

# INVESTIGATION OF DSC TRANSISTOR FAILURES

Presenter:

Doug White

Organization/Date:

Orbiter/02-14-02

## Observations:

- TT&E of a Dedicated Signal Conditioner (DSC) which had failed during the STS-92 mission (Oct. '00) found two defective Raytheon transistors (P/N JANTXV2N3019, Lot Date Code 7525)

## Concern:

- These transistor failures may be indicative of a problem specific to the 7525 LDC
- Due to their extensive usage throughout the vehicle, these failures could have a significant impact on the fleet if determined to be lot related

## Discussion:

- The DSC CVRD module Q503 transistor failures (detached base and emitter bond wires) are illustrated in Figures 1 through 4

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## Discussion: (cont)

### Bond Wires Appear to be Attached to Die

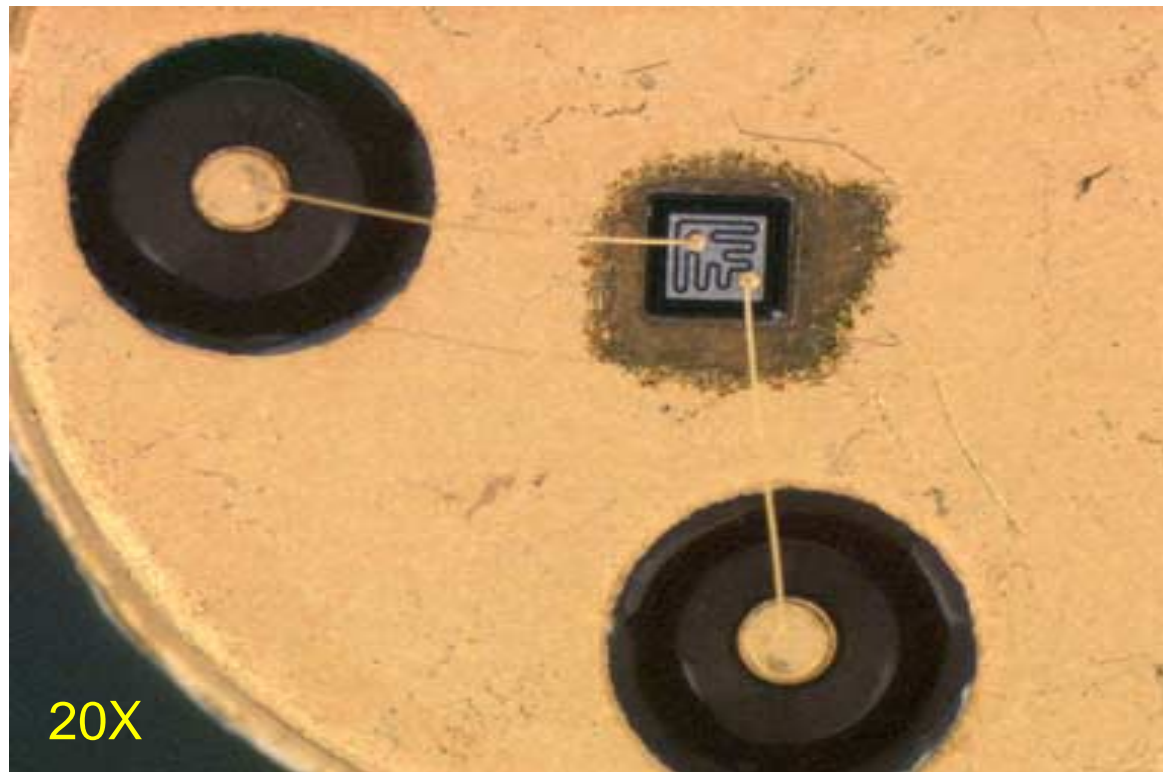


Figure 1

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**Discussion: (cont)**

**Closer Examination Shows Bond Wires Are Actually Detached**

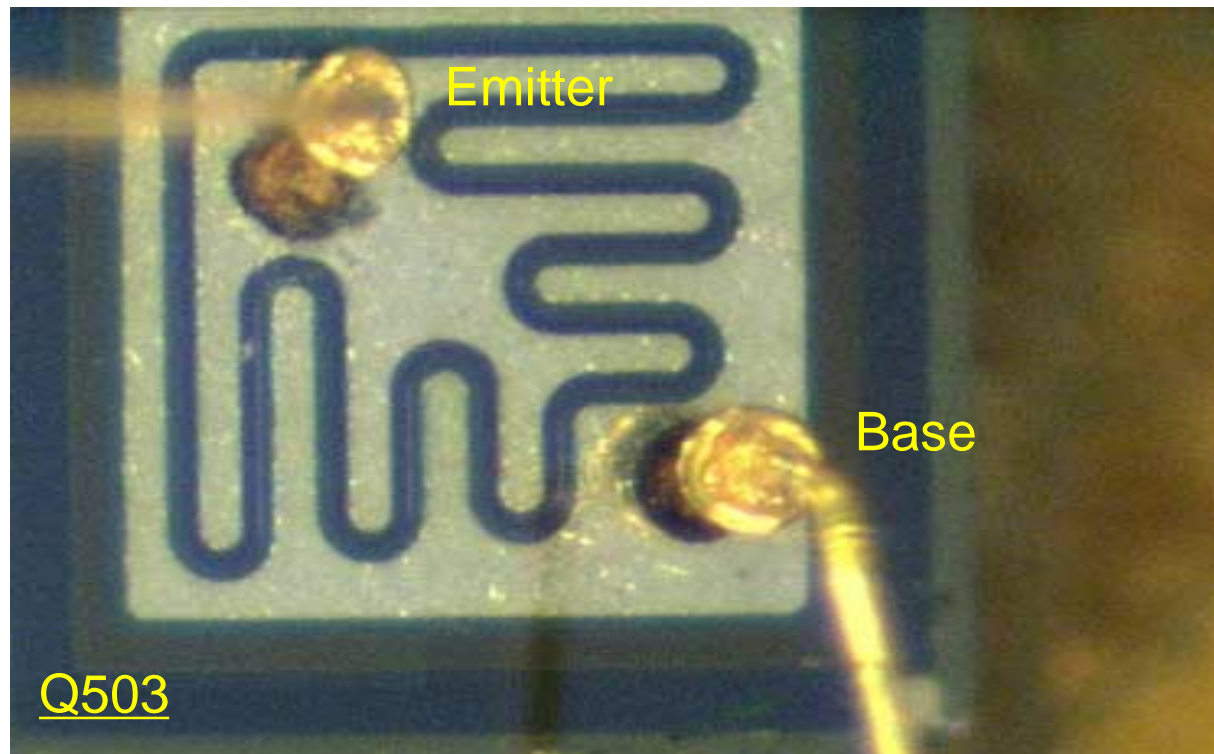


Figure 2

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## Discussion: (cont)

