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(NASA-CR-158743) SLICING OF SILICON INTO SHEET MATERIAL. SILICON SHEET GROWTH DEVELOPMENT FOR THE LARGE AREA SILICON SHEET TASK OF THE LOW COST SILICON SOLAR ARRAY PROJECT (Varian Associates, Lexington,

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SLICING OF SILICON INTO SHEET MATERIAL

Silicon Sheet Growth Development for the Large Area Silicon Sheet Task of the Low Cost Silicon Solar Array Project

ELEVENTH QUARTERLY REPORT

By

J. R. FLEMING

DOE/JPL 954374-78/8
Distribution Category - UC-63

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Silicon Sheet Growth Development for the
Large Area Silicon Sheet Task of the Low
Cost Silicon Solar Array Project

ELEVENTH QUARTERLY REPORT

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J. R. FLEMING

January 20, 1979

Reporting Period October 28, 1978 to December 29, 1978

JPL Contract No. 954374

Varian Associates
Lexington Vacuum Division
121 Hartwell Avenue
Lexington, Massachusetts 02173

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, under NASA Contract NAS7-100 for the U. S. Department of Energy (DOE).

The JPL Low-Cost Solar Array Project is funded by the DOE and forms part of the DOE Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays.

S-100-Q11

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1.0 SUMMARY

Tests on mineral oil slurries have shown that the potential for workability and low cost is present. However, slurries tested to date which had sufficient lubricity have exhibited wafer breakage problems near the end of the run for as-yet unknown reasons.

The first test of the large prototype saw under cutting force control was largely successful in that the controller worked perfectly. Unfortunately a technique error (excessive stroke shortening) caused blade breakage and low yield.

The latest run of the large saw pointed up the fact that an indication of end-of-stroke vertical motion, or "bounce", is necessary. A circuit to provide such indication has been fabricated and installed. Preliminary tests show it to be excessively noise sensitive, and we are now working on grounding and shielding to reduce this sensitivity.

2.0 PROGRESS

2.1 Slurry Tests

Previous tests with a slurry fluid of low viscosity (100 SUS) mineral oil with lard oil lubricity additive mixed 5:1 by volume have shown mixed results. The drag force problem has been eliminated. Cutting times have been made reasonable by increasing the amount of abrasive, which should not be necessary in newer saws due to decreased abrasive "laydown" in the return path to the slurry bucket. Yield has been poor, and wafer quality has ranged from poor to excellent.

In Test #2-3-28, we reduced the proportion of lard oil to 40:1, which is recommended for many applications. If the large amount of lard oil was causing the problem, this reduction should allow the yield to be raised. All conditions were standard except the abrasive mix, which was increased to 0.48 kg/l (4 lg/gal) as in Test #2-3-27.

Unfortunately, there was too little lard oil to prevent the drag force problem, and several fuses blew. At 41 mm (1.6 in.) cut depth the mineral oil/lard oil ratio was decreased to 20:1 by adding lard oil. No more fuses blew, but wafer breakage started almost immediately.

Final yield was 66%. Cutting time was 38.3 hours, bow was 198 μm (.008 in.) and taper was 87 μm (.0035 in.).

We conclude that mineral oil slurries with lubricity additives seem workable, but lard oil may not be the right additive. We will test other additives.

2.2 Prototype Tests

In Test #2-7-05, we first tested the feed force controller. This controller uses the fact that the ingot is mounted on a spring loaded table, much like the bounce fixture. The deflection of this table is sensed by an LVDT, and the resulting signal is compared to a reference signal which is proportional to the desired total load. Depending on the results of the comparison, the motor driving the bladehead into the work is sped up, slowed down, or kept at constant speed. To avoid instability, the signal to the motor is the integral of the "error" or difference between the LVDT and reference signals.

The run started very well. Cutting rate was high, so we increased the load to full load very slowly.

About 1/3 of the way through the run, a banging noise was noticed. Hindsight shows that this was due to a worn bearing. The bearing had accumulated slurry due to insufficient slurry bucket sealing.

At the time of the run, we could not tear down the machine sufficiently to discover the worn bearing without terminating the run. It seemed (wrongly) that the noise was something banging against the inside of the slurry bucket, and that shortening the stroke reduced the noise for a while.

The operator continually shortened the stroke until the final stroke was about 50 mm (2 in.). Since the volume of blades worn away is roughly constant, this short stroke caused excessive blade height wear. With about 2.5 mm (.1 in.) of ingot left to be cut, blades started breaking. By the time the blades were sufficiently into the submount to remove the wafers, enough blades had broken to make the final yield 31%.

