

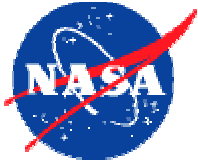
# **Defect Measurement and Analysis of JPL Ground Software: A Case Study**

**John N. Spagnuolo Jr.**

**John D. Powell**

GSAW

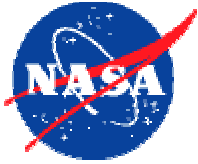
03/30/2004



# Agenda



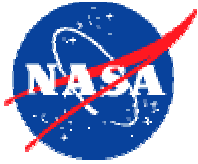
- Introduction
- Models and Data
- Defect Metrics Case Study on a JPL Project
- Conclusion



# Introduction



- Purpose
  - Predictable quality in JPL ground software via the development of Defect Prediction Models
    - Predict defects early in project's life cycle
    - Applicable across projects throughout JPL

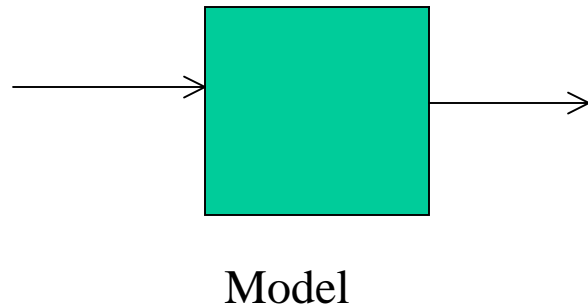


# Defect Prediction Models



Critical  
Discriminators

Defect  
Predictions



Defects by Size

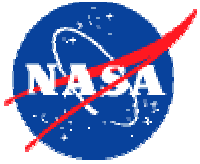
- # defects =  
 $f(\text{KSLOC}, \text{Critical Discriminators})$

Defects by Criticality by Size

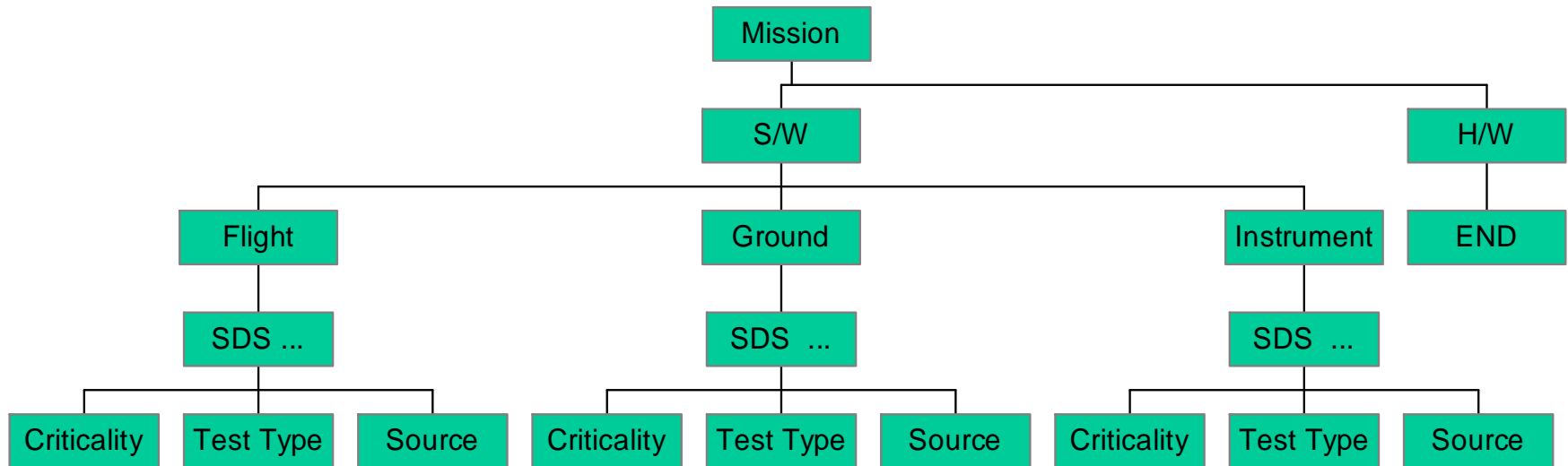
- # defects =  
 $f(\text{KSLOC}, \text{Critical Discriminators}, \text{Criticality})$

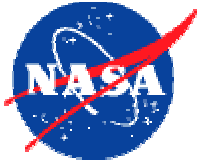
Defects by Test Type by Size

- # defects =  
 $f(\text{KSLOC}, \text{Critical Discriminators}, \text{Test Type})$



