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C5 Stability Augmentation Subsystem Reliability Analysis, AWTS Testing, and Physical Audit

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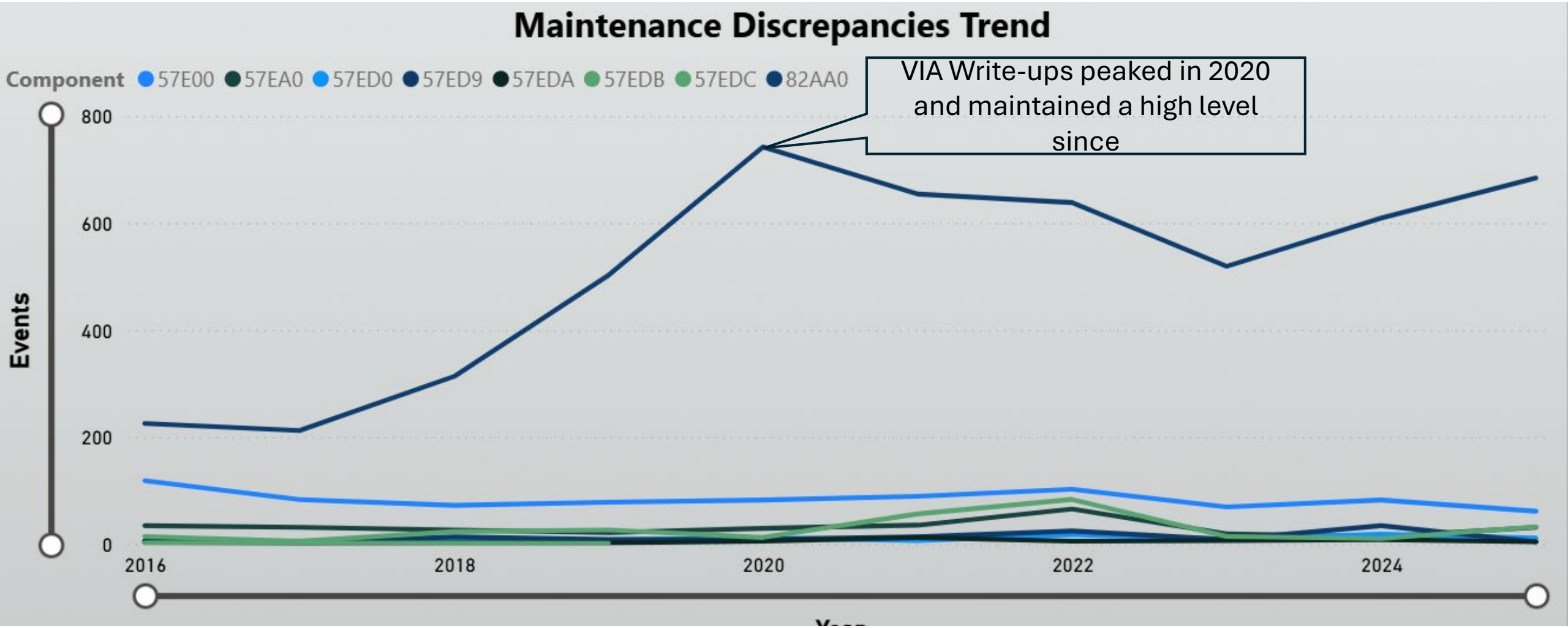
Ground Rules and Assumptions

- On-Equipment Records from REMIS
- Work Unit Codes:
  - 57000 – Integrated Guidance and Flight Controls
  - 57EXX – Stability Augmentation Subsystem
  - 82AA0 – Versatile Integrated Avionics (VIA)
- 01/01/2016-12/31/2025
- Cannot Duplicate Records:
  - Action Taken Code: H – Equipment Checked, No Repair Required (On-Equipment Work Only)
  - How Malfunction Codes:
    - 672 – Built in Test (BIT) False Alarm
    - 799 – No Defect
    - 812 – No Defect, Indicated Defect Caused by Associated Equipment Malfunction
    - 948 – Operator Error