Cutting time was long, 41.6 hours, again because of the short stroke. NTV was 105 μm (.004 in.) and bow was 324 μm (.013 in.). These were also probably a result of excessive blade wear.

In spite of the problems, the feed force controller worked very well, and we still feel that our problems are associated with learning how to use the prototype.

2.3 Other Progress

The prototype tests have pointed up the necessity of displaying the bounce to the operator so that good decisions can be made as to when to shorten the stroke. The information is already contained in the LVDT signal. A peak-to-peak detector circuit has been designed and built, and is now being installed. Since the frequencies are low (about 0.1 - 1 Hz), time constants must be long, so impedances must be high, which makes the circuit very noise sensitive.

3.0 PROBLEMS

No significant problems occurred during the reporting period.

4.0 PLANS

Plans for the next quarter include:

- Further testing of mineral oil slurry vehicles with various additives.
- "Fine Tuning" and testing of the bounce indicator circuit on the large prototype.
- Testing the large prototype under both baseline and more stringent conditions.
- Tests and operation of the 686 bounce fixture.
- Continued investigation of abrasive recycling.

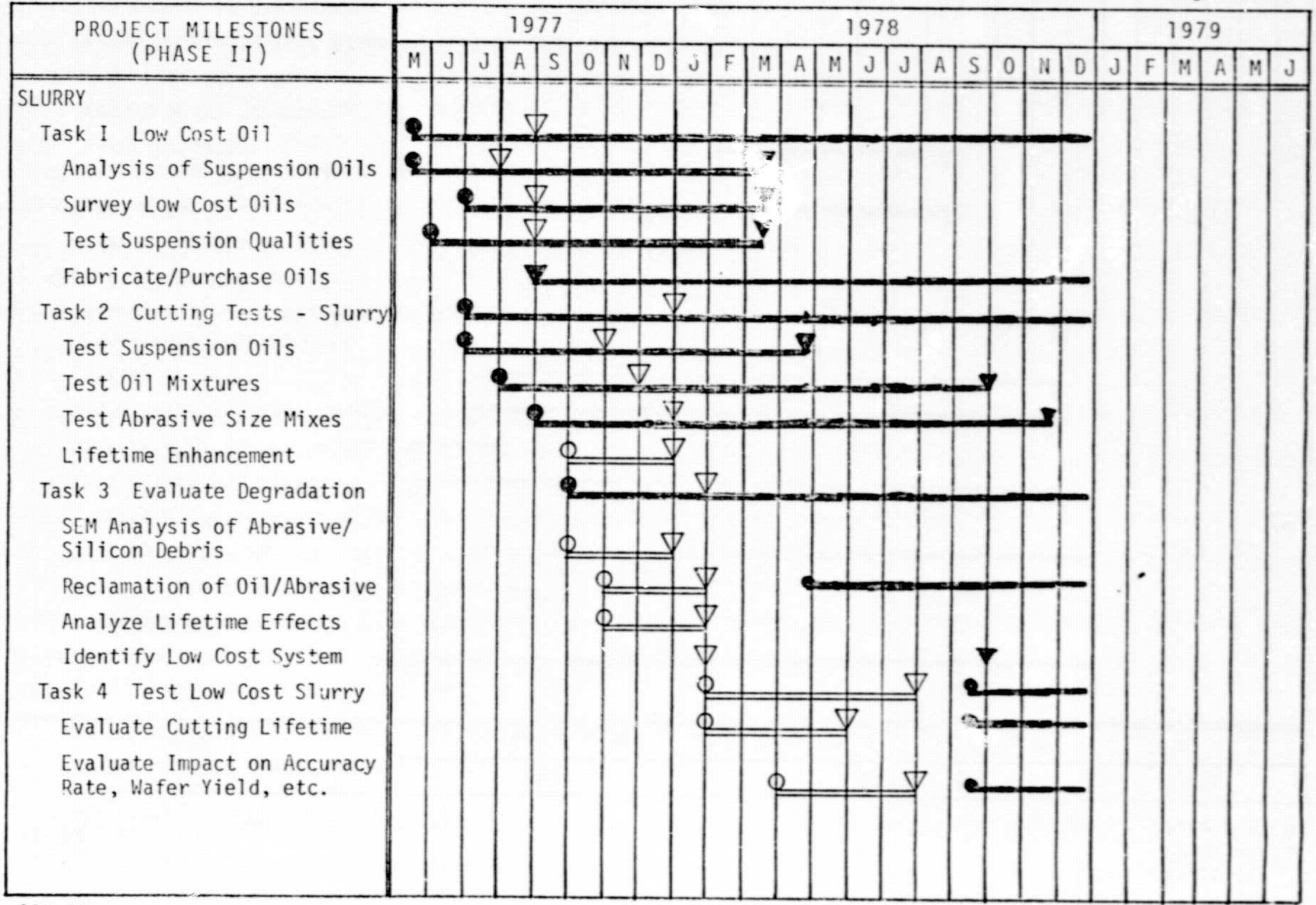
SLICING TEST SUMMARY

PARAMETER	TEST	2-3-28	2-7-05		
Material		Si	Si		
Size	(mm)	100 dia	100 dia		
Area/Slice	(cm^2)	78.5	78.5		
Blade Thickness	(mm)	0.15	0.15		
Spacer Thickness	(mm)	0.36	0.36		
Blade Height	(mm)	6.35	6.35		
Number of Blades		150	975		
Load	(gram/blade)	85	85		
Sliding Speed	(cm/sec)	58.16	- -		
Abrasive	(type/grit size)	SiC/#600	SiC/#600		
Oil Volume	(liters)	7.6	37.9		
Mix	(kg/liter)	0.48	0.36		
Slice Thickness	(mm)	0.278	0.285		
Kerf Width	(mm)	0.230	0.224		
Abrasive Kerf Loss	(mm)	0.080	0.074		
Cutting Time	(hours)	38.33	41.58		
Efficiency	(full test)	0.954			
	(typical)	1.293			
	(maximum)	1.686			
Abrasion Rate (cm^3/hr/bl)	(full test)	0.047	0.042		
	(typical)	0.064			
	(maximum)	0.083			
Productivity (cm^2/hr/bl)	(full test)	2.049	1.889		
	(typical)	2.784			
	(maximum)	3.611			
Yield		66%	31%		
Slice Taper	(mm)	0.087	0.105		
Slice Bow	(mm)	0.099	0.162		
Abrasive Utilization	(cm^3/kg)	74.23	125.44		
Oil Utilization	(cm^3/liter)	35.63	45.16		
Blade Wear Ratio	(cm^3/cm^3)	0.042	- -		

MAN-HOURS AND COSTS (PHASE II)

During the reporting period of October 28, 1978 to December 29, 1978, total man-hours were 706.5 hours and total costs were $29,458. Previous expenditures were 13192.7 hours and $588,030. As of December 29, 1978, total program man-hours were 13899.2 hours and total program costs were $617,488.

Varian Associates/Lexington Vacuum Division
JPL Contract 954374
Starting Date: 1/9/76 (I) 5/19/77 (II)