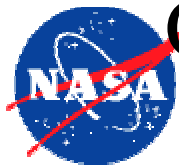
# Classification Hierarchy





# Project High Level Statistics

- Number of PFR's:
  - 453 in test, 127 in operations
- Defect density is 1.2 / LKSLOC
- Average Hours to repair:
  - 12.3 hours in test, 18.6 hours in operations
- PFR's per SDS not proportional to work hours per SDS
- Trend Breaker SDSs
  - Personnel Turnover and Code Breakage
  - Highly Interconnected SDS's



# OPS and TEST: Differences and Similarities



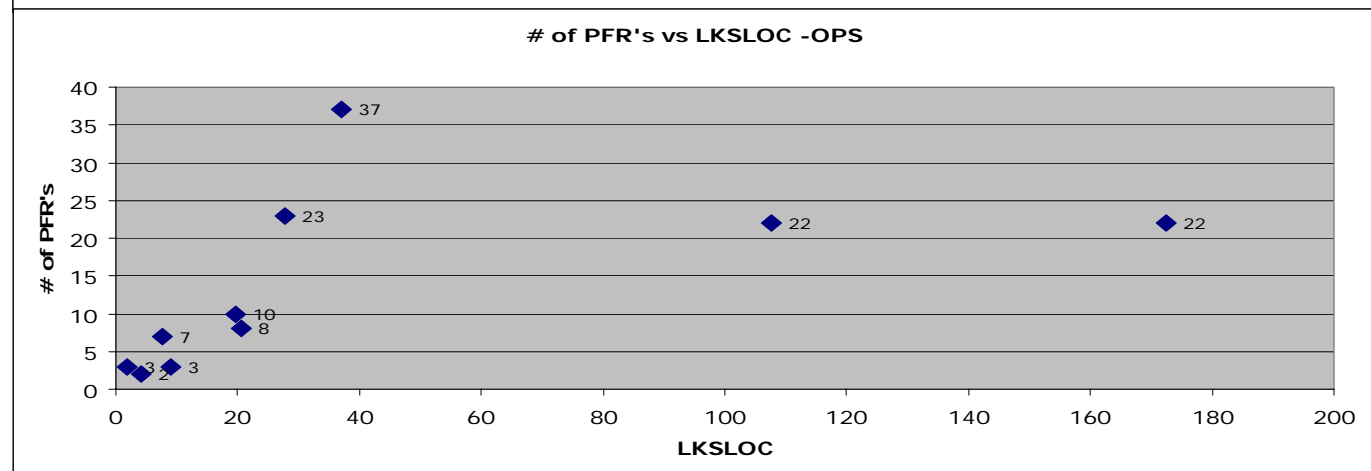
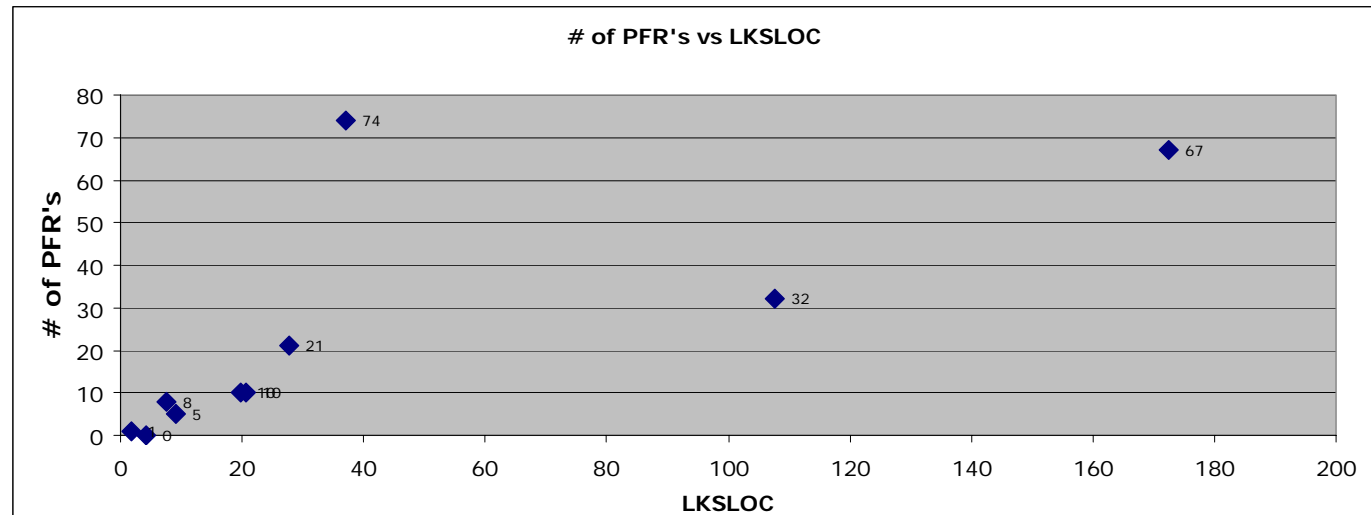
## Number of PFR's vs LKSLOC

