TAILORING AND TEST EFFECTIVENESS

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BIOGRAPHY

Thomas E. Gindorf has been involved in the management of technical reliability and environmental design compatibility and testing for over 30 years at the Jet Propulsion Laboratory. Mr. Gindorf holds a BS degree in physics and a MS degree in systems management. His experience in providing or managing activities which provide reliability and environmental requirements includes Ranger; Surveyor; Mariners 64, 67, 69, 71, 73; Viking; Voyager; Galileo; Mars Observer; Topex; Cassini and numerous science instruments. Mr. Gindorf received the NASA Exceptional Service Medal for his efforts on Voyager Radiation Control to ensure compatibility with Jupiter's severe trapped radiation environment,

ABSTRACT

For the past several years NASA Code Q has sponsored a set of trend analysis studies of past spacecraft programs to better develop tailoring guidance and improve test effectiveness. The absence" of available data from other government or military programs greatly impedes the analyses. However, the analyses performed to date on JPL programs accomplish two major objectives: (1) the consequences of significance for the environments/conditions analyzed indicate certain strengths and weaknesses which are helpful in the design of test programs and (2) the types of analyses performed establish a useful template which addresses specific issues that can be easily used when additional data does become available. This paper is an overview of the reports available in JPL D-11295 Rev. A, Environmental Test Effectiveness Analysis Reports (For NASA Office of Safety and Mission Assurance - Code Q).

KEYWORDS

Test Tailoring
Dynamics
Thermal
EMC
Flight Anomaly
Test Effectiveness
Failures

APPROACH

The study consisted primarily of evaluation of JPL programs due to limited availability of other data. Brainstorming of relevant issues worthy of evaluation was performed. These issues were prioritized and are being systematically studied. In order to disseminate the results into the aerospace community and to stimulate similar studies in the test community, the trend reports were collected into a document which will be continual y added to and corrected as more data becomes available or as different issues are evaluated.

This paper is a compilation of succinct summaries of the 22 Test Effectiveness Trend Analyses currently in the report. In order to be succinct, the format consistently followed is to reflect the issue, conclusion, and major tables or figures supporting the conclusion. For more detailed discussion of the content, the document JPL D-11295 Rev. A has been provided.

CLOSING REMARKS

In an era when many S/C have been flown, there is an opportunity to learn from each other's experiences if the appropriate data is collected and shared. This has not been the history of the Aerospace community, i.e. to systematically collect and share test and flight data. It is with great anticipation that we await successful implementation of the new Space System Engineering Database being developed by Aerospace Corporation and contributed to by NASA. The availability of more complete data will greatly facilitate accurate information retrieval and test program improvement. In this era of cheaper, faster, better spacecraft, we can do well to learn the lessons of the past and judiciously apply that knowledge to make programs more effective. The content of the analysis efforts to date will be greatly enhanced with more and complete data,

TETA

Objective

Identify trends in the test anomaly history for environmental tests performed for a number of flight projects to determine test effectiveness. The types of trends that are considered include:

1. Comparisons of the effectiveness of environmental tests for different flight projects for which test parameters, such as levels and durations, are different.

2. Comparisons of the anomalies occurring during different environmental tests' performed on a single flight project or instrument, for comparison among different projects.

TETA STATUS

Released - Significant Trend Reports

TETA-TO-0001 Rev A Powered-on Assembly Vibration Testing on the Voyager and Galileo Programs

TETA-TO-0002 Comparison of JPL Procured Flight Hardware with System Contractor Procured Flight Hardware

TETA-TO-0003 Environmental Test Effectiveness As Indicated by Voyager and Galileo Anomalies

TETA-TO-0004 Comparison of Voyager and Galileo Problem/Failures on Electrical and Electronic Subsystems

TETA-TO-0005 EMC Testing Significance

TETA-TO-0006 Effectiveness of Galileo Assembly Level Dynamic Tests

TETA-TO-0007 Relationship of Design Changes and Waived (EMC) Requirements to Design Maturity

TETA-TO-0008 Problem/Failure Cause

TETA-TO-0009 Test Effectiveness and Reliability Growth in JPL Programs

TETA-TO-0010 Causes of Anomalies During Thermal-Vacuum Tests

TETA-TO-0011 Effectiveness of Vacuum Environment in the Thermal-Vacuum Test

TETA-TO-0012 Assessment of EMI Grounding Problems Encountered in Flight Hardware Prior to System Level EMI Tests.

TETA-TO-0013 Impact of Hardware Complexity on Problem/Failures

TETA-TO-0014 Problem/Failure History vs. Origin of Flight Hardware

TETA-TO-0015 Closure Time for Design Related PFRs

TETA-TO-0016 Adequacy of Prelaunch Testing Based on Early Flight Anomalies

TETA-TO-0017 Correlation of Advances in the Spacecraft Digital Technology with EMC Test Failure Rate

TETA-TO-0018 Trend of Defects Observed During Galileo Assembly Level Dynamics Tests

TETA-TO-0019 Effectiveness of Galileo Assembly Level Dynamics Test versus Number of Axes Tested

TETA-TO-0020 EMC Testing Failures - Waivers vs. Design Changes

TETA-TO-0021 The Use of Ground Testing to Reduce Potential Inflight Anomalies

TETA-TO-0022 EMI Anomalies Encountered Prior to Acceptance Testing

TETA-TO-0001. Rev. A

Powered-On Assembly Vibration Testing On The Voyager And Galileo Programs

Issue

Is powered-on vibration necessary/useful?

