NiCd CELL RELIABILITY IN THE MISSION ENVIRONMENT

William K. Denson; Reliability Analysis Center, Rome, NY
Glenn C. Klein; Gates Aerospace Batteries, Gainesville, FL

INTRODUCTION

This paper summarizes an effort by Gates Aerospace Batteries (GAB) and the Reliability Analysis Center (RAC) to analyze survivability data for both General Electric and GAB NiCd cells utilized in various spacecraft. For simplicity sake, all mission environments are described as either LEO or GEO. "Extreme value statistical methods" are applied to this database because of the longevity of the numerous missions while encountering relatively few failures. Every attempt has been made to include all known instances of cell-induced-failures of the battery and to exclude battery-induced-failures of the cell. While this distinction may be somewhat limited due to availability of in-flight data, we have accepted the learned opinion of the specific customer contacts to ensure integrity of the common databases.

This paper advances the preliminary analysis reported upon at the 1991 NASA Battery Workshop. That prior analysis was concerned with an estimated 278 million cell-hours of operation encompassing 183 satellites. That paper also cited "no reported failures to date" [see Reference 1]. This analysis reports on 428 million cell hours of operation encompassing 212 satellites. This analysis also reports on seven "cell-induced-failures."

MISSION ENVIRONMENT

Several assumptions have been made concerning both the mission environment and the overall population of cells by which the numbers of cell-hours or cell-cycles are estimated. First for simplicity sake, all mission environments are described as either LEO (predominantly rapid and repetitive cycling) or GEO (predominantly long periods of overcharge followed by brief duty cycles). Generally Polar Orbits are incorporated into the LEO analysis, and Highly Elliptical orbits are incorporated into the GEO analysis. LEO is considered to
experience sixteen cycles per day. Second, the analysis assumes twenty-two cells per battery and two batteries per satellite.

The third area of assumption becomes more an area of definition and discrimination. Defining the words *failure*, *termination*, and *deterioration* can lead to both endless discussion and endless dissension. For purposes of this analysis, *failures* is defined as: outright failure or termination of a cell and/or a battery. Deterioration is defined as: expected performance had deteriorated or degraded to the point that the original mission intention has been significantly limited or compromised either by manifestation of immediate performance deterioration or the limiting of expected life. Discriminating between cell-induced battery failures and battery-induced cell failures encounters the same discussion and dissension. Both definition and discrimination are hampered by different levels of telemetry sophistication for receiving in-flight performance data. This analysis unilaterally accepts both definition and discrimination as proffered by the responsible technical personnel.

It should also be noted that the analysis is being performed at the complete satellite battery level and not the individual cell level, since this is the level for which the data was collected.

**MISSION PERFORMANCE**

Table 1 contains the detail and arithmetical summary of the 212 satellites reported in this analysis. Details include cell capacity rating, mission environment, launch date and years of operation. Neither customer, program or reason for satellite termination is identified in this listing. Note that four specific indicators of operational life were used since this information was extracted from several sources. They are final or total years of operation, data as of December 1987, data as of January 1991, and data as of April 1992. Total LEI Mission Years reported are 331.7 years; total GEO Mission Years reported are 777.9 years. Note that specific failure data is not included in Table 1.
MISSION SUMMARY

The last page of Table 1 provides the total Mission Summary, the LEO Mission Summary, and the GEO Mission Summary. For 212 spacecraft analyzed, 1109.5 Total Mission Years have accumulated. This equivalent 428 million cell-hours is considerably greater than the 278 million cell-hours reported on last year [Reference 1]. In addition, the previous report did not differentiate between the various mission environments.

For the LEO Mission Environment, 74 spacecraft or satellites were analyzed. Accumulated are 332 Total Mission Years or 85 million Total Cell-Cycles. For the GEO Mission Environment, 138 spacecraft or satellites were analyzed. Accumulated are 778 Total Mission Years or 300 million Total Cell-Hours.

As previously stated, cell-induced failures are not cited or summarized in Table 1. Neither will these failures be tabulated separately due to their sensitive nature. In brief summary, one "long term" GEO has occurred, and six LEO failures have occurred ranging from approximately four thousand to thirty-two thousand cycles. Again note that a cell-induced performance failure does not necessarily imply a mission termination.

STATISTICAL ANALYSIS OF RELIABILITY DATA

A simple method of analyzing reliability data is to determine a failure rate by dividing the number of observed failures by the number of operating hours or cycles. The use of a failure rate inherently assumes that the rate of failures are occurring in a time independent random manner.