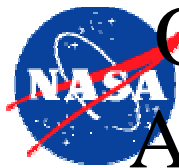
### TEST

	# of pfr's/S
EM	5
TDG	0
Telecommand	32
FTP Server	8
COM	10
Common Software	10
Earth Terminal Server	1
UI Client	74
UI Server	21
Telemetry	67

### OPS

	# of pfr's
EM	3
TDG	2
Telecommand	22
FTP Server	7
COM	8
Common Software	10
Earth Terminal Server	3
UI Client	37
UI Server	23
Telemetry	22





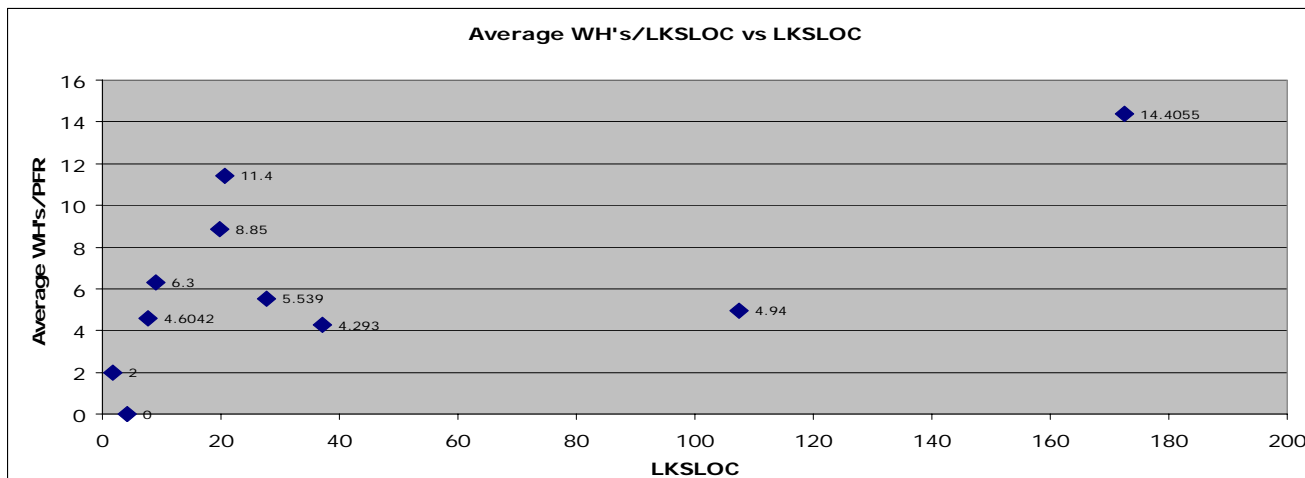
# OPS and TEST: Differences and Similarities