SCH 6/15/77
Updated 1/20/79

SLICING OF SILICON INTO SHEET MATERIAL

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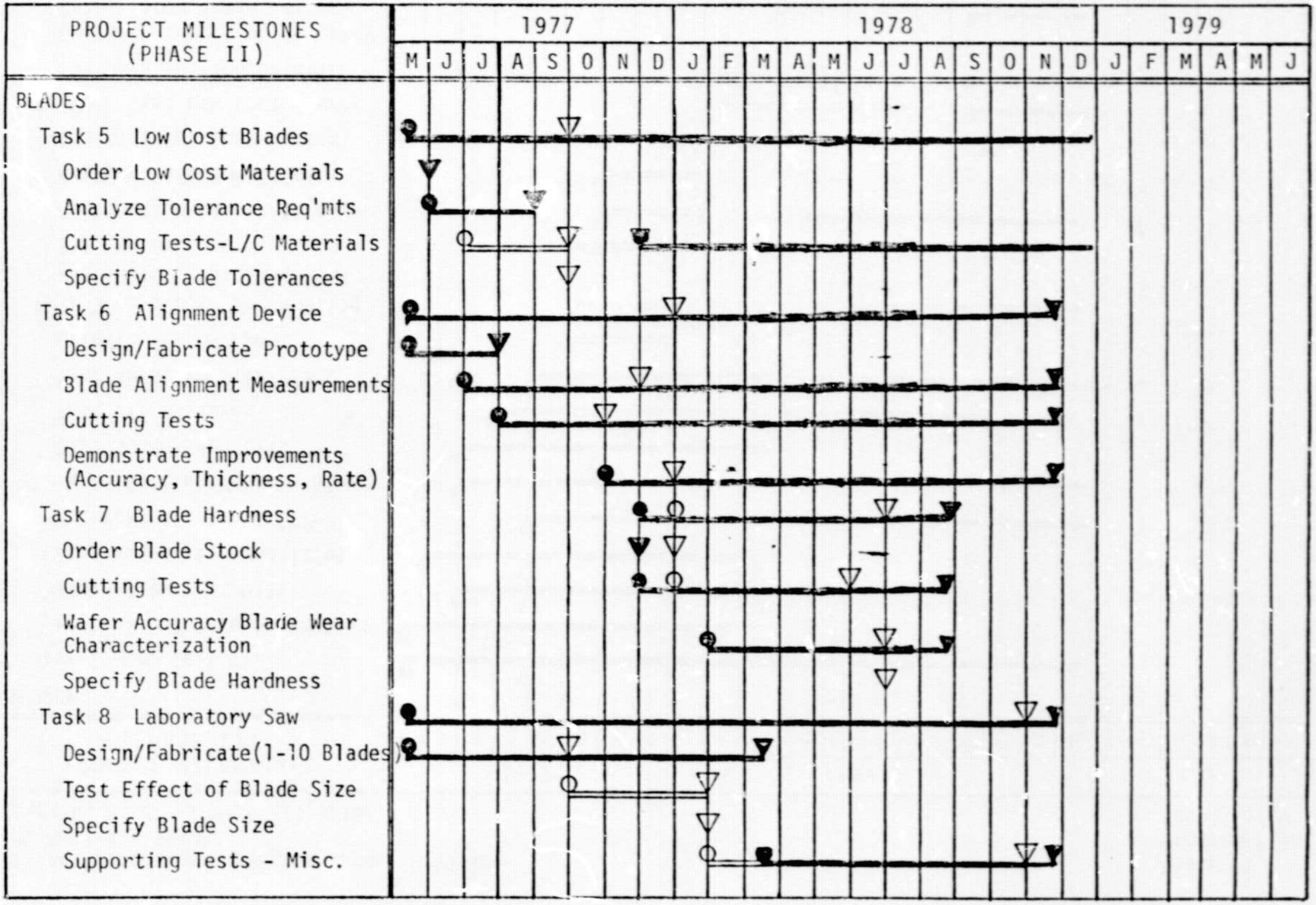