### SEM of Detached Base and Emitter Bond Wires

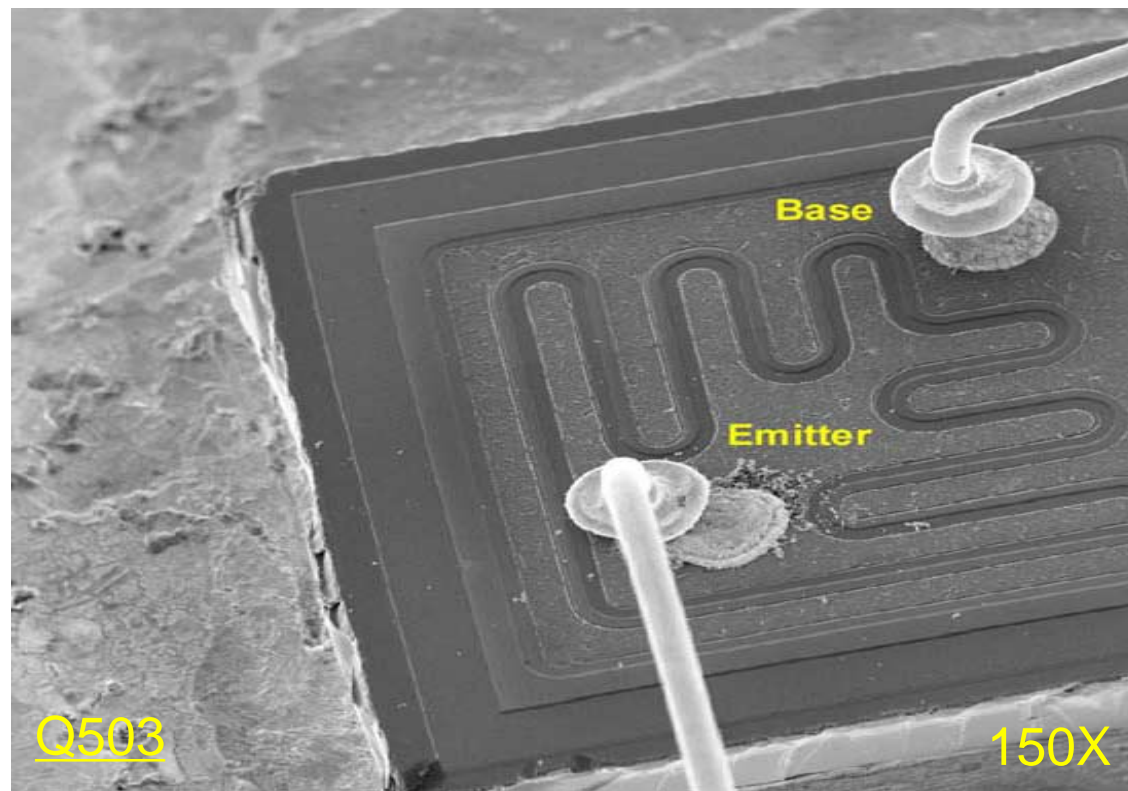


Figure 3

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## Discussion: (cont)

### SEM Showing Intermetallics In Bond Region

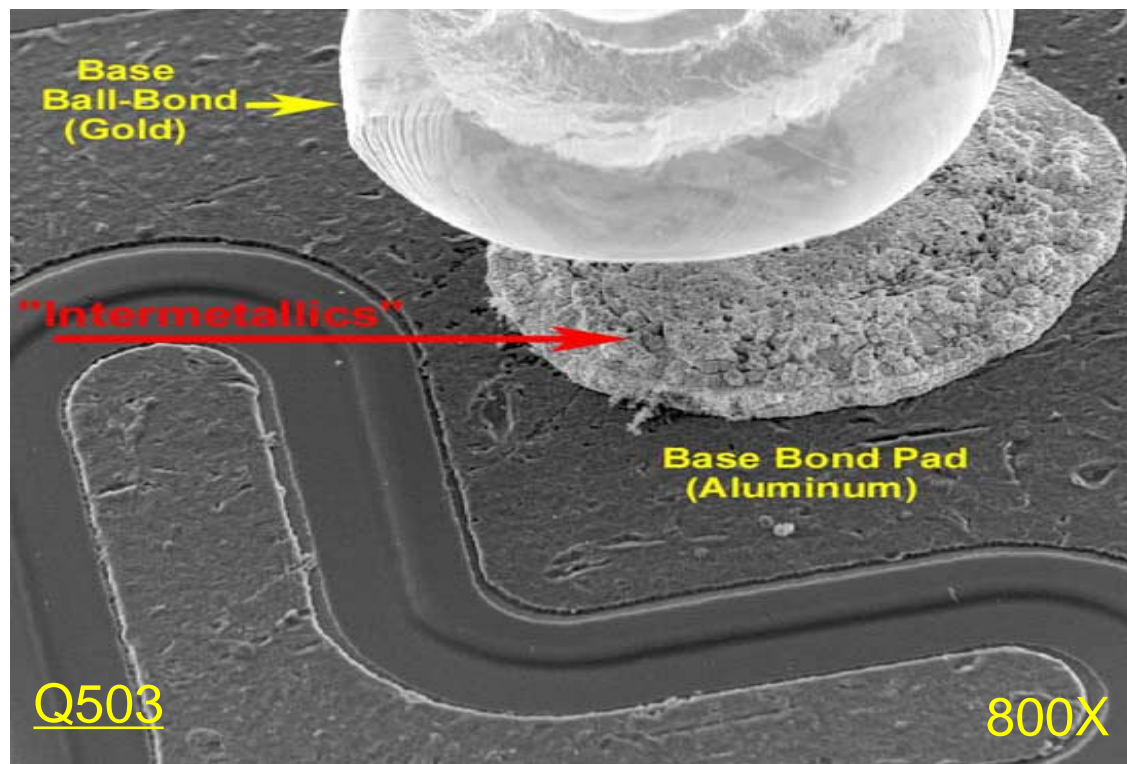


Figure 4

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## Discussion: (cont)

