Solid Rocket Booster Integrated Assemblies Support
Final Report

Prepared for:

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Under:

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Task Order No. 6

20 April 2001

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ABSTRACT

April 20, 2001

Gray Settle
bd Systems
600 Boulevard South
Suite 304
Huntsville, Alabama 35802

Dear Gray,

Attached is the final report that the Integrated Electronics Assembly Supportability Team (ISAT) presented to the Solid Rocket Booster Project Office on April 16. It is the culmination of two months of effort by representatives from all of the Engineering Directorate Departments, the Safety and Mission Assurance Office, the SRB Project, and SRB Operations, with support from United Space Alliance, L3 Communications and Honeywell. This report will serve as my final report on the task I have been performing as co-chairman of the ISAT team.

The problem reporting system was first documented and agreed to by USA, L3, and MSFC S&MA to assure that all problems would be included in the study. Then over 11,000 reports were gathered, categorized, and filtered. This data was used to assess the SRB IEAs for safety issues, reliability issues and supportability issues. The conclusions were that there were no safety issues at this time, both the flight reliability and the ground reliability of the 20 year old boxes are very high and the screens used between missions are effective, and that there are some supportability issues with the Aft IEAs in flying until at least 2020.

Based upon these conclusions the team made recommendations, which were broken down into things we believed were mandatory to meet supportability and things we believed were prudent actions to mitigate identified risks. The report was very well received by the Project Office. They were most complementary on the approach that had been taken, and said they did not believe any other such in-depth study had ever been performed on any Space Shuttle hardware.

James F. Blanche
bd Systems

Integrated Electronics Assembly Supportability Assessment Team

Final Presentation

ISAT Presentation
4/16/2001

- Introduction
- Strategy
- Database Consolidation
- Findings
- Conclusions
- Recommendations
- Adequacy of Qualification Test and Screens
- Wearout of Other SRB Avionics Boxes

Charter

- Assess the impact of aging and usage on SRB Forward and Aft Integrated Electronic Assemblies (IEA's)
- Determine the relative position of the IEA's on their expected reliability curves
- Provide recommendations, with supporting rationale, for any upgrades necessary to maintain reliability and logistics supportability through the year 2020
- If upgrades are recommended the team will define a roadmap for the design and implementation of the upgrade
- Assess the other reusable boxes on the SRB to determine if the screening tests between flights are adequate
- Assess the other reusable boxes on the SRB to determine if they are wearing out

Team Membership

Discipline	MSFC and Industry Team
Chairman	Jack Bullman / ED10, 4-9009
Avionics	Roger Baird / ED15, 4-3332 Jim Blanche / BD Systems, 4-3707 David Beeson / ED16, 4-0768
Supportability	Jim Sledd / ED42, 4-4058 Kevin Takada / ED42, 4-5616
S&MA	Charlie Chesser / QS01, 4-0107 Randall Tucker / QS21, 4-0640
Materials	Dion Jones/ED33, 4-8637 Jerry Wright / ED37, 4-4443
Statistics	Fayssal Safie / QS40, 4-5278 Bob Fuerst / HEI, 4-7031
SRB Operations	Tom Milner / MP41, 4-3984
SRB Project	Barry Guynes / MP41, 4-4979
Dynamics & Loads	Phil Harrison / ED21, 4-1521
Thermal	Dallas Clark / ED25, 4-9521 Scott Worley / ED16, 4-2252
Stress	Charles Meyers / ED22, 4-7192

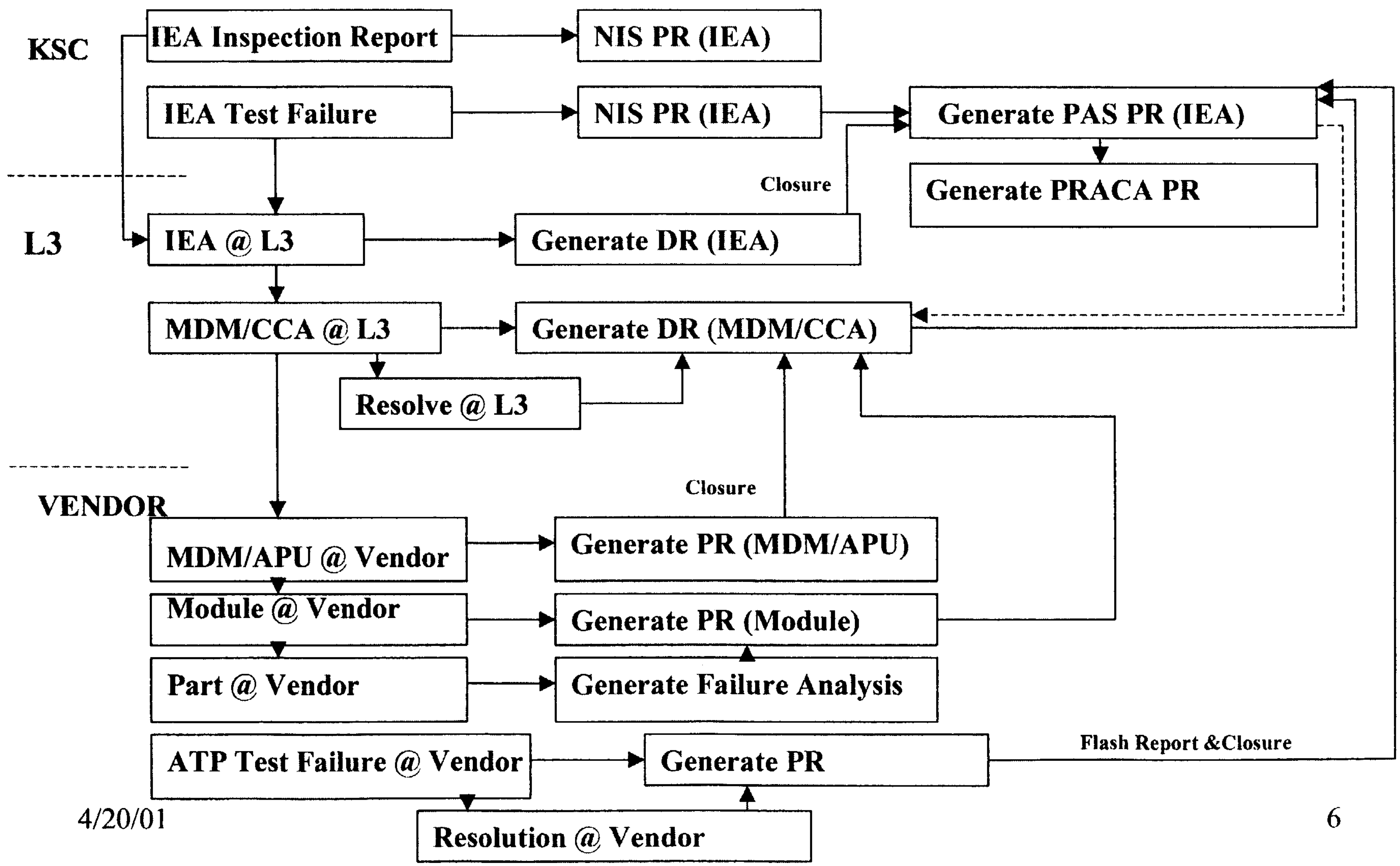
Advisory Panel

Mike Miller / USA
Jim Lacassagne / USA
Jerry Marguilles / USA
Charles Hartman / L3
Phil DiMarco/L3
Brad Bowhay / USA

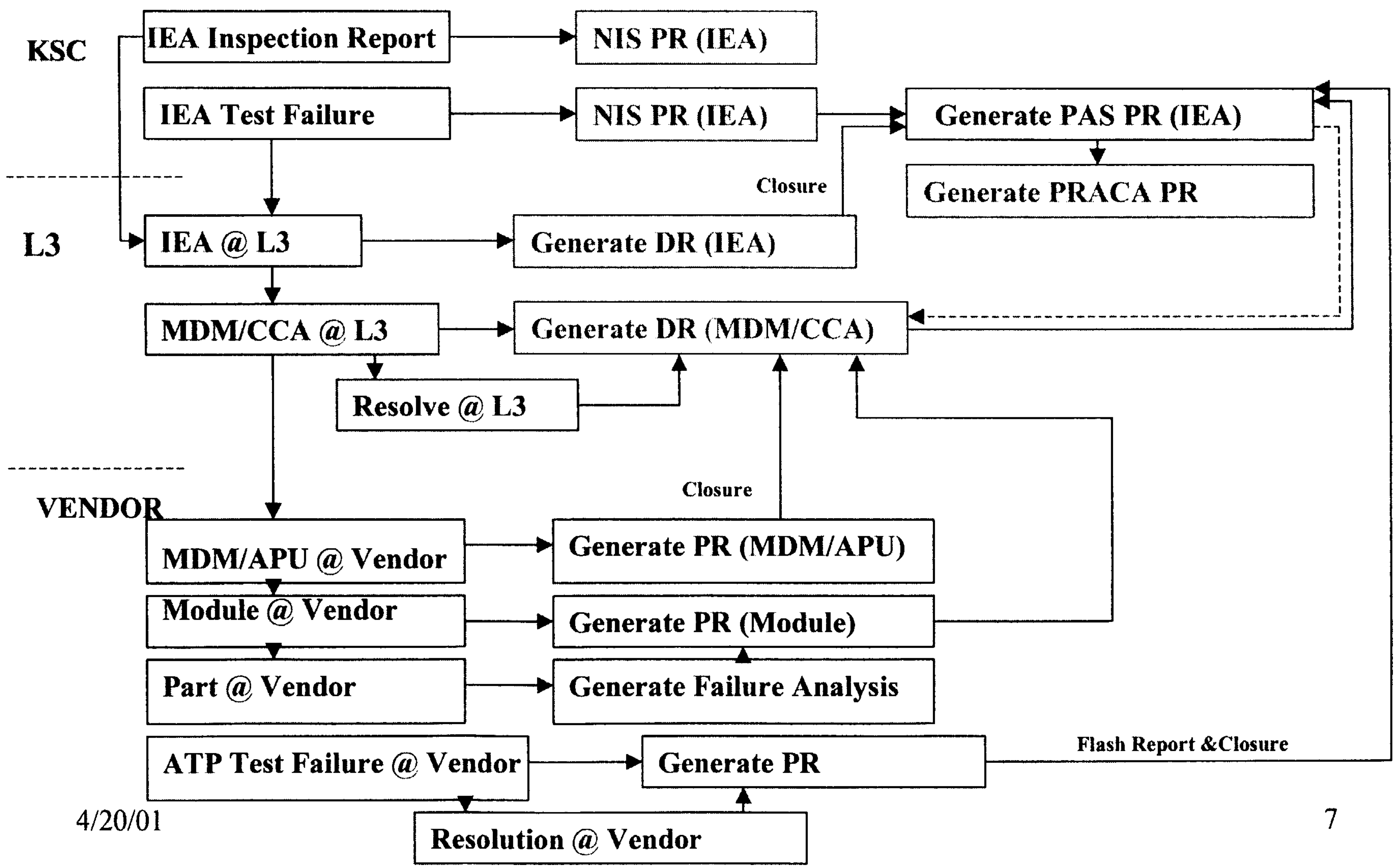
Strategy

- Consolidate databases
- Review and interpret data
- Report findings
- Provide recommendations

Database Consolidation



Database Consolidation



ISAT Failure Data Reviewed

- **Total Reports Reviewed** **11,455**

- **L3 Database** **9,648**
- **NIS Database** **1,663**
- **PRACA Database** **144**

- **Filtered to:**
  - **Test Failures** **790**
  - **Inspection Rejects** **4,074**

Definitions

Maintenance action – nonconformance which is detected during inspection

Failure – nonconformance which is detected during testing

Hard water impact – when an IEA shows external damage that indicates a harder than normal impact and initiates a complete teardown inspection

Obsolete part – a component which is no longer being produced.

Aging – effects due solely to time. Affects both stored and operating equipment/components/parts, e.g., resistor drift

Wear-out – effects due to operation; number of cycles, duty cycle, time in operation, and percent of operating capacity

GIDEP Alert – report of an actual or potential problem with parts, components, materials, or manufacturing processes which may have multiple applications in Government or industry.

Wear and tear – degradation to hardware resulting from age, use, maintenance and mishandling.

Findings

Programmatic Decisions Which Affected the Database

1981-1983 Corrosion of housing and external connectors led to connector greasing procedure and tunnel cable jacket redesign.

1987 Post-Challenger, instituted Modification Block – Harnesses R&R, Dale Resistor changeout implemented

1988-1989 MDM incorporation of power cross-strapping retrofit

- Completion of Modification Block
- Refurbishment authority given to USBI
- Change to Internal Inspection Criteria. New criteria calls for more detailed inspection
- PIC alerts
- Instituted connector sealing fix
- Bayonet connector anomaly and rash of "bird caging" anomalies. Thermal and vibration verification tests reinstituted in 1997 to screen for water impact (originally discontinued in 1993).

Findings

Programmatic Decisions Which Affected the Database

1998 PIC Raytheon transistor alert

1999 MDM solder lug inspections. APU controller module lap solder joint inspections.

2000 Low problem report count because:

- December 1998 – May 1999 Shuttle fleet grounded pending resolution of Orbiter wiring inspection. IEAs continued to be processed.
- July 1999 – December 1999 no flights during this period while waiting for Space Station payload. IEAs continued to be processed.

