The decision, in 1962, to design the AGC using integrated circuit logic devices was critical to Apollo Computer’s success and a key moment in the history of computing. Eldon Hall's *Journey to the Moon* recounts this decision process.

Following are copies of integrated circuit purchase orders for components required in the evaluation processes and the view graphs used to report the evaluation’s conclusions to the NASA Program Office.

1. The evaluation process included procuring ICs from multiple vendors. Listed are copies of the most significant purchase orders placed by MIT/IL in 1962 and early 1963. These ICs were used to do extensive electrical evaluations which included building the computer pictured in Fig. 49 of *Journey to the Moon*. This work was under the direction of Dave Hanley as a parallel effort with the main line AGC design under the direction of Alonso and Hopkins using core-transistor logic.

2. The collection of view graphs summarizes the information presented to Mr. Charles W. Frick, NASA JSC Apollo Program Manager, in Nov. 1962. The presentation reported on the Lab's efforts to evaluate integrated circuits and the conclusions drawn concerning program impact of a proposed change in the AGC logic design from the core-transistor logic to integrated circuit logic. The requested change followed the presentation in a letter to the Mr. Frick from Dr Draper.
This is the first integrated circuit purchase order for the Apollo Program by MIT/IL. Delivery was just a few days. There were a few earlier orders including the first by MIT/IL to Texas Instruments in 1959 for 64 ICs at $1000 each. That TI order was not delivered until late 1962.
The third order placed with Fairchild. All were delivered in just a few days. It was apparent that Fairchild had these quantities in stock.
The previous orders were for Fairchild's commercial grade devices. Apollo production procurements would require a detailed specification. In this order the mechanical configuration of the gate element is specified and the electrical characteristics remain the same as the commercial grade device. Deliveries were on schedule.
At this point in time larger quantities were needed to continue design and construction of the IC version Apollo Guidance Computer. As required, delivery time was just a few days.
Note: On time delivery and a significant price reduction.
Development of additional sources of supply started early in 1962. Above is the PO for the first significant order from an alternate source. Devices were delivered late.
Motorola delivered late and did not develop into a satisfactory source of supply.
Based upon the satisfactory evaluation of the devices delivered per Purchase Order placed in Sept 1962, # IL 127194 above, this order was placed. The order was canceled in Nov. 1963 for failure to deliver. Texas Instruments continued working on the project and became a significant source of supply in about one year.
The first order to Transitron resulted in satisfactory devices delivered on time.
PURCHASE ORDER

Massachusetts Institute of Technology
Cambridge, Massachusetts

Date Mailed: April 11, 1963

Account Number: 55-191-35-23

To: Fairchild Semiconductor Corporation
33 North Road
Bedford, Massachusetts

ATTN: Mr. Bruce Gore

Account Manager: XXXXXXXXXXX

75 Cambridge Parkway

Date Required: APR 13

DELIVERY:

1. 3000 logic elements, Nor gate - NASA Drawing 1066771
   Rev. 1 in TO-5 package
   $15.00 each
   45,000.00

   SPECs:
   2. Exception: size TO-5.
   3. DELIVERY:
      1000 units - May 3, 1963.
      Release - on or before 6/3/63.

This order is based on your quotation No. 77-375A.

PRICE CERTIFICATION:

Seller certifies that prices appearing in this quote are not in excess of those charged to any other customer for like items in similar quantities under similar conditions. The reference to any other customer refers to agencies of the United States Government and commercial customers.

The attached provisions relating to interpretation of records, renegotiation and non-discrimination are hereby made a part of this order.

Apply Priority - 1A-1C
Certified Order - 1A-1C
Date Req. - APR 13
Govt. Contract - 1A-1C

NOTE: FOB shipping charges added to total

Yoc-Hall-Kent-Allen

45,000.00

APR 15 1963
Transitron became the first alternate source that delivered significant quantities on time. Also note, the specification # 1006771 included quality control requirements that were waived for these devices. Fast delivery was a priority at this time.
This order was for evaluation units. Delivery was late. Westinghouse did develop into a source of supply.
In November 1962 the MIT/IL prepared the following view graphs for a presentation to Charles W. Frick, NASA JSC Apollo Program Manager. The presentation was a report on the Lab's efforts to evaluate integrated circuits and the program impact of a proposed change in the AGC logic design from the core-transistor logic to integrated circuit logic.

