A COMPARATIVE EVALUATION OF MEDIUM TRANSPORT AIRCRAFT

Prepared By:

U.S. ARMY TRANSPORTATION MATERIEL COMMAND
FOREWORD

In anticipation of a formal statement of a requirement, by the Army, for an aircraft in the medium transport class, two aircraft manufacturers have submitted, unsolicited proposals.

In addition to the proposals submitted by De Havilland and Fairchild, interest has been evidenced by other aircraft manufacturers.

Since there has not been a formal solicitation for proposals, the Army has not established a standardized format for the presentation of aircraft cost and performance data. The data submitted by De Havilland and Fairchild, therefore, are not directly comparable. This circumstance has resulted not only in the problem of reconciliation of data but has brought into focus, the need for an accepted formula for comparing economic tradeoffs between cost and performance.

This analysis, in staff study format, attempts to reconcile the data as submitted by the two manufacturers and introduces a proposed technical basis for economic comparison. The data submitted by the contractors has for the most part been made comparable by the evaluation method but has been supplemented by judgement where necessary.

In order that this evaluation may provide as many comparative indices as possible, discussion will be sub-divided into parts dealing with specific performance or cost areas.

Lengthy detailed discussion on specific areas will be shown on appropriate charts and/or tables and be incorporated as study annexes. Within the body of the study proper, a summary of the detailed discussion and/or the most repre-
A note of caution is here added. In order that as many as possible of the alternate courses of action may be explored, various aircraft have been compared employing various alternate engine installations to the extent available data would permit. Considerable risk, therefore, exists that attention is drawn to an evaluation of the relative merit of engines. The question of "best engine" is not intended to be a part of the problem of comparison of the referenced aircraft but is included to provide a basis for multiple comparative indices.
To provide the Department of the Army with a comparative evaluation of proposed aircraft in the medium transport class.
II ASSUMPTIONS

It is assumed that:

a. The Department of the Army will desire to compare aircraft from as many indices as possible.

b. The Department of the Army will desire to determine and examine the trade-offs between cost and performance.

c. Data submitted by the manufacturers is valid in so far as they commit themselves.
III FACTS BEARING ON THE PROBLEM

a. Aircraft technical proposals are not directly comparable.

b. Army STOL requirements, as stated, do not provide a basis for economic evaluation of possible compromises between cost and performance.

c. Aircraft technical proposals do not evidence a basis for cost merit and performance evaluation of alternate engines.

d. Proposals have not been received from all interested producers having aircraft transport capability there by precluding a completed objective evaluation of relative merit.
IV. DISCUSSION

General - The unsolicited proposal from De Havilland on the Caribou II is proposed to be powered by the General Electric T-64 engine.

The unsolicited proposal from Fairchild on the Friendship has three power options -- the General Electric T-64, the Rolls Royce Dart 8 and the Rolls Royce Dart 12.

The study group determined that the analysis would be extended to the Lycoming T-55 engine in both aircraft and that the Caribou I with the Pratt and Whitney R-2000 engine would be used as the base point for evaluation.

The study group further determined that the Caribou II would be evaluated for performance with the Pratt and Whitney R-2800 engine. The Rolls Royce Dart 12 would be added to the Caribou II.
## DISCUSSION - PART 1

### CARGO VERSATILITY

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DE HAVILLAND</th>
<th>FAIRCHILD</th>
</tr>
</thead>
<tbody>
<tr>
<td>LETTERS</td>
<td>AC-1A</td>
<td>AC-II</td>
</tr>
<tr>
<td>20 + 4 SEATS</td>
<td>24 + 6 SEATS</td>
<td>24 + 4 SEATS</td>
</tr>
<tr>
<td>TROOPS</td>
<td>32</td>
<td>34</td>
</tr>
<tr>
<td>CARGO VOLUME</td>
<td>1085 cu. ft.</td>
<td>1577 cu. ft.</td>
</tr>
<tr>
<td>(2)M274 MULES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>HONEST JOHN ON TRAILER</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>105 MM HOWITZER</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>FUEL SERVICING TRAILER A-1A</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>
**DISCUSSION - PART 1 (A)**

**AIRCRAFT AND ENGINE COMBINATION CONSIDERED**

<table>
<thead>
<tr>
<th>A/C</th>
<th>AC-1A</th>
<th>CARIBOU II</th>
<th>FAIRCHILD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P &amp; W R-2000</td>
<td>P &amp; W R-2000</td>
<td>GE T-64</td>
</tr>
<tr>
<td></td>
<td>LYC T-55</td>
<td>GE T-64</td>
<td>LYC T-55</td>
</tr>
<tr>
<td>POWER</td>
<td>RR DART 8</td>
<td>LYC T-55</td>
<td>RR DART 8</td>
</tr>
<tr>
<td>OPTIONS</td>
<td>RR DART 8</td>
<td>RR DART 12</td>
<td>RR DART 12</td>
</tr>
</tbody>
</table>
**DISCUSSION - PART 2**

"STOL Characteristics"

Detail discussion and performance curves attached as Tab "A".