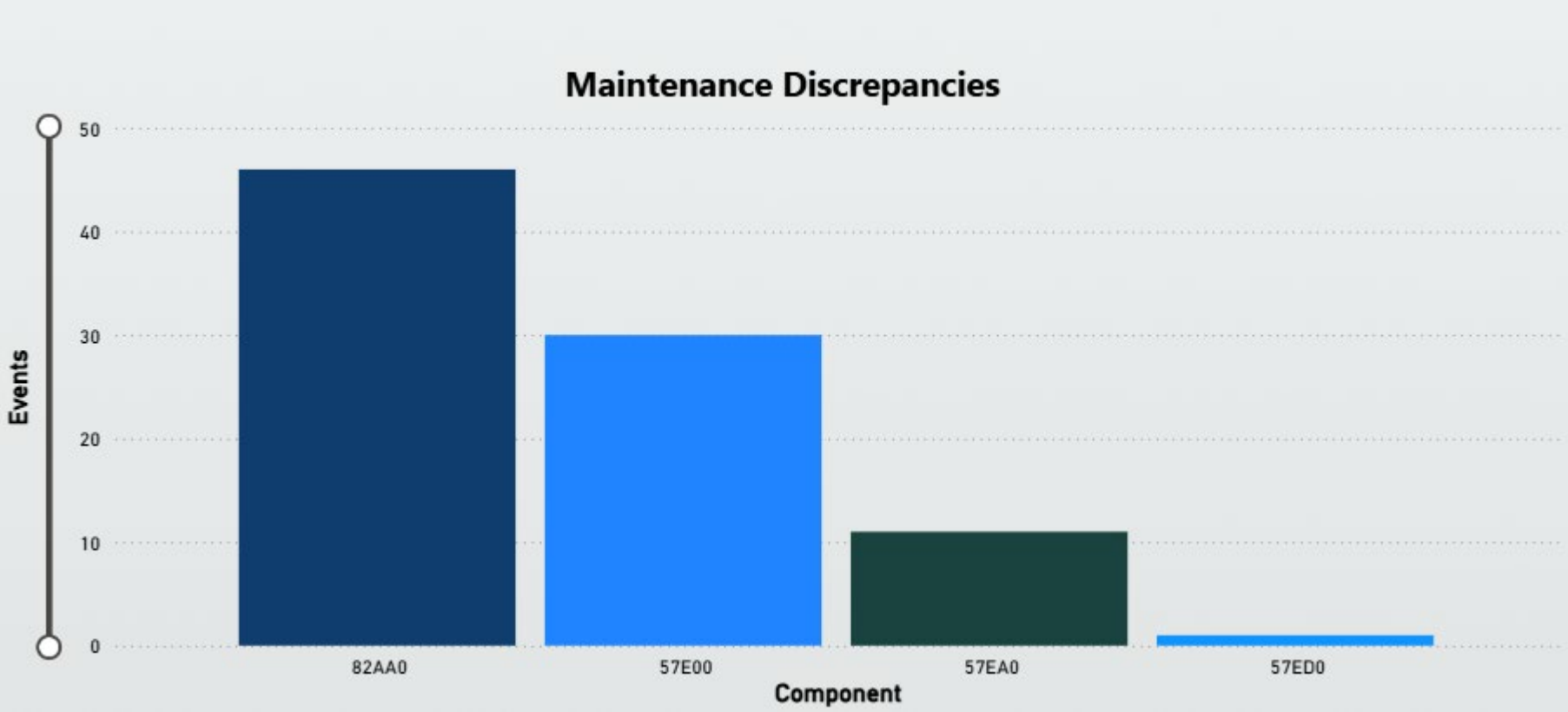
Ground Rules and Assumptions Continued

- Additional Search Parameters
  - Corrective Action Narrative: “CND”, “Cannot Duplicate”
  - How Mal Code: 901 – Intermittent
  - Discrepancy : “Uncommanded YAW”
    - Specifically called out by SPO engineering as area of interest for analysis
    - Uncommanded Yaw data will be considered separate from CND Datasets

Total Maintenance Events

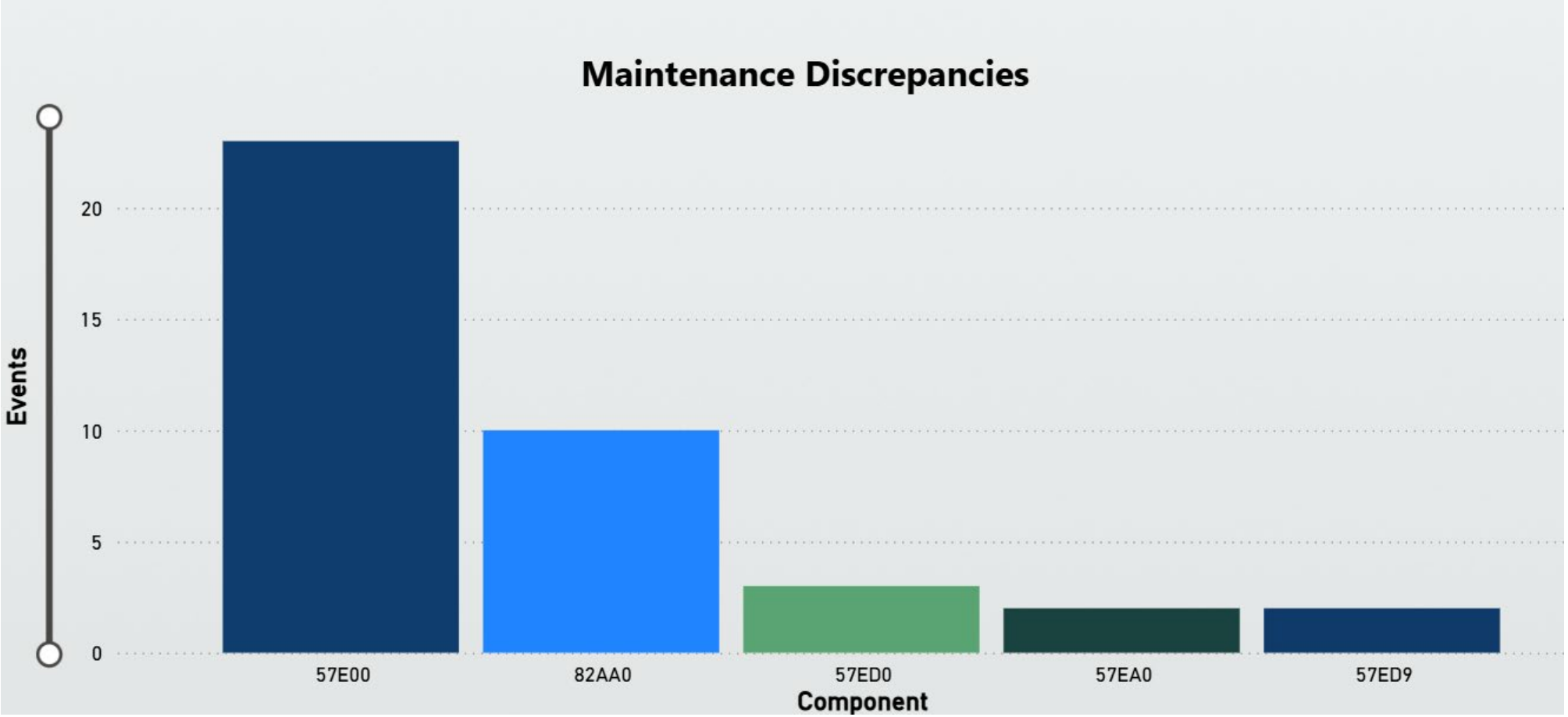


TO Defined Cannot Duplicate Events



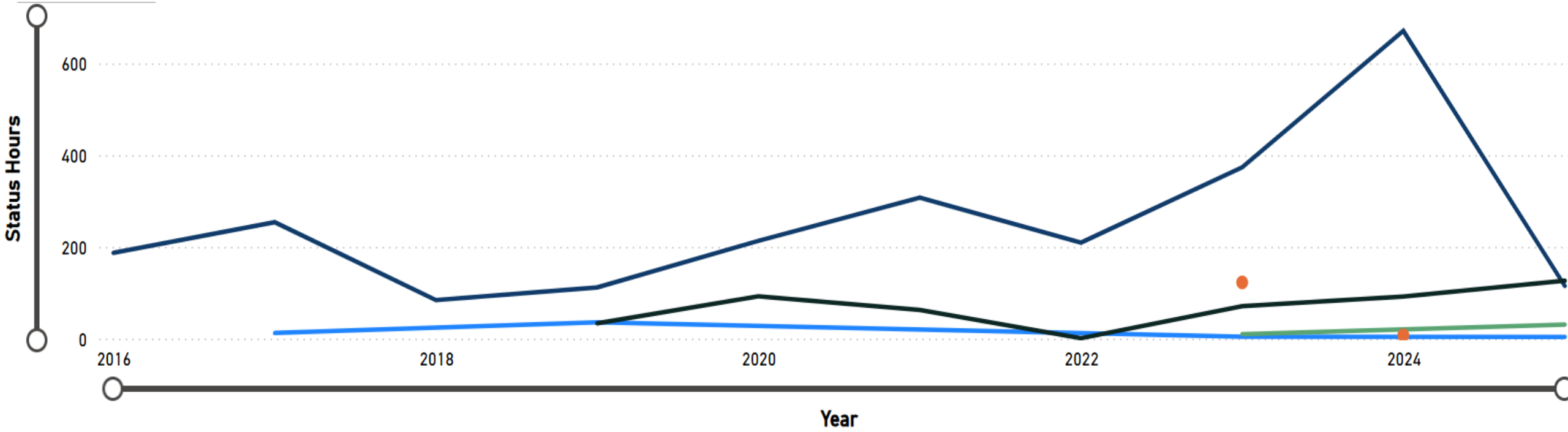
276 Maintenance Man Hours (MMH) and 458 NMC Hours aligned to CND events across fleet