Starting Date: 1/9/76 (I) 5/19/77 (II)

Phase II
Program Plan



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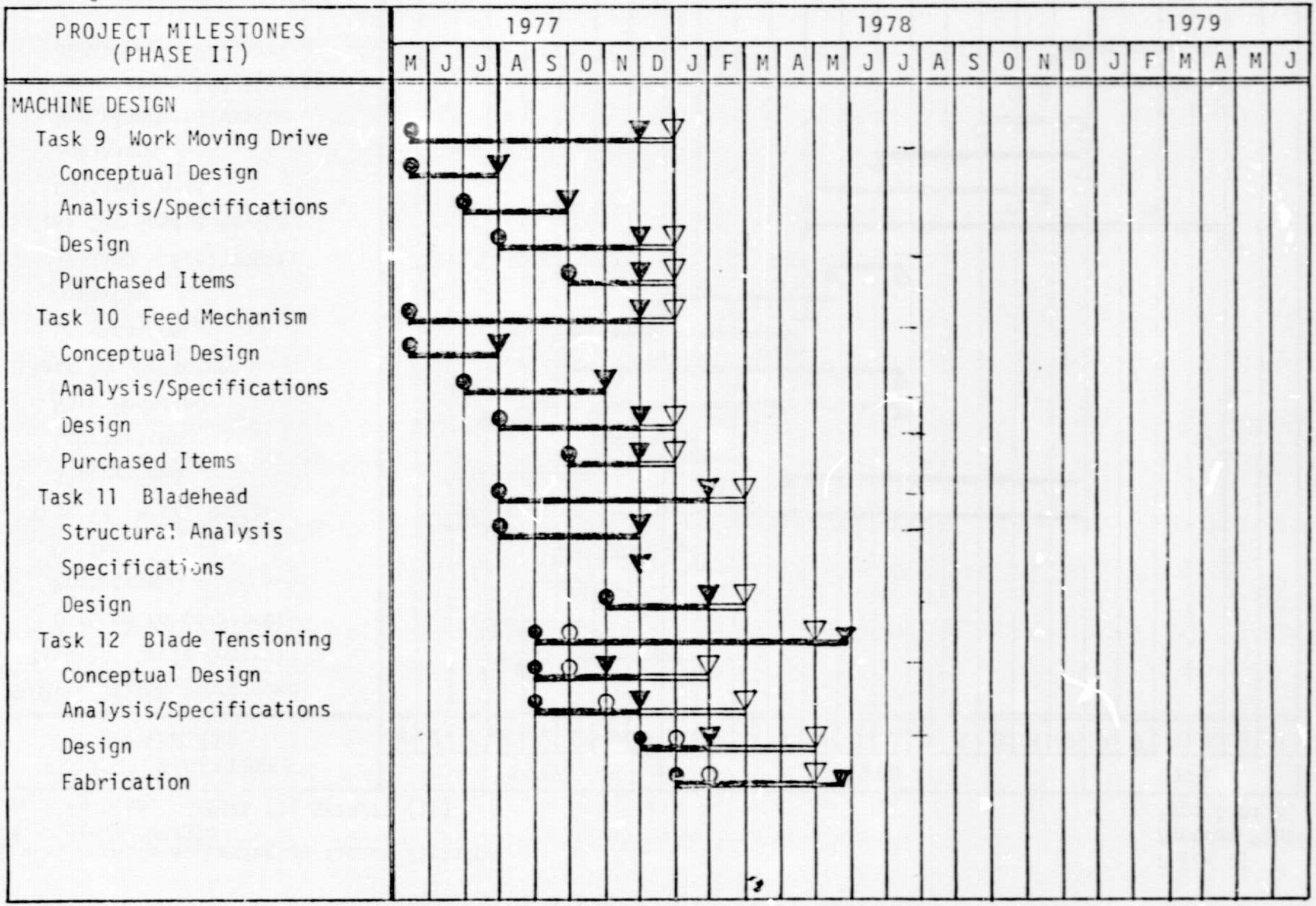