**Summary**

a. The army has described STOL capability as the ability to clear a 50 foot obstacle in 1000 feet from start and to land over a 50 foot obstacle and stop in 1000 feet.

b. *True STOL capability was not developed by the Caribou I nor is it offered by the Caribou II or any other current proposal.*

c. Proposals offer relative STOL capability only thru compromises to other performance characteristics.

d. Civil transport design requirements provide the same absolute STOL capability if these same compromises are accepted.

e. The basis for economic evaluation of trade-offs between cost and performance is thereby led to the next Part, Part 3 - "Payload and Range Characteristics".
DISCUSSION - PART 3
"Payload and Range Characteristics"

Detail discussion and performance curves attached as Tab "B".

Summary - The following chart entitled "Gross Transport Capability" demonstrates and summarizes the fields of usefulness of these various aircraft configurations compared in more detail in Tab "B".

GROSS TRANSPORT CAPABILITY

If the area under Caribou I curve = 100; Then:

- MK II, T-55 = 160
- MK II, T-64 = 176
- M258 - T-64 = 211
T-64 VS DART RDA 10/RDA 12
6000 FT + 95°F (31.7°C)

(BASICALLY A COMPARISON OF ENGINES)

GROSS WEIGHT
1000

On this chart it will be noticed that the behavior of the Fairchild aircraft in takeoff capability versus gross weight has severely deteriorated. This is a reflection of engine sensitivity to inlet air density which results from a high compression ratio chosen to maximize the fuel economy of the engine. The T-64, although it offers excellent fuel economy, suffers extremely from the efforts and design features necessary for this achievement on hot, humid, or high altitude atmospheric conditions.
DISCUSSION - PART IV

TAKEOFF POWER COMPARISON
5000 FT - STATIC

SHAFT HORSEPOWER (100 HP)

TEMPERATURE (°F)

T55
DART (CIVILIAN VERSION)
DART B (CIVILIAN VERSION)
R 2000
STANDARD DAY
DISCUSSION - PART 6
"R&D Required Relative Design Effort"

Detailed discussion attached as Tab "C".

Summary

DESIGN & DEVELOPMENT STATUS
(% COMPLETION) COMPARISON

<table>
<thead>
<tr>
<th>Component</th>
<th>De Havilland</th>
<th>Fairchild</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing, 38,000 LBS.</td>
<td>5%</td>
<td>98%</td>
</tr>
<tr>
<td>L. Gear, 38,000 LBS.</td>
<td>5%</td>
<td>95%</td>
</tr>
<tr>
<td>Fuselage</td>
<td>15%</td>
<td>80%</td>
</tr>
<tr>
<td>Tail Assy</td>
<td>5</td>
<td>97%</td>
</tr>
<tr>
<td>Flight Test</td>
<td>0</td>
<td>98%*</td>
</tr>
<tr>
<td>Dart Installation</td>
<td>0</td>
<td>100%</td>
</tr>
<tr>
<td>Status (Av of %)</td>
<td>4-1/4%</td>
<td>94-3/4%</td>
</tr>
</tbody>
</table>

*42,000 pound wing in being has civil certification with Dart 8.

N.B. The De Havilland charge (ECP-YAC-1-46) increasing gross weight, 2,500 pounds to 28,500 pounds, was $150,000 non-recurring, with $4,000 per aircraft. This indicates major effort will be required for 9,500 pounds more.

Basic to this situation is the Fairchild possession of actual airplanes very similar to those proposed for the army; and the total paper status of the De Havilland proposed aircraft. In order to support this statement, it is offered that the Fairchild aircraft will utilize existing weights and a wing requiring very minor revisions and that this wing is currently certificated at 38,000 pounds gross weight and is momentarily expected to receive
certification at 42,000 pounds gross weight capability. Fairchild is accordingly rated as 98% complete on this very major design effort. In contrast De Havilland has yet to produce a 38,000 pound wing design. In fact, the De Havilland expectation of minor modification and the continued use of the AC-1 wing jigs and tooling appears extremely optimistic. Attention is invited to the fact that 150,000 dollars engineering costs were incurred together with 4,000 dollars per production aircraft for an increase in gross weight capability for the original 26,000 pound AC-1 wing of only 2500 pounds thereby reaching 28,500 pounds gross weight. It does not appear reasonable, then, that De Havilland can achieve an additional 30% gross weight capability using existing engineering, existing tooling, or existing jigs. It appears further that serious difficulties can be encountered by De Havilland during this program. Similar discussion can be applied to all of the items of the aircraft. In short, De Havilland faces a vastly greater undertaking than does Fairchild and accordingly the risks to the U. S. are far greater in purchasing the Caribou II.
DISCUSSION - PART 7

"R&D Cost"

The following listed costs represent only the skeleton costs as a basis of comparison of the two proposals. Program costs will be covered under the economic analysis part of this discussion.

The De Havilland proposal is for the production of five aircraft, one of which is to be retained at the plant.

The Fairchild proposal is for production of three aircraft due to the already existing FAA certification of the aircraft.

Both proposals were arbitrarily reduced to the common denominator of four aircraft for the purpose of equitable comparison.