Since it is known that batteries typically exhibit wearout characteristics, or an increasing failure rate in time, a failure rate is too simplistic of a metric describing the reliability of the battery.

Weibull analysis is often used to quantify, from empirical time (or cycle) to failures data, the rate of occurrence of failure as a function of time. A complete Weibull analysis usually consists of plotting the cumulative percentage of failures against time on Weibull probability paper when a large percentage of the population
has failed. This methodology, however, looses its usefulness when the population contains few or no failures. Since there have been a relatively small percentage of the population failing, alternative analysis methods were required.

The appropriate analysis methodology under these circumstances is the use of confidence limits in conjunction with the Weibull distribution. Nelson [Reference 2] has proposed such a methodology which will be used in this analysis. Background on the Weibull distribution and Nelson's methodology is given in the following paragraphs.

The probability density function $f(t)$ of the Weibull time to failure distribution is;

$$f(t) = \frac{\beta}{\alpha} \left(\frac{t}{\alpha}\right)^{\beta-1} e^{-\left(\frac{t}{\alpha}\right)^\beta}$$

where

- $\alpha$ = characteristic life, time to 63% population failure
- $\beta$ = Weibull shape parameter
- $t$ = time

The reliability (probability of survival to a time $t$) is;

$$R(t) = e^{-\left(\frac{t}{\alpha}\right)^\beta}$$

And the hazard rate $h(t)$ (or instantaneous failure rate), given the part has survived until time $t$ is;

$$h(t) = \left(\frac{\beta}{\alpha}\right) \left(\frac{t}{\alpha}\right)^{\beta-1}$$
To estimate the value of the characteristic life in the Weibull distribution, the following maximum likelihood estimator is typically used:

\[ \alpha = \left[ \frac{\sum_{i=1}^{n} T_i^\beta}{r} \right]^{\frac{1}{\beta}} \]

where

- \( T_i \) = Time to fail of the \( i \)th part or survival time of the \( i \)th part if it has not failed
- \( r \) = Number of failures
- \( n \) = Total population of parts

Since the database contains few failures, the characteristic life implied by this estimate is suspect. As stated previously, the appropriate analysis methodology to use under these conditions is to apply confidence limits to derive worst case reliability values. From this, lower bound estimates of lifetimes can be made within a given confidence level. To accomplish this, the Chi-square distribution can be utilized. The lower confidence limit for the Weibull distribution is:

\[ \alpha = \left[ \frac{\sum_{i=1}^{n} T_i^\beta}{r} \right]^{\frac{1}{\beta}} \left[ 2r / \chi^2 (C; 2r + 2) \right]^{\frac{1}{\beta}} \]

where

- \( \chi^2 \) = the chi-square percentile at C% confidence and \( r \) failures

This value of characteristic life was then calculated for various values of betas and various confidence levels for both LEO and GEO. Table 1 summarizes the data used. The sum of the individual survival times raised to the power beta, as a function of beta, are as follows:
<table>
<thead>
<tr>
<th>$\beta$</th>
<th>$\sum_{i=1}^{T_i^{\beta}}$</th>
<th>LEO</th>
<th>GEO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>331.9</td>
<td>331.9</td>
<td>777.9</td>
</tr>
<tr>
<td>2</td>
<td>2,911</td>
<td>2,911</td>
<td>6,220</td>
</tr>
<tr>
<td>3</td>
<td>38,182</td>
<td>38,182</td>
<td>57,977</td>
</tr>
<tr>
<td>4</td>
<td>624,847</td>
<td>624,847</td>
<td>588,803</td>
</tr>
<tr>
<td>5</td>
<td>11,472,255</td>
<td>11,472,255</td>
<td>6,357,012</td>
</tr>
<tr>
<td>6</td>
<td>$2.236 \times 10^8$</td>
<td>$2.236 \times 10^8$</td>
<td>$7.215 \times 10^7$</td>
</tr>
</tbody>
</table>

The values of the Chi-square percentiles are given as follows:

<table>
<thead>
<tr>
<th>C Confidence Level</th>
<th>Chi-Square Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LEO (6 failures)</td>
</tr>
<tr>
<td></td>
<td>GEO (1 failures)</td>
</tr>
<tr>
<td></td>
<td>14 Degrees of Freedom</td>
</tr>
<tr>
<td>.25</td>
<td>10.17</td>
</tr>
<tr>
<td>.50</td>
<td>13.34</td>
</tr>
<tr>
<td>.75</td>
<td>17.12</td>
</tr>
<tr>
<td>.90</td>
<td>21.06</td>
</tr>
<tr>
<td>.95</td>
<td>23.68</td>
</tr>
<tr>
<td>.975</td>
<td>26.12</td>
</tr>
<tr>
<td>.990</td>
<td>29.14</td>
</tr>
<tr>
<td>.995</td>
<td>31.32</td>
</tr>
<tr>
<td>.999</td>
<td>36.12</td>
</tr>
<tr>
<td></td>
<td>4 Degrees of Freedom</td>
</tr>
<tr>
<td>.25</td>
<td>1.923</td>
</tr>
<tr>
<td>.50</td>
<td>3.357</td>
</tr>
<tr>
<td>.75</td>
<td>5.385</td>
</tr>
<tr>
<td>.90</td>
<td>7.779</td>
</tr>
<tr>
<td>.95</td>
<td>9.488</td>
</tr>
<tr>
<td>.975</td>
<td>11.14</td>
</tr>
<tr>
<td>.990</td>
<td>13.68</td>
</tr>
<tr>
<td>.995</td>
<td>14.86</td>
</tr>
<tr>
<td>.999</td>
<td>18.47</td>
</tr>
</tbody>
</table>

1992 NASA Aerospace Battery Workshop -442- Nickel-Cadmium Technologies Session
The resulting lower limit characteristic life estimates as a function of confidence (C) and beta value are summarized in the following table for both LEO and GEO applications.

### α FOR LEO APPLICATIONS

<table>
<thead>
<tr>
<th>β</th>
<th>0.25</th>
<th>0.50</th>
<th>0.75</th>
<th>0.90</th>
<th>0.95</th>
<th>0.975</th>
<th>0.990</th>
<th>0.995</th>
<th>0.999</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>65.3</td>
<td>49.8</td>
<td>38.8</td>
<td>31.5</td>
<td>28.0</td>
<td>25.4</td>
<td>22.8</td>
<td>21.2</td>
<td>18.4</td>
</tr>
<tr>
<td>2</td>
<td>23.9</td>
<td>20.9</td>
<td>18.4</td>
<td>16.6</td>
<td>15.7</td>
<td>14.9</td>
<td>14.1</td>
<td>13.6</td>
<td>12.7</td>
</tr>
<tr>
<td>3</td>
<td>19.6</td>
<td>17.9</td>
<td>16.5</td>
<td>15.4</td>
<td>14.8</td>
<td>14.3</td>
<td>13.8</td>
<td>13.5</td>
<td>12.8</td>
</tr>
<tr>
<td>4</td>
<td>18.7</td>
<td>17.5</td>
<td>16.4</td>
<td>15.6</td>
<td>15.2</td>
<td>14.8</td>
<td>14.4</td>
<td>14.1</td>
<td>13.6</td>
</tr>
<tr>
<td>5</td>
<td>18.6</td>
<td>17.7</td>
<td>16.8</td>
<td>16.1</td>
<td>15.7</td>
<td>15.4</td>
<td>15.1</td>
<td>14.9</td>
<td>14.5</td>
</tr>
<tr>
<td>6</td>
<td>18.8</td>
<td>17.9</td>
<td>17.2</td>
<td>16.6</td>
<td>16.3</td>
<td>16.1</td>
<td>15.8</td>
<td>15.6</td>
<td>15.2</td>
</tr>
</tbody>
</table>

### α FOR GEO APPLICATIONS

<table>
<thead>
<tr>
<th>β</th>
<th>0.25</th>
<th>0.50</th>
<th>0.75</th>
<th>0.90</th>
<th>0.95</th>
<th>0.975</th>
<th>0.990</th>
<th>0.995</th>
<th>0.999</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>809</td>
<td>463</td>
<td>289</td>
<td>200</td>
<td>164</td>
<td>139</td>
<td>117</td>
<td>105</td>
<td>84</td>
</tr>
<tr>
<td>2</td>
<td>80.4</td>
<td>60.9</td>
<td>48.1</td>
<td>40.0</td>
<td>36.2</td>
<td>33.4</td>
<td>30.6</td>
<td>28.9</td>
<td>25.9</td>
</tr>
<tr>
<td>3</td>
<td>39.2</td>
<td>32.6</td>
<td>27.8</td>
<td>24.6</td>
<td>23.0</td>
<td>21.8</td>
<td>20.6</td>
<td>19.8</td>
<td>18.4</td>
</tr>
<tr>
<td>4</td>
<td>28.0</td>
<td>24.3</td>
<td>21.6</td>
<td>19.7</td>
<td>18.8</td>
<td>18.0</td>
<td>17.2</td>
<td>16.8</td>
<td>15.9</td>
</tr>
<tr>
<td>5</td>
<td>23.1</td>
<td>20.7</td>
<td>18.8</td>
<td>17.5</td>
<td>16.8</td>
<td>16.2</td>
<td>15.7</td>
<td>15.4</td>
<td>14.7</td>
</tr>
<tr>
<td>6</td>
<td>20.5</td>
<td>18.7</td>
<td>17.3</td>
<td>16.3</td>
<td>15.7</td>
<td>15.3</td>
<td>14.9</td>
<td>14.7</td>
<td>14.1</td>
</tr>
</tbody>
</table>