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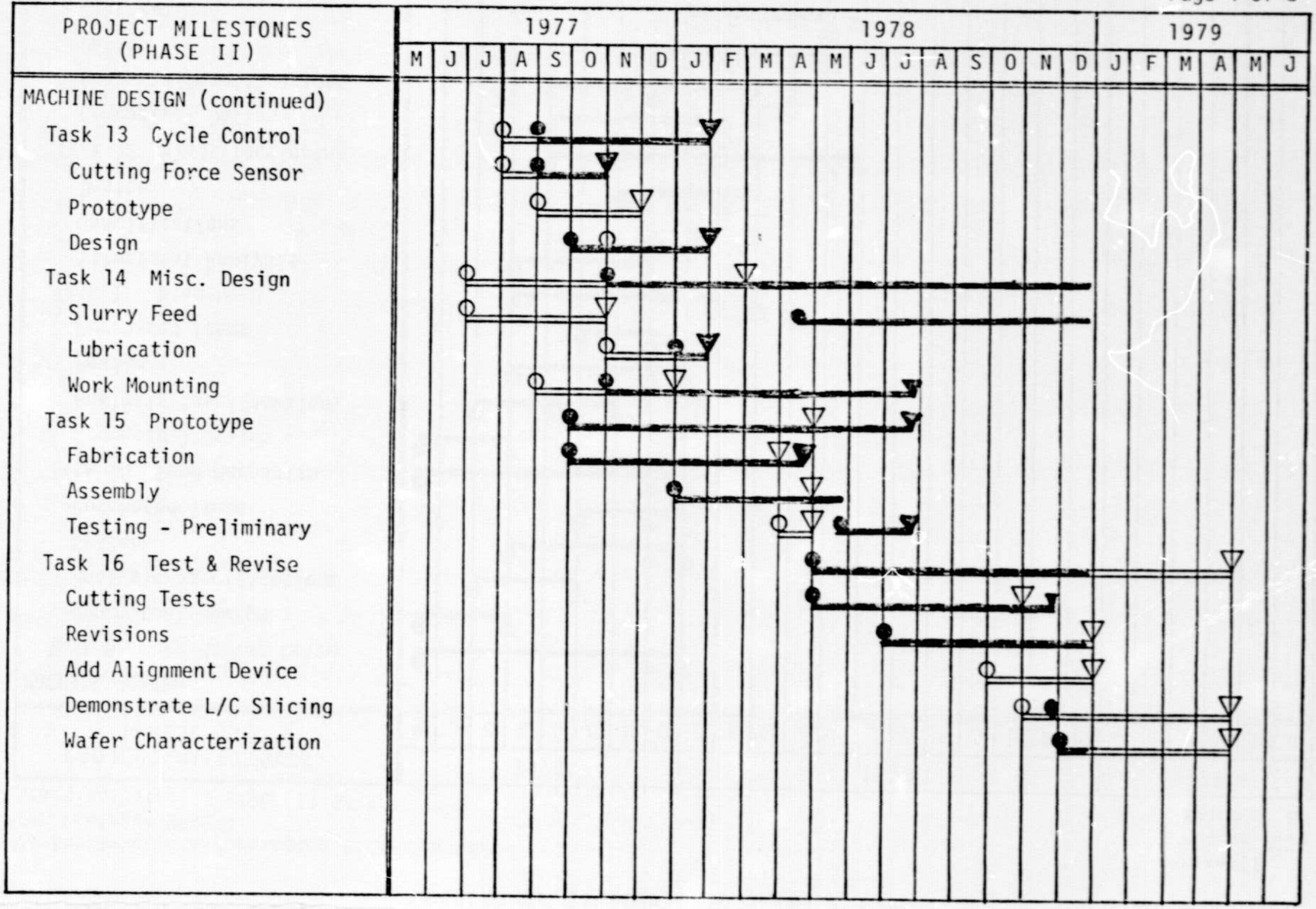