Conclusion

Power-on is an important interrogation method during vibration testing to uncover electrical problems.

Significance of Problem Failures
Uncovered by Power On Vibration

	Voyager	Galilee
Total Vibration PFR's	84	20
Number of problems/failures attributed to power-on vibration which are not believed to be otherwise detectable.	44	14
Number of problems detected by powered-on vibration requiring redesign/rework and which if undetected would have had major mission impact,	3	1

Summary Of Power-On Vibration Results

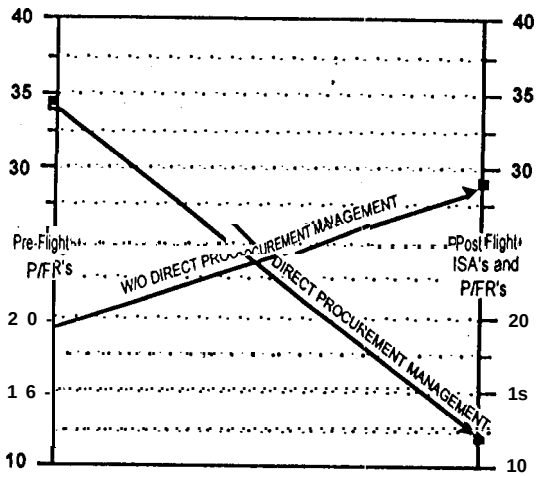
	Voyager	Galileo
Percentage of Problems Requiring Powered-On Vibration for Detection	52% (44/84)	70% (14/20)
Percentage Of Detected Problems Which Have Major Mission Consequence In The Absence Of Redesign/Rework.	7% (3/44)	7% (1/14)

Cornparing Four Similar Subsystems

	Pre-Launch Problem/Failures	Flight Problem/Failures	Ratio
JPL	34	12	-3:t
CTR	19		~2:3
RATIO	~1.8:1	-02::1	

JPL vs. CTR: ~80% HIGHER 60% FEWER

Relationship of Flight Hardware Problems with or without Direct Procurement Management



TETA-TO-0002

Comparisen of JPL Procured Flight Hard ware with System Contractor Procured Flight Hardware

Issue

Does directly procured hardware problem identification/flight performance differ from contractor procured hardware?

cclnclusion

Far fewer pre-launch PFRs on contractor managed procurements and significantly more flight problems than on directly managed procurements suggest deficiencies in contractor procurement management and problem reporting systems.

TA-TO-0003

Environmental Test Effectiveness as Indicated by Voyager and Galileo Anomalies

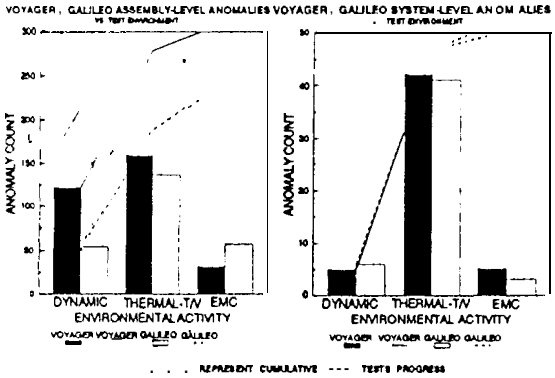
Issue

Which environmental tests are most effective in finding problems?

Conclusions

On average, thermal vacuum tests are ~200% more effective at the assembly level and ~750% more effective at the system level than vibration testing. EMC test effectiveness is similar to vibration in detecting problems.

	Assy Ratio T/V PFRs VIB PFRs	System Ratio T/V PFRs VIB PFRs
Voyager	1.3	8
Galileo	3.0	7
Average	-2.1	-7.5



TETA-TO-0004

Comparison of Voyager and Galileo Problem/Failures on Electrical and Electronic Subsystems

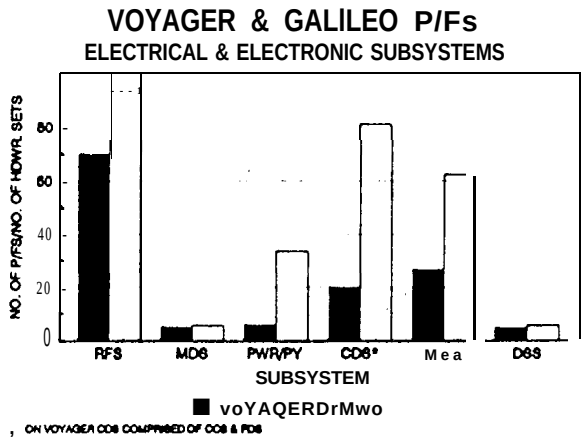
Issue

Does complexity of electronic hardware track in the test programs?

Conclusion

Galileo had significantly more P/Fs than Voyager on similar electrical hardware. Difference not clearly defined, but attributed to greater functional complexity. Designs are more complex, but design process improvement appears to be at a slower pace.