As an example, if a beta value of 4 is assumed, one can be 90% confident that the characteristic life for LEO applications is a minimum of 15.6 years.

If it is desired to calculate the time (t) to the P percentile failure of the population, the following can be used:

\[
t = \alpha \left[ -\ln \left( 1 - \frac{P}{100} \right) \right]^{1/\beta}
\]
If the characteristic life is the lower confidence limit as tabulated previously, the
time to P percent failure will also be the lower confidence limit. For example, using
the characteristic life of 15.6 years for beta = 4 and 90% confidence, the worst case
time (at 90% confidence) to reach 1% failure is;

$$t = 15.6 \left[ -\ln \left( 1 - \frac{1}{100} \right) \right]^{\frac{1}{4}} = 4.94 \text{ years}$$

In this example, there is 90% confidence that the time to 1% failure will be
greater than 4.94 years.

**DISCUSSION ON LONGEVITY OF LEO MISSIONS**

Let us assume that five years in LEO environment (29,200 cycles) is a typical
mission life time requirement. Then several superlatives can be shown. First, 24 of
the 74 LEO missions analyzed were operated beyond that benchmark including one
mission for 22 years. Second, testing of a four-cell pack of 26.5 Amp-Hour cells has
recently achieved 11.7 years (68,110 cycles) in a LEO test regime. This cell pack (Pack
No. 0026G) is currently under test at Crane-NSWC at 10°C and 20% DOD.

**SUMMARY AND RECOMMENDATIONS**

This database contains substantial updating and upgrading from our previous
report. The previous report cited 183 satellites operating for 278 million cell-hours
and "no reported failures." This report contains 212 satellites operating for 428
million cell-hours and seven reported failures. We continue to use the extreme
value statistical methods of Wayne Nelson as the most viable analysis technique
due to relatively few failures.

Predictions of the Characteristic Life and times to percentile failures based upon
assumed $\beta$ values has shown a small decrease in the "predicted life" due to the
observance of failures. However, these estimates appear more realistic because any
failure improves the estimation of Confidence Intervals; and because the total base
of survivability increased 54%.
<table>
<thead>
<tr>
<th>RATING</th>
<th>MISSION</th>
<th>LAUNCH DATES</th>
<th>YEARS OF OPERATION</th>
<th>LEO YEARS</th>
<th>GEO YEARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>LEO</td>
<td>66/02</td>
<td>(1.25)</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>66/02</td>
<td>(4.5)</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>66/10</td>
<td>(2.0)</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>66/12</td>
<td>(20)</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>67/01</td>
<td>(0.9)</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>67/03</td>
<td>(2.4)</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>67/04</td>
<td>(2.8)</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>LEO</td>
<td>67/04</td>
<td>(22.0)</td>
<td>22.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>67/11</td>
<td>17.8*</td>
<td>17.8</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>67/11</td>
<td>(2)</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>68/08</td>
<td>(0.2)</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>68/08</td>
<td>(0.9)</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>68/12</td>
<td>(7.2)</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>69/02</td>
<td>(4.8)</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>69/04</td>
<td>(1.75)</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>70/01</td>
<td>(1.4)</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>70/12</td>
<td>(0.7)</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>70/12</td>
<td>(0.8)</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>71/01</td>
<td>14.6*</td>
<td>14.6</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>71/12</td>
<td>(11.5)</td>
<td>11.5</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>72/01</td>
<td>13.6*</td>
<td>13.6</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>72/06</td>
<td>14.0*</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>72/07</td>
<td>(5.75)</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>72/10</td>
<td>(2.2)</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GEO</td>
<td>72/11</td>
<td>(10.6)</td>
<td>10.6</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>72/12</td>
<td>(7.25)</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GEO</td>
<td>73/04</td>
<td>(10.2)</td>
<td>10.2</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>73/08</td>
<td>(9.8)</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>73/11</td>
<td>(2.6)</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>73/12</td>
<td>(5.0)</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GEO</td>
<td>74/04</td>
<td>(9.0)</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GEO</td>
<td>74/10</td>
<td>(9.8)</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>74/11</td>
<td>10.8*</td>
<td>10.8</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>75/01</td>
<td>(5.0)</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GEO</td>
<td>75/05</td>
<td>(9.5)</td>
<td>9.5</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>75/05</td>
<td>10.2*</td>
<td>10.2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>75/06</td>
<td>(4.5)</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>LEO</td>
<td>75/06</td>
<td>(3.0)</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>75/09</td>
<td>9.9*</td>
<td>9.9</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>75/10</td>
<td>(0.4)</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>75/11</td>
<td>(5.6)</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>75/?</td>
<td>(1.0)</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>76/01</td>
<td>9.6*</td>
<td>9.6</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 1: Cont'd.