Cannot Duplicate Events by Corrective Action Analysis



40 additional write ups under Action Taken J & X include “CND” in Corrective Action or Discrepancy
These write ups account for 229 MMH’s and 48 NMC Hours

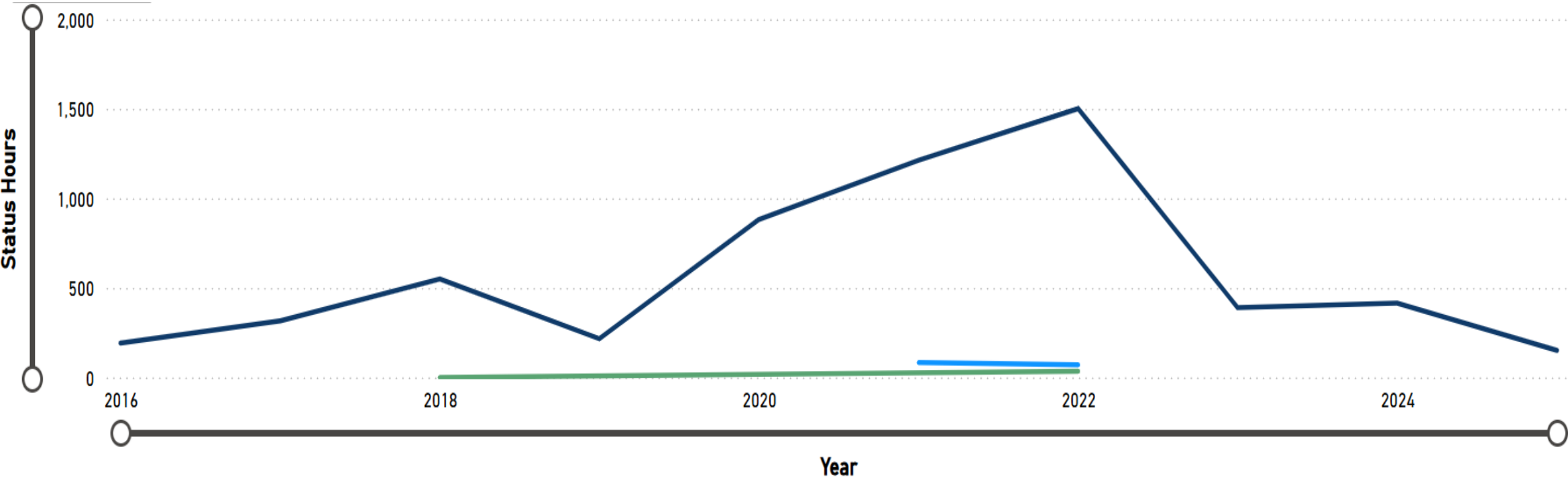
NMC Trend
82AA0



Unscheduled, Non-mission Capable Maintenance hours trended up from 2016 – 2024

2,535 NMCMU Hours, $23,420,129 in NMC “Cost”

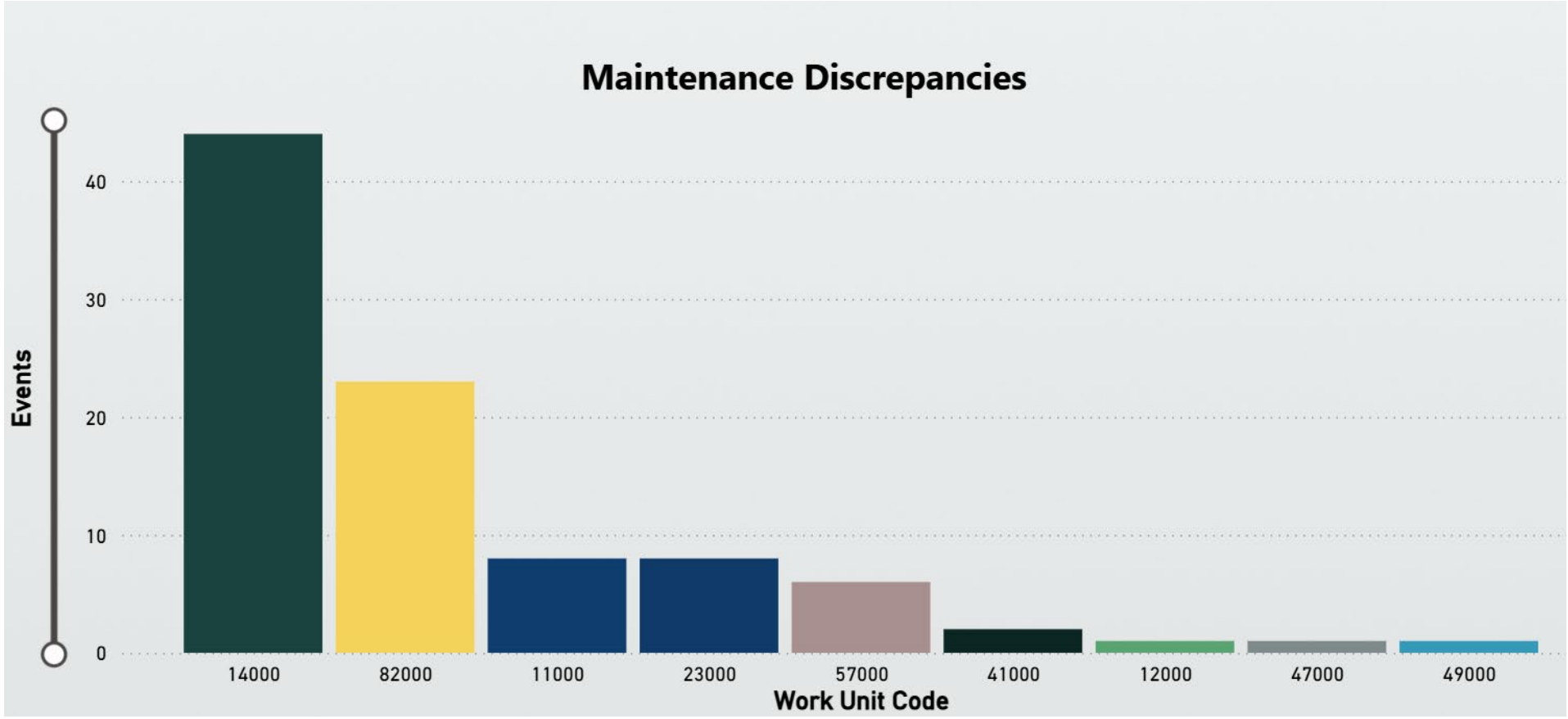
NMC Trend
57000



Unscheduled, Non-mission Capable Maintenance hours trended up from 2016 – 2022

5,981 NMCMU Hours, $55,275,446 in NMC “Cost”