<table>
<thead>
<tr>
<th></th>
<th>DE HAVILLAND</th>
<th>FAIRCHILD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROPS @ $25,000 ea.</td>
<td>.25</td>
<td>.20</td>
</tr>
<tr>
<td>T-64 ENGINES @ $200,000</td>
<td>2.00</td>
<td>1.60</td>
</tr>
<tr>
<td>AIRFRAME DESIGN &amp; DEV</td>
<td>6.50</td>
<td>6.94</td>
</tr>
<tr>
<td>SUPPORT (R&amp;D ONLY)</td>
<td>4.01</td>
<td>4.01</td>
</tr>
<tr>
<td>TOTAL RDT&amp;E</td>
<td>12.76</td>
<td>12.75</td>
</tr>
</tbody>
</table>

* Fairchild costs could be reduced ½ if Army test program is curtailed by reason of existing civil data, accepting Fairchild proposal for three instead of four aircraft.
DISCUSSION - PART 8
"Comparison of Delivery Capabilities"

<table>
<thead>
<tr>
<th></th>
<th>DE HAVILLAND</th>
<th>FAIRCHILD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>G N J K</td>
</tr>
<tr>
<td>DEL 1ST ARMY Proto.</td>
<td>37</td>
<td>10 17 15 17</td>
</tr>
<tr>
<td>ARMY Test (Log)</td>
<td>12</td>
<td>6 9 6 9</td>
</tr>
<tr>
<td>ARMY Test (Eng)</td>
<td>6</td>
<td>2 2 2 2</td>
</tr>
<tr>
<td>DEL 1ST PROD (F/GO AH'D)</td>
<td>8</td>
<td>10 14 11 13</td>
</tr>
<tr>
<td>TIME IN MONTHS</td>
<td>57</td>
<td>28 42 34 47</td>
</tr>
</tbody>
</table>

If Army waives testing on Fairchild in view of civil experience data, this becomes:

<table>
<thead>
<tr>
<th></th>
<th>DE HAVILLAND</th>
<th>FAIRCHILD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>G N J K</td>
</tr>
<tr>
<td>DEL 1ST Proto (A/C #2)</td>
<td>37</td>
<td>10 17 15 17</td>
</tr>
<tr>
<td>ARMY Test (Log &amp; Eng)</td>
<td>12</td>
<td>2 3 3</td>
</tr>
<tr>
<td>DEL 1ST PROD (FR GO-AH'D)</td>
<td>8</td>
<td>10 14 11 13</td>
</tr>
<tr>
<td>TOTAL TIME, MOS.</td>
<td>57</td>
<td>22 34 29 30</td>
</tr>
</tbody>
</table>

MINIMUM SAVING, 258N = 15 MOS.

MAXIMUM SAVING, 258J = 28 MOS.

DISCUSSION - PART 9, "ECONOMIC EVALUATION GENERAL"

This evaluation is based upon the framework of the mission requirement and military characteristics of the aircraft and pertinent, comparative economic variables. Cost considerations in the FEMO (including R&D) and maintenance areas (echelons 1 through 5) are evaluated in relation to the operating performance data at various mission requirements to see what expenditures achieve in the form of work accomplishment. This enables a logic of choice of those cost alternative which provide the most in effective value.
In determining costs of operating the aircraft involved in this analysis, the following bases have been applied:

FLYING HOUR COST BASIS

Cost per flying hour for aircraft includes:

a. PEMA (including R&D) costs per flying hour

Maintenance costs per flying hour at echelons 1, 2, 3, 4, 5
Equals total costs per flying hour

b. PEMA costs = \( \frac{100\% \text{ total program} - 15\% \text{ residual value}}{10 \text{ years}} \) = 8.5% amortization per year

SUPPORT FUNDING REQUIREMENTS (PARTS AND TOOLING)

Support funding requirements for parts and tooling is based upon allowable Program Percentages and past experience with the Caribou I (R2000-13). Included are electronics and deferred amortization of previously indicated R&D expenses. In other areas of analysis, allowance is made for residual value remaining in PEMA expenditures after a certain timeframe.
DISCUSSION - PART 9A

BLOCK TON NAUTICAL MILES PER AIRCRAFT PER YEAR

The block ton nautical miles per aircraft per year has been computed for 100, 250 and 400 nautical mile ranges and represents the work accomplishment which can be achieved by the various aircraft at these ranges. The block ton nautical miles per aircraft per year are based upon the following formulae:

Block speeds in nautical miles/hour X flying hours per aircraft per year X payload in tons.

The average block ton nautical miles per aircraft for these three ranges is shown along with the percentage of work accomplishment, using the Caribou I (R2000-13) as a base of 100%.

CHART 2-A

BLOCK TON NAUTICAL MILES PER A/C PER YEAR

(BLOCK SPEEDS IN N. MI./HR. X F.H. PER A/C PER YEAR X PAYLOAD IN TONS)

(IN THOUSANDS)