<table>
<thead>
<tr>
<th>RATING</th>
<th>MISSION</th>
<th>LAUNCH DATES</th>
<th>YEARS OF OPERATION</th>
<th>LEO YEARS</th>
<th>GEO YEARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>LEO</td>
<td>76/03</td>
<td>(4.0)</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>LEO</td>
<td>76/03</td>
<td>(1.0)</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>GEO</td>
<td>76/03</td>
<td>(3.0)</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>GEO</td>
<td>76/04</td>
<td>(3.0)</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>76/05</td>
<td>[8.5]</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GEO</td>
<td>76/07</td>
<td>[9.1]</td>
<td>9.1</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>76/07</td>
<td>9.1</td>
<td>9.1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GEO</td>
<td>77/03</td>
<td>8.4*</td>
<td>8.4</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>77/05</td>
<td>8.2*</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>GEO</td>
<td>77/06</td>
<td>(7)</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>77/08</td>
<td>[13]</td>
<td>13.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>77/12</td>
<td>(3.0)</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>78/01</td>
<td>7.7*</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>78/02</td>
<td>7.6*</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>78/02</td>
<td>(0.6)</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>78/02</td>
<td>14.2</td>
<td>14.2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>GEO</td>
<td>78/03</td>
<td>(5.5)</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>78/03</td>
<td>7.4*</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>GEO</td>
<td>78/04</td>
<td>(3.8)</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GEO</td>
<td>78/05</td>
<td>7.2**</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>78/05</td>
<td>[6.0]</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>78/06</td>
<td>[7.2]</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GEO</td>
<td>78/08</td>
<td>(0.3)</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>78/10</td>
<td>12.2**</td>
<td>12.2</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>78/10</td>
<td>11.2**</td>
<td>11.2</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>78/11</td>
<td>12.2**</td>
<td>12.2</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>78/12</td>
<td>[2.8]</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>GEO</td>
<td>78/12</td>
<td>6.7*</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GEO</td>
<td>79/08</td>
<td>6.0*</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>79/09</td>
<td>10.5</td>
<td>10.5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>79/10</td>
<td>[10]</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>80/02</td>
<td>(4.4)</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>80/02</td>
<td>[9.8]</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>80/04</td>
<td>9.7**</td>
<td>9.7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>80/05</td>
<td>(1.0)</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>GEO</td>
<td>80/09</td>
<td>(2.8)</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>GEO</td>
<td>80/11</td>
<td>4.8*</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>80/12</td>
<td>11.3</td>
<td>11.3</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>81/02</td>
<td>(4.5)</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>GEO</td>
<td>81/05</td>
<td>(3.6)</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>GEO</td>
<td>81/05</td>
<td>8.6**</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>81/05</td>
<td>10.9</td>
<td>10.9</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>81/07</td>
<td>11.0</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>GEO</td>
<td>81/08</td>
<td>4.0*</td>
<td>4.0</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 1: Cont'd.