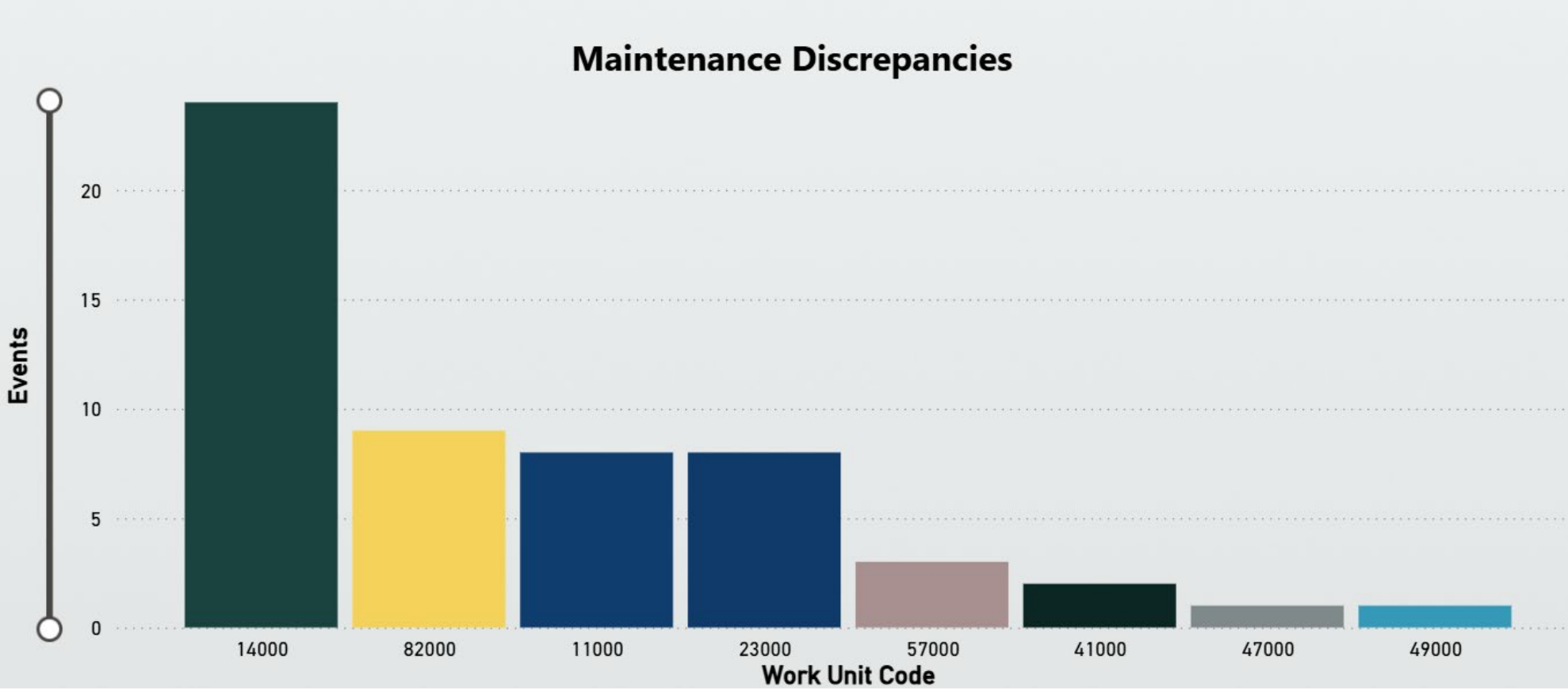
“Uncommanded Yaw”