<table>
<thead>
<tr>
<th></th>
<th>100 N. MI. RADIUS</th>
<th>250 N. MI. RADIUS</th>
<th>400 N. MI. RADIUS</th>
<th>AVERAGE WORK ACCOMPLISHMENT FOR 100, 250, 400 N. MI. RADIUS</th>
<th>% AVERAGE WORK ACCOMPLISHMENT FOR 100, 250, 400 N. MI. RADIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARIBOU I (R2000-13)</td>
<td>135</td>
<td>204</td>
<td>181</td>
<td>173</td>
<td>100.0%</td>
</tr>
<tr>
<td>CARIBOU I (DART 8)</td>
<td>163</td>
<td>369</td>
<td>286</td>
<td>273</td>
<td>157.5%</td>
</tr>
<tr>
<td>CARIBOU II (T-55)</td>
<td>296</td>
<td>363</td>
<td>282</td>
<td>313</td>
<td>180.9%</td>
</tr>
<tr>
<td>CARIBOU II (T-64-4)</td>
<td>309</td>
<td>449</td>
<td>365</td>
<td>374</td>
<td>215.9%</td>
</tr>
<tr>
<td>M 258-K (T-64-8)</td>
<td>322</td>
<td>584</td>
<td>525</td>
<td>477</td>
<td>275.3%</td>
</tr>
<tr>
<td>M 258-J (DART 8)</td>
<td>292</td>
<td>615</td>
<td>546</td>
<td>485</td>
<td>279.7%</td>
</tr>
<tr>
<td>M 258-N (DART 12)</td>
<td>322</td>
<td>574</td>
<td>494</td>
<td>463</td>
<td>267.2%</td>
</tr>
<tr>
<td>CARIBOU II (DART 8)</td>
<td>294</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 258 (T-55)</td>
<td>319</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DISCUSSION - PART 9A
"BLOCK TON NAUTICAL MILE"

The formula used in arriving at these total costs per block ton nautical mile are based upon the following formula:

\[
\frac{\text{Total costs per aircraft per year}}{\text{Block ton nautical miles per aircraft per year}}
\]

These total costs per block ton nautical mile are calculated separately on the basis of 100, 250 and 400 nautical mile ranges as shown by the following tabular data in Chart 2C and by the bar chart date in Chart 2B.

It may be noted that the aircraft with greater state of the art development in the form of one or more of the following reflect the more favorable cost picture:

1) Longer maximum allowable operating times, or
2) Greater payloads, or
3) Higher block speeds, or
4) Lower acquisition costs and/or lower maintenance costs.

CHART 2C

<table>
<thead>
<tr>
<th>TOTAL (FEMA &amp; MAINTENANCE) COSTS PER BLOCK TON NAUTICAL MILE</th>
<th>100 N. MI. RADIUS</th>
<th>250 N. MI. RADIUS</th>
<th>400 N. MI. RADIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARIBOU I (R2000-13)</td>
<td>.60¢</td>
<td>.39¢</td>
<td>.44¢</td>
</tr>
<tr>
<td>CARIBOU I (DART 8)</td>
<td>.62</td>
<td>.27</td>
<td>.35</td>
</tr>
<tr>
<td>CARIBOU II (T-55)</td>
<td>.48</td>
<td>.39</td>
<td>.50</td>
</tr>
<tr>
<td>CARIBOU II (T-64-4)</td>
<td>.64</td>
<td>.44</td>
<td>.54</td>
</tr>
<tr>
<td>M 258-K (T-64-8)</td>
<td>.63</td>
<td>.35</td>
<td>.39</td>
</tr>
<tr>
<td>M 258-J (DART 8)</td>
<td>.41</td>
<td>.19</td>
<td>.22</td>
</tr>
<tr>
<td>M 258-N (DART 12)</td>
<td>.39</td>
<td>.22</td>
<td>.26</td>
</tr>
</tbody>
</table>
The format and methods used are the same as those contained in the preceding charts on total costs per block ton nautical mile except that just the maintenance costs at echelons 1, 2, 3, 4, and 5 are computed with the PEMA (including R&D) costs excluded.

It may again be observed that the aircraft evidencing greater development in the form of reduced procurement and/or maintenance costs in relation to their operating performance characteristics or work accomplishment achieved again present the better cost picture.

**MAINTENANCE COSTS PER BLOCK TON NAUTICAL MILE**

**PEACETIME BASIS - FY 70**

(MAINTENANCE COSTS PER A/C PER YEAR - BY BLOCK TON N. MI./YR.)

(IN DOLLARS AND CENTS)

<table>
<thead>
<tr>
<th></th>
<th>100 N. MI. RADIUS</th>
<th>250 N. MI. RADIUS</th>
<th>400 N. MI. RADIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARIBOU I (R2000-13)</td>
<td>.12¢</td>
<td>.08¢</td>
<td>.09¢</td>
</tr>
<tr>
<td>CARIBOU I (DART 8)</td>
<td>.08¢</td>
<td>.06¢</td>
<td>.10¢</td>
</tr>
<tr>
<td>CARIBOU II (T-55)</td>
<td>.09¢</td>
<td>.07¢</td>
<td>.09¢</td>
</tr>
<tr>
<td>CARIBOU II (T-64-4)</td>
<td>.19¢</td>
<td>.13¢</td>
<td>.16¢</td>
</tr>
<tr>
<td>M258-K (7-64-8)</td>
<td>.18¢</td>
<td>.10¢</td>
<td>.11¢</td>
</tr>
<tr>
<td>M258-J (DART 8)</td>
<td>.05¢</td>
<td>.02¢</td>
<td>.03¢</td>
</tr>
<tr>
<td>M258-N (DART 12)</td>
<td>.05¢</td>
<td>.03¢</td>
<td>.03¢</td>
</tr>
</tbody>
</table>
This cost per flying hour data for the various aircraft contained in this chart is based upon the methods of analysis enumerated in Part 9a.