- The 2N3019 transistor design employs gold bond wires attached (via thermal compression) to an aluminum die substrate forming a strong intermetallic bond
- Diffusion of aluminum into gold results in the formation of an intermetallic compound which tends to exhibit a purple coloration, at and around the periphery of the aluminum-to-gold interface
  - The presence of this material is not, in and of itself, an indication of an inferior mechanical connection
  - However, if the intermetallic compound progresses to develop Kirkendall voids, the integrity of the mechanical connection may be undermined
    - The potential for void formation is accelerated in the presence of certain contaminants (i.e., chlorine, bromine, fluorine, etc.)

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## Actions Taken/In-Work:

- Conducted PRACA history search to identify all 2N3019 transistor failures (refer to Figure 5)
  - Identified 16 CARs documenting 19 transistor failures (various manufacturers)
  - Due to incomplete documentation, only 8 CARs confirmed to involve Raytheon transistors
  - No records contained information regarding destructive failure analysis
    - One record indicated that transistor was de-lidded and photographed, but in most cases transistors were simply R&R'd
- Four recent failures led us to investigate LDC 7525 as a potential lot problem
  - Aerospace Corporation failure database
  - GIDEPs
  - Additional failure analysis at NSLD
  - Destructive testing of randomly selected parts at Hi-Rel

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## Actions Taken/In-Work: (cont)