432 Man hours, 11 Distinct JCN’s, 33 Distinct Work Unit Codes.

6 Tails effected, 60% of write-up against a single tail (Shut-off Valves, Bypass Valves, LVDT’s, VIA’s R2’ed)

Tail 1 Work Unit Codes



- 37 NMC Hours, 97 MMHrs

Tail 1 Discrepancies and Corrective Actions

Discrepancy	Corrective Action
(X) UNCOMMANDED YAW INPUT 20 LEFT @ 21,000 FT, 310 KNOTS, 2500 COPILOT PARTION AUTOPILOT FEET ON THE FLOOR SELF CORRECTED BACK TO THE RIGHT	VIA #1 OPS CK C/W, OPS CK GOOD, NDN
(X) UNCOMMANDED YAW INPUT 20 LEFT @ 21,000 FT, 310 KNOTS, 2500 COPILOT PARTION AUTOPILOT FEET ON THE FLOOR SELF CORRECTED BACK TO THE RIGHT	VIA #1 REINSTALLED
(X) UNCOMMANDED YAW INPUT 20 LEFT @ 21,000 FT, 310 KNOTS, 2500 COPILOT PARTION AUTOPILOT FEET ON THE FLOOR SELF CORRECTED BACK TO THE RIGHT	VIA #2 REINSTALLED
(X) ACFT IMPOUNDED DUE TO UNCOMMANDED YAW MOVEMENT IMPOUND OFFICIAL: MSGT HORAK 925-329-2954	REINSTALLED VIA #1 OPS CHK REQ SEE JCN 220101334
(X) UNCOMMANDED YAW MOVEMENT DURING DSCNT SPEED 280KTS, FL110 @APPROX 1824Z UNCOORDINATED TURN FELT AND PROCEEDED TO GET WORSE UNTIL AUGMENTATION WAS DISENG	VIA #1 RE-INSTALLED MOC GOOD
(/) UNCOMMANDED YAW AUG INPUT CAUSES AUTOPILOT TO DISENGAGE	VIA #2 R2
(X) ACFT IMPOUNDED DUE TO UNCOMMANDED YAW MOVEMENT IMPOUND OFFICIAL: MSGT HORAK 925-329-2954	R2D LVDT. OPS CK GD. 1C-5M-2-9-3 PARA 4.5.7
(/) UNCOMMANDED YAW AUG INPUT CAUSES AUTOPILOT TO DISENGAGE	REPLACED LT AILERON HYDRAULIC PRESSURE SWITCH. OPS CHK GOOD
(X) UNCOMMANDED YAW MOVEMENT DURING DSCNT SPEED 280KTS, FL110 @APPROX 1824Z UNCOORDINATED TURN FELT AND PROCEEDED TO GET WORSE UNTIL AUGMENTATION WAS DISENG	EBAS CK BAD, SEE 220381300 WES 027
(X) UNCOMMANDED YAW MOVEMENT DURING DSCNT SPEED 280KTS, FL110 @APPROX 1824Z UNCOORDINATED TURN FELT AND PROCEEDED TO GET WORSE UNTIL AUGMENTATION WAS DISENG	EBAS CK GOOD
(X) UNCOMMANDED YAW MOVEMENT DURING DSCNT SPEED 280KTS, FL110 @APPROX 1824Z UNCOORDINATED TURN FELT AND PROCEEDED TO GET WORSE UNTIL AUGMENTATION WAS DISENG	R2 #1 ENG HPSOV--LKC K DUE (SEE JCN 220455400); OPS CK DUE (SEE 220455401)
(X) UNCOMMANDED YAW INPUT 20 LEFT @ 21,000 FT, 310 KNOTS, 2500 COPILOT PARTION AUTOPILOT FEET ON THE FLOOR SELF CORRECTED BACK TO THE RIGHT	LOWER RUDDER CHANNEL B EHSV REPLACED LK CK GOOD
(X) ACFT IMPOUNDED DUE TO UNCOMMANDED YAW MOVEMENT IMPOUND OFFICIAL: MSGT HORAK 925-329-2954	EHSV R2D LK+OP CK GD 1C-5M-2-9-3 PARA 4.5.7
(X) UNCOMMANDED YAW INPUT 20 LEFT @ 21,000 FT, 310 KNOTS, 2500 COPILOT PARTION AUTOPILOT FEET ON THE FLOOR SELF CORRECTED BACK TO THE RIGHT	UPPER RUDDER CHANNEL B EHSV R2D, LEAK CK GOOD
(X) UNCOMMANDED YAW INPUT 20 LEFT @ 21,000 FT, 310 KNOTS, 2500 COPILOT PARTION AUTOPILOT FEET ON THE FLOOR SELF CORRECTED BACK TO THE RIGHT	OPS CK C/W, OPS CK GOOD, NDN
(X) ACFT IMPOUNDED DUE TO UNCOMMANDED YAW MOVEMENT IMPOUND OFFICIAL: MSGT HORAK 925-329-2954	UPPER RUDDER CH.A EHSV RECONNECTED. OPS CK GD IAW 1C-5M-2-9-3 PARA 4.5.7
(X) UNCOMMANDED YAW MOVEMENT DURING DSCNT SPEED 280KTS, FL110 @APPROX 1824Z UNCOORDINATED TURN FELT AND PROCEEDED TO GET WORSE UNTIL AUGMENTATION WAS DISENG	LOWER RUDDER MANIFOLD BYPASS SOV 2J1 R2
(X) UNCOMMANDED YAW MOVEMENT DURING DSCNT SPEED 280KTS, FL110 @APPROX 1824Z UNCOORDINATED TURN FELT AND PROCEEDED TO GET WORSE UNTIL AUGMENTATION WAS DISENG	R2 UPPER RUDDER 1J1 IAW 1C-5M-2-9-1PG2-200 PARA2.14.52 LK AND MOC GOOD
(X) UNCOMMANDED YAW INPUT 20 LEFT @ 21,000 FT, 310 KNOTS, 2500 COPILOT PARTION AUTOPILOT FEET ON THE FLOOR SELF CORRECTED BACK TO THE RIGHT	R2'D UPPER & LOWER RUDDER MANIFOLD B CHNL EHSV. SEE JCN 213394002 WES 007/8
(X) UNCOMMANDED YAW MOVEMENT DURING DSCNT SPEED 280KTS, FL110 @APPROX 1824Z UNCOORDINATED TURN FELT AND PROCEEDED TO GET WORSE UNTIL AUGMENTATION WAS DISENG	CENTERING SPRING R2'D SEE JCN 220391300 033. YAW AUG M TEST OPS CK GD.

Supply Chain Details

- Leading Tail (Tail 1)
  - 1 LVDT MICAP: $305K
  - VIA Requisitions:
    - 1 MICAP at Travis: $489K
    - 2 Requisitions at alternate locations totaling $732K
  - $1.53M in parts swapped on Tail 1 over the course of three years, above parts did not fix issue
  - Final write ups were to replace Engine High Pressure Shut off Valve and Safe-tie manual O2 Shut off Valve on Engine 1 in Feb-2022

Maintenance Analysis

- Over the last 10 years, the SAS saw a significant reliability drop
- Unscheduled NMCM hours followed general maintenance and CND trends
- A spike in “Uncommanded Yaw” events occurred from 2019-2022, majority of maintenance events against a single tail
  - None of the write ups from above tail were present in CND dataset
  - Significant Costs were incurred from LRU replacements
  - Final write ups against Engine 1 Shit off Valves in early 2022, no new occurrences since
  - No AWTS testing has been done on Tail 1, awaiting aircraft in PDM cycle