Range Of Differences: 1.4 X to 5.7X More



TETA-TO-0005

EMC Testing Significance

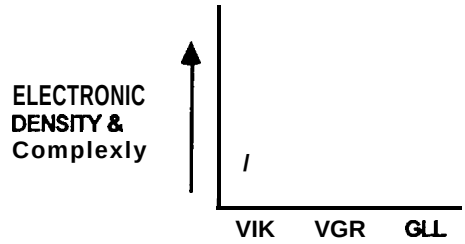
Issue

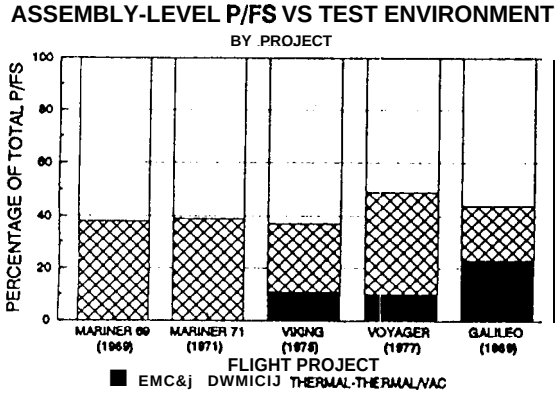
Is EMC testing significant as a screen for flight hardware?

Conclusion

EMC significance has increased as complexity and electronics density have increased.

	% PFRs In Thermal Assy Tests	% PFRs In Dynamics Assy Tests	% PFRs In EMC Assy Tests
Viking	-62%	-28%	-10%0
Voyager	-"50%	~40%	-1 0%
Galileo	-58%	-20%0	-22%





TETA-TO-0006

Effectiveness of Galileo Assembly Level Dynamics Testing

Issues

Which dynamics testing was most effective in finding problems?

Conclusions

Sine testing is the most perceptive assembly level dynamics test*.

TOTAL GLL TOTAL DYN TESTS	PROBLEMS FAILURES	% SINE*	% RAN M**	% ACOUSTIC	% SHOCK
252	66	-6870	-27%	-3%	~1.5%

QUAL % SINE	QUAL % RANDOM	FA % SINE	FA % RANDOM
67%	25%	69%	31%

↑

MOST PERCEPTIVE AS WORKMANSHIP SCREEN

* Sine test was performed before random test. Also, sine test can be a severe overtest if not carefully administered. Excessive cycles can build at resonant frequencies in non-flight manner.

**Uncertain P/Fs (28) are proportionally distributed between random and sine tests.

Test Effectiveness Study

Table 1. Dynamic Test Failures vs. Test Environment

Test Env.	Total Tests			Failures			Yield	
	Qual/ PF	FA	Total	Qual/ PF	FA	Total	Relative To All Tests	Relative to Specific Env.
1. Random Vib.	66	46	112	6	4	10	4.0%	8.9%
2.Sine vib.	66	46	112	16	9	25	9.9%	22.3%
3.Sinc or Random*	-.	-.	--	16	12	28	11.1%	UNK
4 Shock	14	0	14	1	--	1	0.4%	7%
5 Acoustic	14	0	14	2	--	2	0.8%	14%
Total	160	92	252	41	25	66	26.2%	--

* Could not redetermined if failure occurred during sine or random vibration.

Table 2, provided below, was developed by distributing the failures attributed to "sineorrandom" vibration, Item 3 in Table 1 above, to each of the sine and random vibration environments proportionally as indicated in Table 1.

Table 2. Dynamic Test Failures with Distributed Unknown Test Environment

Test Env.	Total Tests			Failures			Yield	
	Qual/ PF	FA	Total	Qual/ PF	FA	Total	Relative To All Tests	Relative to Specific Env.
1. Random Vib.	66	46	112	10.4	7.1	18	7.1%	16.1%
2. Sine Vib.	66	46	112	27.6	17.3	45	17.9%	40.2%
3. Sine or Random	--	--	--	--	Dist	--	--	--
4 Shock	14	0	14	1	--	1	0.4%	7%
5. Acoustic	14	0	14	2	-	2	0.8%	14%
Total	160	92	2s2	41	25	66	26.2%	--

TETA-TO-0007

Relationship of Design Changes and Waived (EMC) Requirements to Design Maturity

Issue

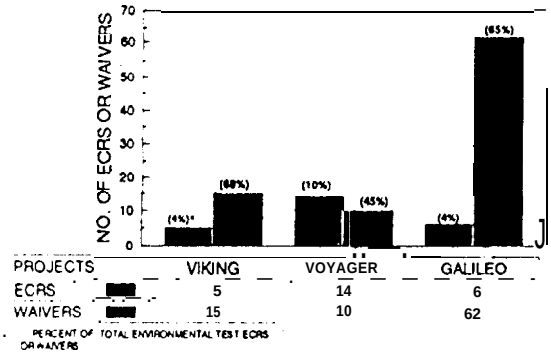
What is the significance of design maturity on EMC anomalies and their disposition?

Conclusion

Design changes due to EMC anomalies are significantly greater for new hardware designs. Past programs provide a strong experience base from which to waive anomalies on inherited designs. Suggests test levels may be unnecessarily conservative for programs with significant experience.