IEA Breakdown

- Integrated Electronics Assembly
  - Housing
  - Harness Assembly
  - MDM
  - PIC
  - Circuit Card Assemblies (CCAs)
  - EEE Parts

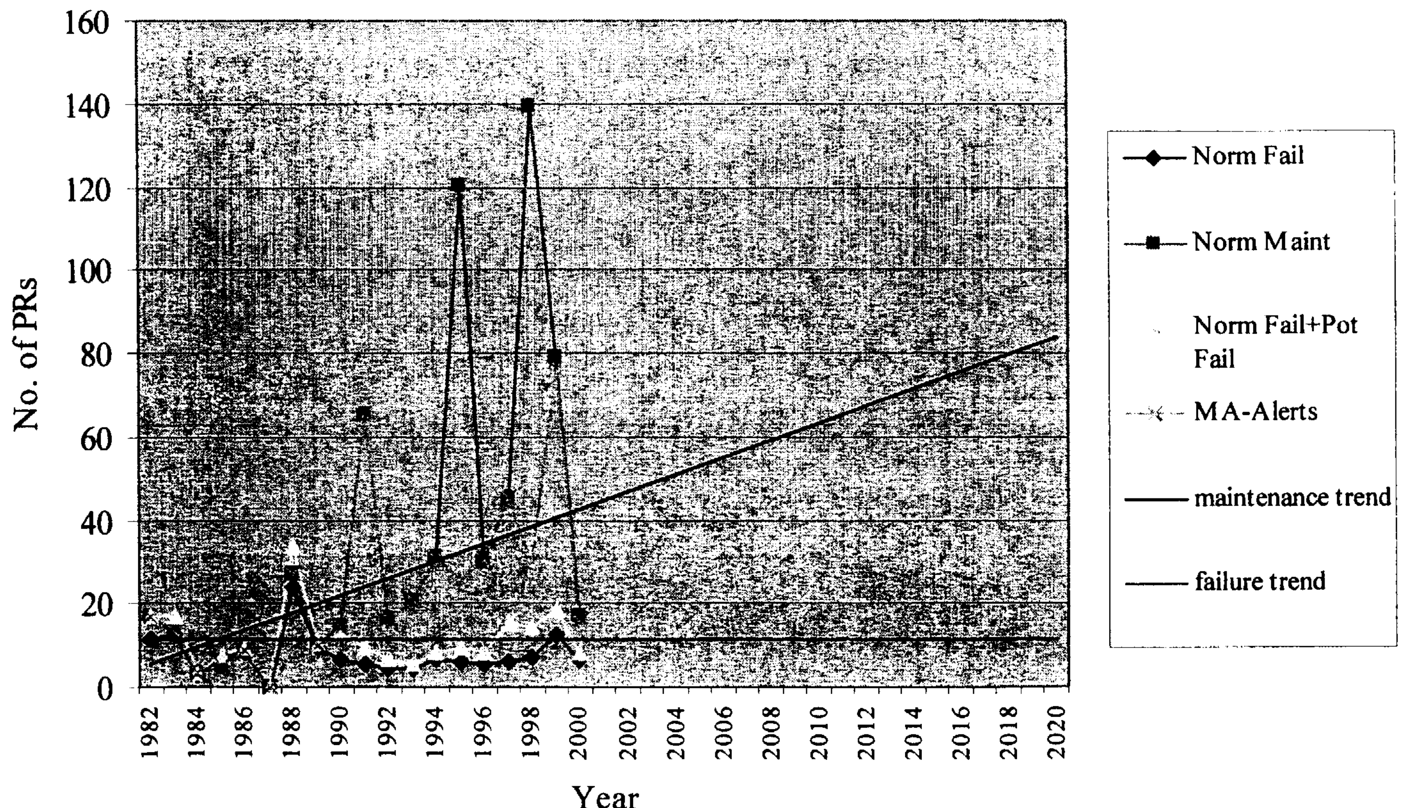
Condition of Hardware
Integrated Electronics Assembly

- The IEA'S were designed in the 1970's
- The IEA'S were originally designed for a life of 10 years and qualified for 20 flights
  - 50 IEAs in inventory (26 Aft, 24 Forward)
  - 17 IEAs (8 Aft, 9 Forward) are 23 years old (Components 25+)
  - The average IEA is 18 years old
  - The current fleet leader has 15 flights
  - The average IEA has had 9 flights
- In over 100 flights 10 IEA'S have been lost (5 FWD & 5 AFT)
  - Premature Water Impact Switch activation STS 4 – 2 Fwds, 2 Afts
  - Challenger STS 51L – 2 Fwds, 2 Afts
  - Water Impact STS 85 – IEA S/N 49
  - Slap-down STS 93 – IEA S/N 52
- No hardware has been lost due to a failure of IEA electronics during flight

Condition of Hardware

Integrated Electronics Assembly

Normalized Failures and Maintenance Actions for All IEAs



$y = -0.0007x + 11.293$

$y = 2.0617x + 3.3125$

Condition of Hardware

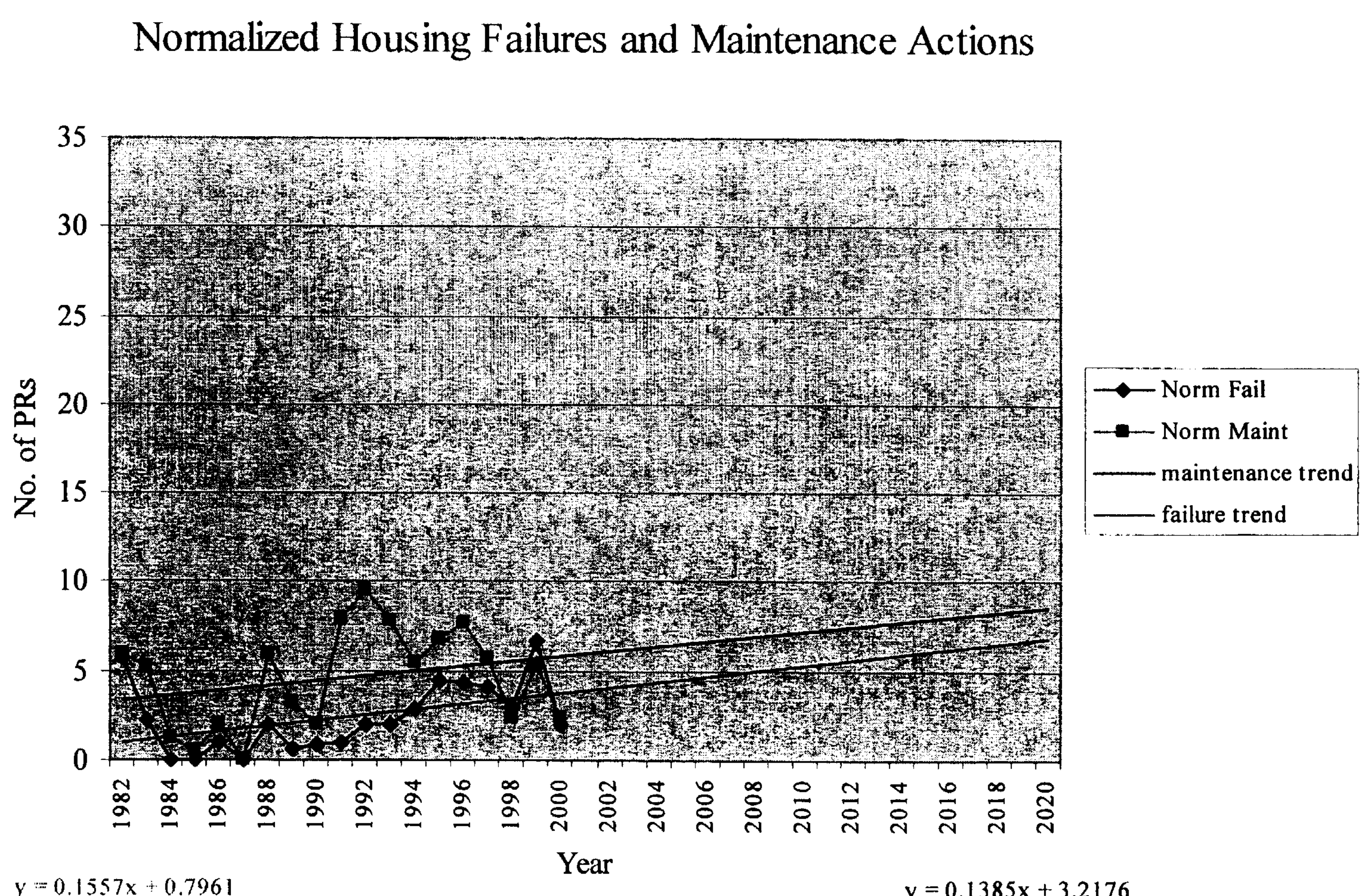
Housing

Loss of pressure is the leading cause of test failure. This is frequently caused by salt water corrosion at an external connector. Occurrence of this type of failure was greatly reduced after implementation of a sealing repair incorporated in 1996.

Hard water impact, which is a random event, is another major contributor to maintenance actions against the housing. The majority of impacted IEAs are aft. Precluding redesign of the SRB to protect the aft IEA or moving the aft IEA to a more benign environment, the maintenance actions and failures cannot be avoided.

Condition of Hardware

Housing



Condition of Hardware
Distributor Harness

Forward and aft distributor harnesses are likely to have numerous defective crimps. An L3 study indicates there are potentially over 5000 defective crimps in the IEA harnesses.

Nearly one third of all harness maintenance actions and failures are attributed to mishandling.

Aft IEA harnesses sustain more failures and maintenance than forward harnesses, largely due to the increased inspections that occur to an aft IEA.

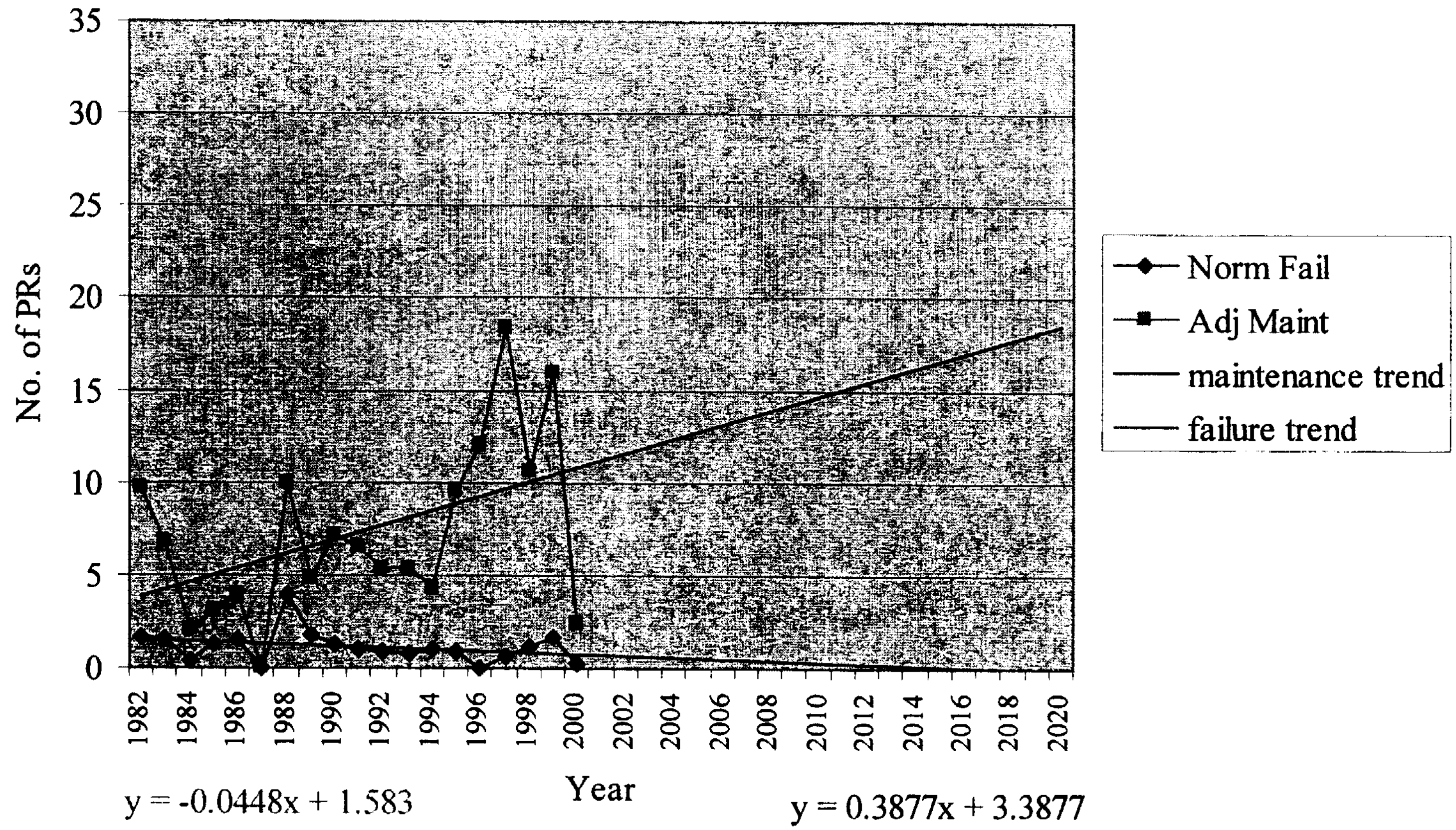
Although failure trends appear constant, research of the maintenance actions indicates that numerous inspection reports were generated which would likely have been identified as test failures, given the chance to fail.

Maintenance actions are increasing rapidly.