<table>
<thead>
<tr>
<th>RATING</th>
<th>MISSION</th>
<th>LAUNCH DATES</th>
<th>YEARS OF OPERATION</th>
<th>LEO YEARS</th>
<th>GEO YEARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>GEO</td>
<td>81/09</td>
<td>4.1*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>GEO</td>
<td>81/11</td>
<td>4.0*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>81/12</td>
<td>10.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>GEO</td>
<td>82/01</td>
<td>3.85*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>GEO</td>
<td>82/02</td>
<td>10.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>LEO</td>
<td>82/02</td>
<td>0.8</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>82/03</td>
<td>10.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>GEO</td>
<td>82/04</td>
<td>(1.8)</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>GEO</td>
<td>82/06</td>
<td>9.9</td>
<td></td>
<td>9.9</td>
</tr>
<tr>
<td>50</td>
<td>LEO</td>
<td>82/07</td>
<td>8.5**</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>GEO</td>
<td>82/08</td>
<td>9.7</td>
<td></td>
<td>9.7</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>82/09</td>
<td>9.6</td>
<td></td>
<td>9.6</td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>82/10</td>
<td>9.5</td>
<td></td>
<td>9.5</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>82/10</td>
<td>9.5</td>
<td></td>
<td>9.5</td>
</tr>
<tr>
<td>17</td>
<td>GEO</td>
<td>82/11</td>
<td>2.8*</td>
<td></td>
<td>2.8</td>
</tr>
<tr>
<td>22</td>
<td>GEO</td>
<td>82/11</td>
<td>9.4</td>
<td></td>
<td>9.4</td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>83/02</td>
<td>9.2</td>
<td></td>
<td>9.2</td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>83/02</td>
<td>2.5*</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>30</td>
<td>LEO</td>
<td>83/03</td>
<td>9.1</td>
<td>9.1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>GEO</td>
<td>83/04</td>
<td>7.8*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>LEO</td>
<td>83/05</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>LEO</td>
<td>83/06</td>
<td>4.2</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>GEO</td>
<td>83/06</td>
<td>2.2*</td>
<td></td>
<td>2.2</td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>83/06</td>
<td>8.8</td>
<td></td>
<td>8.8</td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>83/06</td>
<td>8.8</td>
<td></td>
<td>8.8</td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>83/07</td>
<td>9.0</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>GEO</td>
<td>83/07</td>
<td>2.1*</td>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>12</td>
<td>GEO</td>
<td>83/08</td>
<td>8.6</td>
<td></td>
<td>8.6</td>
</tr>
<tr>
<td>12</td>
<td>GEO</td>
<td>83/08</td>
<td>4.0**</td>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td>40</td>
<td>GEO</td>
<td>83/08</td>
<td>8.5</td>
<td></td>
<td>8.5</td>
</tr>
<tr>
<td>24</td>
<td>GEO</td>
<td>83/09</td>
<td>8.5</td>
<td></td>
<td>8.5</td>
</tr>
<tr>
<td>4</td>
<td>GEO</td>
<td>84/01</td>
<td>(1.6)</td>
<td></td>
<td>1.6</td>
</tr>
<tr>
<td>6</td>
<td>LEO</td>
<td>84/02</td>
<td>8.5</td>
<td></td>
<td>8.5</td>
</tr>
<tr>
<td>50</td>
<td>LEO</td>
<td>84/03</td>
<td>6.8**</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>LEO</td>
<td>84/04</td>
<td>5.5</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>84/06</td>
<td>7.8</td>
<td></td>
<td>7.8</td>
</tr>
<tr>
<td>4</td>
<td>LEO</td>
<td>84/08</td>
<td>3.0**</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>GEO</td>
<td>84/08</td>
<td>1.0*</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>21</td>
<td>GEO</td>
<td>84/08</td>
<td>1.0*</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>25</td>
<td>GEO</td>
<td>84/08</td>
<td>7.7</td>
<td></td>
<td>7.7</td>
</tr>
<tr>
<td>15</td>
<td>GEO</td>
<td>84/09</td>
<td>7.6</td>
<td></td>
<td>7.6</td>
</tr>
<tr>
<td>12</td>
<td>GEO</td>
<td>84/10</td>
<td>5.0</td>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td>17</td>
<td>GEO</td>
<td>84/10</td>
<td>2.6*</td>
<td></td>
<td>2.6</td>
</tr>
<tr>
<td>50</td>
<td>LEO</td>
<td>84/10</td>
<td>6.2*</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>RATING</td>
<td>MISSION</td>
<td>LAUNCH DATES</td>
<td>YEARS OF OPERATION</td>
<td>LEO YEARS</td>
