



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

**R&D QUARTERLY STATUS REPORT**

**REPORTING PERIOD: 15 April 1995  
THROUGH 15 July 1995**

**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**

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**Prepared by:**

**Texas Instruments  
Defense Systems & Electronics Group  
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**07 July, 1995**



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**LIQUIFIED METAL JET PROGRAM (LMJP)**  
**AUTOMATION AND ROBOTICS RESEARCH INSTITUTE (ARRI)**  
**R&D QUARTERLY STATUS REPORT**  
**DATA ITEM 0002AA**  
**15 APRIL 1995 THROUGH 15 JULY 1995**

**1.0 INTRODUCTION**

This report covers the period from 15 April 1995 through 15 July 1995. The Quarterly Technical Reports are organized by the statement of work (SOW) listed in section 5.0 of the proposal. These are listed as follows:

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

Technical problems associated with the nozzle design and fabrication have been solved. A new jeweled orifice plate supplier has been located and orifices have been successfully procured and tested. The nozzle sealing problem has also been resolved and over 50 nozzles have been assembled with no leaks. The remaining problem to be solved is believed to be caused by particulates in the solder. Improved filtering methods have been developed and are currently in test. System testing with the new nozzle design and micro filtered solder is expected to resume operations in mid July. Final fabrication and assembly of the copper system is expected to be complete by mid August.

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## **2.0 PROGRESS DURING THE REPORTING PERIOD**

- Identified and incorporated improvements for nolead system reliability including a nozzle redesign, new orifice vendor, and assembling nozzles in house.
- Identified and designed several methods of filtering solder for evaluation
- Completed design and started fabrication of copper system.
- Began assembly of copper system fluidizer pressure vessel.
- Resolved XY table issues with custom designed and fabricated hardware/software. This eliminated the need of purchasing a new table and thus saving the project of at least \$20,000.
- Completed design and order placement for copper system fluidizer containment vessel and silicon carbide heater elements.

Improvements on miniaturization of the deflection system were completed and successfully tested.

## **3.0 PLANNED ACTIVITIES FOR NEXT REPORTING PERIOD**

- Demonstrate resolution of particulate problem
- Demonstrate PWB fabrication capability
- Produce solder coupons for evaluation
- Demonstrate proper copper droplet formation

## **4.0 EQUIPMENT PURCHASE OR CONSTRUCTED**

### **Assembled/Constructed:**

- Completed nolead system modifications to reduce intermetallic contamination.
- Constructed filtration system to filter particulates from solder.
- Began manufacturing copper system.
- Constructed and tested 16 new nozzle assemblies

### **Purchased:**

- None

**5.0 NOTIFICATION OF KEY PERSONNEL CHANGES**

None

**6.0 INFORMATION FROM TRIPS, MEETINGS, AND SPECIAL CONFERENCES**

Meetings with MicroFab to discuss future cooperative efforts. Attended NEPCON 95 conference in Anaheim, Ca. Held program review of this project at ARPA offices in Washington D.C.

**LIQUEFIED METAL JET PROGRAM  
AUTOMATION AND ROBOTICS  
RESEARCH INSTITUTE (ARRI)  
QUARTERLY TECHNICAL REPORT**

**REPORTING PERIOD: 15 April 1995  
THROUGH 15 July 1995**

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**LIQUIFIED METAL JET PROGRAM (LMJP)**  
**AUTOMATION AND ROBOTICS RESEARCH INSTITUTE (ARRI)**  
**QUARTERLY TECHNICAL REPORT**  
**15 APRIL THROUGH 15 JULY 1995**

**1.0 INTRODUCTION**

This report covers the period from April 1995 through 15 July 1995. The Quarterly Technical Reports are organized by the statement of work (SOW) listed in section 5.0 of the proposal. These are listed as follows:

- Reports and demonstration.
- Equipment.
- System test and experimentation.
- Test coupon evaluation.
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Technical problems associated with the nozzle design and fabrication have been solved. A new jeweled orifice plate supplier has been located and orifices have been successfully procured and tested. The nozzle sealing problem has also been resolved and over 50 nozzles have been assembled/rebuilt with no leaks. The remaining problem to be solved is believed caused by particulates in the solder. Improved filtering methods have been developed and are currently in test. System testing with the new nozzle design and micro-filtered solder is expected to resume in mid July. Final fabrication and assembly of the copper system is expected to be completed by mid August.

**2.0 REPORTS AND DEMONSTRATION, SOW 5.1**

- Weekly Progress Reports - Weekly progress reports are available.