Condition of Hardware

Distributor Harness

Adjusted Harness Failures and Maintenance Actions (Normalized)

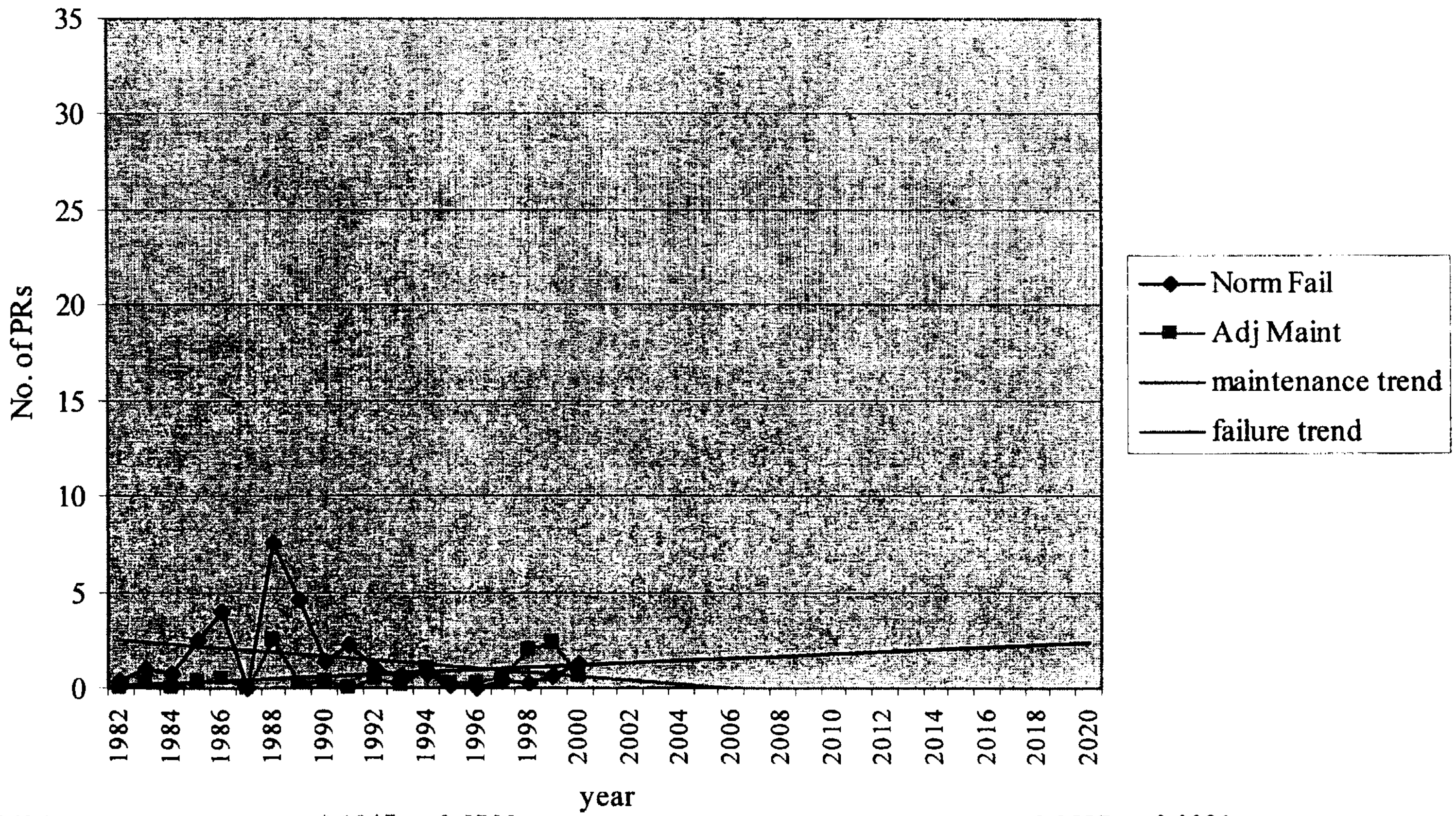


Condition of Hardware
MDM

Approximately 30% of all MDM failures are attributed to handling damage which occurred during power bus cross-strapping separation procedures.

Condition of Hardware
MDM

Adjusted MDM Failures and Maintenance Actions (Normalized)



y = -0.1047x + 2.5755

y = 0.0587x + 0.0391

Condition of Hardware
PICs

PICs in IEAs which are returned to L3 for hard water impact are purged from the SRB fleet.

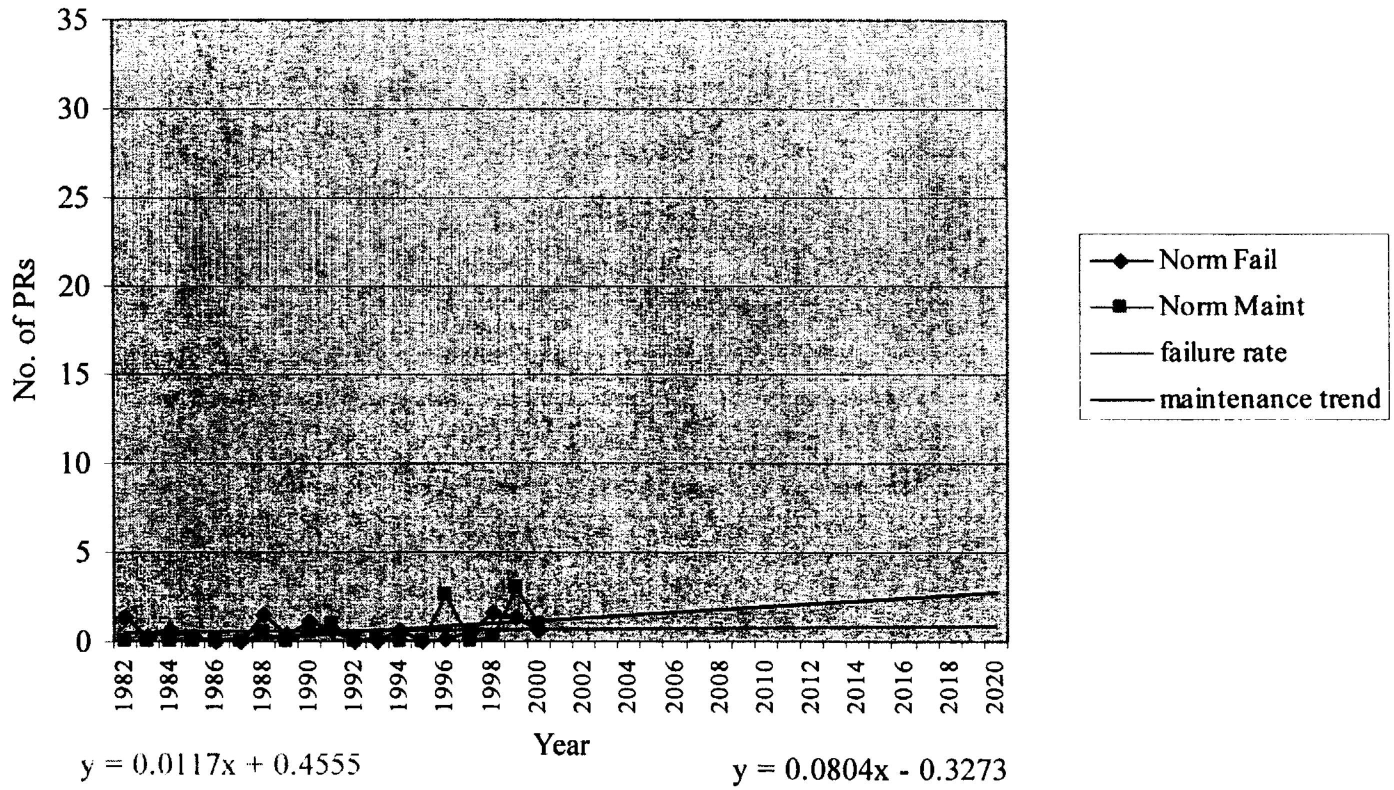
Some PICs have the silver-cased tantalum capacitors which are identified in a GIDEP alert.

- One failure, detected during testing, was been associated with the Silver/Tantalum capacitors.

Condition of Hardware

PICs

Adjusted PIC Failures and Maintenance Actions (Normalized)



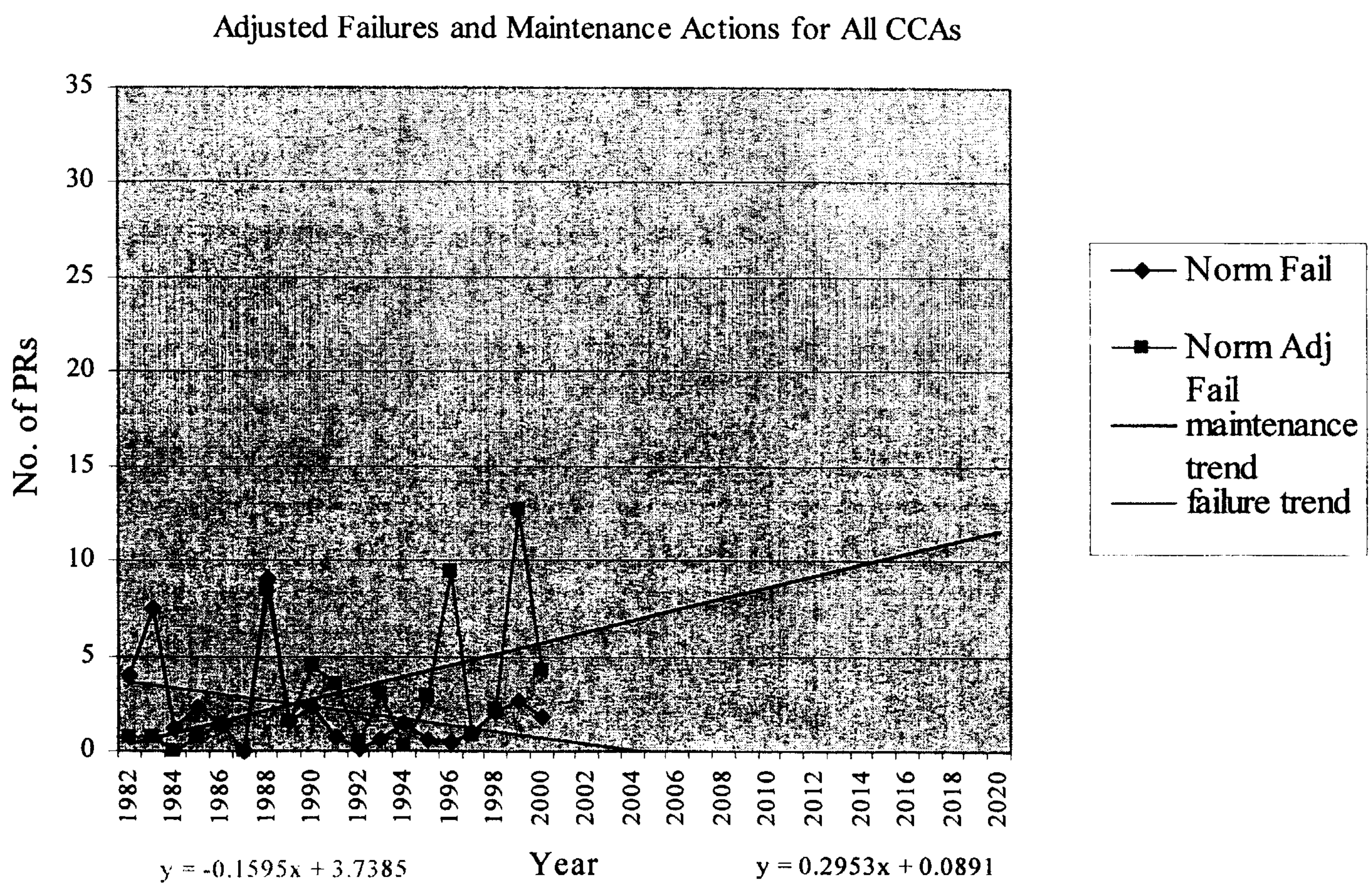
Condition of Hardware
Circuit Card Assemblies

Numerous problem reports have been generated against the circuit card assemblies because of parts alerts and suspected hard water impacts.

The majority of impacted CCA are located in the aft IEA. Precluding redesign of the SRB to protect the aft IEA or moving the aft IEA to a more benign environment, the maintenance actions and failures cannot be avoided.

Even after the database was adjusted to remove cards affected by alerts and hard water impacts, the CCAs clearly exhibit a rapidly increasing maintenance action trend.

Condition of Hardware
Circuit Card Assemblies



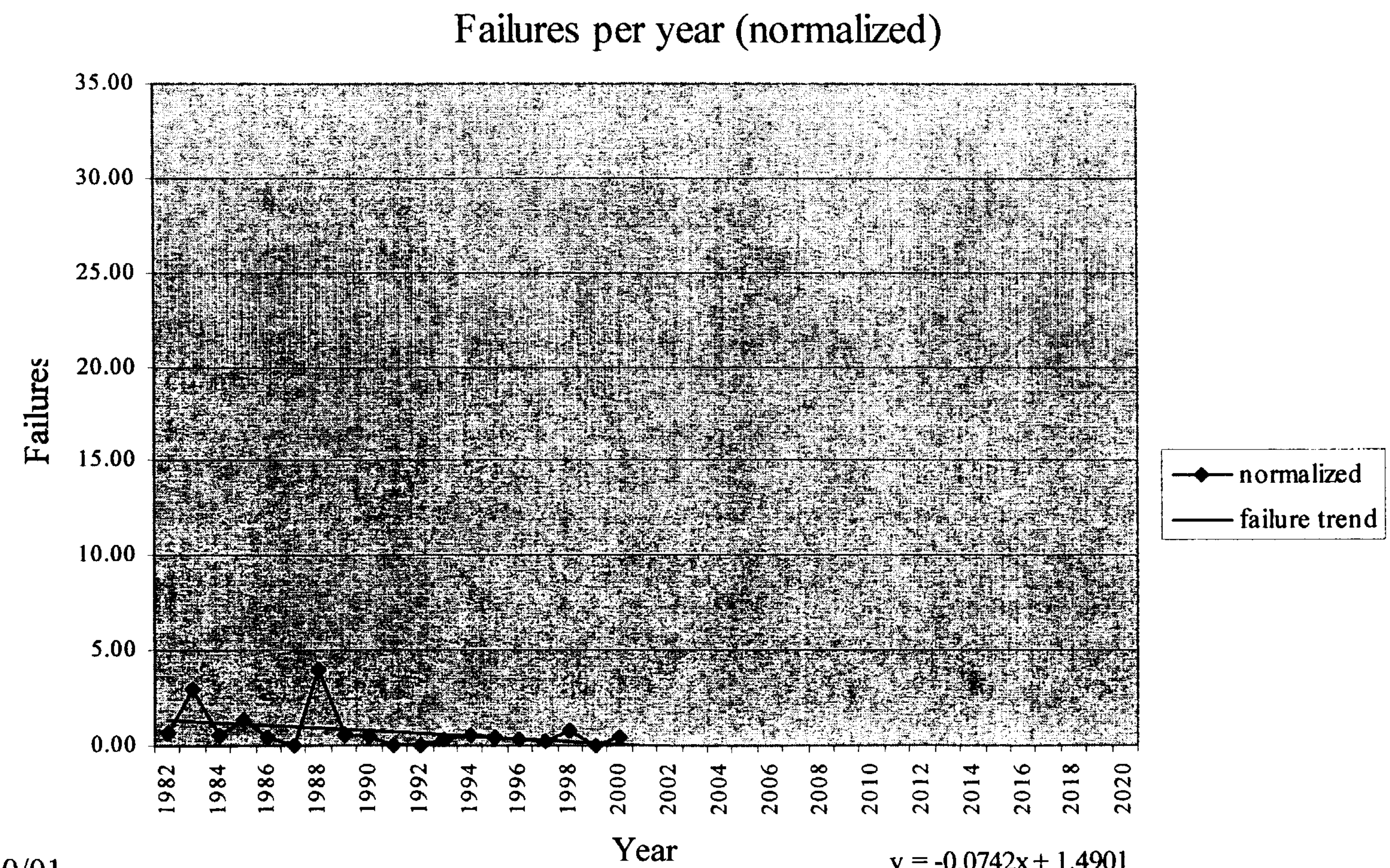
Condition of Hardware

EEE Parts

Failure rate for EEE Parts is constant.