<td>GEO YEARS</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>--------------</td>
<td>-------------------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>15 GEO</td>
<td>84/11</td>
<td>.8*</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 GEO</td>
<td>84/11</td>
<td>7.6</td>
<td>7.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 GEO</td>
<td>84/11</td>
<td>7.6</td>
<td>7.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 GEO</td>
<td>85/02</td>
<td>7.2</td>
<td>7.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35 GEO</td>
<td>85/02</td>
<td>[0.6]</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 GEO</td>
<td>85/03</td>
<td>2.5**</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 GEO</td>
<td>85/04</td>
<td>7.0</td>
<td>7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 GEO</td>
<td>85/06</td>
<td>2.8**</td>
<td>2.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 GEO</td>
<td>85/06</td>
<td>0.2*</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35 GEO</td>
<td>85/06</td>
<td>[4.5]</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 GEO</td>
<td>85/07</td>
<td>7.0</td>
<td>7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 GEO</td>
<td>85/08</td>
<td>[6.0]</td>
<td>6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 GEO</td>
<td>85/08</td>
<td>6.7</td>
<td>6.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 GEO</td>
<td>85/08</td>
<td>6.7</td>
<td>6.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 GEO</td>
<td>85/10</td>
<td>6.5</td>
<td>6.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35 GEO</td>
<td>85/10</td>
<td>6.5</td>
<td>6.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 GEO</td>
<td>86/02</td>
<td>[4.0]</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 GEO</td>
<td>86/03</td>
<td>6.9</td>
<td>6.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 GEO</td>
<td>86/09</td>
<td>5.8</td>
<td>5.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 GEO</td>
<td>86/10</td>
<td>5.7</td>
<td>5.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 GEO</td>
<td>86/11</td>
<td>3.1**</td>
<td>3.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35 GEO</td>
<td>86/12</td>
<td>6.3</td>
<td>6.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 GEO</td>
<td>87/02</td>
<td>5.2</td>
<td>5.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 GEO</td>
<td>87/06</td>
<td>4.8</td>
<td>4.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 GEO</td>
<td>87/07</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 GEO</td>
<td>87/09</td>
<td>2.2**</td>
<td>2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 GEO</td>
<td>87/09</td>
<td>2.2**</td>
<td>2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 GEO</td>
<td>87/09</td>
<td>5.3</td>
<td>5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 GEO</td>
<td>87/11</td>
<td>5.4</td>
<td>5.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35 GEO</td>
<td>88/02</td>
<td>3.0**</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 GEO</td>
<td>88/03</td>
<td>(0.8)</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 GEO</td>
<td>88/03</td>
<td>4.1</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 GEO</td>
<td>88/04</td>
<td>1.7</td>
<td>1.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 GEO</td>
<td>88/06</td>
<td>1.5</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 GEO</td>
<td>88/06</td>
<td>1.5</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 GEO</td>
<td>88/07</td>
<td>4.0</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 GEO</td>
<td>88/07</td>
<td>3.7</td>
<td>3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 GEO</td>
<td>88/08</td>
<td>1.3**</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 GEO</td>
<td>88/09</td>
<td>3.6</td>
<td>3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 GEO</td>
<td>88/09</td>
<td>3.5</td>
<td>3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35 GEO</td>
<td>88/12</td>
<td>3.3</td>
<td>3.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35 GEO</td>
<td>89/02</td>
<td>3.1</td>
<td>3.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 GEO</td>
<td>89/03</td>
<td>3.0</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 GEO</td>
<td>89/05</td>
<td>2.9</td>
<td>2.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 1: Cont'd.