C5 SAS AWTS Testing

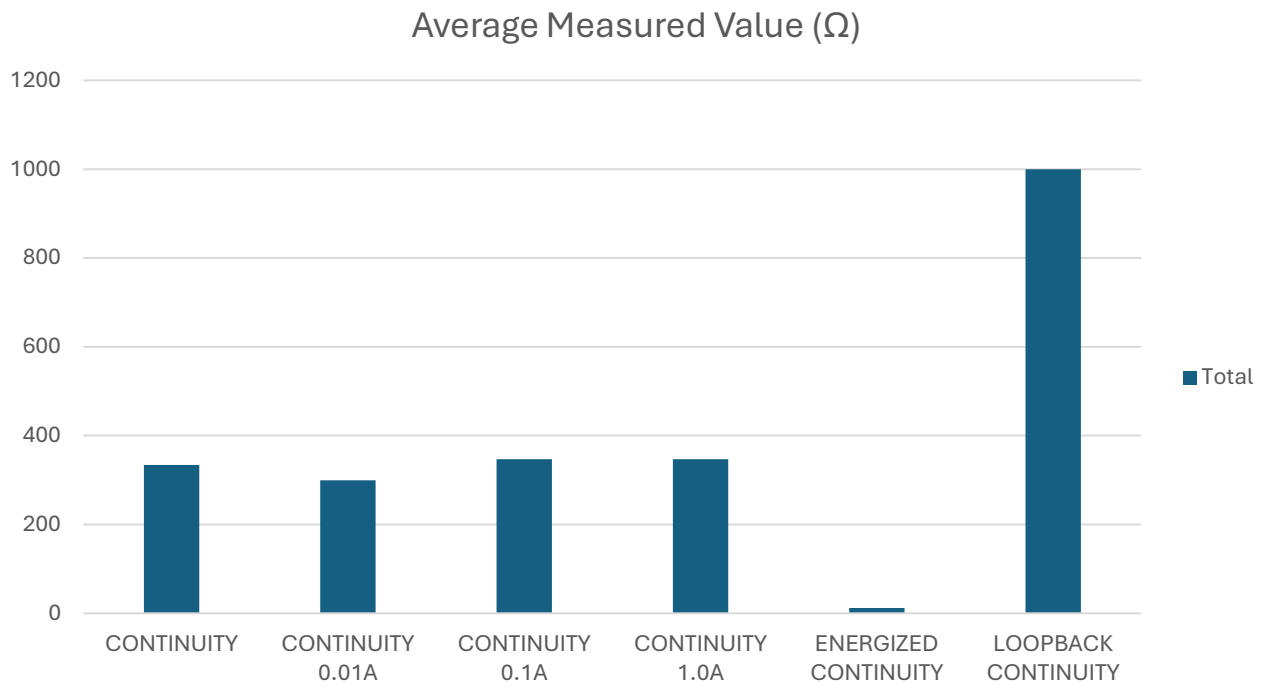
- Tails tested while at Robins for PDM, as well as TDY by Kihomac SME's
- SAS Tests Yaw Augmentation, Lateral Augmentation, and Pitch Augmentation Circuits
- To date, 6 tails have been tested, all showing extensive failures
- Can be followed up by Horizontal Stab AWTS testing if necessary

Failed Yaw AWTS Tests Tail 2

Test Type	Result	Measured Value (Ω)	Max Limit(Ω)	From Address	To Address
CONTINUITY 0.01A	HIGH	7.2694	4.47	P924A_E E6	AIRFRAME GND
CONTINUITY 0.01A	HIGH	7.6687	4.48	P924A_B B10	AIRFRAME GND
CONTINUITY 0.1A	HIGH	7.2005	4.45	P924A_E E6	AIRFRAME GND
CONTINUITY 0.1A	HIGH	7.6378	4.46	P924A_B B10	AIRFRAME GND
CONTINUITY 1.0A	HIGH	7.1979	4.45	P924A_E E6	AIRFRAME GND
CONTINUITY 1.0A	HIGH	7.6442	4.46	P924A_B B10	AIRFRAME GND
ENERGIZED CONTINUITY	HIGH	7.6429	5	P924A_B E10	AIRFRAME GND
ENERGIZED CONTINUITY	HIGH	7.7227	5	P924A_E B13	J501C 32
ENERGIZED CONTINUITY	HIGH	8.0696	5	P924A_B F8	AIRFRAME GND
ENERGIZED CONTINUITY	HIGH	8.0711	5	P924B_E B13	J501C 31

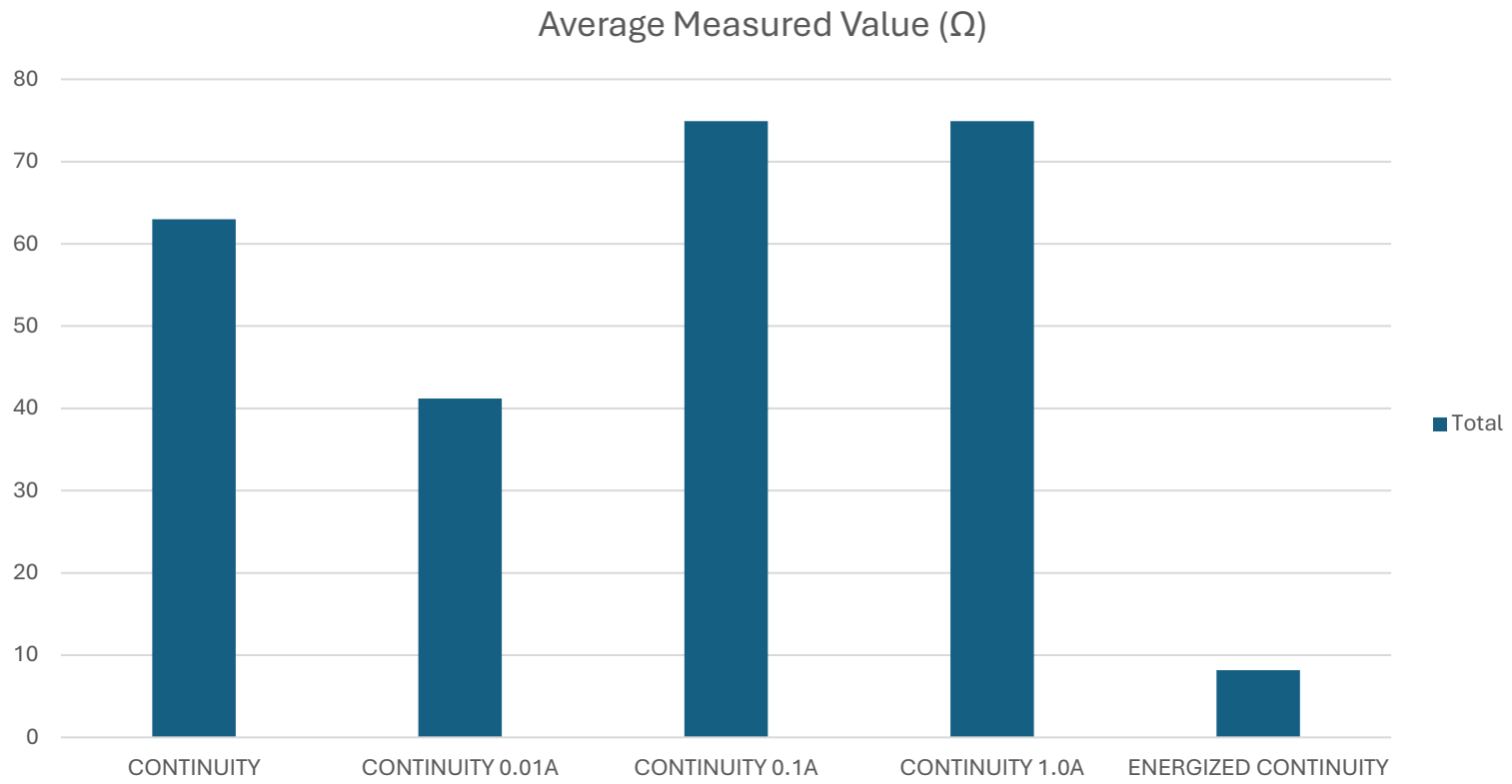
- AWTS Tail 2 Failed Yaw Tests
- Consistent Resistance measurements from P924A connector