Condition of Hardware

EEE Parts



Criteria for Upgrades

- Safety
- Reliability
- Supportability

Safety Assessment

- SRB IEA Safety Analysis consists of:
  - Original and change COQs documented and maintained
  - Hazard Analysis: Identifies all hazards
    - Controls identified and verified by tests/inspections
  - FMEA/CIL: Identifies all failure modes
    - All Crit. I/IR failure modes identified in CIL and verified
    - CIL establishes inspections & tests
  - S&MA reviews/approves ECPs, MRBs and Problem Reports

SYSTEM IN PLACE TO CONTROL IEA FLIGHT SAFETY RISKS

Safety Assessment

- Safety findings from ISAT review:
  - Flight Safety screens are adequate
    - Only 2 IEA flight “failures” identified in SRB life
      - STS-51C on-pad launch abort
        - » Box-level tests not updated to support new design and did not detect design error
      - STS-93 TVC Pressure measurement erratic
        - » Bent connector socket pin caused ‘open’ circuit
      - » **Both failures occurred as a result of process escapes.**
  - » No hardware flight safety failures in history of IEA

NO FLIGHT SAFETY CONCERNS SURFACED DURING ISAT REVIEW

IEA Reliability Assessment

- IEA reliability has been reviewed in two contexts:
  - Reliability trend analysis of failures occurring during ground processing
  - Demonstrated reliability using flight history
- In both contexts, it is necessary to determine if the failure rate is constant or is increasing as a function of time

IEA Reliability Assessment

- IEA Reliability Trend Analysis
  - Two possible approaches for assessment of IEA reliability from failure history:
    - Quantitative analysis – use a failure model (e.g. Weibull model) which probabilistically characterizes the failure history and determines, using the model parameter, if wearout is occurring
    - Qualitative analysis – use trend analysis of historical failure data
  - Quantitative analysis is not feasible since IEA time to failure data is unavailable (not recorded)

IEA Reliability Assessment

- IEA Reliability Trend Analysis, cont'd.
  - In the absence of time to failure data, trend analysis can be used to project reliability trends
    - Generate graph of total failures at IEA level normalized to flights per year
    - Generate graph of total failures at SRU level normalized to flights per year

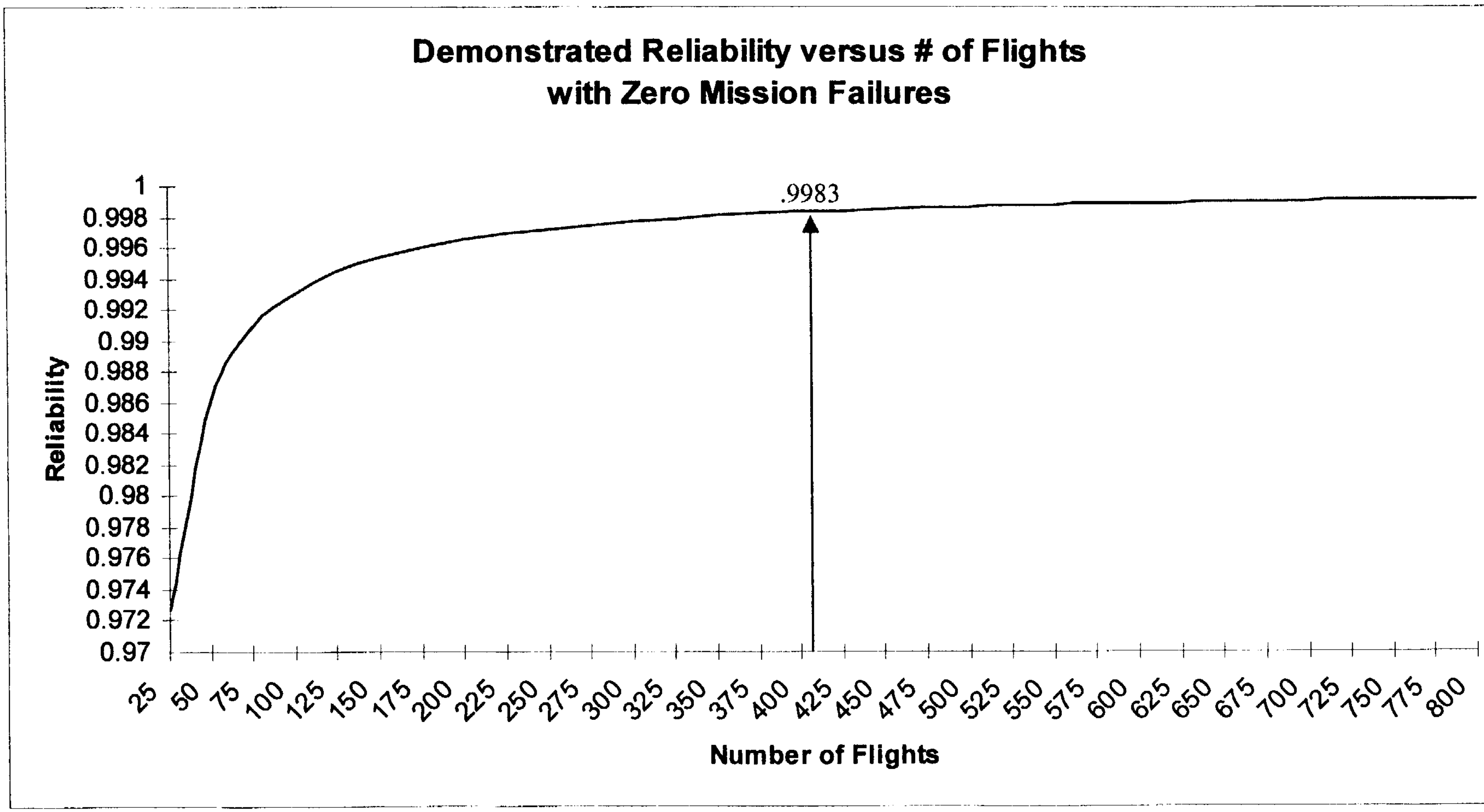
IEA Reliability Assessment

- IEA Reliability Trend Analysis Summary
  - Based on trend analysis of IEA failure data, there is no evidence of an upward trend at either the IEA or SRU level that indicates the presence of wearout mechanism(s)
  - As a result, constant failure rate can be assumed when estimating flight reliability
  - There is no guarantee that wearout will not occur in the next 20 years, only that it is not yet occurring

IEA Reliability Assessment

- IEA Demonstrated Flight Reliability Summary
  - Flight history to date shows that IEA demonstrated reliability is
    - .9983 for one IEA flight (1 in 588)
    - .9932 for one STS mission (1 in 147)
    - Based on zero in-flight mission failures in 102 missions (408 IEA flights)

IEA Reliability Assessment



IEA Reliability Assessment

- IEA Reliability Conclusions
  - Extensive prelaunch/postflight IEA inspections and tests have significantly enhanced flight reliability
  - Based on trend analysis of IEA failure data, there is no evidence of an upward trend at either the IEA or SRU level that indicates the presence of wearout mechanism(s)
  - Trend analysis supports the assumption of constant failure rate
  - Future flight reliability is expected to remain unchanged unless wearout phenomenon occurs in the next 20 years of useage

Supportability Assessment

- Obsolescence/Spare Parts
- Attrition of IEAs
- Turn-around time
- End of Qualification Life

Supportability Assessment
Obsolescence/Spare Parts

<u>L3 CCAs</u>

- Spare parts have been identified by the manufacturer for all hardware
- Parts are either in stock, readily available or alternates have been found except for possibly 3 resistors and 1 relay which are being reviewed by L-3.

Supportability Assessment
Obsolescence/Spare Parts

<u>MDM – Honeywell</u>

- No spare modules.
- Comprised of 90% custom made hybrids.
- Op Amps, CMOS die, PROM flat packs, Analog Multiplexer all identified as obsolete in 1984.
- Spare hybrids in stock
- 51 Flight MDMs in present inventory.

Supportability Assessment
Obsolescence/Spare Parts

EMDM – Honeywell

- No obsolete parts.
- Several parts must be replaced within each unit because of improper screening (GIDEP Alert).
- 27 units produced.

Supportability Assessment

Obsolescence/Spare Parts

Signal Conditioners – Eldec

- Manufactured by Eldec, now maintained by L-3.
- Connector is not available and there is no substitute.
- To date L-3 has not purchased any EEE piece parts stock as spares nor have they done an obsolescence study on the cards.
- L-3 does have the EEE parts lists for the CCAs but several parts are governed by Eldec source control drawings which L-3 does not have.
- MSFC has requested all design documentation from Eldec.
- Spare signal conditioner cards could be sacrificed to obtain board edge connectors.

Supportability Assessment
Obsolescence/Spare Parts

APU Controller – Sundstrand

- No obsolescence issues for EEE parts.
- All parts still available
- New printed wiring board artwork or a new printed wiring board layout needed to build new controllers.
- MSFC has requested all design documentation from Sundstrand.

Supportability Assessment
Attrition

- Key Assumptions
  - Flight attrition –
    - hard water impact (1 Fwd and 1 Aft IEA lost in 102 flights to date)
    - Loss of vehicle (half of historical rate of 1 in 102 flights)
  - Failure rate – constant IEA failure rate based on observed failure history (supported by trend analysis)
  - Mishandling - increasing rate of mishandling PRs over time based on historical data (supported by trend analysis)
  - Maintenance actions - increasing rate of maintenance actions over time based on historical data (supported by trend analysis)
  - Flight rate – 6 flights per year through 2020

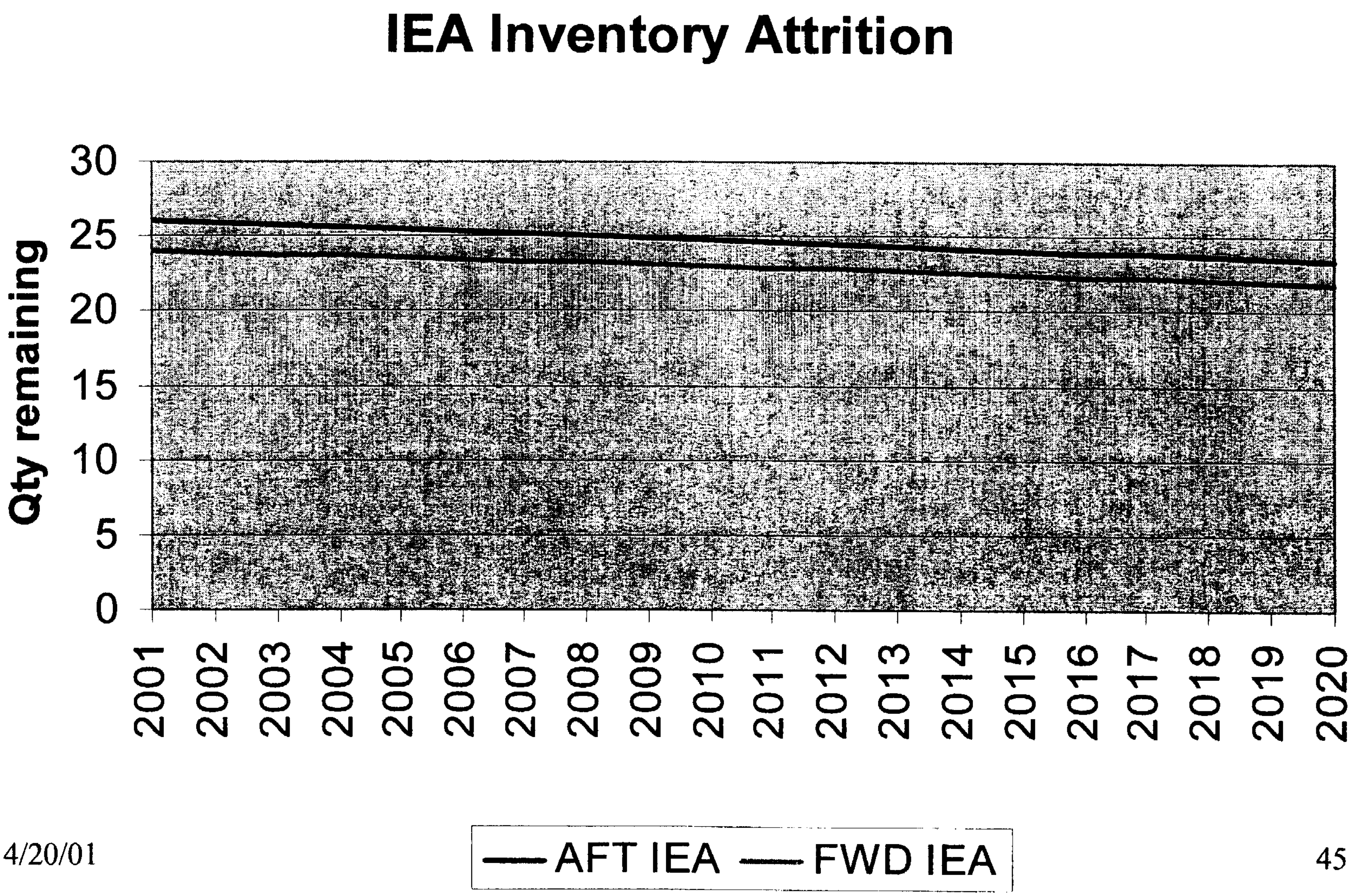
Supportability Assessment
Attrition

IEA Attrition Analysis:

- Model the IEA inventory available for flight as a function of time
- Account for inventory attrition due to in-flight loss, failures during processing, mishandling, maintenance, etc.