**Costs per Flying Hour (FY 70 & FY 65)**

<table>
<thead>
<tr>
<th></th>
<th>CARIBOU</th>
<th>CARIBOU</th>
<th>M258</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>R2000-13</td>
<td>Dart 8</td>
<td>T-64</td>
<td>T-55</td>
</tr>
<tr>
<td>1 PEM A C.P.F.H. = FY 70</td>
<td>$150</td>
<td>$207</td>
<td>$328</td>
</tr>
<tr>
<td>MAINTENANCE C.P.F.H. = FY 70</td>
<td>$40</td>
<td>$32</td>
<td>$137</td>
</tr>
<tr>
<td>TOTAL C.P.F.H. = FY 70</td>
<td>$190</td>
<td>$239</td>
<td>$465</td>
</tr>
<tr>
<td>1 PEM A C.P.F.H. = FY 65</td>
<td>$150</td>
<td>$207</td>
<td>$328</td>
</tr>
<tr>
<td>MAINTENANCE C.P.F.H. = FY 65</td>
<td>$51</td>
<td>$87</td>
<td>$1,370</td>
</tr>
<tr>
<td>TOTAL C.P.F.H. = FY 65</td>
<td>$201</td>
<td>$294</td>
<td>$1,698</td>
</tr>
</tbody>
</table>

1 INCLUDES R. & D.
This chart shows separate cost stratifications between the portions which are R&D and those which are PEMA.

Note that DeHavelland charges for 5 aircraft of which Department of the Army gets title to 4 aircraft; whereas, Fairchild charges for 4 aircraft and Department of the Army title to all of them. Support costs for engine sets, repair parts and tools reflect support costs only for 4 aircraft apiece.

<table>
<thead>
<tr>
<th>RESEARCH AND DEVELOPMENT AND PRODUCT IMPROVEMENT COSTS</th>
<th>(IN MILLIONS OF DOLLARS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CARIBOU</td>
</tr>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>R2000-13 Dart 8</td>
</tr>
<tr>
<td>PROPELLER SYSTEMS</td>
<td>-</td>
</tr>
<tr>
<td>ENGINE SETS</td>
<td>-</td>
</tr>
<tr>
<td>PROTOTYPE AIRFRAME COST:</td>
<td>-</td>
</tr>
<tr>
<td>( \frac{4}{5} ) to US Army, 1 to DeHavelland, ( \frac{1}{5} ) to Fairchild</td>
<td></td>
</tr>
<tr>
<td>SUPPORT COSTS FOR 3 ENGINE SETS, REPAIR PARTS, TOOLS</td>
<td>-</td>
</tr>
<tr>
<td>TOTAL R. &amp; D.</td>
<td>-</td>
</tr>
<tr>
<td>E.C.P. AIRFRAME - FY 64 - 65 (PEMA)</td>
<td>.24</td>
</tr>
<tr>
<td>DATA TO PROVISION (DRAWINGS, ET( _ )) PEMA</td>
<td>.13</td>
</tr>
<tr>
<td>5 PARTS MANUAL (PEMA)</td>
<td>.36</td>
</tr>
<tr>
<td>SUB-TOTAL</td>
<td>.73</td>
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<tr>
<td>AIRFRAME PRODUCT IMPROVEMENT FY 66 - 70 (PEMA)</td>
<td>.30</td>
</tr>
<tr>
<td>ENGINE PRODUCT IMPROVEMENT FY 64 - 70 (PEMA)</td>
<td>-</td>
</tr>
<tr>
<td>TOTAL APPLICABLE, R. &amp; D. AND PRODUCT IMPROVEMENT (FY 64 - FY 70)</td>
<td>1.03</td>
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</tbody>
</table>
In the break-even point analysis it is desired to show how many follow-on aircraft must be delivered in order to justify an investment in research and development costs in the form of prototypes and other necessary related research and development and product improvement costs.

An arbitrary goal is established to get back $2.00 of aircraft for every $1.00 of launching costs described above. This requires use of the following formula:

$$2 \left( \frac{\text{Applicable R. & Dev. and Imp. Costs} + \text{Learning Curve}}{\text{Flyaway Cost Basis Used}} \right)$$

Equals break-even point in units. This represents the amount of follow-on aircraft necessary to justify this investment.

<table>
<thead>
<tr>
<th>BREAK-EVEN POINT - 200 AIRCRAFT (IN MILLIONS OF DOLLARS)</th>
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<tbody>
<tr>
<td><strong>CARIBOU</strong></td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>R2000-13</td>
</tr>
<tr>
<td>LEARNING CURVE</td>
</tr>
<tr>
<td>TOTAL LAUNCHING COSTS</td>
</tr>
<tr>
<td>② FLYAWAY COST</td>
</tr>
<tr>
<td>BREAK-EVEN FACTOR (A/C UNITS)</td>
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<tr>
<td>BREAK-EVEN POINT IN A/C UNITS</td>
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</tbody>
</table>

① BREAK-EVEN POINT = $2.00 OF AIRCRAFT RECEIVED FOR EVERY $1.00 OF LAUNCHING COSTS

① EXCLUDES R. & D. ENGINE PRODUCT IMPROVEMENT & ELECTRONICS
The purpose of this chart is to determine which type of aircraft gives the most for our money, costs considered in relation to work accomplishment, with all conclusions contingent upon the cost alternative chosen being within the framework of criterion established, as mentioned in the general discussion Part 9.

Total program costs net of 15% residual value per aircraft plus cumulative maintenance costs per aircraft for 10 years have been computed and added together to give total net costs. The total net costs for the Caribou I (R2000-13) is used as a base representing 100% and a percentage net cost relationship is computed for all other aircraft in relation to this 100% base.