Failed Yaw AWTS Tests Tail 3



- Results from Tail 3 summarized due to high failure count
- Continuity Outliers measuring >1 MΩ removed for visualization services
- Expected Values are .5, 2, and 5 Ω

Failed Yaw AWTS Tests Tail 4

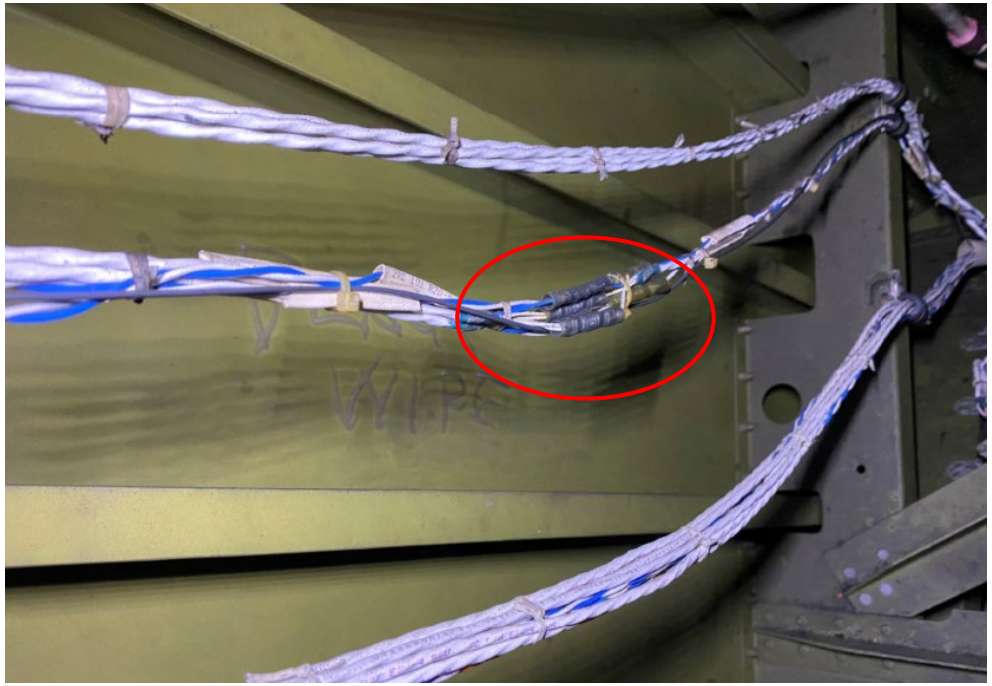


- Results from Tail 4 summarized due to high failure count
- Continuity Outliers measuring >1 MΩ removed for visualization services
- Expected Values are .34, 2, 4.4, and 5 Ω

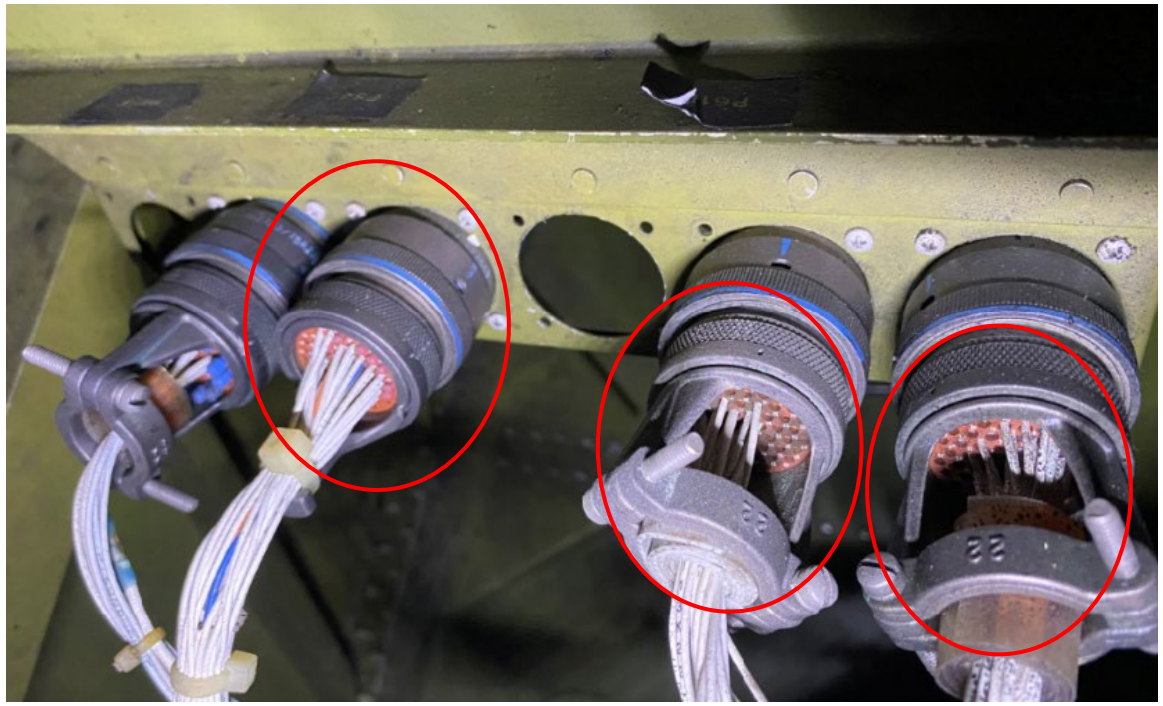
Analysis

- All Yaw failures due to high resistance across tails tested
- Tail 3 and Tail 4 showed significant issues with Yaw Augmentation circuits
- Even after removing outlier data, Tail 3 and Tail 4 measurements are highly suspicious
- Failures indicate poor wiring health: corrosion, damaged conductors, interruptions in wire path