## Average Number of Work Hours vs LKSLOC

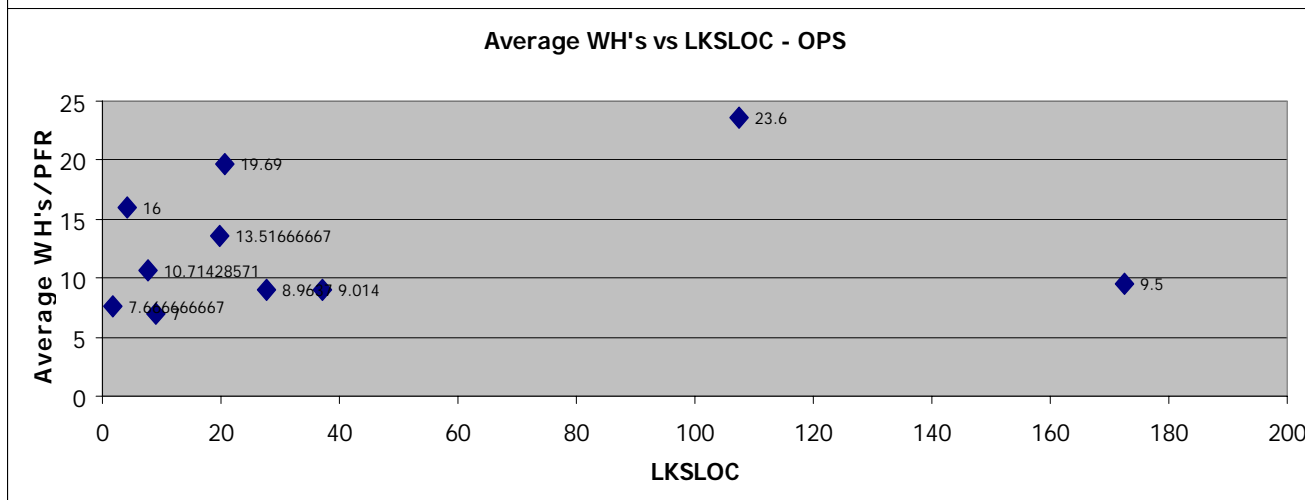
### TEST

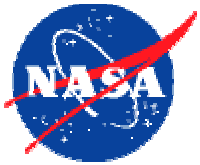
	Av # of WH's /SDS
EM	6.3
TDG	0
Telecommand	4.94
FTP Server	4.6042
COM	11.4
Common Software	8.85
Earth Terminal Server	2
UI Client	4.293
UI Server	5.539
Telemetry	14.4055



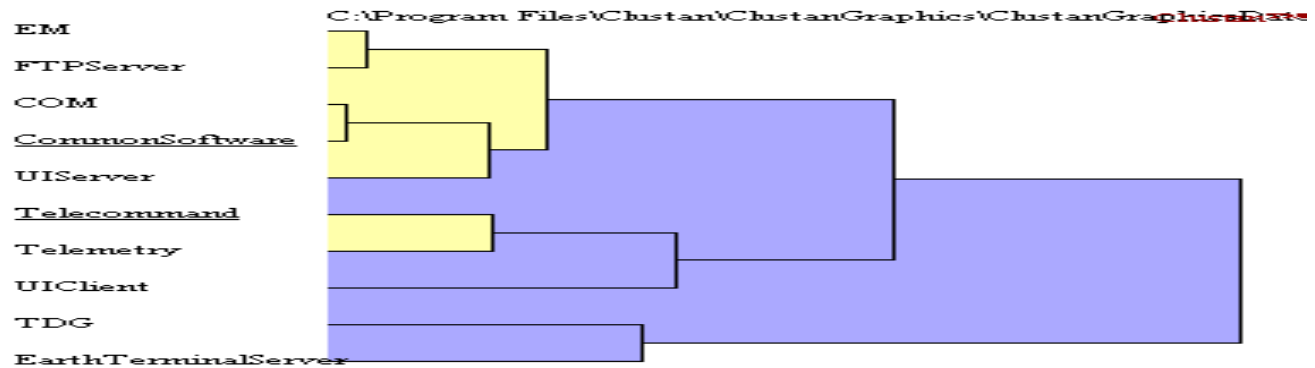
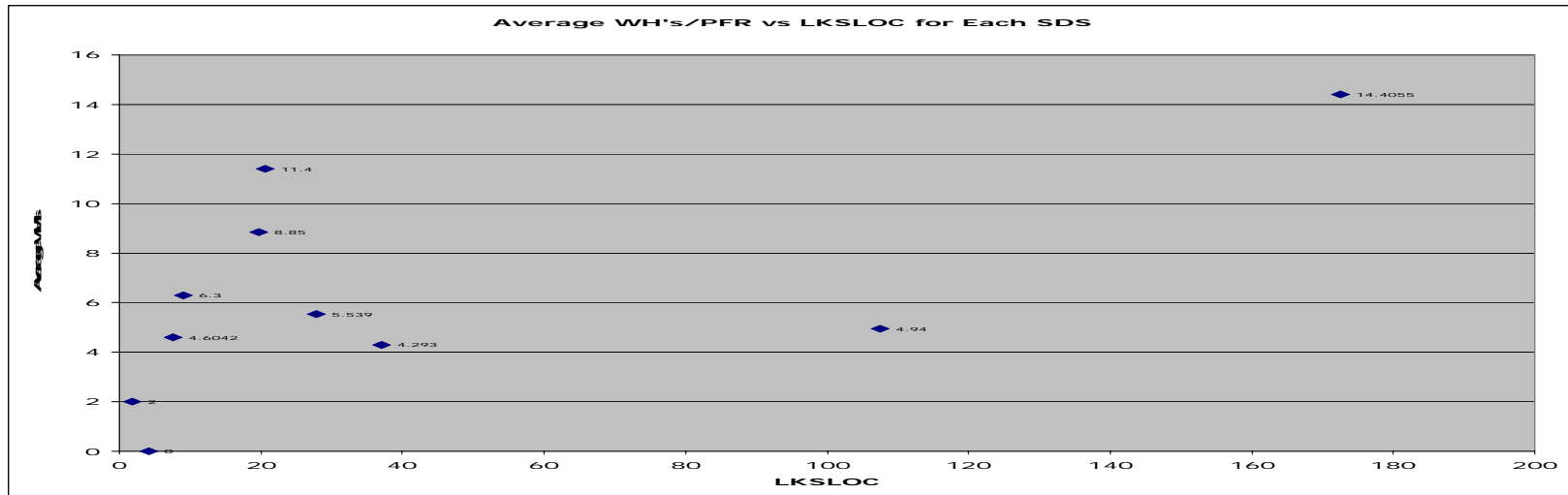
### OPS