**STATUS AS OF JULY, 1992**

<table>
<thead>
<tr>
<th>RATING</th>
<th>MISSION</th>
<th>LAUNCH DATES</th>
<th>YEARS OF OPERATION</th>
<th>LEO YEARS</th>
<th>GEO YEARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>GEO</td>
<td>89/06</td>
<td>2.8</td>
<td></td>
<td>2.8</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>89/06</td>
<td>2.8</td>
<td></td>
<td>2.8</td>
</tr>
<tr>
<td>40</td>
<td>GEO</td>
<td>89/06</td>
<td>2.8</td>
<td></td>
<td>2.8</td>
</tr>
<tr>
<td>21</td>
<td>GEO</td>
<td>89/08</td>
<td>2.6</td>
<td></td>
<td>2.6</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>89/08</td>
<td>2.6</td>
<td></td>
<td>2.6</td>
</tr>
<tr>
<td>5</td>
<td>GEO</td>
<td>89/09</td>
<td>2.5</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>89/09</td>
<td>2.5</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>89/10</td>
<td>2.4</td>
<td></td>
<td>2.4</td>
</tr>
<tr>
<td>24</td>
<td>LEO</td>
<td>89/11</td>
<td>2.4</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>89/12</td>
<td>2.3</td>
<td></td>
<td>2.3</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>89/12</td>
<td>2.3</td>
<td></td>
<td>2.3</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>90/01</td>
<td>2.1</td>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>10</td>
<td>LEO</td>
<td>90/02</td>
<td>2.1</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>LEO</td>
<td>90/02</td>
<td>2.1</td>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>90/03</td>
<td>2.0</td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>18</td>
<td>GEO</td>
<td>90/06</td>
<td>1.8</td>
<td></td>
<td>1.8</td>
</tr>
<tr>
<td>15</td>
<td>LEO</td>
<td>90/07</td>
<td>1.7</td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>90/07</td>
<td>1.7</td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>17</td>
<td>GEO</td>
<td>90/08</td>
<td>1.7</td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>21</td>
<td>GEO</td>
<td>90/08</td>
<td>1.7</td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>90/08</td>
<td>1.7</td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>90/08</td>
<td>1.7</td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>32</td>
<td>GEO</td>
<td>90/10</td>
<td>1.5</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>90/10</td>
<td>1.5</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>90/11</td>
<td>1.4</td>
<td></td>
<td>1.4</td>
</tr>
<tr>
<td>40</td>
<td>GEO</td>
<td>90/11</td>
<td>1.4</td>
<td></td>
<td>1.4</td>
</tr>
<tr>
<td>30</td>
<td>LEO</td>
<td>90/12</td>
<td>1.3</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>91/01</td>
<td>1.2</td>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td>32</td>
<td>GEO</td>
<td>91/03</td>
<td>1.1</td>
<td></td>
<td>1.1</td>
</tr>
<tr>
<td>50</td>
<td>LEO</td>
<td>91/04</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>LEO</td>
<td>91/05</td>
<td>0.9</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>GEO</td>
<td>91/07</td>
<td>0.8</td>
<td></td>
<td>0.8</td>
</tr>
<tr>
<td>17</td>
<td>GEO</td>
<td>91/08</td>
<td>0.7</td>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>40</td>
<td>GEO</td>
<td>91/08</td>
<td>0.7</td>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>50</td>
<td>LEO</td>
<td>91/09</td>
<td>0.6</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>GEO</td>
<td>91/11</td>
<td>0.3</td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td>50</td>
<td>LEO</td>
<td>91/11</td>
<td>0.3</td>
<td></td>
<td>0.3</td>
</tr>
</tbody>
</table>

**TOTAL LEO MISSION YEARS** 331.7

**TOTAL GEO MISSION YEARS** 777.9
TABLE 1: Cont’d.

STATUS AS OF JULY, 1992

MISSION SUMMARY:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL MISSION YEARS</td>
<td>1109.5</td>
</tr>
<tr>
<td>TOTAL MISSION DAYS</td>
<td>0.40 Million</td>
</tr>
<tr>
<td>TOTAL MISSION HOURS</td>
<td>9.72 Million</td>
</tr>
<tr>
<td>TOTAL BATTERY HOURS</td>
<td>19.44 Million</td>
</tr>
<tr>
<td>TOTAL CELL HOURS</td>
<td>427.65 Million</td>
</tr>
<tr>
<td>TOTAL SPACECRAFT ANALYZED</td>
<td>212</td>
</tr>
</tbody>
</table>

LEO MISSION SUMMARY:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL MISSION YEARS</td>
<td>331.7</td>
</tr>
<tr>
<td>TOTAL MISSION DAYS</td>
<td>0.12 Million</td>
</tr>
<tr>
<td>TOTAL MISSION CYCLES</td>
<td>1.94 Million</td>
</tr>
<tr>
<td>TOTAL BATTERY CYCLES</td>
<td>3.87 Million</td>
</tr>
<tr>
<td>TOTAL CELL CYCLES</td>
<td>85.22 Million</td>
</tr>
<tr>
<td>TOTAL SPACECRAFT ANALYZED</td>
<td>74</td>
</tr>
</tbody>
</table>

GEO MISSION SUMMARY:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL MISSION YEARS</td>
<td>777.9</td>
</tr>
<tr>
<td>TOTAL MISSION DAYS</td>
<td>0.28 Million</td>
</tr>
<tr>
<td>TOTAL MISSION HOURS</td>
<td>6.81 Million</td>
</tr>
<tr>
<td>TOTAL BATTERY HOURS</td>
<td>13.63 Million</td>
</tr>
<tr>
<td>TOTAL CELL HOURS</td>
<td>299.81 Million</td>
</tr>
<tr>
<td>TOTAL SPACECRAFT ANALYZED</td>
<td>138</td>
</tr>
</tbody>
</table>
This reporting format and analysis technique were the pathfinder for similar databases anticipated for the NiH2 and NiMH Product Lines. We find this format to be sufficiently stable and mature to apply to those product lines. Our expectations are to update on a bi-annual basis and report on the database every four to five years.

REFERENCES