Supportability Assessment

Attrition



Supportability Assessment

IEA Recertification Process

Days required to process an IEA, excluding refurbishment/recertification time:

31 days from SRB flight retrieval to prepare for refurbishment/recertification

327 days to build-up, checkout, transfer, stack, and launch operations for a forward IEA

284 days for build-up, checkout, transfer, stack and launch operations for an aft IEA

Supportability Assessment
IEA Recertification Process

The IEA test sets at L-3 are antiquated and are frequently out of service for repair.

Approximately 3 out of every 4 electrical test failures detected at L-3 are determined to be test set failures.

Testing of IEAs at L-3 is the “bottle neck” in the recertification process.

Supportability Assessment

IEA Process Rate

Estimate the average time added to a forward and aft IEA process flow by a single problem report.

Groundrules and assumptions:

Cosmetic maintenance reports will not be included.

Maintenance reports generated from alerts, hard water impacts and suspect conditions will be separated. Typically, these maintenance actions were pre-coordinated to minimize the impact to nominal process flow. Therefore they will normally add less time to the process flow than other maintenance actions. These reports do not appear to follow a trend, so estimation of time required to process the hardware implicated by these reports will be added as an offset to the time-estimation calculation.

Failure and maintenance actions which cannot be classified as being associated with either the forward or aft IEAs will be divided equally between both.

Supportability Assessment

IEA Process Rate

Estimate the average time added to a forward and aft IEA process flow by a single problem report.

Groundrules and assumptions, cont'd.:

Corrosion on aft IEAs appears to be less prevalent since incorporation of sealing techniques to the connectors. However, until the complete cleaning/sealing process is incorporated on all the aft IEAs, the assumption must be made that the IEAs are still susceptible to corrosion.

For simplicity, straight line approximations are used in this calculation. However, at the beginning of Shuttle operations, there were an unusually large amount of failures recorded. To most accurately track the failure data, failures and maintenance actions recorded in 1981 will not be displayed on this chart.

Supportability Assessment

IEA Process Rate

Estimate the average time added to a forward and aft IEA process flow by a single problem report.

Basis for calculations:

Determine the number of problem reports generated against forward and aft IEA hardware.

Using data provided by USA and L-3, estimate the amount of time required to address each type problem report.

Calculate the likelihood of each module to receive a problem report.

Calculate the weighted average of problem reports each module has received.

Multiply the weighted average by the estimated time required to address the problem report. This is the weighted average time required for each type problem report.

Add the weighted times together to determine the average number of days added to an IEA process flow for a single problem report.

To generate a chart for IEA process rate, multiply the average number of days per single problem report by a factor of 1.5 to compensate for occasional parallel processing of problem reports.

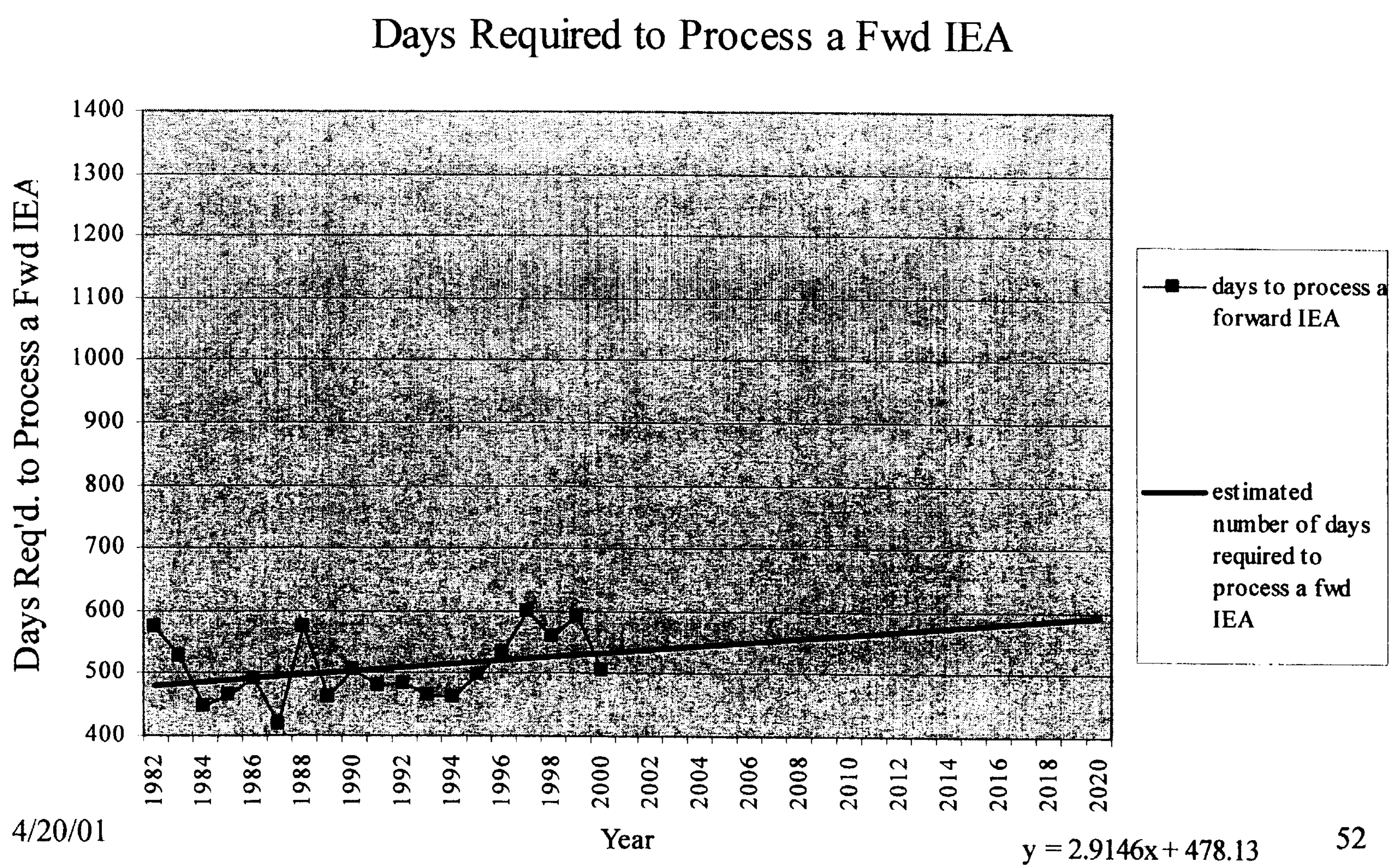
Supportability Assessment

IEA Process Rate

Calculation of Number of Days Required Per Problem Report				
combined descrepancies (maintenance		percent of total descrepancies	days added to process flow with a problem report	days * percentage
CCA	491	19.7%	17	3.3
Harness	895	35.8%	30	10.7
Housing	788	31.5%	12	3.8
MDM	194	7.8%	18	1.4
Other	130	5.2%	15	0.8
total	2498	Average number of work days added to a nominal IEA flow for a single problem report		20.1

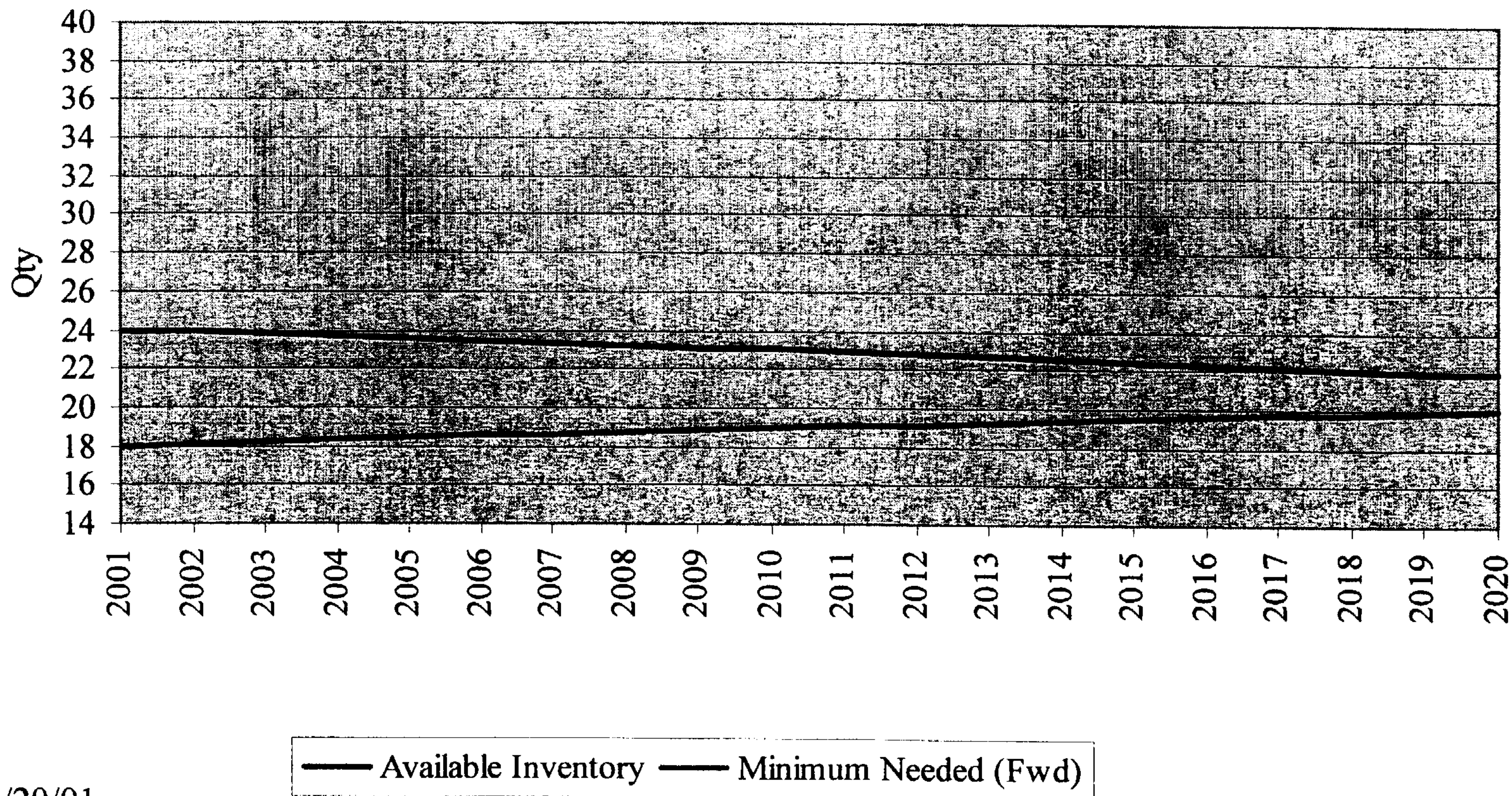
An additional 2367 problem reports were written against IEA hardware as a result of alerts, hard water impact and suspect conditions. These are random occurrences which are not expected to increase, therefore the Processing Time trend curve will be offset to reflect these discrepancies (2367 discrepancies / 20 years) to account for future random occurrences.

Supportability Assessment
IEA Process Rate



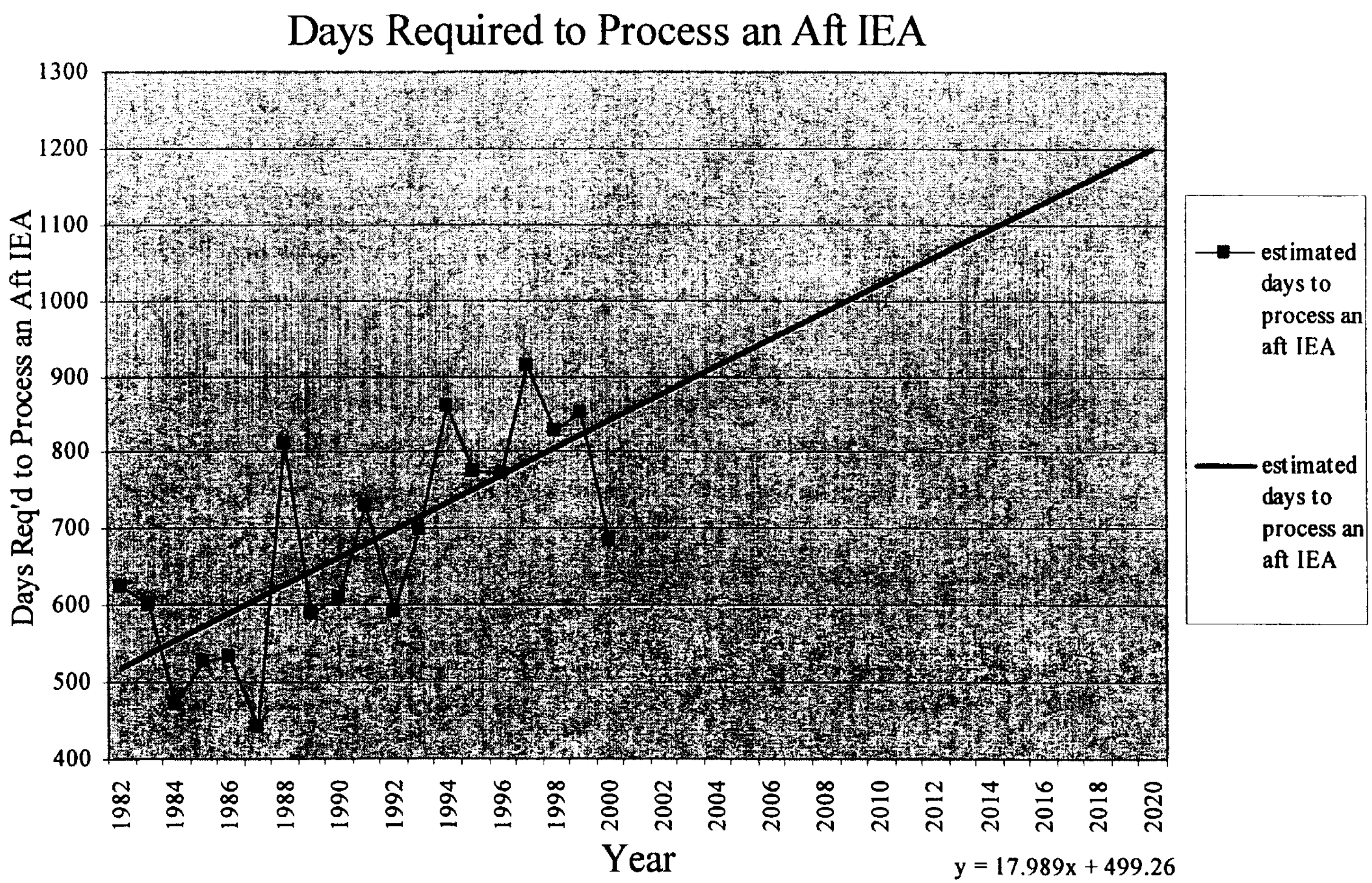
Supportability Assessment
Forward IEA Supportability