	RATIO OF ECRS	RATSO OF WAIVERS
VOYAGER (MOSTLY NEW DESIGN)	2.3	1
GLL (VGREXPERIENCE/INH.)	1	10.3

ECRS & WAIVERS RESULTING FROM VIKING, VOYAGER & GALILEO EMC TESTING



TETA-TO-0008

Problem/Failure Cause

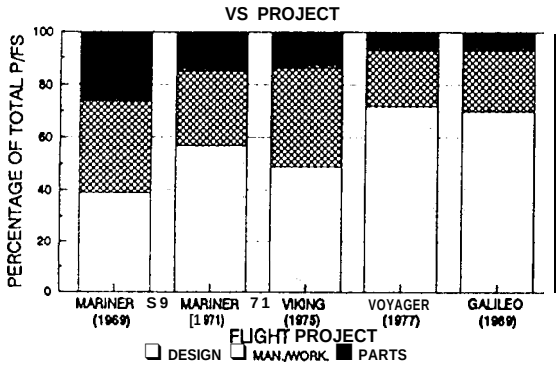
ISSUE

What are the principal causes of test problem/failures on JPL hardware, and how 'do they compare to the TIROS and NOAA programs?

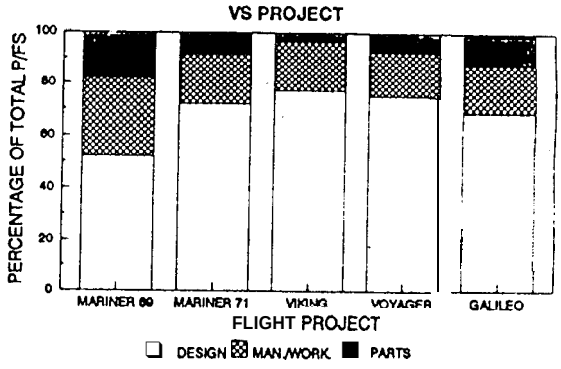
Conclusion

Design problems represent -60% of the problems/failures revealed during testing, while parts related problems are the cause ~ 12% of the time. By contrast to TIROS-NOAA, design causes were -32%, while parts causes were --28% for S/C built by a major system contractor. May suggest significant differences in the parts program.

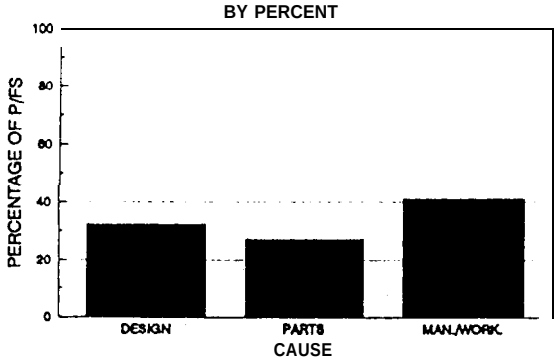
ASSEMBLY-LEVEL **P/FS BY CAUSE**



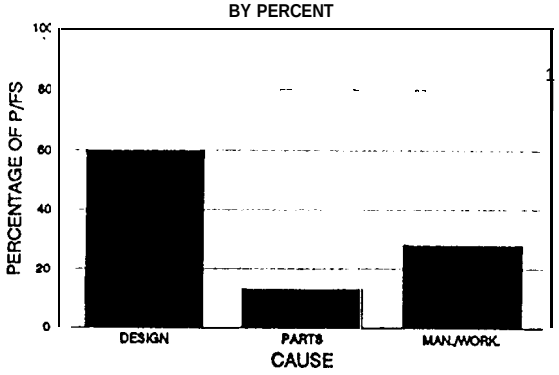
SYSTEM-LEVEL P/FS BY CAUSE



P/F CAUSES FOR TDR DATA BASE



P/F CAUSES FOR COMPOSITE JPL DATA BASE



TETA-TO-0009

Test Effectiveness and Reliability Growth in JPL Programs

Issue

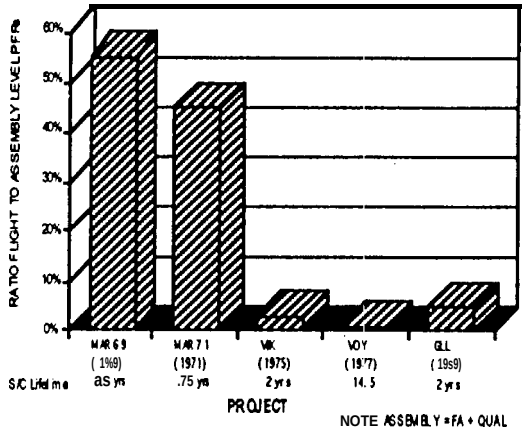
Has assembly test effectiveness improved and reliability y growth occurred on JPL programs?

Conclusion

Significantly improved assembly test effectiveness and reliability growth has occurred over the last 20 years.

	Ratio of Flight PFRs to Assy PFRs
Mariner (1969)	-.55
Mariner (1971)	-.45
Viking (1975)	**-.03**
Voyager (1977)	-.02
Galileo (1989)"	-.05

Effectiveness of Test Program and Reliability Growth as a Function Time (As of 4/15/92)



*Flight Anomalies normalized by S/C years
•Test Anomalies normalized by no. of hardware sets undergoing hardware testing.

