installation of electric actuators show that the design results in a coupling of boom rotation and boom tilt motions which may limit the ability to precisely position the tube head.

(8) Bearings for rotary motion were inadequate and were replaced by bushings. The linear motion bearings seem to have been selected on loading for a horizontal fully extended configuration. They have an inadequate design safety margin when required to carry torsional loads. All torsion loads from the head are transmitted back to the base of the cart through these bearings. There is concern they could “peel off” their track.

(9) The cable take-up assembly has not been evaluated. Spring adequacy for cable tension should be checked.

(10) Automated protective devices to prevent collision between the x-ray tube head and structure being inspected are not incorporated in either the design or fabrication.
D. Expected Economic Impact
A successful Cart design and product would allow Digiray to demonstrate the capabilities of Reverse Geometry X-ray® imaging for defect detection in airframes and aircraft components at commercial and military aircraft maintenance facilities. Successful demonstrations would allow Digiray to market a new product line of x-ray imagers for commercial and military aircraft inspection for enhanced safety and durability assessment of aircraft.

E. Benefits to DOE
Defect detection by x-ray imaging is a key technology in the Nondestructive evaluation core competency of LLNL. A field capable Reverse Geometry X-Ray® imaging system could enhance and extend LLNL’s x-ray imaging capabilities.

F. Industry Area
Industry areas with potential benefits from this project are the commercial airline operators, aircraft original equipment manufacturers, military aircraft inspection services, petrochemical (e.g. pipeline inspection), electronics (circuit board inspection), medical, and advanced materials (e.g. composites) manufacturers.

G. LLNL Point of Contact for Project Information
Kenneth W. Dolan
Lawrence Livermore National Laboratory
P. O. Box 808, Mail Stop L-333
Livermore, CA 94550
tel (510) 422-7971
fax (510) 422-3834

H. Company Size and Point(s) of Contact
Richard Albert
Digiray Corporation
2239 Omega Rd
San Ramon, CA 904583
tel (510) 838-1510
fax (510) 838-1986

I. Project Examples
Prototype hardware.

J. Release of Information
Kenneth W. Dolan, Group Leader for Radiation Applications, Nondestructive Evaluation Section
tel. (510) 422-7971

RELEASE OF INFORMATION
I have reviewed the attached Project Accomplishment Summary prepared by Lawrence Livermore National Laboratory and agree that the information about our CRADA may be released for external distribution.

Richard Albert
Digiray Corporation
President

Date: 2/28/95