Previously, in Chart a percentage work accomplishment relationship was determined for each aircraft shown below. We then determine which aircraft gives us the most for our money in terms of percentage effective value through use of the following formula:  

\[
\% \text{ Effective Value} = \frac{\% \text{ Work accomplishment}}{\% \text{ Net costs}}
\]

<table>
<thead>
<tr>
<th>10 YEARS CUMULATIVE COST ON 200 AIRCRAFT</th>
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<tr>
<td>PEACETIME BASIS - MAXIMUM COSTS</td>
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<tr>
<td>(IN MILLIONS OF DOLLARS)</td>
</tr>
<tr>
<td>CARIBOU</td>
</tr>
<tr>
<td>I</td>
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<tr>
<td>R2000-13</td>
</tr>
<tr>
<td>NET PROGRAM COST (NET OF 15% RESIDUAL VALUE)</td>
</tr>
<tr>
<td>MAINTENANCE COSTS FOR 10 YEARS (FY 70 BASIS)</td>
</tr>
<tr>
<td>TOTAL NET COSTS</td>
</tr>
<tr>
<td>% NET COSTS</td>
</tr>
<tr>
<td>% WORK ACCOMPLISHMENT</td>
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<tr>
<td>1 % EFFECTIVE VALUE</td>
</tr>
</tbody>
</table>

\[
1 \% \text{ EFFECTIVE VALUE} = \frac{\% \text{ WORK ACCOMPLISHMENT}}{\% \text{ NET COSTS}}
\]
V. CONCLUSIONS

It is concluded that:

a. The technical data within available proposals is not adequate for decision.

b. The Army requirement is not sufficiently precise for a firm finding among the proposed aircraft.

c. That STOL performance is not by itself, a useful criterion for evaluation.

d. Loading and unloading time militates against the advantage of higher speed ranges afforded by turbine driven aircraft when used for short haul operations.

e. Caribou II is a high risk program in that:

(1) Empty weight is unlikely to be realized, disposable load will suffer.

(2) Dependent upon T-64 engine program success.

(3) Performance in cruise is low for effective turbine economy.

(4) No operational experience exists for the airframe.

(5) Deliveries will be late (56 months).

f. Fairchild F-27 proposal offers somewhat lower risk in that:

(1) STOL flap and movable tail have been flown on F-27.

(2) Growth to 42,000 pounds weight is in final stage at Fairchild.

(3) Performance data exists for service aircraft in airline use.

(4) Service fixes now on production aircraft.

(5) Does not depend on one engine.

(6) Deliveries could begin in 30 months.

g. The Caribou I may in reality satisfy current Army requirements better than proposed turbine driven models.
VI RECOMMENDATIONS

It is recommended that:

a. That the Army defer decision until need and value criteria be re-studied.

b. That a source selection be made based upon design competition under rigidly comparable conditions, (after completion of a, above).

c. That no decision be made which would exclude any competitor at this time.
The original document which defines air worthiness requirements for civil aircraft was known as Department of Commerce Bulletin 7a. Among its very interesting requirements were two which are worthy of review. One was that an aircraft to be air worthy should take off full loaded at 1,000 feet or less. Among the other rules we find one that the landing speed could not be in excess of 65 miles an hour. Today the United States Army has a very similar requirement, stating that a STOL airplane must take off and clear a fifty foot obstacle in 1,000 feet of runway.

Civil aviation generally operates at somewhat longer runway length, in order to assure safe flight in the event of engine failure. Accordingly, there is imposed FAA regulatory control over the legal takeoff gross weight from specific runway lengths under temperature, wind, and runway gradient conditions so that after engine failure it is possible to either decelerate and stop within the runway length, or to continue flight and successfully clear a 50 foot obstacle at the end of the runway.

The design engineer faced with the requirement to produce a fixed wing STOL aircraft, immediately sets about the review of all techniques for achieving very slow flight with large loads. He is aware that this must be a special sort of an airplane, particularly because of the attitude of those who are about to purchase it. He therefore sets up the following list of required elements:

a. The STOL airplane must have as high a power to weight ratio as is possible. This means that the engines must be very powerful, and wherever
possible the airplane must be reduced in weight to the absolute minimum structural criterion that might be used.

b. Weight reduction is required and the only visible source of disposable weight is airframe, since the customer has demanded large numbers of auxiliaries, special equipment, etc. The engineer realizes that his weight reduction program is greatly limited, in that if he reduces his structure weight to the strength requirement for that gross weight corresponding to takeoff in 1,000 feet; he will not have an aircraft capable on other days and on longer runways of carrying large loads. Obviously, he may not reduce his structure weights very far without jeopardizing this everyday use of the aircraft for most of its potential transport capability. Accordingly, he selects a reasonable gross weight for which he intends STOL performance and then specifies an additional higher gross weight for use on missions where it is desirable to carry much larger loads off longer runways.

c. Rough fields will require rugged landing gears. The engineer refers to texts and tables for information relating to the structural loads to be inspected from an irregular and rough terrain. Among his most interesting discovery is the fact that for many fixed wing aircraft the most severe landing gear loads result from taxi speed operation. Careful evaluation of the strength requirements imposed by the long runway maximum load condition and the taxiing associated therewith, result in a few rapid computations as to the resulting strength of such a landing gear for the much lower weights to be expected under STOL and rough field operation. This computation reveals the strength for high weights results in almost equivalent strength for low
weights and very rough field operation. Accordingly, some small amount of additional structural weight and strength is designed into the landing gear.