TETA-TO-00 I Q

Causes of Anomalies during Thermal-Vacuum Tests

Issue

What was the cause of anomalies during assembly thermal-vacuum tests?

Conclusion

For Voyager and Galileo, design defects were the major cause, Suggests additional design analyses and improved reviews earlier in the development cycle may be cost effective compared to the impact on cost and schedule caused by redesign/rework later.

Hard ware-Related Anomaly Causes-Percentages

Workmanship & Manufacturing	27%
Parts & Materials	30%
Design	43-44%.

Assembly-Level Thermal/Vacuum Test Causes

Cause	Voyager		Galileo		Total	
	Number	%	Number	%	Number	%
Design	16	43	15	44	31	43.6
Workmanship and Manufacturing	10	27		26.5		268
Parts and Materials	11	30	10	29.5	21	29.6
Total	37	100	34	100	71	100

TET ----0011

Effectiveness of Vacuum Environment in the Thermal-Vacuum Test

Issue

Is vacuum necessary for a thermal test to be effective?

Conclusion

Vacuum during testing of electronic hardware is a significant factor in the effectiveness of the thermal test because of the relationship to individual part/junction temperatures and performance parameters.

A vacuum environment can also, be an important factor in uncovering problems not influenced by temperature per se.

Table 1. Assembly-Level TV Test

PROGRAM	VOYAGER		GALILEO	
DEPENDENCY	NUMBER	PERCENT	NUMBER	PERCENT
Number where temperature only required	9	19.6	7	19.4
Number where temperature & vacuum both required due to influence of vacuum on temperature	10	21.7	17	47.2
Number where vacuum alone required	21	45.7	8	22.2
Number where dependency was undetermined	4	8.7	3	8.3
Number where none of the specific environments was required	2	4.3	1	2.8
TOTALS	46	100	36	100

Table 2. System-Level TV Test

PROGRAM	VOYAGER		GALILEO	
DEPENDENCY	NUMBER	PERCENT	NUMBER	PERCENT
Number where temperature only required	0	0	4	10.3
Number where temperature & vacuum both required due to influence of vacuum on temperature	6	13	5	12.8
Number where vacuum alone required	29	63	14	35.9
Number where dependency was undetermined	2	4.3	2	5.1
Number where none of the specified environments was required	9	19.6	14	35.9
TOTALS	46	100	39	100

TETA-TO-0012

Assessment of EMI Grounding Problems Encountered in Flight Hardware Prior to System Level EMI tests

Issue

When are **EMI** grounding problems most prevalent and what are the implications for hardware development?

Conclusion

Most (EMI) grounding problems are uncovered during functional testing during the early hardware development stage rather than during EMC testing. This suggests that EMC grounding design guidelines be more rigorously implemented and that EMI tests for detecting grounding problems be developed/performed to check out grounding design at the beginning of assembly level functional testing to minimize schedule and costs impact associated with delays.

	PFRs	Fraction Of Total EMI Problems Detected
All EMI Test (All Causes)	227	2/3
EMI Grounding Problems (Found In Functional Tests)	110	1/3

Table 1. Comparison of PFRs Due to EMI Grounding Problems with Total Number of EMI PFRs From EMC-Tests

Projects	No. of EMI PFRs Obtained From EMC - Tests (Normally At End Of Assy Test Program)	No. Of EMI PFRs From Grounding Problems Not ecorded In EMC - Tests
Seasat	2	0
Mariner-Mars (1969)	11	10
Mariner-Mars (1971)	5	27
Mariner-Venus	2	8
Mars Observer	24	16
Magellan	18	3
Galileo	43	13
Voyager	68	21
Viking	44	12
	227	110

(*) Tests were sparse and only on system level

TETA-TO-0013

Impact of Hardware Complexity on Problem Failures

Issue

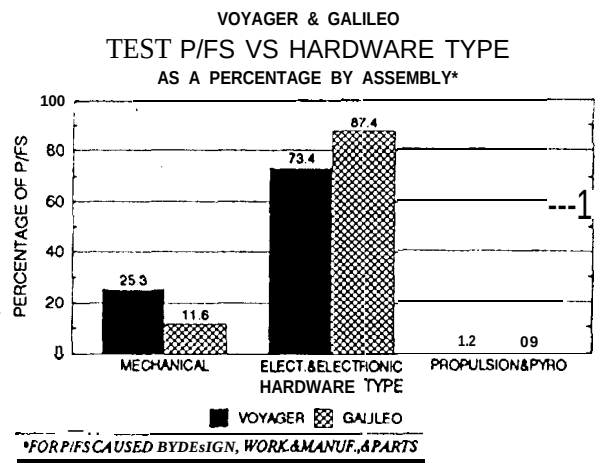
What is the relationship of design complexity to hardware problems?

Conclusion

Mechanical complexity differences were not determinable. Electrical complexity as distinguished by part count directly correlates to significant increase in problem/failures.

Percent of P/Fs on Electrical and Electronic Hardware

	P/Fs	No. Of Parts In Affected Hdwr
Voyager	73.4%	31,000
Galileo	87.4%	40,000
	19% Inc	29% Inc



TETA-TO-0014

Problem/Failure History vs. Origin Of Flight Hardware

Issue

Relationship of rigor of environmental test program to flight results

Conclusion

Based on limited evaluations to date, conservative environmental tests programs correlate with reliable spacecraft performance. Less conservative programs considered to date have experienced a higher incidence for flight problems and operational difficulties.