	Average # of WH
EM	7
TDG	16
Telecommand	23.6
FTP Server	10.71428571
COM	19.69
Common Software	13.51666667
Earth Terminal Server	7.666666667
UI Client	9.014
UI Server	8.9637
Telemetry	9.5

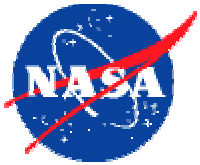




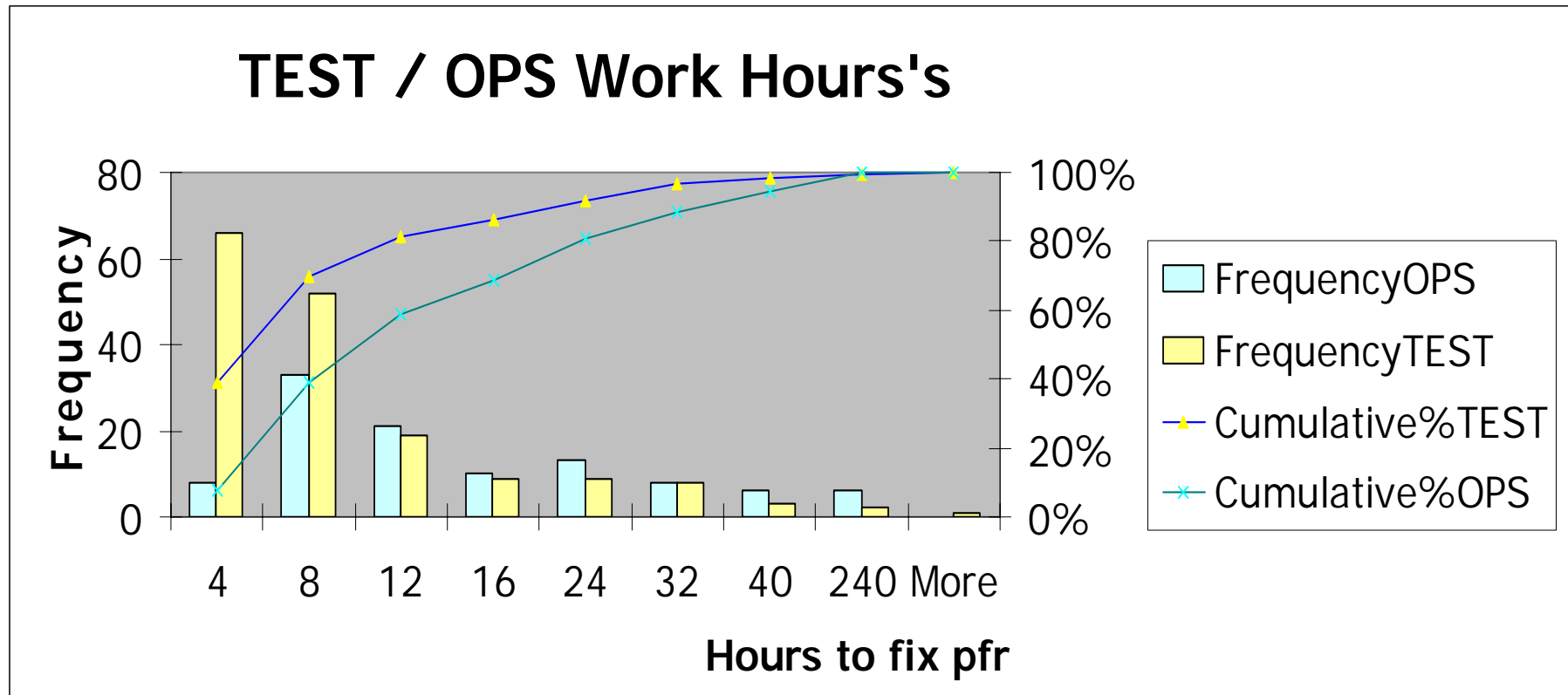
# Empirical Data supporting Outlier Status