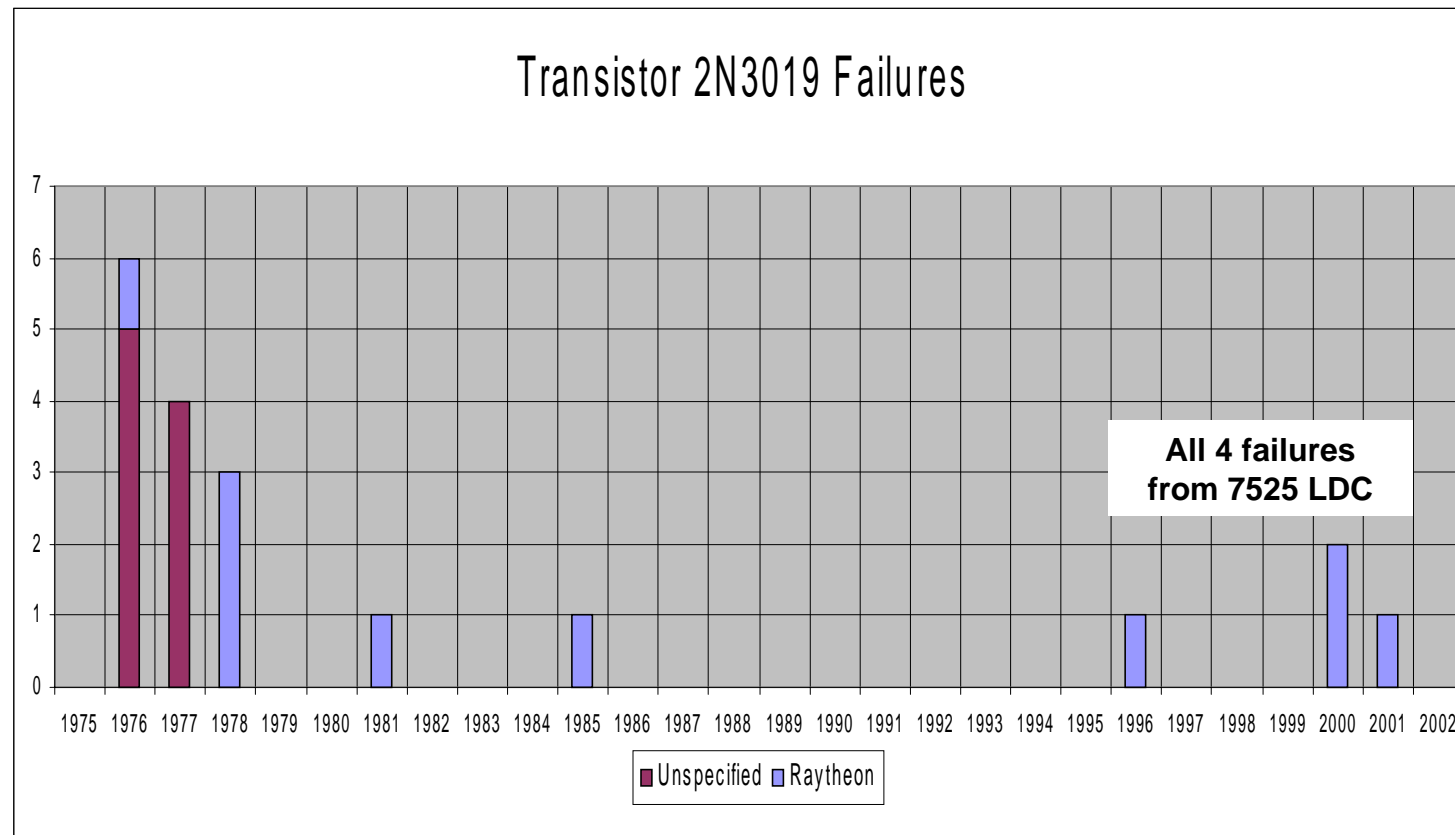


Figure 5

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## Actions Taken/In-Work: (cont)

- The Aerospace Corporation parts history database was queried for failure information on 2N3019 transistors and other related parts
  - The resultant data indicate that the semiconductor industry process control was not idealized during the era in question
  - The data showed infrequent occurrences of contamination at the lot level with parts manufactured by Raytheon and Motorola
    - The contamination events seemed to be clustered sporadically in the late 1960s through the mid 1970s, then briefly recurred in the early 1980s
    - No specific part numbers or lot numbers could be identified having more failures than any other group

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## Actions Taken/In-Work: (cont)

- GIDEP search of 2N3019 transistors found 5 records
  - One record related to lifted bond wires but problem was attributed to insufficient bonding (i.e., improper melt)
- Expanded GIDEP search to all JANTX(V) transistors identifying one record that dealt specifically with intermetallic growth (refer to Table 1)
  - GIDEP report T9-A-78-02 issued 10/78 in response to failures of transistors utilizing gold ball bonds on aluminum die metallization
    - Failures isolated to lifted lead bonds primarily caused by intermetallic growth
  - Upon further investigation, determined that failed parts were re-screened in accordance with MIL-STD-975 without limiting the maximum junction temperature to 175 deg. C
    - MIL-STD-975 does not take into consideration the fact that bimetallic bonding systems may be subjected to multiple high temperature excursions which are detrimental to bonding integrity

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## Actions Taken/In-Work: (cont)

### GIDEP Search Summary

| <u>Doc. #</u> | <u>Date</u> | <u>Mfg</u>           | <u>Part Number</u> | <u>LDC</u>           | <u>Problem Description</u>                                      |
|---------------|-------------|----------------------|--------------------|----------------------|---|
| T9-A-78-02    | 10/78       | Various              | JANTX(V)           | Various              | Detailed discussion on prior page                               |
| R1-A-79-02A   | 2/80        | Motorola<br>Raytheon | JANTXV2N3019       | 7848<br>?            | Shorter than required external leads                            |
| EA-F-80-08    | 12/80       | Fairchild            | JANTXV2NXXXX       | Various              | General audit (unspecified findings)                            |
| BZ-A-80-01D   | 3/81        | Fairchild            | JANTX              | 7701<br>thru<br>8032 | Certain transistors may not meet burn-in reqt's per MIL-S-19500 |
| Z4-A-81-01    | 3/81        | Raytheon             | JTX2N3019          | 7840<br>7848         | Failed lead bonds due to underbonding (improper melt)           |
| R4-A-91-01    | 8/91        | Raytheon             | JANTXV2N3019(s)    | 8735<br>8748         | Internally shorted due to loose metallic particles              |