Forward IEA Supportability

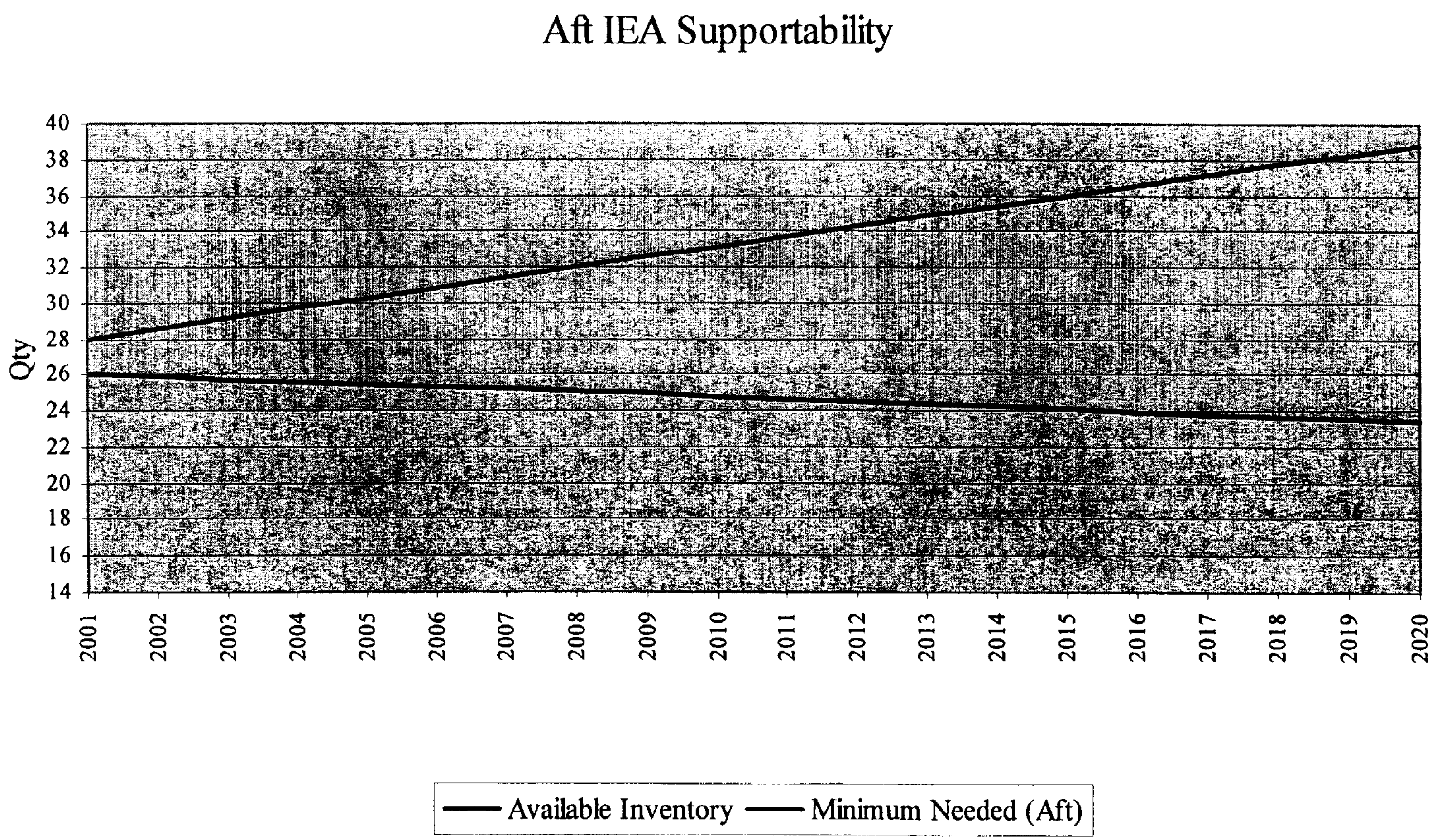


Supportability Assessment

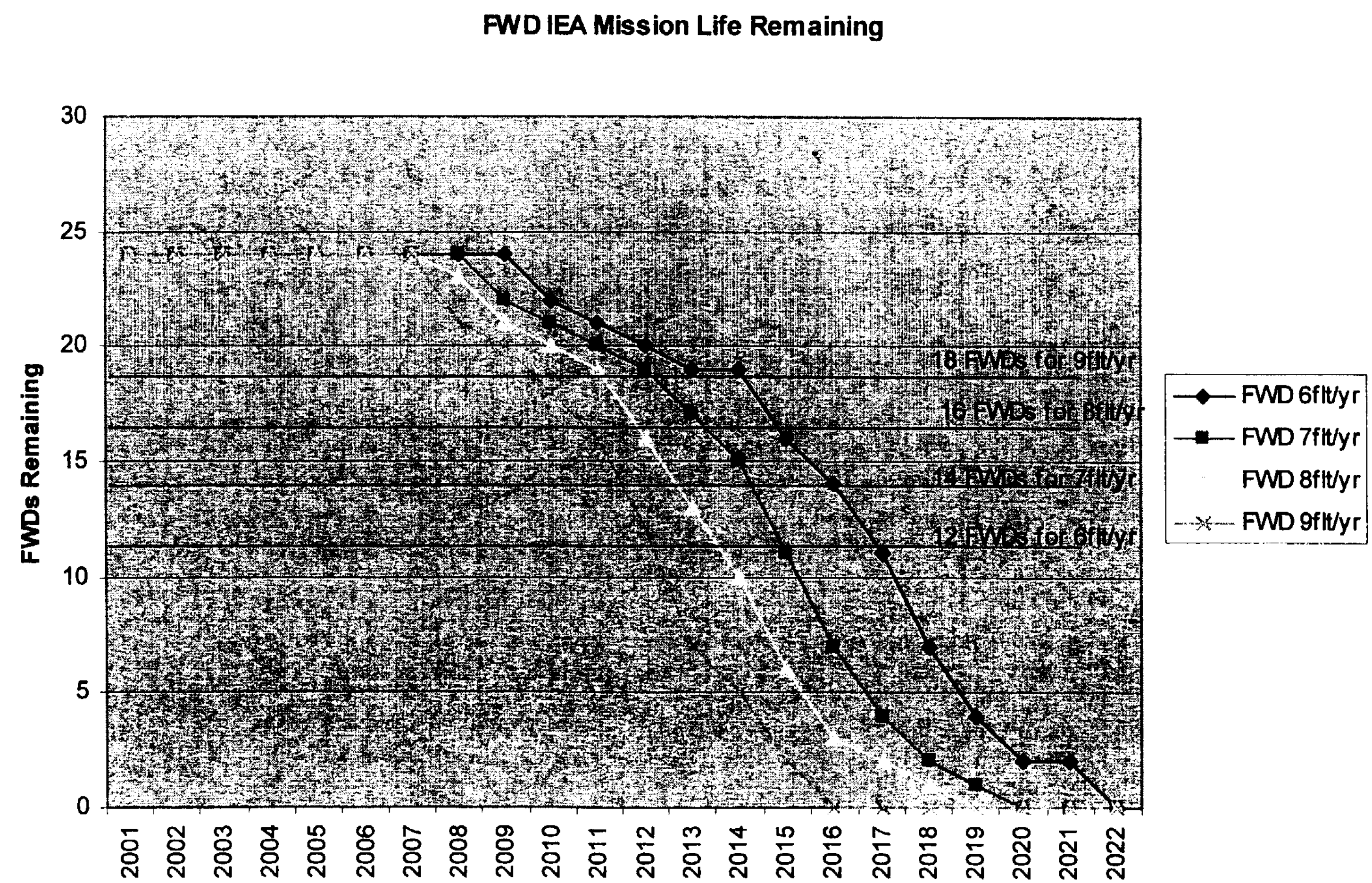
IEA Process Rate



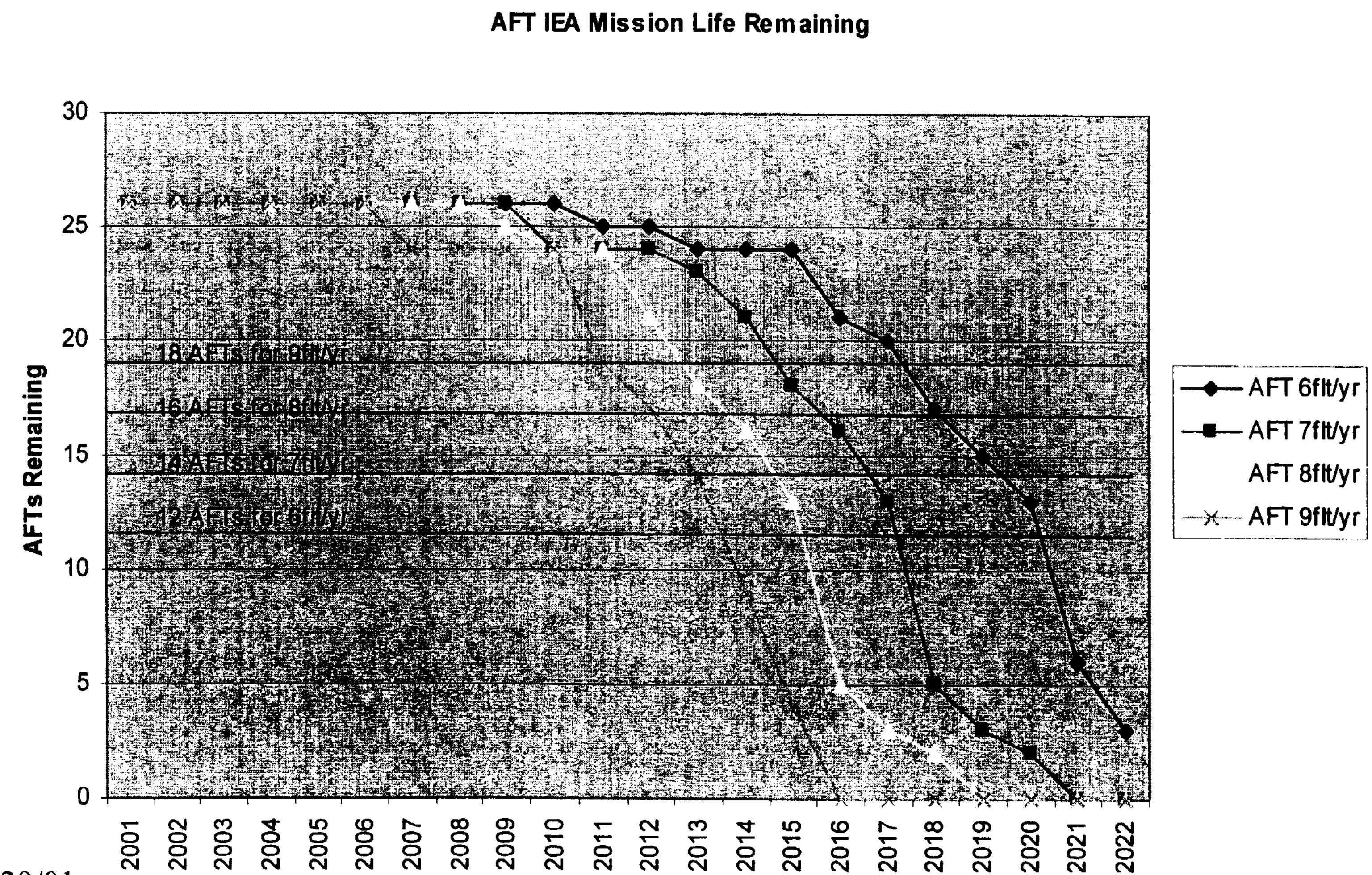
Supportability Assessment
Aft IEA Supportability



Supportability Assessment
Estimation of End of 20 Mission Qualification Life



Supportability Assessment
Estimation of End of 20 Mission Qualification Life



Conclusions

Safety: No flight safety concerns surfaced during this review.

Reliability: Reliability of the IEA is outstanding and there is no evidence of an upward trend at either the IEA or SRU level that indicates the presence of wearout mechanism(s). Future flight reliability is expected to remain unchanged unless wearout phenomenon occurs in the next 20 years of usage.

Supportability: Attrition, combined with a projected increase in process flow time for the IEAs, requires either additional flight inventory of IEAs or reduction in the time required to process an IEA.

IEAs will reach their 20 mission Qualification life prior to 2020.