The flight programs studied, whose hardware development conformed to the consistently rigorous environmental test program, included Viking Orbiter, Voyager, Galileo and the Magellan Synthetic Aperture Radar (SAR). The S/C correlated to date tested to less conservative standards are the Magellan S/C and Mars Observer.

Ratio of average rate of flight P/Fs for the first 3 years of flight to prelaunch (ground test) PFRs:

FLT hardware tested to JPL D-1489 level requirements: Ranged from 1.7 To 5.2
MGN FLT hardware not so tested: 20.0
(Mission Successful)
MO FLT hardware not so tested*: -
(Mission Failed)

* Data incomplete when study performed, S/C failed August 1993.

Table 1. Measure of Effectiveness of Product Assurance Requirements in Reducing Flight PFRs

Program	No Of SS	No. Of Hdwr Sets	No. Of Flt S/C	No. Of Test PFRs/ Total No. Of SS	No. Of Flt PFRs per S/S i No Of S/C-Yrs, For 1st 3 Yrs Of Flt	Ave Rate Flt PFRs/No. Of Prelaunch PFRs (COL.6/COL.5) X 10^{-3}
iking rbiter	14	3	2	49	0.83	1.7
oyager	15	3	2	46	0.24***	5.2***
alileo	15	1	1	180	0.42	2.3
agellan ass A 1489 fwr*	3	1	1	1 S6	0.78	5.0
agellan D-1489**	5	1	1	63	1.27	20.0

* Since this includes the SAR which is as complex as the rest of MGN Flt hardware, the results obtained are upper limit conservative values.

** e.g. modified thermal & vibration test

*** Values for Voyager for the entire time since launch (in its 15th yr. of operation) are significantly different; column 6 value is, =.06; the corresponding value for column 7 is 1.3.

Table 2. Distribution Of PFRs On Mars Observer According To Cognizance Of Subsystems In Which PFRs Occurred+

Cognizance of Hardware	No. of Subsys. or Inst.	No. of PFRs	Ave
JPL	10	63	6.3
System contractor	8	102	12.8

+ Thirty five PFRs were assigned to system-level or sic testing.

TETA-TO-0015

Closure Time For Design Related PFRs

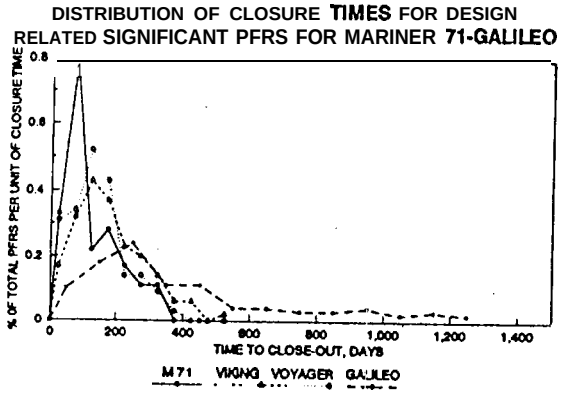
Issue

What correlation exists of S/C complexity to the elapsed time between opening and closing of design-related PFRs?

Conclusion

The closure time for JPL in-house programs design-related PFRs increased chronologically from Mariner 71 to Galileo. S/C complexity also increased with each mission. Efforts to shorten the time to closure have led to the implementation of a concurrent engineering concept so that the reliability engineer is in parallel with the problem identification/ resolution rather than in series,

Earliest Program-Mariner 71, to Latest the Program-Galileo:
Threefold Increase in Closure Times



TETA-TO-0016

Adequacy of Prelaunch Testing Based on Early Flight Anomalies

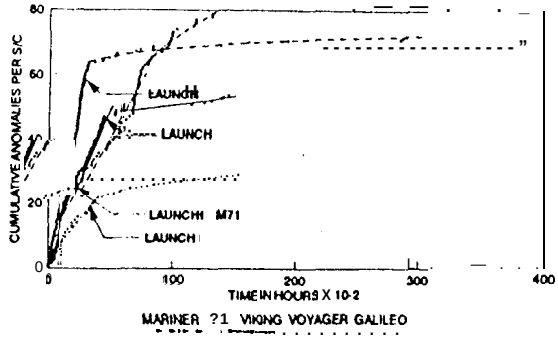
Issue

Inference of the correlation of rate of prelaunch problem/failure to the rate during the early part of S/C flight on prelaunch test adequacy.

Conclusion

On three of four JPL flight programs, the in flight problem/failure rate immediately after launch is similar to the rate during prelaunch operations . Additional ground functional testing would likely reduce early flight problems.

REGRESSION OF ANOMALIES VS TIME
PRE & POST LAUNCH



TO-001 7

Correlation of Advances in Spacecraft Digital Technology with EMC Test Failure Rate

Issue

Correlation between the problem/failure rate in EMC testing and the evolution of electronic technology?

conclusion

Increased complexity and sophistication of electronic hardware has resulted in a significant increase in the number of failures resulting from EMC testing of S/C. The continuing evolution of electronic technology portends increasing numbers of EMC test failures; test programs and hardware development schedules will need to be adjusted accordingly.