Table 1

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|   |   |
|---|---|
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## Actions Taken/In-Work: (cont)

- In an effort to isolate the transistor problem to a particular manufacturer or LDC, NSLD performed additional failure analysis
  - Three of 4 failed parts showed signs of chlorine contamination
  - No human trace elements were found

### NSLD Failure Analysis Summary

| Ref. Des. | Mfg.     | LDC      | Curve Tracer | PIND   | Leads Visually Intact | Chlorine | Human Contaminants |
|-----------|----------|----------|--------------|--------|-----------------------|----------|--------------------|
| Q503      | Raytheon | CRP 7525 | Failed       | Failed | No-Both               | Yes      | No                 |
| Q504      | Raytheon | CRP 7525 | Failed       | Passed | No-Emitter            | No       | No                 |
| Q701      | Raytheon | CRP 7525 | Failed       | N/A    | No-Both               | Yes      | No                 |
| Q503      | Raytheon | CRP 7525 | Failed       | N/A    | No-Both               | Yes      | No                 |
| Q503      | Raytheon | CRP 7403 | Passed       | N/A    | Yes-Both              | Yes      | Yes                |
| Q504      | Raytheon | CRP 7403 | Passed       | N/A    | Yes-Both              | Yes      | Yes                |

Table 2

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## Actions Taken/In-Work: (cont)

- To obtain more data, located additional 2N3019 transistors (with various LDCs) were shipped to Hi-Rel Laboratories, Inc. for comprehensive Destructive Physical Analysis (refer to Table 3)
  - Of particular interest are the results of bond wire strength tests (i.e., pull tests) since that is the only conclusive method of determining the integrity of the gold-to-aluminum bonds
  - Hi-Rel results showed that transistors with “abundant” quantities of chlorine contamination failed bond wire strength testing
    - The 7525 LDC transistors showed what appears to be process induced chlorine contamination (i.e., non-human)

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## Actions Taken/In-Work: (cont)