Recommendations

- Supplement L-3 IEA test sets with two SAITS units.
  - This is a mandatory action to support the program through 2020
  - The IEA test sets at L3 <u>will not</u> continue to operate for another 20 years
  - L3 is currently using the third test set for spare parts
  - Access to test sets is a bottleneck in the IEA process flow
  - The SAITS units should be provided to L3 as quickly as possible

Recommendations

- Perform Delta-Qualification tests on IEA.
  - This is a mandatory action to meet supportability until 2020
  - IEAs and SRUs will run out of Qualification life and Acceptance Vibration life before 2020
  - Use the existing IEAs qualification units (S/N 009 and S/N 010) for the delta qualification

IEA QUALIFICATION LIFE REMAINING

Flight Total	IEA S/N	ITEM	Vibration Minutes Remaining	Remaining Flights
8	011	MS1	14.7	11
9	011	S3C	3.0	7
8	011	S3L	6.9	11
7	011	APU	31.5	13
7	011	APB	23.7	13
9	011	SHC	3.0	7
1	011	PIC	46.1	19
1	011	PIC	46.1	19
1	011	PIC	46.1	19
1	011	PIC	46.1	19
9	011	PB1	3.0	7
9	011	SCC	3.0	7
9	011	CPD	3.0	7
9	011	CPD	3.0	7
6	011	CV1	22.6	14
9	011	MDM	3.0	7
6	011	MS1	27.2	14
9	011	S3C	3.0	7
9	011	S3L	3.0	7

Recommendations

- Direct USA to perform an assessment of the optimal mix of hardware upgrades, process upgrades, and increased assets to meet projected supportability requirements including the possibility of just one SAITS at L-3 and one at USA

Hardware	Process
• Rebuild harnesses*	• L-3 Test Sets**
• Build additional IEAs	• Increased Personnel
3. Move Aft IEA forward	

* Believed to be high value added

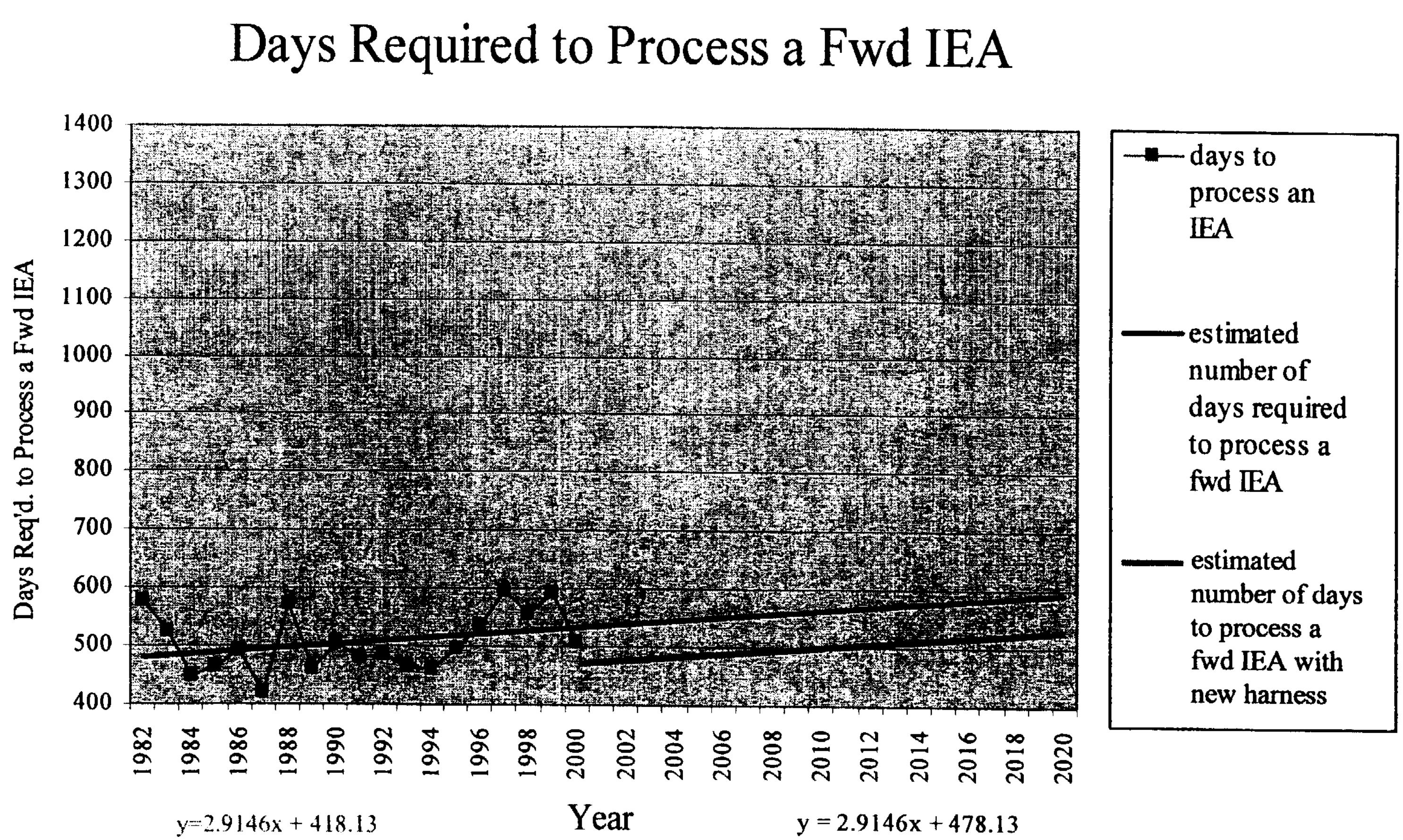
**Recommended as a mandatory change

Recommendations

- If the recommended rebuild of harnesses is incorporated, the ISAT suggests the following implementation:
  - Machine 2 aft and 2 forward housings
  - Repair 4 EMDMs
  - Populate the new housings with new harnesses and EMDMs
  - Implement connector sealing process to aft IEAs
  - As IEAs are returned to L-3, transfer cards and signal conditioner harness to new housing