SAS Audit Findings

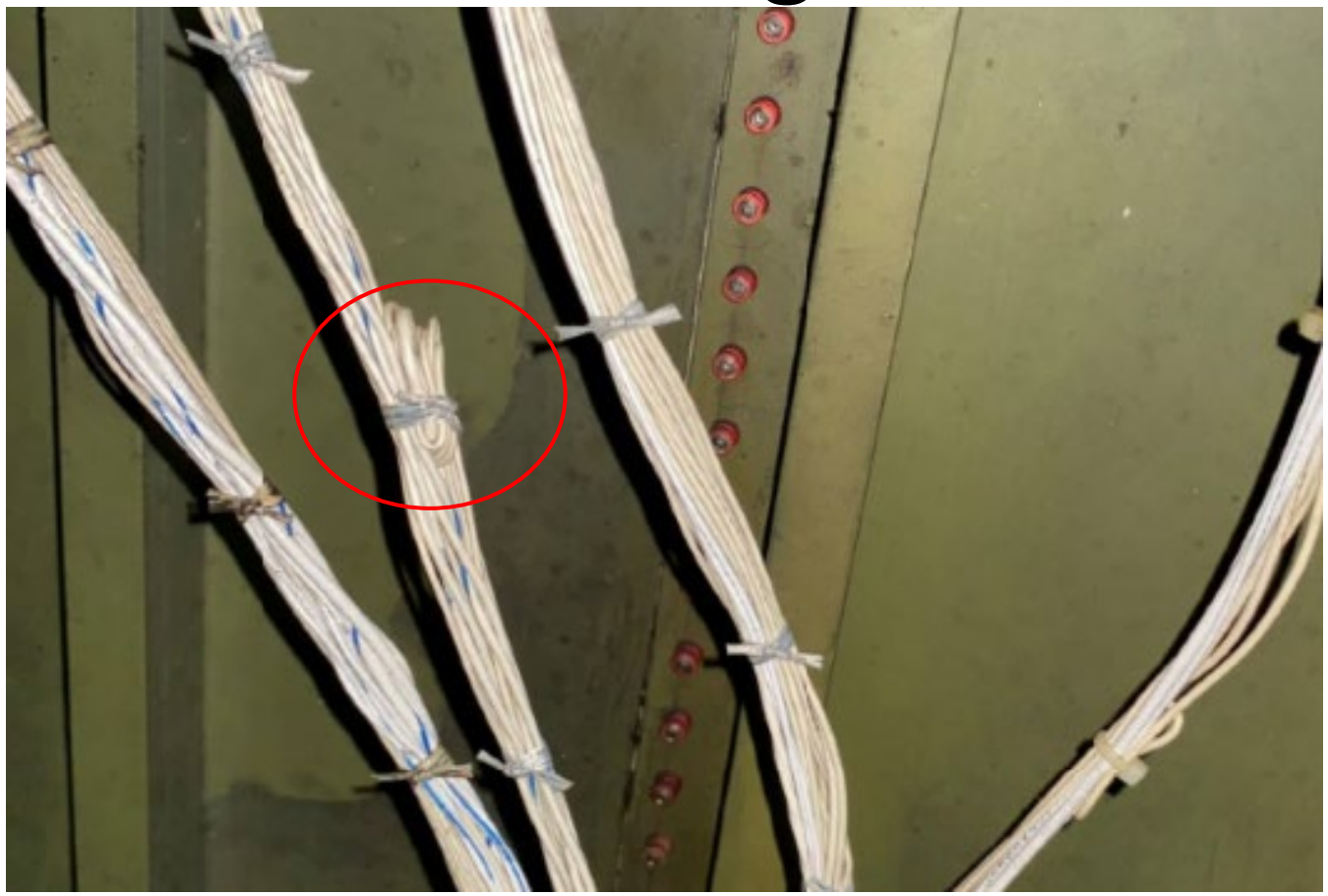


- Non-environmental splices, splices not staggered



- Multiple Cannon-Plugs missing sealing pins

SAS Audit Findings



- Extreme wire bend radius

Back-up

Lateral Test Failures

Failed Lat AWTS Test Tail 2

Test Type	Result	Measured Value (Ω)	Connector Identifier	Max Limit
CONTINUITY	HIGH	16.9341	P924B_A E11 to AIRFRAME GND	12
CONTINUITY 0.01A	HIGH	8.6378	P924A_B H14 to J536D E	8.3
CONTINUITY 0.01A	HIGH	9.2449	P924B_D H9 to J536D E	8.07
CONTINUITY 0.01A	HIGH	14.7182	J536D D to J536D E	14.51
CONTINUITY 0.1A	HIGH	5.5137	P924B_A E11 to AIRFRAME GND	3.91
CONTINUITY 0.1A	HIGH	8.3462	P924B_D H9 to J536D E	8.05
CONTINUITY 0.1A	HIGH	8.3555	P924A_B H14 to J536D E	8.29
CONTINUITY 1.0A	HIGH	14.533	J536D D to J536D E	14.5
ENERGIZED CONTINUITY	HIGH	7.2221	K84X A1-A2 Closed	5
ENERGIZED CONTINUITY	HIGH	7.5779	K84AD A1-A2 Closed	5
ENERGIZED CONTINUITY	HIGH	8.1596	K84AE A1-A2 Closed	5
ENERGIZED CONTINUITY	HIGH	8.361	K84Y A1-A2 Closed	5

Failed Lat AWTS Tests Tail 4

- Results from Tail 4 summarized due to high failure count
- Expected Values are 2 & 5 Ω

Failed Lat AWTS Tests Tail 3

Test Type	Result	Measured Value	Connector Identifier	Max Limit (Ω)
CONTINUITY 0.01A	HIGH	6.8382	P924A_E B6 to AIRFRAME GND	6.71
CONTINUITY 0.01A	HIGH	7.4178	P924B_B H14 to J536D F	7.39
CONTINUITY 0.01A	HIGH	7.9497	P924A_E D11 to P924A_A E11	7.6
CONTINUITY 0.01A	HIGH	8.6474	P924A_B E8 to J536D C	8.3
CONTINUITY 0.1A	HIGH	6.7579	P924A_E B6 to AIRFRAME GND	6.69
CONTINUITY 0.1A	HIGH	7.4398	P924B_B H14 to J536D F	7.36
CONTINUITY 0.1A	HIGH	7.8638	P924A_E D11 to P924A_A E11	7.6
CONTINUITY 0.1A	HIGH	8.5743	P924A_B E8 to J536D C	8.29
CONTINUITY 1.0A	HIGH	6.794	P924A_E B6 to AIRFRAME GND	6.69
CONTINUITY 1.0A	HIGH	7.4919	P924B_B H14 to J536D F	7.36
CONTINUITY 1.0A	HIGH	7.8656	P924A_E D11 to P924A_A E11	7.6
CONTINUITY 1.0A	HIGH	8.5764	P924A_B E8 to J536D C	8.29
ENERGIZED CONTINUITY	HIGH	6.8607	K84X A1-A2 Closed	5
ENERGIZED CONTINUITY	HIGH	7.5167	K84Y A1-A2 Closed	5
ENERGIZED CONTINUITY	HIGH	7.678	K84AD A1-A2 Closed	5
ENERGIZED CONTINUITY	HIGH	8.5788	K84AE A1-A2 Closed	5