LIQUEFIED METAL JET PROGRAM
AUTOMATION AND ROBOTICS RESEARCH INSTITUTE (ARRI)

R&D QUARTERLY STATUS REPORT
PROGRAM FINANCIAL STATUS

REPORTING PERIOD: 15 JULY 1994 THROUGH 15 OCTOBER 1994

Sponsored by:

Advanced Research Projects Agency (ARPA)
Contract Management Office (CMO)
Liquefied Metal Jet Program (LMJP)

ARPA Order No. 9328/03

Issued by: ARPA/CMO
Under Contract No.: MDA972-93-C-0035

Deliverable Item Sequence No.: 0002AA

Prepared by:

Texas Instruments
Defense Systems & Electronics Group
13500 North Central Expressway
Dallas, Texas 75243

12 October, 1994

TEXAS INSTRUMENTS

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. Agency Use Only (Leave Blank)	2. Report Date	3. Report Type and Dates Covered
	October 12, 1994	*Quarterly Technical Report*

4. Title and Subtitle
R & D Quarterly Status Report
Program Financial Status

5. Funding Numbers
C-MDA972-93-C-0035

6. Author(s) Mr. Nick Dringenburg, Dr. Charles Smith, Mr. Patrick DuBois, Mr. Elwin Whetsel, and Dr. John Priest

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Automation Robotic Research Institute
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Texas Instruments Inc
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8. Performing Organization Report Number
0002AA

9. Sponsoring/Monitoring Agency Name(s) and Address(es)
Advanced Research Projects Agency (ARPA)
Contract Management Office (CMO)
Virginia Square Plaza
3701 North Fairfax Drive
Arlington, VA 22203-1714

10. Sponsoring/Monitoring Agency Report Number
ARPA Order Number 9328/03

11. Supplementary Notes

12a. Distribution/Availability Statement
Approved for Public Release; Distribution Unlimited

12b. Distribution Code

13. Abstract (Maximum 200 words)

No lead system integration began with the testing of ball deflection. Problems with ball mass, distance to apply deflection forces, and field strength dictated a decreased ball size and increased deflection length.

14. Subject Terms
Liquefied Metal Jet (LMJ)

15. Number of Pages
84

16. Price Code

17. Security Classification of Report	18. Security Classification of this Page	19. Security Classification of Abstract	20. Limitation of Abstract
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

LIQUEFIED METAL JET PROGRAM
AUTOMATION AND ROBOTICS RESEARCH INSTITUTE (ARRI)

R&D QUARTERLY STATUS REPORT
DATA ITEM 0002AA
15 JULY 1994 THROUGH 15 OCTOBER 1994

1.0 INTRODUCTION

Our program has initiated test and evaluation of the no lead system, pursued several risk reduction activities, and continued design efforts for the copper system. A request for technical schedule extinsion has been submitted. The reason for a program extension request is the three month delay that initially occurred in the subcontracting process between Texas Instruments and The University of Texas at Arlington, some of the technical difficulties we are having in developing deflection technology for the metal jet technology; and delays that are occurring in getting approval for purchasing research equipment. Risk reduction efforts have included the temporary hiring of an experienced contract engineer to help resolve the deflection difficulties and focus more resources on deflection.

2.0 PROGRESS DURING THE REPORTING PERIOD

- Redesigned and assembled the no lead system based on test results
- Completed initial investigation of several types of filtration material and selected best for use in no lead system
- Continued preliminary design of the copper system
- Continued to evaluate selected materials for the copper system fluidizer, pot and tubing
- Continue work with POCO Graphite in Decatur, TX to develop a containment system for liquid copper
- Completed materials analysis report for filtering materials and copper construction materials completed by The University of North Texas

3.0 PLANNED ACTIVITIES FOR NEXT REPORTING PERIOD

- Resolve problems in deflection system
- Continue risk reduction testing of construction materials for copper system
- Complete detailed design of Copper Fluidizer and Droplet Generator

4.0 EQUIPMENT PURCHASED OR CONSTRUCTED

Assembled/Constructed:

- Revised no lead system and control system

Purchased

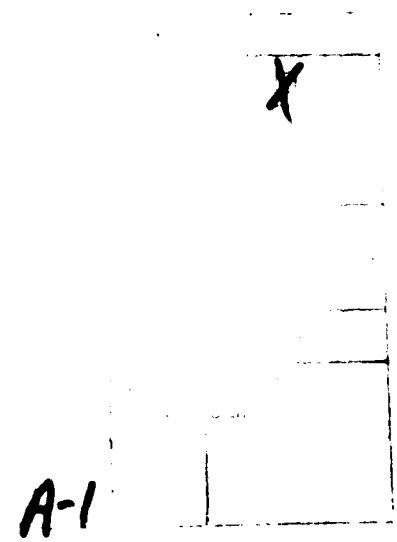
- Contract Engineering
- Directed Energy Pulse Generator

5.0 NOTIFICATION OF KEY PERSONNEL CHANGES

None

6.0 INFORMATION FROM TRIPS, MEETINGS, AND SPECIAL CONFERENCES

- An informal design review was held with Texas Instruments personnel at their Attleboro plant. This included some of their top experts in material science. A trip report was developed and is available.
- Meetings were held with Delco Electronics, Byrd Precision, and M.I.T. Delco is very interested in high temperature jetting applications.