### **3.0 EQUIPMENT, SOW 5.2**

Major Program accomplishments reached during this period include:

- Identified and incorporated improvements for nolead system reliability including a nozzle redesign, new orifice vendor, and assembling nozzles in house.
- Identified and designed several methods of filtering solder for evaluation
- Completed design and started fabrication of copper system.
- Began assembly of copper system fluidizer pressure vessel.
- Resolved XY table issues with custom designed and fabricated hardware/software. This eliminated the need of purchasing a new table and thus saving the project of at least \$20,000.
- Completed design and order placement for copper system fluidizer containment vessel and silicon carbide heater elements.
- Improvements on miniaturization of the deflection system were completed and successfully tested.

#### **3.1 Fluidizer, SOW 5.2.1**

The fluidizer module for the LMJ system converts the solid metal feedstock to liquid. The fluidizer module introduces the metal feedstock at a predetermined rate into a high temperature melt chamber. Propelling forces are required to drive the liquid metal jet at the predetermined velocity. The resulting liquefied metal is transitioned to the droplet generator for subsequent droplet formation.

The nolead fluidizer design continues to operate to specification and performs satisfactorily.

Detailed design of the copper fluidizer is complete. All materials have been ordered and 50% of them have been received.

### **3.2 Droplet Generator, SOW 5.2.2**

The proprietary droplet generator for the LMJ system accepts the liquefied metal from the fluidizer and provides the control of the instability required to excite the jet stream into a repeatable droplet formation. In addition, the droplets have a charge induced by an induction plate as they break away from the jet. A signal level is provided to charge the droplets so 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.

Process reliability problems have been resolved with the exception of the suspected particulate contamination problem.

### **3.3 Jet/Droplet Stream, SOW 5.2.3**

A path for the droplets to be charged and deflected is provided in the design of the system. The path also provides for alternative atmospheres for experimentation.

As stated in the last report the revised environmental chamber is fully operation and performing as expected.

The copper system design is complete.

### **3.4 Target Chamber, SOW 5.2.4**

The test coupons (i.e., samples) on which the experiment is run, reside in a fixture to hold the coupon and a chamber to provide for controlled inert atmosphere. This chamber provides controlled heat for coupon preheating, and provides for optical observation and instrumentation. In addition to the chamber, a precision motion control system to position the coupon for pattern writing has been 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 nolead target chamber is complete and fully operational.

Design of the copper system target chamber is complete and in fabrication.

### **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 includes personal computers, programmable logic controller, data acquisition software, Computer Aided Design (CAD) data, Network Control program interface and custom programming. Facility related subtasks includes, fume handling capabilities, safety systems and thermal management equipment.

The system control computer for the nolead is complete. Resolved XY table issues with custom designed and fabricated hardware/software. This eliminated the need of purchasing a new table and thus saving the project of at least \$20,000

### **4.0 SYSTEM TEST AND EVALUATION, SOW 5.3**

Several system and subsystem tests have been conducted including:

- Nozzle tests.
- Filtration techniques testing.
- Improved deflection system tests

### **5.0 TEST COUPON EVALUATION, SOW 5.4**

Evaluation of the test coupons will begin in the next reporting period.

### **6.0 TECHNOLOGY TRANSFER, SOW 5.5**

United States manufacturers continue to visit the lab for technology transfer. Serious discussions are being held with MicroFab of Plano Texas with regard to future cooperative efforts.

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AUTOMATION AND ROBOTICS  
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PROGRAM FINANCIAL STATUS**

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R & D STATUS REPORT  
PROGRAM FINANCIAL STATUS  
JULY 1995

WORK BREAKDOWN TASK ELEMENT	PLANNED EXPEND	ACTUAL EXPEND	% COMPLETE	BAC*	LRE**	REMARK
MANAGEMENT	98,109	77,596	79.09%	98,109	98,109	
EQUIPMENT	814,187	865,921	106.35%	814,187	814,187	
SYSTEM TEST & E	68,789	0	0.00%	68,789	68,789	
SAMPLE EVALUATI	107,130	0	0.00%	107,130	107,130	
TECHNICAL TRANS	39,469	0	0.00%	39,469	39,469	
SUB-TOTAL	\$1,127,684	\$943,517	83.67%	\$1,127,684	\$1,127,684	
FEE	71,470	41,448	57.99%	71,470	71,470	
MANAGEMENT RESERVE UNALLOCATED RESOURCES						
TOTAL	\$1,199,154	\$984,965	82.14%	\$1,199,154	\$1,199,154	

CUMULATIVE TO DATE AT COMPLETION  
\$941,110 \$1,127,684

\*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