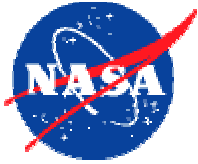


$$V_i = \{ \text{Log}(\text{LKSLOC}_i), \text{Log}(\text{Average PFR fix time for SDS}_i), \text{Log}(\text{Coupling measure SDS}_i) \}$$



# On Average: OPS PFR's cost more to fix than TEST PFR's

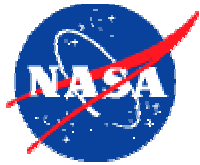




# Conclusions

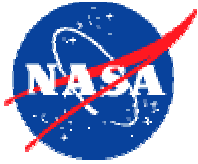


- Desired defect data recording techniques
  - Requires little additional effort
    - Work Hours to Fix a defect
    - Consistency in filling PFR fields
  - Significantly increases power of analysis
    - Enhancing predictive capability
    - Determining appropriate Corrective Actions to resolve delta's (predicted – actual)
    - Process Improvement for subsequent projects



# Backup Slides

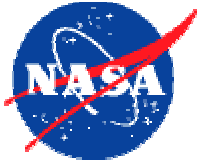




# High Level Goals



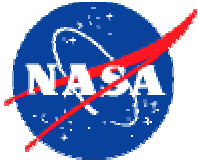
- Make use of JPL defect data to:
  - Support Analysis to:
    - Determine Trends
    - Determine Exceptions to Trends
      - Find Explanations (i.e. Critical Discriminators) of Exceptions
  - Support Decision Making by:
    - Enhancing predictive capability
      - Prediction tools for Managers
      - Guidance by SQI Personnel
    - Determining appropriate Corrective Actions to resolve delta's
      - $\text{delta} = \text{predictions} - \text{actuals}$
    - Process Improvement



# Terminology - 1



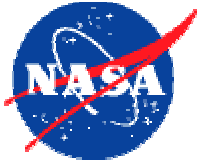
- Software Development Set (SDS)
  - Logical portions of the software system used for segregation of SQI M&B metrics data
- Defect Collection and Categorization
  - Individual Defects must be analyzed during collection
    - Defects must be categorized by SDS
    - Defect must be categorized by characteristics of SQI M&B Defect Prediction models
      - Size
      - Criticality
      - Test type
  - Defect Data Repository must be analyzed for trends



# Terminology - 2



- Definition of “Repair Hours” per PFR
  - Fix
    - Find and Write up Problem
    - Analyze Problem
    - Determine Solution
    - Code Solution
    - Unit Test
  - Large Scale Testing
    - Integration
    - Regression
  - Documentation
    - Additions
    - Corrections

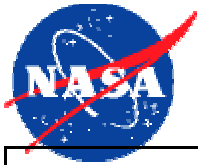


# Desired Defect Data



- Relationships
  - Density (by Size)
  - Complexity Correlation
  - Interconnectivity Correlation
- Individual Defect Characteristics
  - Criticality
  - Test Phase of Discovery
  - Development Phase Introduction/Cause
  - Effort to Repair
- Groupings
  - SDS
  - Version

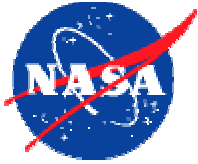




# Test Defect Data



Project	TOTAL Defects	Classifiable Defects	Req	Desgn	Code	Un-Classifiable	Criticality				KSLOC	Defect / KSLOC
							1	2	3	4		
Project 1	55	39	0	21	18	16			1	38	18400	2.98913
Project 2-1	65	36	1	11	24	29			1	35	20620	3.152279
Project 2-2	162	95	4	0	91	67			6	89	34552	4.688585
Project 3	28	12	0	5	7	16				12		
Project 4	12	11	0	8	3	1				11		
Project 5	31	20	1	4	15	11				20		
Project 6	9	6	2	2	2	3				6		
Project 7-1	234	99	1	16	82	135					880000	0.265909
Project 7-2	66	34	0	9	25	32		1	4	29	12800	5.15625
Project 8	41	14	0	1	13	27				14	15000	2.733333
Project 9	1300	1300	Hardware Defects									
Project 10	24	21	6	7	8	3			1	20	48867	0.491129
Project 11	63	27	1	8	18	36			2	25		
Project 12-1	17	17					0	2	15	0	9098	1.868543
Project 12-2	3	3					0	2	1	0	4182	0.71736
Project 12-3	147	147					6	36	105	0	107554	1.366755
Project 12-4	35	35					0	6	29	0	7656	4.571578
Project 12-5	30	30					1	7	22	0	20553	1.459641
Project 12-6	8	8					0	2	6	0	19708	0.405927
Project 12-7	3	3					0	0	3	0	1757	1.707456
Project 12-8	171	171					1	20	146	4	37125	4.606061
Project 12-9	59	59					0	1	58	0	27752	2.125973
Project 12-10	163	163					4	38	119	2	172554	0.944632
Project 12-11 to 15	160	160				0						
<b>TOTALS</b>	<b>2886</b>	<b>2510</b>	<b>16</b>	<b>92</b>	<b>306</b>	<b>376</b>	<b>12</b>	<b>115</b>	<b>519</b>	<b>305</b>		