R&D STATUS REPORT
PROGRAM FINANCIAL STATUS
SEPTEMBER 1994

	CUMULATIVE TO DATE	AT COMPLETION
	$544,835	$1,127,684

WORK BREAKDOWN TASK ELEMENT		PLANNED EXPEND	ACTUAL EXPEND	% COMPLETE	BAC*	LRE**	REMARKS
MANAGEMENT	1.0	98,109	47,174	48.08%	98,109	98,109	
EQUIPMENT	2.0	814,187	459,891	56.48%	814,187	814,187	
SYSTEM TEST & EVAL	3.0	68,789	0	0.00%	68,789	68,789	
SAMPLE EVALUATION	4.0	107,130	0	0.00%	107,130	107,130	
TECHNICAL TRANSFER	5.0	39,469	0	0.00%	39,469	39,469	
SUB-TOTAL		$1,127,684	$507,065	44.97%	$1,127,684	$1,127,684	
FEE		71,470	37,770	52.85%	71,470	71,470	
MANAGEMENT RESERVE							
UNALLOCATED RESOURCES							
TOTAL		$1,199,154	$544,835	45.43%	$1,199,154	$1,199,154	

*BUDGET AT COMPLETION (BAC) CHANGES ONLY WITH THE AMOUNT OF ANY SCOPE CHANGES. (NOT AFFECTED BY UNDERRUN OR OVERRUN).

**LATEST REVISED ESTIMATE
BASED ON CURRENTLY AUTHORIZED WORK:

(1) IS CURRENT FUNDING SUFFICIENT FOR THE CURRENT FY? (EXPLAIN IN NARRATIVE IF "NO"). YES

(2) WHAT IS THE NEXT FISCAL YEAR'S FUNDING REQUIREMENT AT CURRENT ANTICIPATED LEVELS? 0

(3) HAVE YOU INCLUDED IN THE REPORT NARRATIVE ANY EXPLANATION OF THE ABOVE DATA AND ARE THEY CROSS REFERENCED? NO

LIQUEFIED METAL JET PROGRAM
AUTOMATION AND ROBOTICS RESEARCH INSTITUTE (ARRI)

QUARTERLY TECHNICAL REPORT

REPORTING PERIOD: 15 JULY 1994 THROUGH 15 OCTOBER 1994

Sponsored by:

Advanced Research Projects Agency (ARPA)
Contract Management Office (CMO)
Liquefied Metal Jet Program (LMJP)

ARPA Order No. 9328/03

Issued by: ARPA/CMO
Under Contract No.: MDA972-93-C-0035

Deliverable Item Sequence No.: 0002AB

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	October 12, 1994	Quarterly Technical Report

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Quarterly Technical Report

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No lead system integration began with the testing of ball deflection. Problems with ball mass, distance to apply deflection forces, and field strength dictated a decreased ball size and increased deflection length.

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Liquefied Metal Jet (LMJ)	5
	16. Price Code

17. Security Classification of Report	18. Security Classification of this Page	19. Security Classification of Abstract	20. Limitation of Abstract
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LIQUEFIED METAL JET PROGRAM
AUTOMATION AND ROBOTICS RESEARCH INSTITUTE (ARRI)
QUARTERLY TECHNICAL REPORT
DATA ITEM 0002AB
15 JULY 1994 THROUGH 15 OCTOBER 1994

1.0 INTRODUCTION

This report covers the period from 15 July 1994 through 15 October 1994. The Quarterly Technical Reports are organized by the Statement of Work (SOW) listed in Section 5.0 of the proposal. These are:

- Reports and demonstration
- Equipment
- System test and experimentation
- Test coupon evaluation
- Technology transfer.

Our program has initiated test and evaluation of the no lead system, pursued several risk reduction activities, and continued design efforts for the copper system. A request for technical schedule extension has been submitted. The reason for a program extension request is the three month delay that initially occurred in the subcontracting process between Texas Instruments and The University of Texas at Arlington, the technical difficulties we are having in developing deflection technology for the metal jet technology; and delays that are occurring in getting approval for purchasing research equipment. A risk reduction effort has included the proposal to hire an experienced contract engineer to help resolve the deflection difficulties and focus more resources on deflection.

2.0 REPORTS AND DEMONSTRATION, SOW 5.1

1. Material Analysis Report - filtering materials and copper construction materials.
2. Minutes from TI Attleboro design review.

3.0 EQUIPMENT, SOW 5.2

Major Program milestones reached during this period include:

- All computer interface completes.
- Crude copper shot from a test nozzle on September 9, 1994.
- Tested copper and construction material compatibility.
- Researched potential heating methods for Copper System.
- Designed Copper System Head Assembly.
- Fabricated a prototype copperhead to test nozzle designs.