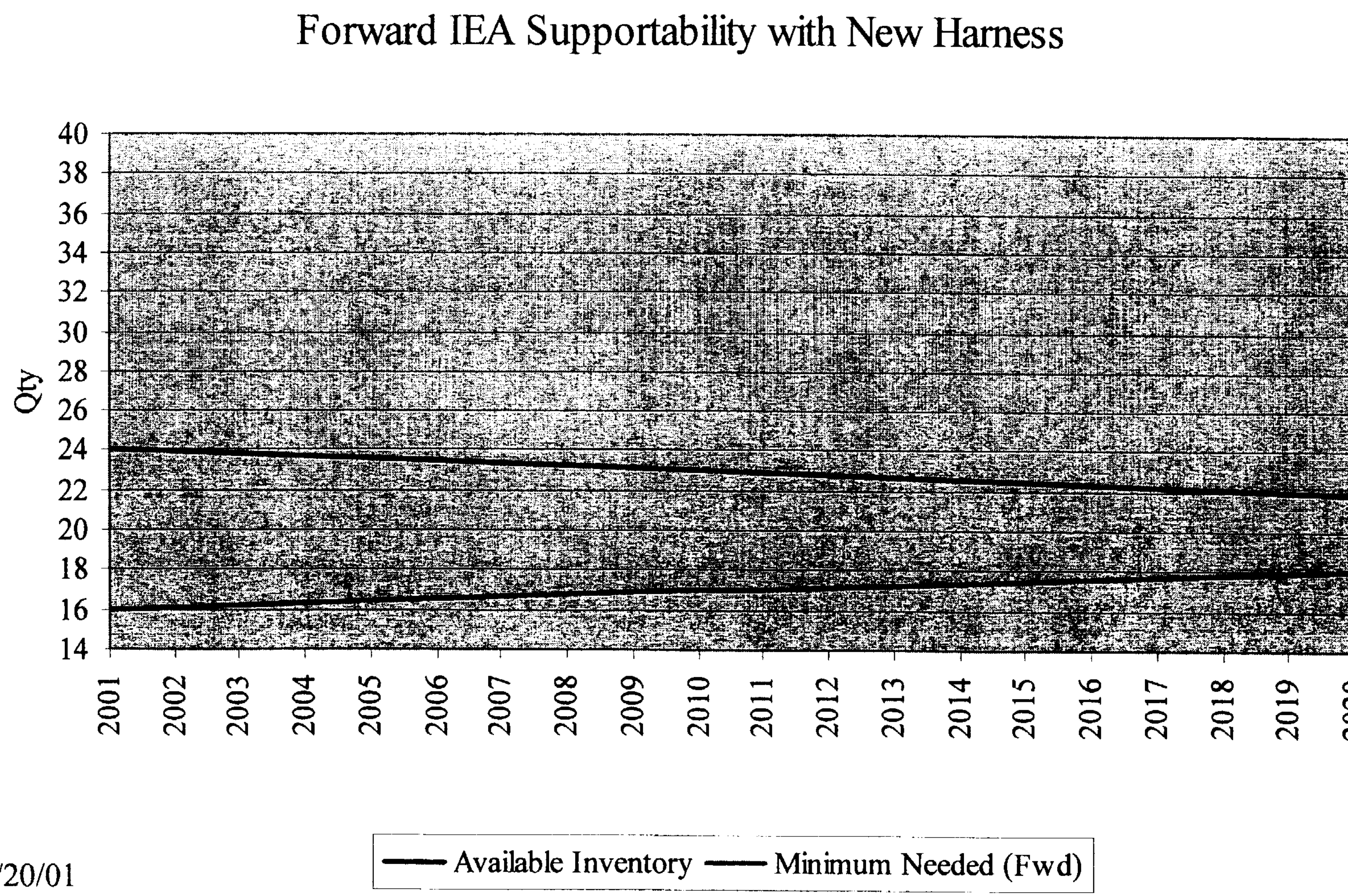
Recommendations

New Harness Impacts to Forward IEA Process Time



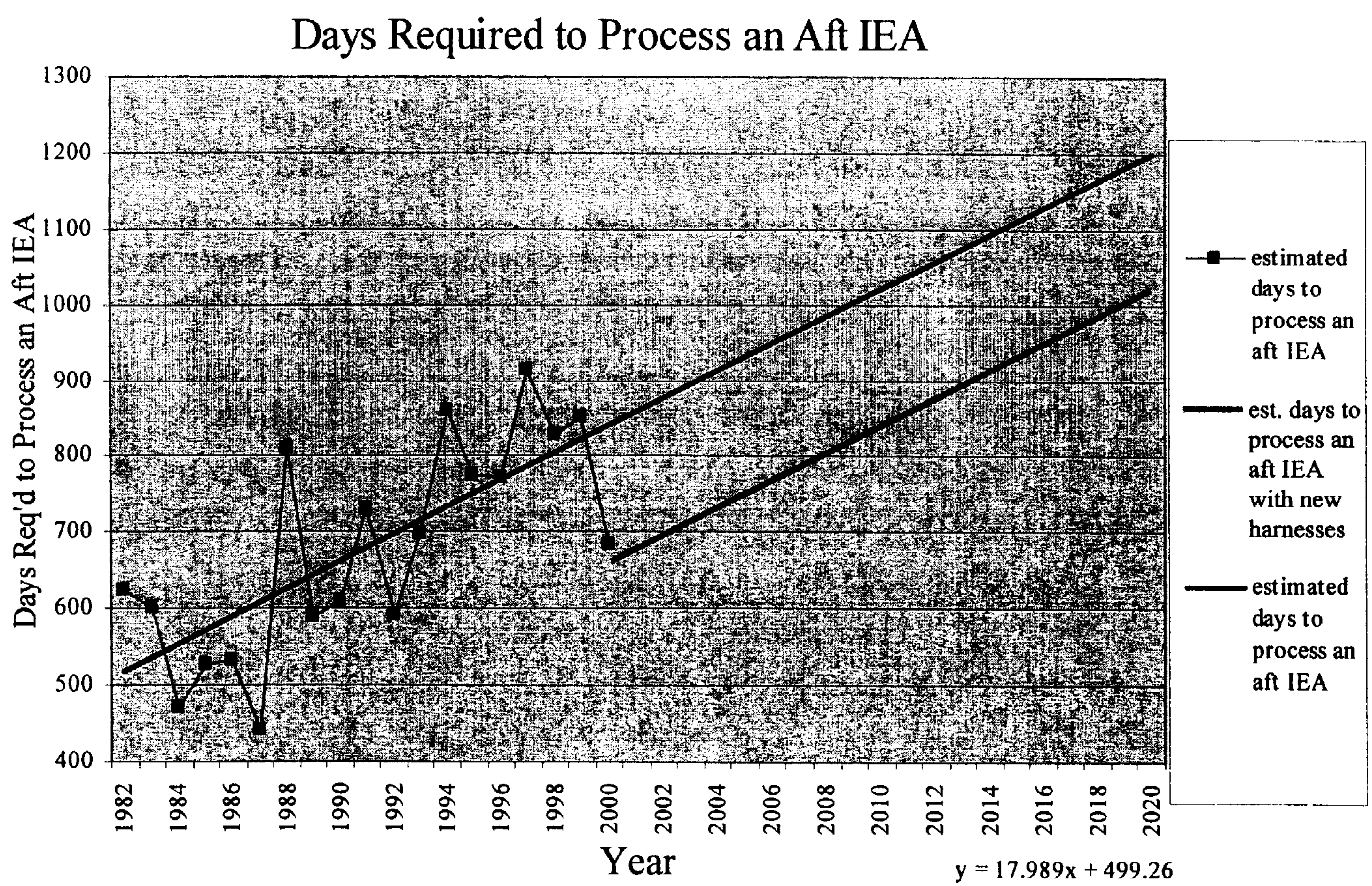
Recommendations

New Harness Impacts to Forward IEA Process Time



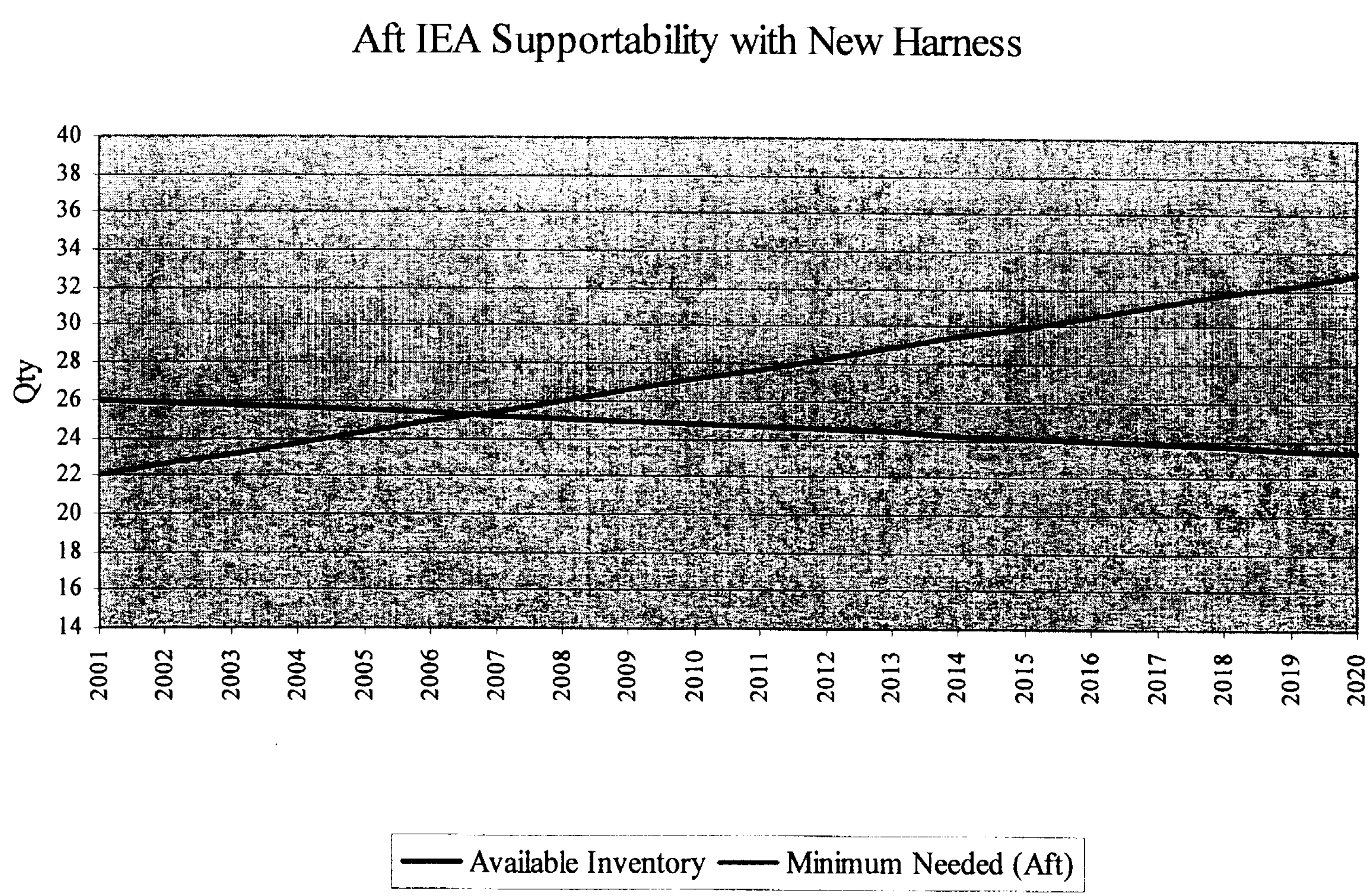
Recommendations

New Harness Impacts to Aft IEA Process Time



Recommendations

New Harness Impacts to Forward IEA Process Time



Recommendations

- Develop and maintain the capability to build a spare of each CCA which has one spare or less.
  - ISAT believes this is a prudent action to mitigate the risk of losing an entire IEA for lack of one CCA
  - In most cases the parts are in stock, readily available, or alternate parts are obtainable.
  - In some cases unpopulated printed wiring boards are available.
  - There may be a problem with printed wiring board designs for signal conditioning cards and the APU Controller.
  - If the artwork is unobtainable, re-layout the boards.

Condition of Hardware

Circuit Card Assemblies

IEA CCA'S

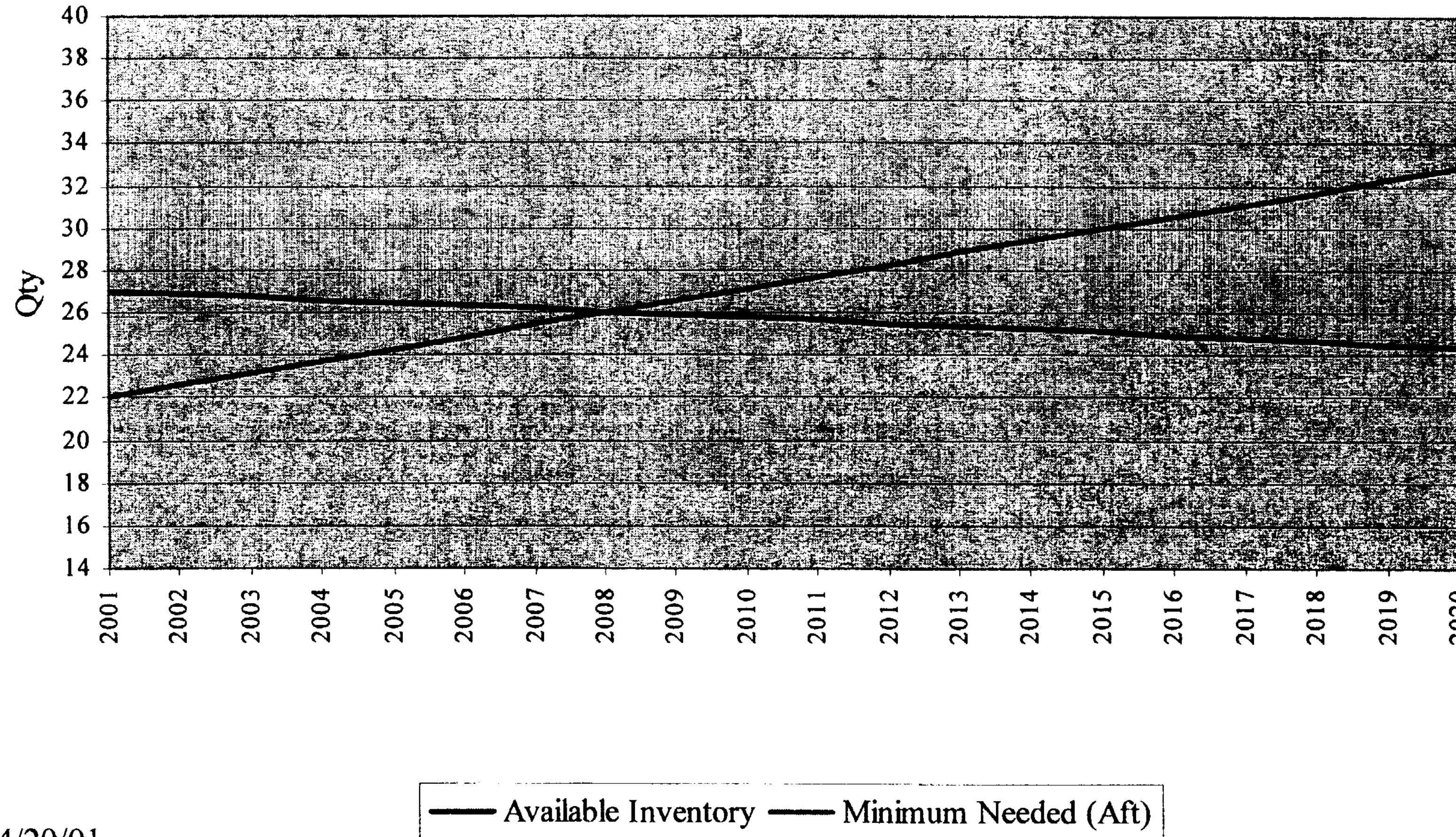
CODE	NAME	LOST	REMAINING	Qty/26Aft	Qty/24Fw	Spares	
RL1	Recovery Logic I-A	5	24	0	24	0	
RL2	Recovery Logic II-C	5	24	0	24	0	
APU	APU Controller	11	53	52	0	1	-1
CV2	Converter, Res. To Volt	5	27	26	0	1	0
CPD	Converter, Pulse to DC Volt	10	53	52	0	1	-1
RL3	Recovery Logic III	5	25	0	24	1	
SHL	.5 A Switch Driver 5 V	5	25	0	24	1	
PBIS	Power Bus Isolation Supply	20	102	52	48	2	0
MS1	Miscellaneous IV	10	54	52	0	2	0
AB2	Converter, ABA-2	5	28	26	0	2	1
AB1	Converter, ABA-1	6	28	26	0	2	1
CV1	Converter, Res. To Volt	10	52	26	24	2	1
MS3	Miscellaneous III	5	26	0	24	2	
SHH	.5 A Switch Driver 28 V	5	27	0	24	3	
APB	APU Bite Module	10	56	52	0	4	2
S3C	3A Combination Switch	10	56	52	0	4	2
S3L	3 A Switch Driver 5V	20	105	52	48	5	3
SCC	Signal Conditioner Calibratio	10	55	26	24	5	4
AB3	Converter, ABA-3	5	30	0	24	6	
AB4	Converter, ABA-4	6	31	0	24	7	
SHC	.5 A Combination Switch Driv	20	108	52	48	8	6

Recommendations

- Build one APU Controller Module and machine one Aft housing
  - One APU Controller Module and a housing would put an additional Aft IEA into use.
  - ISAT believes that this is a high value action that will add assets at relatively low cost.

Recommendations

Aft IEA Supportability with New Harness, Additional IEA



Recommendations

- Purchase the piece parts to repair the EMDMs
  - There is currently only one spare MDM available
  - IEAs are already qualified to fly 20 missions with EMDMs
  - This is a low cost, prudent action to mitigate the risk of losing an IEA for lack of an MDM (these are simple discrete diodes and transistors)
  - This falls into the same category as the capability to build spare CCAs

Recommendations

- Implement the new sealing process on all Aft IEAs
  - This sealing process together with the three step cleaning procedure instituted by L-3 has produced a dramatic drop in pressure loss failures and salt water intrusion reports
  - This equates to reduced maintenance actions

Recommendations
General

- Create a common problem report database and perform continuing reliability and supportability trend analyses predictions for the IEAs. This is a mandatory action to recognize an upward trend in the failures from wear out or end-of-life early enough to respond to it
- Perform periodic retraining of technicians to heighten awareness of risks and prevention of handling damage
- Perform failure analysis on failed EEE parts to determine root cause for all reported failures

Summary of Recommendations

- Supplement L-3 IEA test sets with two SAITS units.
- Perform Delta-Qualification tests on the IEA.
- Direct USA to perform an assessment to determine the optimal mix of hardware upgrades, process upgrades, and increased assets to meet projected supportability requirements. (ISAT recommends new harnesses and SAITS to L3)
- Develop and maintain the capability to build a spare of each CCA which has less than one spare.
- Build one APU Controller Module and machine one Aft housing
- Purchase the piece parts to repair the EMDM's
- Implement the new sealing process on all Aft IEAs

Summary of Recommendations, (continued)

- Create a common problem report database and perform continuing reliability and supportability trend analyses predictions for the IEAs. This is a mandatory action to recognize an upward trend in the failures (wear out or end of life) early enough to respond to it

- Perform periodic retraining of technicians to heighten awareness of risks and prevention of handling damage

- Perform failure analysis on failed EEE parts to determine root cause for all reported failures

Adequacy of Original Qualification Program and Screens

- The basic testing philosophy for electronics at MSFC is:
  - Qualification testing is performed to qualify a hardware design for flight. Test levels are to the expected flight environments plus some margin. Testing is run for the number of mission to be flown.
  - Acceptance testing is is performed to find any workmanship defects in the unit. This test is run after the original hardware build and after work is performed on the unit. The tests run may vary depending on the hardware, its application, and the work done but normally include functional testing, vibration testing and thermal cycling.
  - Screening tests are established for each piece of reusable hardware and are run to find any anomalies that have resulted from the previous flight, from latent defects, or are cumulative problems from wear and tear over the life of the unit

Adequacy of Original Qualification Program

- IEAs were originally qualified for 20 mission exposure to expected mission environments in 3 phases: 1 mission, 6 missions and 13 missions
- Aft IEA underwent delta qualification for a boost phase random vibration exceedence
- 20 mission delta qualification was run under Change Order 101
- 20 mission delta qualification was run with an EMDM
- 20 Acceptance Test Vibrations were run on the IEA

Original Qualification Was Adequate

Are the Screens In Place Adequate?

- During refurbishment all IEAs are cleaned and inspected; functionally tested; thermally tested; and vibration tested.
- All Aft IEAs are opened and inspected after every flight
- All Fwd IEAs are opened and inspected after every third flight
- Testing verifies that all redundancy is functioning
- There have been two problems that escaped the screens in 408 IEA flights
  - One of these was from a design change improperly implemented, and the other from operator error

<u>Screens Are Adequate</u>

Assessment of Screening Tests on Remaining Avionics Boxes

SCREENING TESTS

FOR ELECTRICAL LRU'S AND NETWORKS/CIRCUITS/CABLES

- All Flight Critical Circuits/Networks are redundant (1R)
- All Electrical LRU's receive the following prior to each flight:
  - Cleaning and visual inspection
  - Bench Test (Functional)
- Critical LRU's receive the following additional tests prior to each flight
  - Thermal Cycling
  - Vibration
  - Automatic Checkout
  - Shuttle Interface Test (SIT)
- Cables (wires) and connectors receive the following tests prior to each flight
  - Insulation Resistance
  - Dielectric Withstanding Voltage
  - Continuity Check
  - Connector/Pin Inspection

Assessment of Screening Tests on Remaining Avionics Boxes

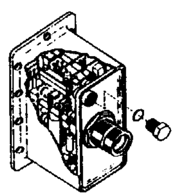
SCREENING TESTS
FOR ELECTRICAL LRU'S AND NETWORKS/CIRCUITS/CABLES

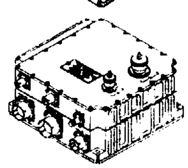
- **NOTE**:It is impossible to assure there are no latent defects. Testing is done to assure all critical functions are performing and that redundant circuits are functioning. Testing verifies that hardware has no overt defects; but latent defects are possible in:

  EEE Parts
  Printed Wiring Boards
  Solder Joints
  Mechanical Fasteners
  Connectors

- **Based on limited review, the ISAT has not identified any obvious deficiencies in the screening of the other SRB avionics boxes.**

Assessment of Remaining Avionics Boxes





RSS Safe & Arm Device	1998	New S&A Device
DFI Battery DFI Distributor Dedicated Signal Conditioner Wide Band Signal Conditioner Sensor Timing Unit	1998 2000	SWAR C-Band Controller
Altitude Switch Assembly	2003	New ASA
Range Safety Distributor Integrated Receiver/Decoder	2003	CRD