d. Aerodynamics, of course, should provide the answer to this conflicting situation. The engineer immediately turns to methods to augment wing lift, resulting in great lifting capability at low air speeds. He is pleased to find much information on this subject, and would be surprised at its extent were he not aware that the ordinary transport aircraft is designed to civil standards which lay great emphasis on the minimum operating speed. These civil standards, CAR 408, base engine-out performance requirements on a group of equations which use the square of the stalling speed to define numerical performance values. Use of the stalling speed, and squaring it moreover, has given great emphasis to maintaining low stalling speeds and thereby minimizing the difficult burdens placed on the performance of the transport aircraft. The engineer accordingly selects double, triple, slotted flaps, blown flaps, etc.

With these basics set down, the engineer reviews what has been accomplished. Privately, he has reached the opinion that he is designing an aircraft that is very much like any other transport airplane, to a set of requirements which have been phrased with the left hand as it were, but which, in essence, have demanded a normal or near normal CAR 408 transport airplane.

This was the concept for the Caribou AC-1. It was not achieved at the intended gross weight. It is assumed that the -LA modification which increases
gross weight to 28,500 lbs. and takeoff distance and landing distance
requirements to 1235 feet can be regarded as evidence that the 1,000 foot
requirement is considerably less important than the gross transport capability
of the aircraft.

It must be offered that too great diligence in securing a STOL Caribou I
resulted in the need to structurally improve the airplane for more normal
use at higher gross weights. It may be surmised that the effort to design
and bring into being the Caribou II is an effort which only partly realizes
the situation discussed in earlier paragraphs. The Caribou II offers nothing
to the state of the art. The difficulties in design recited here may explain
why ordinary transport aircraft such as the Fairchild F27 can be quite
competitive as STOL aircraft for the Army.

The following facts which bear on the problem, in this study, of pro-
viding sound recommendations to the Department of the Army must be born in
mind:

a. Aircraft technical proposals are not directly comparable. The
Army does not at present have a standardized format for the presentation of
aircraft performance.

b. Army stated STOL requirements do not provide a basis for good
compromise between performance and cost. Previous mention of Army willingness
to compromise the stated STOL capability of the Caribou I indicates that
these STOL requirements are neither particularly firm, nor are they particularly
valuable against the needs of the Army for gross air transport capability.
Further indicated is the unstated recognition that STOL is relatively unaffected.
In any event, an evaluation cannot and should not be conducted against these requirements at their present level of definition.

c. Proposals submitted by the various manufacturers offer STOL capabilities only by compromise to other desirable performance. This is a natural consequence to a natural fact; aircraft takeoff and fly better at a lower weight. In short, STOL capability is a direct result of removing desirable cargo from the aircraft and making repeated trips to transport it.

d. Civil transport design requirements provide the same absolute STOL capability if these same compromises are accepted. In view of the preceding facts it appears these compromises must be accepted to one degree or another. The civil transport design was created under the same restrictive requirements as a military STOL transport, and in consequence is generally equivalent if not superior in its inherent STOL capability.

e. This STOL capability was not fact developed by the Caribou I nor is it offered by Caribou II or any other proposal. Here we refer to any unusual or peculiar difference between these aircraft and normal civil transport aircraft. These airplanes do not, in fact, possess any unusual features, and the design contribution towards STOL is a minor exaggeration of normal features ordinarily adopted to enhance low speed flight capability.

f. Development cost of this program will not contribute to the state of the art. In view of the foregoing statement, it will be apparent that the creation of additional minor distortions to normal transport airplanes will not, in fact, alter the essential relationship between weight and flight capability.
g. STOL capability can be obtained only at the expense of other performance. In a very considerable degree it exists in any good transport airplane simply as a by-product of the airplane broad utility.

In discussing the ramifications of this problem an examination of the aircraft proffered to the U. S. Army, it is concluded that the Army and the manufacturers are both inherently convinced that gross transport capability is the market and consumer item of value.

Gross transport capability comparison will be made in Part 3. The following charts represent the comparison of STOL characteristics of the various aircraft configurations included in the analysis.

Aircraft performance was analyzed first with a graph indicating take-off distance normal versus gross weight as calculated under FAA CAR 4b, and a second chart comparing the same items depicting STOL performance.

It was felt that this near duplication is not only justified but necessary as there are no specific and detailed rules to govern STOL performance comparable to those in CAR 4b. For this reason, the airplanes compared under the CAR 4b rules are more directly comparable.
TAKE-OFF DISTANCE VS GROSS WEIGHT