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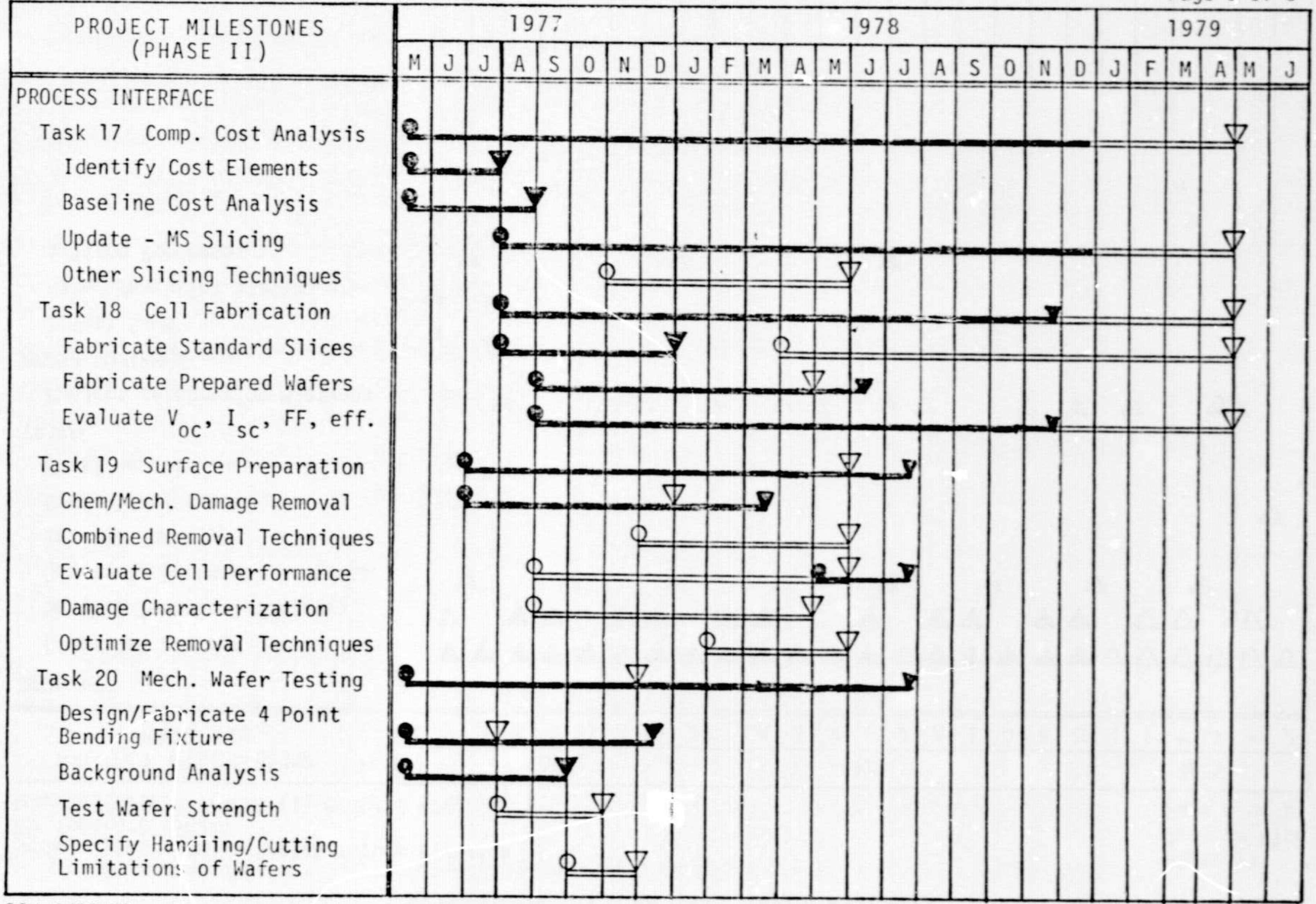