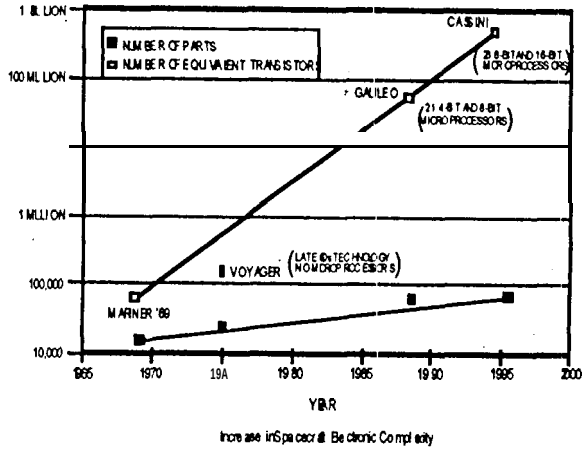
Increase in Number of EMC PFRs vs. Time

Program	PFRs
Mariner 6 (1969)	6
Viking Orbiter (1975)	35
Voyager (1977)	5 8
Galileo (1989)	134

(Three JPL programs built under a system contractor had less EMC-related PFRs.)
The implication of this difference is being evaluated.

Total Number of EMC Test PFRs

Spacecraft	Year Of Launch	Dry Mass (Kgms)	No. Of Science Instr.	No. Of EMC PFRs
Mariner 6	1969	412	5	6
Viking	1975	903	3 (+Lander)	35
Voyager	1977	825	11	58
Galileo	1989	1736	11 (+ Probe)	134
Magellan	1989	1152	1	22
Mars Observer	1991	1047	7	36
Topex/Poseidon	1991	2180	6	50



Increase in Spacecraft Electronic Complexity

TETA-TO-0018

Trend of Defects Observed During Galileo Assembly Level Dynamics Tests

Issue

Relative effectiveness of assembly level dynamics tests in detecting design, workmanship, and manufacturing defects?

Conclusion

Based on Galileo experience, design defects as a single category of problem/failure (P/F) are more prevalent during assembly level dynamics testing than any other type failures.

Dynamic Environments Include Sine, Random Vibration. Acoustic And Shock

Percentages Of Causes For 64 Dynamics Test P/Fs

Design	47%
Workmanship	16%
Manufacturing	8%
Other Problems	30%

Sine Vibration -----> Uncovered at least twice as many P/Fs as any other dynamics environment

Galileo Dynamics Assembly Tests PFR's

	Cause Code *	Qual/PF	FA	Total No	Total %
Failures	Design	22	8	30	47
	Workmanship	7	3	10	16
	Manufacturing	4	1	5	8
	Sub total	33	12	45	70
Problems	Other	6	13	19	30
	Total PFR's	39	25	64	100
	Total Teats	160	92	252	

* Cause Code does not always correspond to that listed on PFR

Dynamics Teat Failures Vs. Test Environment

Assembly Failure / Test Environment vs Cause Code	Qual/PF				FA			
	Design	Workmanship	Manufacturing	Total Tests	Design	Workmanship	Manufacturing	Total Tests
Sine Vibration	11	0	3	66	2	3	1	4d
Random Vibration	5	1	0	66	1	0	0	4d
*Sine or Random**	4	*b*	1	*0*	5	*0*	*0*	0
Acoustic	2	0	0	14	0	0	0	0
Shock	0	0	0	14	0	0	0	0
Total	22	7	4	160	s	3	1	92

* Could not be determined if failure occured during sine or random vibration

TETA-TO-001A

Effectiveness of Galileo Assembly Level Dynamics Test versus Number of Axes Tested

Issue

Relative effectiveness of assembly level dynamics tests versus the number of axes tested?

Conclusion

Based on Galileo experience, the maximum required number of axes in which assemblies must be vibration tested to detect potential design/workmanship defects is two; limiting testing to one axis will leave many such defects undetected. * Performing the third axis of vibration may reveal a few additional defects.

14 Design. Workmanship. and Manufacturing Defects were detected after two axes of Vibration Testing

5 were detected after the first axis of vibration

0 were detected during the third axis of vibration

*Care should be taken to select the two most sensitive axes.

Dynamic Assembly Test Failures by Known Order of Occurrence

Test Environment vs Type of Failure by Axis / Axis		Design	Workmanship	Manufacturing	Total
Sine Vibration	1st	3	1	0	4
	2nd	4	1	2	7
	3rd	0	0	0	0
Random Vibration	1st	1	0	0	1
	2nd	2	0	0	2
	3rd	0	0	0	0
Total		10	2	2	14

TETA-TO-0020

EMC Testing Failures-Waivers vs. Design Changes

Issue

Do the large number of waivers to failed EMC tests reflect overly severe test requirements, and how do the flight results correlate?

Conclusion

Evaluation of EMC Test anomalies resulting in waivers reveal that the anomalies generally resulted from the exceeding of allowable emissions over a very narrow band width of frequencie that do n cause performance problems. The current practice of using the military standards test specifications as a baseline for EMC requirements provides a high degree of conservatism. A higher degree of early tailoring to specific mission requirements would improve cost and schedule impact.