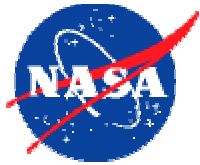


# Project 12

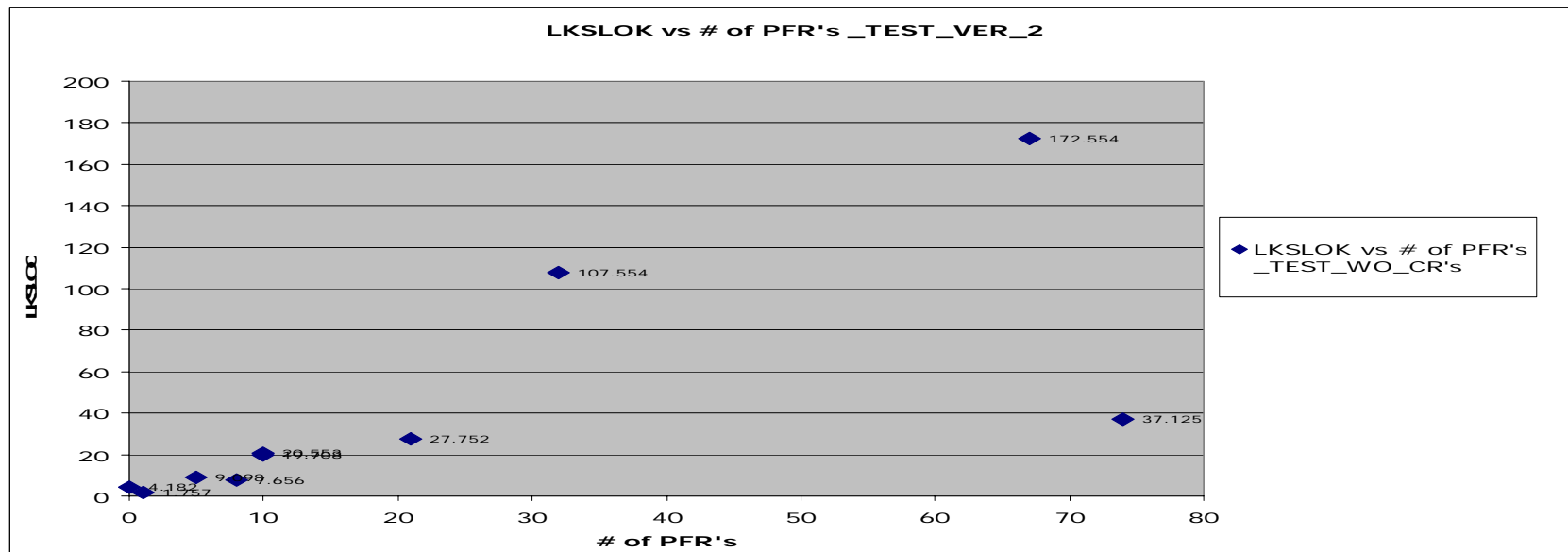
## High Level Observations



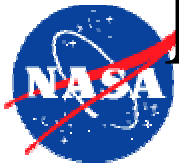
- On Average: OPS PFR's cost more to fix than TEST PFR's
- Trends don't necessarily carry over from TEST to OPS