- Acquired high energy, high frequency pulse generator needed for single ball deflection.
- Acquired and configured data acquisition equipment for copper and tin system.
- Completed, tested and started operating the no lead Shooting System.
- Stream break up tests were successful.
- Deflection of 100 percent balls successful.
- Problems in single ball deflection were identified as ball mass, deflection voltages, and distance to apply deflection forces, and are being worked by decreasing ball size and increasing deflection length.

3.1 Fluidizer, SOW 5.2.1

The fluidizer module for the LMJ system converts the solid metal feedstock to liquid. This includes engineering design, fabrication, thermal management integration, and functional testing of the fluidizer module to introduce the metal feedstock at a predetermined rate into a high temperature melt chamber. Propelling forces are required to drive the LMJ at the predetermined velocity. The resulting liquefied metal is transitioned to the droplet generator for subsequent droplet formation.

The fluidizer design operates to specification and performs satisfactorily. Several minor issues to be worked are the upper valve assembly which may be unnecessary, and the bottom plate is being modified to accommodate a new filter design. The State of Texas sponsored Solder Jet machine was rebuilt and tested to be used as test chamber for droplet parameterization and filter test bench on the ARPA project.

Conceptual design of the fluidizer for the copper system is continuing. Due to the much higher temperature needed to melt copper (2,000°F), a major redesign is being performed. Major issues include:

- Kanthol resistance heating has been selected.
- Carbon graphite construction material for the fluidizer has been selected.
- Sealing bolts, flanges, have been selected and are being evaluated.
- Optical observation and measurement has been discussed with TI and options are being evaluated.
- Manual drop system for shooting copper has been postponed to focus more resources on deflection and system reliability issues that presently limit no lead coupon generation.

3.2 Droplet Generator, SOW 5.2.2

The proprietary droplet generator for the LMJ system will accept the liquefied metal from the fluidizer and provide the instability required to excite the jet stream into a repeatable droplet formation. In addition, the droplets will have a charge induced by an induction plate as they break away from the jet. A signal level will be provided to the charge on the droplets the trajectory

through an electric field can be controlled. After being charged, the droplets will continue through an electrostatic deflection field, to impact the target at a precise location.

New versions of the proprietary, continuous mode generation have been designed, fabricated, and tested off line. As mentioned in the last report, problems include stream instability and a lack of consistent droplet formation. Testing has concluded that problems were mainly due to poor environmental control in the test chamber.

3.3 Jet/Droplet Stream, SOW 5.2.3

A path for the droplets to be charged and deflected will be provided in the design of the system. The path will also provide for alternative atmospheres for experimentation. The no lead system jet stream and target chamber if a large Plexiglas environmental chamber is used to provide an inert gas atmosphere.

Plexiglas has shown to be a problem in testing due to its holding moisture. This will require a change to stainless steel and glass.

Single ball deflection which is needed to generate test coupons was not performed due to equipment problems. A U.T.A. custom designed and built charge amplifier could not provide power levels at frequency necessary to charge individual droplets. This required the purchase of a modified "of the shelf" power switcher. This has contributed to a delay of approximately three months.

The copper system will require a complete redesign because of its higher temperature. Design evaluations have concluded the continued need to use an inert environment for copper. Some risk reduction, copper tests will provide important design information for this effort.

3.4 Target Chamber, SOW 5.2.4

The test coupons (i.e., samples) on which the experiments will be run, reside in a fixture to hold the coupon and a chamber to provide for controlled inert atmosphere. This chamber will provide controlled heat for coupon preheating, and provide for optical observation and instrumentation. In addition to the chamber, a precision motion control system to position the coupon for pattern writing will be designed, acquired and integrated into the LMJ system. A device to catch and collect the unwanted or "guttered" droplets is included in the coupon chamber.

The target chamber is complete and ready for system testing.

3.5 System Control, SOW 5.2.5

System control addresses all items necessary to control and monitor the process. Subtasks include hardware, software, and integration for process control, environmental control, data acquisition and safety. The system control will include personal computers, programmable logic controller, data acquisition software, Computer Aided Design (CAD) data, Network Control program interface and custom programming. Facility related subtasks will include fume handling capabilities, safety systems and thermal management equipment.

The system control computer for the no lead system has been received, installed and configured. The xy table for the no lead has been designed and fabricated using COMPUMOTOR software running on a personal computer. Industrial Proportional Integral Derivative (PID) controllers are used to control all variable parameters (pressure, temperature). The overall system is monitored using a modified National Instruments software program called LABVIEW which runs on a Macintosh computer. The copper based system is expected to use the same basic scheme.

4.0 System Test and Evaluation, SOW 5.3

Several system and subsystem tests have been conducted including:

- Fluidizer Tests
- Environmental Control Tests
- Droplet generator
- Deflection.

5.0 Test Coupon Evaluation, SOW 5.4

6.0 Technology Transfer, SOW 5.5

Several United States manufacturers have been contacted for technology transfer. Serious discussions are being held with MPM, General Motors - Delco Electronics, and Indium Corporation of America.