Percentage of P/Fs Related to Emission Spec Violations, including Magnetics

Voyager	66%
Galileo	77%

Percentage of Waivers Related To Emission Spec Violations

Voyager	70%
Galileo	74%

PFR Statistics for Electromagnetic, Compatibility Tests Spacecraft Mission: Voyager

EMC Test	No of PFRs	Nod Waivers	% of Total		Rationale(s) for PFR
			PFRs	Waivers	
Conducted Emissions	14	2	19	10	Emission measurements above spec. limits
Conducted Susceptibility	6	2	8	10	Hardware susceptible to field levels at certain frequencies
Radiated Emissions	18	2	24	10	Electric field emission measurements above spec. limits
Radiate d Suscept ibility	10	2	13	10	Hardware susceptible to field levels at certain frequencies
Magnetics Emissions	17	10	23	50	Max. magnetic fields spec. limits are exceeded
Isolation & Grounding	10	2	13	10	a) shorted circuits, b) chassis not well grounded, c) isolation less than required by specs.
Tot					

PFR Statistics for Electromagnetic Compatibility Tests Spacecraft Mission: Galileo

EMC Test	No of PFRs	No of Waivers	% of Total PFRs	% of Total Waivers	Rationale(s) fo PFR
Conducted Emissions	38		26	20	Emission measurements above spec. limits
Conducted Susceptibility	9	2	6	6	Hardware susceptible to field levels at certain frequencies
Radiated Emissions	62	9	43	'26	Electric field emission measure ments above spec. limits
Radiated Susceptibiltyy	16	7	11	20	Hardware susceptible to field levels at certain frequent ies
Magnetics Emissions	12	10	8	28	Max. magnetic fields spec. limits are exceeded
Isolation & Grounding	9	0	6	0	a) shorted circuits. b) chassis not well grounded, c) isolation less than required by specs.
Total	146				

Criteria for Assigning Anomaly to Ground Test

Ground Test Assignment	Criteria
Dynamics	The anomaly occurred during or very near the launch phase of the mission or occurred during pyrotechnic events during launch vehicle staging, the deployment of various devices or structures, etc.
Thermal/Vacuum	The anomaly occurred in electronic devices or was related to degradation of materials.
Electromagnetic Compatibility	The anomaly can be correlated to other spacecraft events or is related to grounding or isolation defects.

Summary of Potential Tests"to Detect In-Flight Anomalies

S/C	T/V	DYN	EMC	S/W	LIFE	CAL	RAD	N/T
MM		3	2		2			
VIK1				1	1	2		
VIK2		1		2		2		
VOY1			1					1
VOY2	1		1					2
GLL	3	1	2		1	1	1	4
TOTAL	6	7	6	3	4	5	1	7

TETA-TO-0021

The Use of Ground Testing to Reduce Potential Inflight Anomalies

Issue

Effectiveness of ground testing of flight hardware in reducing flight anomalies

Conclusion

Potentially, 49 percent of the flight anomalies for four JPL flight programs, Mariner71, Viking Orbiter, Galileo, and Voyager, reviewed in this study could have been detected by appropriate additional ground environmental testing. Modification or augmentation of current tests is needed to increase test effectiveness.

Note: S/C Spacecraft
T/V Thermal-Vacuum Test
DYN Dynamics Test (Power On)
EMC Electromagnetic Compatibility
S/W Test of Software or Programming
LIFE Life Test (or Operational Test for an extended period)
N/T No Test
MM Mariner 71
VIK Viking
VOY Voyager
GLL Galileo

TETA-TO-0022

EMI Anomalies Encountered Prior To Acceptance

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Issue

EMI problems tend to be disclosed late in the formal environmental qualification of flight assemblies which affects schedule, costs, and incurs increased risk (waivers). What improvements are necessary to improve this situation?

Conclusions

Problcnl/Failure reports (PFRs) from 5 flight projects, Voyager, Galileo, Magellan, Mars Observer, and Topex, reveal that EMI Problems occur randomly during developmental activities, but that the only formal screen for them is late in the development cycle. Suggest that more early structured and perceptive EMI testing would be beneficial for identifying EMI problems.

The development of a conducted emission test to be added to the standard suite of EMC tests could prove cost effective for identifying developmental, as well as other t ypes of EMI problems.

Number of PFRs for EMI-Related Anomalies during Developmental and Fabrication Testing of Spacecraft Assemblies

SC	Improper Shielding	Conducte d & Radiated Coupling	Spurious Emissions & Undesired Response	RFI	Transients	Grounding
Voyager	40	24	13	8	11	21
Galileo	61	15	8	7	9	13
agellan	6	1	4	2	4	3
Mars Observer	24	10	4	2	4	16
Topex	21	11	4	6	6	9

Number of PFRs during EMC Testing pcr MIL-STD-461/462.

Spacecraft	Conducted Emissions	Conducted Susceptibility	Radiated Emissions	Radiated Susceptibility	Magnetics	Isolation
Voyager	14	6	18	10	17	10
Galileo	38	9	62	16	12	9
Magellan	13	0	6	6	3	0
Mars Observer	9	4	14	8	0	1
Topex	14	9	18	7	0	2

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