# Personnel Turnover and Code Breakage Increase Defect Density- TEST



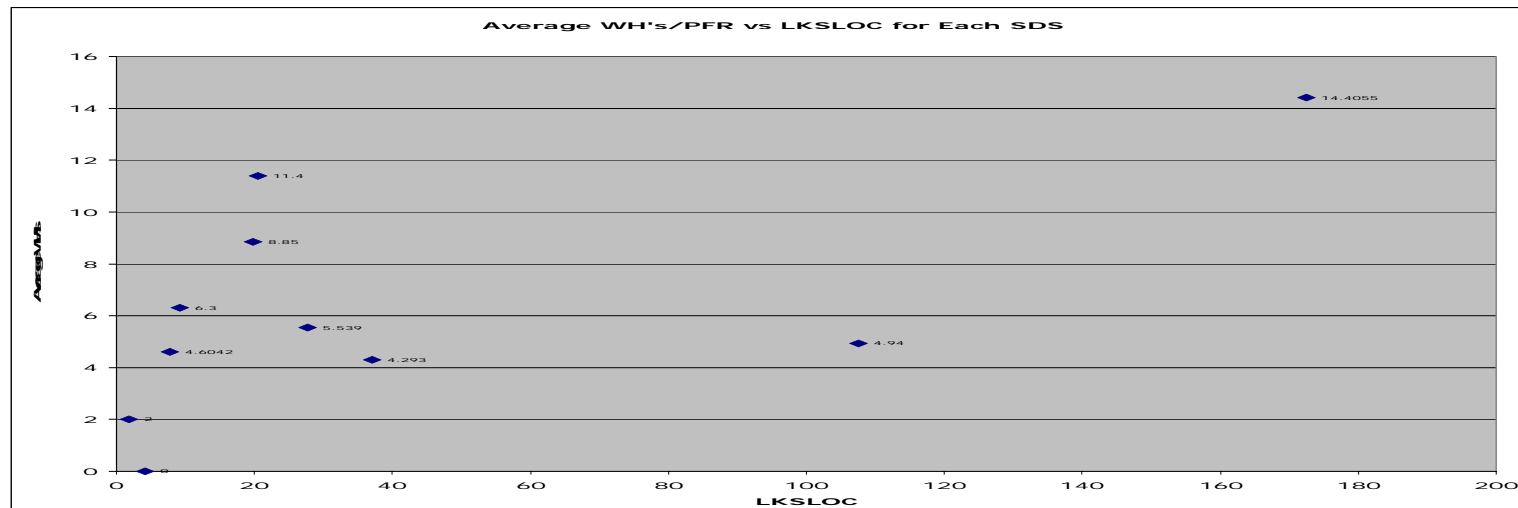
	LKSLOC	# of pfr's
EM	9.098	5
TDG	4.182	0
Telecommand	107.554	32
FTP Server	7.656	8
COM	20.553	10
Common Software	19.708	10
Earth Terminal Server	1.757	1
UI Client	37.125	74
UI Server	27.752	21
Telemetry	172.554	67

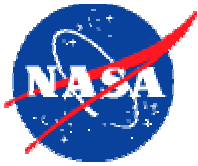


# Determination of CDs for Work Hours per PFR



- Expected Reason for outliers
  - High Interconnectivity
- Confirmed Expectation with Project 12 personnel
- Empirical justification of outliers
  - Interconnectivity ratings from Project 12 personnel
  - Used clustering algorithm for empirical confirmation

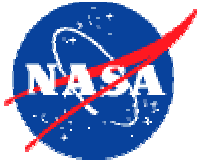




# Progress Metrics



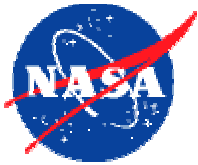
- **2886 Defects** Analyzed and Categorized
- **12 Projects** for which Defect have been Analyzed and Categorized
- **28 SDS's** for which Defect have been Analyzed and Categorized
- Total Effort Working Defect = **11.9 work months**
- 1.13 M&B FTE = < **0.7 Defect FTE**



# Prediction of Work Hours Spent on Selected SW Operations



- Use:
  - Estimated Work Hours per SDS
  - Complexity Estimates of SW Operations in SDS
    - Control Operations
    - Computational Operations
    - Device Dependent Operations
    - Data Management Operations
    - UI Management Operations
    - Interconnectivity Operations
  - LKSLOC of SDS's



# Chart for Work Hours Spent on Selected SW Operations -TEST



	LOWER PARAMETER RATING										HIGHER PARAMETER RATING									
<b>LKSLOC</b>	1.8	4	8	9	20	21	27.8	37	108	173	1.8	4	8	9	20	21	28	37	108	173
Control Operations - WH	0.3							53				0	7	7	18	22	22		30	211
Computational Operations - WH	0.3	0	5	4		18	14.5	53	24						13					181
Device Dependent Operations - WH	0.3	0				13		40	24	121			7	6	18		18			
Data Management Operations - WH		0		5	15	22	21.8		30	181	0.3		5					53		
UI Management Operations - WH	0.3	0	5	4	10	18			24	121							18	66		
Interconnectivity Operations - WH	0.3	0						53	24				7	5	15	22	22			151