SCH 6/15/77
Updated 1/20/79

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Starting Date: 1/9/76 (I) 5/19/77 (II)

PROJECT MILESTONES (PHASE II)	1977								1978												1979					
	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
REPORTS																										
Financial Package		▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▽	▽	▽	▽	▽	▽
Monthly Technical Progress		▼		▼	▼		▼	▼		▼	▼		▼	▼		▼	▼		▼	▼		▽	▽		▽	
Quarterly Technical Progress		▼			▼			▼			▼			▼			▼			▼			▽			
Interim Summary																										
Draft Final Report																									▽	
Final Report																										▽
TRAVEL																										
Project Integration Meetings			▼			▽	▼		▽		▼	▽		▼	▽			▽		▼	▽			▼▽		
MAJOR EQUIPMENT																										
2 Test Saws	▼																									
Wafer Measuring Station	▼																									
Silicon Purchases		▼						▼						▼												

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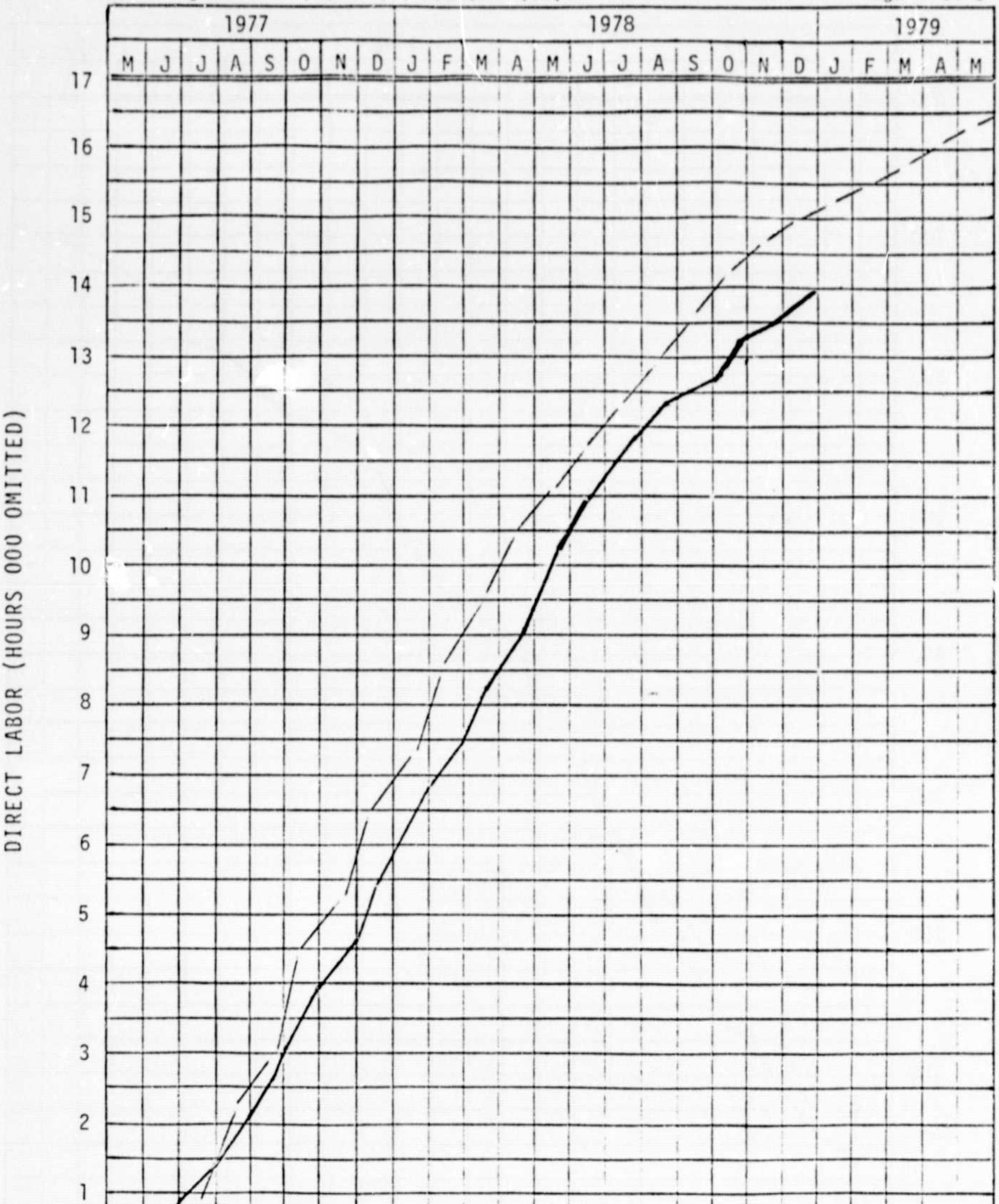