### Hi-Rel Labs. Failure Analysis Summary

| Q    | LDC        | Manufacturer | Transistor   | SRU P/N         | SRU S/N | N.D. Pull to 4 gm | Chlorine  | Human Contaminants | Comments                               |
|------|------------|--------------|--------------|-----------------|---------|-------------------|-----------|--------------------|--|
| tb d | CRP 7525   | RAYTHEON     | JANTXV2N3019 | tb d            | tb d    | FA ILED           | A BUNDANT | NO                 | BASE BALL BOND LIFTED @ 0.2 GM         |
| tb d | CRP 7525   | RAYTHEON     | JANTXV2N3019 | tb d            | tb d    | FA ILED           | A BUNDANT | NO                 | BASE BALL BOND LIFTED BEFORE PULL TEST |
| tb d | CRP 7525   | RAYTHEON     | JANTXV2N3019 | tb d            | tb d    | P ASS             | NO        | NO                 |  |
| tb d | CRP 7525   | RAYTHEON     | JANTXV2N3019 | tb d            | tb d    | P ASS             | NO        | NO                 |  |
| tb d | CRP 7525   | RAYTHEON     | JANTXV2N3019 | tb d            | tb d    | P ASS             | NO        | NO                 |  |
| tb d | CRP 7525   | RAYTHEON     | JANTXV2N3019 | tb d            | tb d    | P ASS             | NO        | NO                 |  |
| Q503 | CRP 7525   | RAYTHEON     | JANTXV2N3019 | MC473-0110-0008 | 165A    | P ASS             | NO        | NO                 | WIRE BROKE AT TOP OF BALL              |
| Q504 | CRP 7525   | RAYTHEON     | JANTXV2N3019 | MC473-0110-0008 | 165A    | P ASS             | NO        | NO                 |  |
| Q504 | CRP 7831   | RAYTHEON     | JANTXV2N3019 | MC473-0110-0005 | 53A     | FA ILED           | A BUNDANT | A BUNDANT          | EMITTER BALL BOND LIFTED @ 1.3 GM      |
| Q503 | CRP 8118   | RAYTHEON     | JANTXV2N3019 | MC450-0034-0043 | 148A    | P ASS             | NO        | NO                 |  |
| Q504 | CRP 8118   | RAYTHEON     | JANTXV2N3019 | MC450-0034-0043 | 148A    | P ASS             | NO        | NO                 | WIRE BROKE AT TOP OF BALL              |
| Q503 | CRP 7429   | RAYTHEON     | JANTXV2N3019 | MC473-0110-1008 | P6      | P ASS             | NO        | NO                 |  |
| Q503 | CRP 7927   | RAYTHEON     | JANTXV2N3019 | MC473-0110-0005 | 53A     | P ASS             | SLIGHT    |                    | WIRE BROKE AT TOP OF BALL              |
| Q503 | CRP 7927   | RAYTHEON     | JANTXV2N3019 | MC473-0110-0005 | 51A     | P ASS             | SLIGHT    |                    | NO BREAK                               |
| Q504 | CRP 7927   | RAYTHEON     | JANTXV2N3019 | MC473-0110-0005 | 51A     | P ASS             | SLIGHT    |                    | NO BREAK                               |
| Q503 | CRP 7706   | RAYTHEON     | JANTXV2N3019 | MC473-0110-0005 | 69A     | P ASS             | NO        | NO                 |  |
| Q504 | CRP 7706   | RAYTHEON     | JANTXV2N3019 | MC473-0110-0005 | 69A     | P ASS             | NO        | NO                 | WIRE BROKE @ TOP OF BALL (NICKED WIRE) |
| Q503 | CRP 7612   | RAYTHEON     | JANTXV2N3019 | MC473-0110-0005 | 40A     | P ASS             | SLIGHT    | SLIGHT             | NO BREAK                               |
| Q504 | CRP 7612   | RAYTHEON     | JANTXV2N3019 | MC473-0110-0005 | 40A     | P ASS             | SLIGHT    | SLIGHT             | NO BREAK                               |
| Q503 | CCXP 7638A | NATIONAL     | JANTXV2N3019 | MC473-0110-0005 | 42A     | P ASS             | NO        | NO                 | NO BREAK                               |
| Q504 | CCXP 7638A | NATIONAL     | JANTXV2N3019 | MC473-0110-0005 | 42A     | P ASS             | NO        | NO                 | NO BREAK                               |
| Q503 | CCABT7506  | TRANSITRON   | JANTXV2N3019 | MC473-0110-0005 | 16A     | P ASS             | MODERATE  | MODERATE           | AL WIRE ON GOLD POST                   |
| Q504 | CCABT7506  | TRANSITRON   | JANTXV2N3019 | MC473-0110-0005 | 16A     | P ASS             | MODERATE  | MODERATE           | AL WIRE ON GOLD POST                   |

Table 3

# INVESTIGATION OF DSC TRANSISTOR FAILURES

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## Actions Taken/In-Work: (cont)

- Destructive Physical Analysis conducted at both NSLD and Hi-Rel indicates that the Raytheon 2N3019 transistors still deliver excellent performance unless there is evidence of abundant chlorine contamination
  - Contaminants introduced during the manufacturing process tend to accelerate intermetallic growth and may contribute to reduced reliability (as evidenced by bond pull test results)
- Limited data available to date points strongly to process induced chlorine contamination of the Raytheon 2N3019 7525 LDC transistors
- The Orbiter investigating team has notified the other Shuttle elements so they may determine their usage (if any) of the 2N3019 transistor
  - Preparation of GIDEP Advisory is in-work

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## Actions Taken/In-Work: (cont)

- Configuration management records indicate that up to 19.4% (191/982) of all 2N3019 transistors installed in OV-102 are from the 7525 LDC

| Description  | Number in DSCs | Number in Other H/W | Total |
|--|----------------|---------------------|-------|
| 2N3019 Raytheon transistors with 7525 LDC                        | 152            | 0                   | 152   |
| 2N3019 Raytheon transistors with unknown LDC                     | 16             | 0                   | 16    |
| 2N3019 transistors with unknown manufacturer/LDC                 | 10             | 13                  | 23    |
| Total  | 178            | 13                  | 191   |
| Total 2N3019 transistors (Raytheon, others & unknowns) in OV-102 |                |                     | 982   |

- Configuration Management is aggressively working to characterize usage of the 2N3019 transistors in the remaining Orbiter vehicles

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