DISTANCE TO CLEAR 50 FOOT OBSTACLE
STANDARD DAY, SEA LEVEL
STILL AIR

(NORMAL - ACCORDING TO CAR 46 REQUIREMENTS)
TAKE-OFF DISTANCE (STOL) vs GROSS WEIGHT

DISTANCE TO CLEAR 50 FOOT OBSTACLE
STANDARD DAY, SEA LEVEL
STILL AIR

STOL LIMITS - STRUCTURAL (LANDING)
Attached Chart I entitled "Gross Transport Capability" demonstrates graphically the fields of usefulness of these various aircraft being compared. In the lower left hand corner will be seen an inclosure labeled Mark I-R2000. This area represents on its vertical axis: payload in thousands of lbs.; and horizontally: range in hundreds of miles. The Caribou Mark I with the reciprocating engines cannot be utilized for any mission wherein the intersection of payload and range falls outside of its boundary. Show next, the Mark II Caribou with the T-55 engine and the Mark II Caribou with the T-6h engine. Finally, is shown, the Fairchild Friendship with the T-6h engine, known as the M-258-K. It should be immediately apparent that the Fairchild airplane has the widest field of utility, or offers the most variety in mission choice of combinations of payload and range. It should be noticed that this aircraft possesses all the performance of this group, together with a range capability and payload which can be achieved by none of the others. It is interesting to note that this aircraft can deliver itself without special fuel tanks to trans-oceanic areas and, thus, carry a substantial portion of its own support as its cargo for such missions. If it can be agreed that these areas represent a broad utility map for each of the aircraft, it may then be noted that by calculating areas and considering the Caribou Mark I with the reciprocating engine to have an area of 100, that the Mark II with the T-55 engine have an area of 160, the Mark II with the T-6h engine have an area of 176 and the M-258 Fairchild with the T-6h have an area of 211. Some immediate conclusions can be drawn:
(a) Unless mission requirements are demanding, the present Caribou Mark I with the reciprocating engine may continue to be very satisfactory since it has a substantial percentage of performance of the Caribou Mark II and its price is approximately half. (See Economic Analysis.)

(b) The Caribou Mark II with the T-55 engine is vastly less expensive than the Mark II with the T-64 engine, and accordingly the rather high deference in engine cost may well dictate that the T-55 be the engine of choice; in the event that the Caribou Mark II appears a desirable aircraft under other important criteria.

(c) The Fairchild is obviously an aircraft of greater versatility, and although not shown here, it is an aircraft of higher speed. This last feature increases its total transport capability to an even greater degree than is shown by the area under the curve.
MISSION PAYLOAD

1000 FOOT FIELD LENGTH

(DE HAVILLAND A/C ONLY)

STD DAY, STILL AIR
CRUISE ALT - 5,000 FT
3 MAN CREW
CARGO BOTH WAYS

NOTE: AC-II (DART 8) DOES NOT FALL ON PAPER
MISSION PAYLOAD

1000 FOOT FIELD LENGTH

(FAIRCHILD A/C ONLY)

STD DAY, STILL AIR
CRUISE ALT - 5,000 FT
3 MAN CREW
CARGO BOTH WAYS

PAYLOAD (1000 LB)

M-258 K (T-64)

AC-1A (R 2000)

M-258 (T-55)

M-258-N (DART 12)

M-258 J (DART 8)

MISSION RANGE (NM)

48
MISSION PAYLOAD (DE HAVILLAND A/C ONLY)

1300 FOOT FIELD LENGTH

STD DAY, STILL AIR
CRUISE ALT - 5,000 FT
3 MAN CREW
CARGO BOTH WAYS

PAYLOAD (1000 LB)

MISSION RADIUS (NM)
MISSION PAYLOAD (FAIRCHILD A/C ONLY)

1300 FOOT FIELD LENGTH

STD DAY, STILL AIR
CRUISE ALT - 5,000 FT
3 MAN CREW
CARGO BOTH WAYS

PAYLOAD (1000 LB)

MISSION RADIUS (NM)

50
MISSION PAYLOAD
1500 FOOT FIELD LENGTH

(FAIRCHILD A/C ONLY)
STD DAY, STILL AIR
CRUISE ALT - 5000 FT
3 MAN CREW
CARGO BOTH WAYS

PAYLOAD (1000 LB)

MISSION RADIUS (NM)

M 285 B (F-35)
M 285 K DART 8
M 285 N DART 12
M 285 K F/64
AC-1A C-2000

51
MISSION PAYLOAD
1000 FOOT FIELD LENGTH

STD DAY, STILL AIR
CRUISE ALT - 5,000 FT.
3 MAN CREW
CARGO BOTH WAYS

PAYLOAD (1000 LB)

MISSION RADIUS (NM)
MISSION PAYLOAD
1300 FOOT FIELD LENGTH

8 EST A/C
STD DAY, STILL AIR
CRUISE ALT - 5,000 FT.
3 MAN CREW
CARGO BOTH WAYS

PAYLOAD (1000 LB)

M 258 K (T-64)
M 258N (DART 12)
AC II (DART 12)
M 259 (T-55)
AC II (T-44)
AC-1A (R2000)

MISSION RADIAL (NM)
53
MISSION PAYLOAD

1500 FOOT FIELD LENGTH

(BEST A/C)

STD DAY, STILL AIR
CRUISE ALT - 5,000 FT
3 MAN CREW
CARGO BOTH WAYS

PAYLOAD (1,000 LB)

MISSION RADIUS (NM)
MISSION PAYLOAD
BERNELLI AIRPLANE & AC-1A

ENGINE:
BERNELLI - (2) R2600
AC-1A - (2) R2000

STD DAY, STILL AIR
CRUISE ALT - 5,000 FT
3 MAN CREW
CARGO BOTH WAYS

PAYLOAD (1000 LB)

MISSION RADIUS (NM)

55