This first view graph lists the conclusions of the effort. The following view graphs expands on each point.
Reliability was a major issue for the Apollo Guidance Computer and all aspects were considered in the evaluation of the proposed integrated circuit design change. Standardization on the single logic component would realize many advantages during the computer's assembly and test as indicated in this view graph. Standardization would also provide benefits for the semiconductor industry but, the study could not evaluate many of the potential risks associated with such an immature semiconductor component. An intensified effort would be necessary to provide the necessary assurance that integrated circuits would realize the reliability required for the Apollo application.

Maintaining a source of supply of quality integrated circuits could be difficult over the production life of the Apollo Computer. The semiconductor industry was dedicated to advancing the "state of the art" and to accomplish this goal it was plagued with process changes, inadvertent and intentional. Such changes contributed to uncertainties in a semiconductor product's functional stability, quality, reliability and production life. Considering the critical reliability and production life time requirements of the AGC in the Apollo System, an approach to IC procurement had to be developed which would insure a supply of quality components.
REDUCED COST

TOTAL COST

COMPONENT

1. Cost Trend (chart)
2. Competitive Sources (correspondence)
3. Volume Break Point (standard business)

FABRICATION

1. Simpler Assy & Test (chart)
2. Reduce Scope of Q.A.
3. Reduce Training & Documentation
   for: Fabrication, Inspection, Assembly, Test
4. Fewer Jigs, Fixtures & Test Equipment
This view graph portrays the IC cost reduction realized during the evaluation procurements.
Integrated circuits introduced major technology improvements in the methods to interconnect electronic components and reduced the labor required during fabrication. Electronic components in an IC are interconnected automatically on the surface of the semiconductor chip. Interconnecting the large numbers of individual electronic components in conventional computer logic circuits such as the core-transistor logic planned for the AGC was labor intensive.

Next multilayer printed circuit boards which were invented in 1959, became commercially available in the early 1960s. Printed boards would allow the interconnections between ICs to be automated. To maximize the advantages of printed board technology, ICs had to be packaged in a flat pack configuration versus the multileaded transistor type package (TO-47) that Fairchild supplied to MIT in the previous orders. This improvement became available when Fairchild introduced a dual NOR gate in a flat pack configuration in 1963. The dual gate and multilayer printed boards became available just in time for the second generation AGC which would be required for the Lunar Landing Module.
**IMPROVED MECHANICAL DESIGN**

<table>
<thead>
<tr>
<th>SIZE</th>
<th>STD. COMP.</th>
<th>MICROLOGIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (in)</td>
<td>24.0</td>
<td>25.625</td>
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<tr>
<td>Width (in)</td>
<td>19.2</td>
<td>20.0</td>
</tr>
<tr>
<td>Depth (in)</td>
<td>7.5</td>
<td>4.4</td>
</tr>
<tr>
<td>Volume (cu in)</td>
<td>3456.0</td>
<td>2136.0</td>
</tr>
</tbody>
</table>

**WEIGHT (lb)**

<table>
<thead>
<tr>
<th></th>
<th>STD. COMP.</th>
<th>MICROLOGIC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100.0</td>
<td>58.0</td>
</tr>
</tbody>
</table>

**THERMAL IMPROVEMENT:**

- Better thermal interface with Spacecraft (Connector)
- Permits Spacecraft coldplate integrity

**Simplifications**

- Front vs. Top Replacement
- Flexible Cable Eliminated
- Tracks, Rails, & Extractor Tool Eliminated

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M.I.T. INSTRUMENTATION LABORATORY