SCH 6/14/77
Updated 1/20/79

Total Hours: 16,435
Hours to Date: 13,899.2

PROGRAM LABOR SUMMARY

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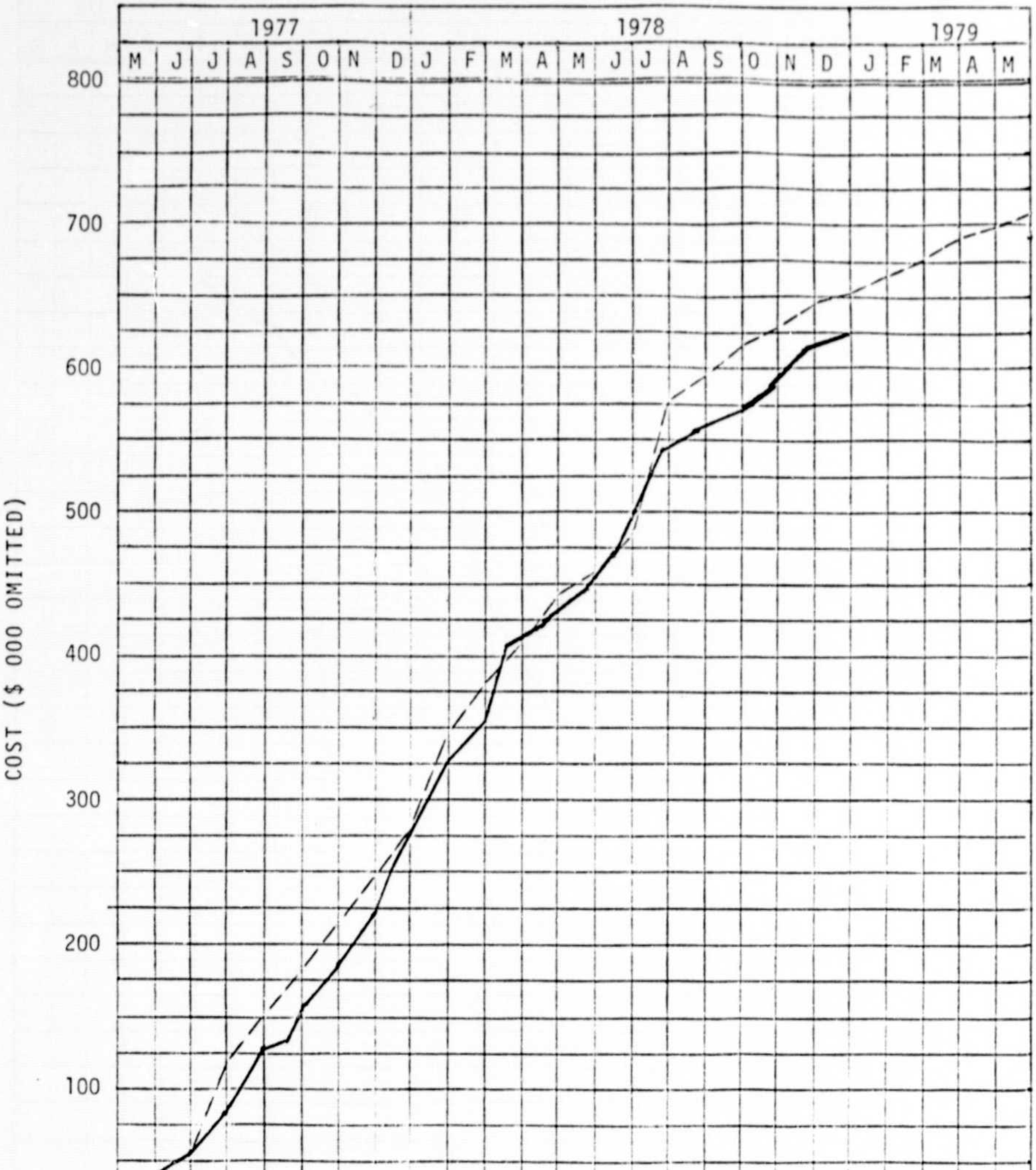

SCH 6/14/77
Updated 1/20/79

Total Cost: $708,210
Incurred Cost: $617,488

Planned -------
Incurred ———

PROGRAM COST SUMMARY