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11/62
<table>
<thead>
<tr>
<th>BLOCK NAME</th>
<th>UNIQUE SUBASSEMBLIES (STICKS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROPE</td>
<td></td>
</tr>
<tr>
<td>ROPE DRIVER</td>
<td></td>
</tr>
<tr>
<td>ERASABLE MEMORY</td>
<td></td>
</tr>
<tr>
<td>POWER SUPPLY</td>
<td></td>
</tr>
<tr>
<td>CLOCK SCALER</td>
<td></td>
</tr>
<tr>
<td>BIT BLOCK</td>
<td></td>
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<tr>
<td>SERVICE BLOCK</td>
<td></td>
</tr>
<tr>
<td>SENSE BLOCK</td>
<td></td>
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<tr>
<td>PRIORITY</td>
<td></td>
</tr>
<tr>
<td>SEQUENCE GEN</td>
<td></td>
</tr>
<tr>
<td>INTERFACE</td>
<td></td>
</tr>
<tr>
<td>SPL CONTROL</td>
<td></td>
</tr>
</tbody>
</table>

**TOTALS**

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**M.I.T. INSTRUMENTATION LABORATORY**

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**11/62**
An increased computational capacity would be possible in a smaller volume and became necessary when the functional requirements of the Lunar Landing Module were developed during the NASA JSC sponsored Implementation Meetings in 1964.

<table>
<thead>
<tr>
<th>COMPUTATIONAL TIMES, µ SEC</th>
<th>Std. Parts</th>
<th>Micrologic</th>
</tr>
</thead>
<tbody>
<tr>
<td>MULTIPLICATION</td>
<td>640</td>
<td>90</td>
</tr>
<tr>
<td>TRANSFER CONTROL</td>
<td>40</td>
<td>11</td>
</tr>
<tr>
<td>ADDITION</td>
<td>40</td>
<td>22</td>
</tr>
<tr>
<td>COUNTER INCREMENT</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>BRANCH LOGIC</td>
<td>80</td>
<td>22</td>
</tr>
<tr>
<td>ALL OTHERS</td>
<td>40</td>
<td>22</td>
</tr>
</tbody>
</table>

| SPEED INDEX               | 1          | 2 1/2 +    |

| POWER (FULL SPEED)        | 45W        | 80W (NOW)  |
|                          | 40W (1964) |            |

| INTERFACE SPECIFICATION   | Only feasible interface inspection at higher Assy |
|                          | Complete interface inspection possible at lowest replaceable assembly |

11/62
SIMPLIFIED LOGISTICS

1. REDUCED COST OF UNIT SPARE
   Spare at lower assembly level. (stick not block)
   Throwaway of less expensive unit.

2. REPLACEMENT UNIT HAS MULTIPLE USE.

3. REDUCED COSTS OF SPARES INVENTORY

   COMPUTER SPARE
   
   Std. Parts
   22 Blocks
   Micrologic
   approx. 80 Sticks (of which 49 are unique)

4. SIMPLIFIED TRAINING OF ASTRONAUT & FIELD
   SERVICE PERSONNEL
   (Simpler Spares Replacement)
The development plan presented in this slide explains how the redesign of the logic section of the AGC could be phased into the hardware design with minimum disruption to production schedules.

Following the presentation, a letter was sent from Dr. Draper to Mr. Frick formalizing the requested design change. NASA responded in Dec. 1962 with the approval. Copies of both letters are in the Appendix of "Journey To The Moon".
Opposition developed rapidly. A Raytheon engineer made a worst case analysis and proved that under worst case conditions Micrologic would not function. To prevent such an occurrence the logic gate needed to be carefully specified and logic design ground rules enforced.

Soon after NASA approval, reliability statisticians took over and proved mathematically that the computer's failure rate would be excessive. Then in early 1964, when the second generation, Block II, computer design introduced the dual Micrologic gate in a flat pack configuration, Bellcom engineers raised objections. Their objections were based on the sealing difficulty that the industry was experiencing with the flat pack. NASA JSC performed an independent investigation and found that most military programs were planning to use the flat pack and that the sealing difficulty was solvable. However, the reliability predictions continued to raise questions about the computer's potential to meet the requirements of lunar missions. It was not until computers in field service were operating for extended periods without failure that the questioning faded away.

Following is a sample of the memoranda and letters that relate to these reliability issues and the actions that NASA took. These are referenced in "Journey To The Moon".

See the AGC-LVDC Comparison Study and the set of Memos.

Eldon C Hall