# JPL/NASA TEST EFFECTIVENESS PROGRAM

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# INTRODUCTION

- JPL'S ASSURANCE TECHNOLOGY PROGRAM OFFICE
- DRIVERS
- PROGRAM TE PROGRAM ORGANIZATION
- CURRENT ACTIVITIES
- TEST EFFECTIVENESS DRAFT WORKING GROUP CHARTER

# JPL ASSURANCE TECHNOLOGY PROGRAM OFFICE STRUCTURE

OEMA
ASSURANCE TECHNOLOGY
PROGRAM OFFICE (ATPO)
T. Gindorf (Manager)

⓪ AM - Jean Henderson

① Advanced Packaging and Manufacturing Assurance
P. Barela (PEM)

- AIP (QM)
- SRM&QA Training Course Development (QM)
- Supplier Quality
- Metrology and Calibration (QT)
- NDE (LaRC) LCR - Olivas

② EEE Parts
S. Kayali (PEM)

- EEE Parts (QM)

③ Payload Reliability Assurance
S. Cornford (PEM)

Payload Assurance
- Spacecraft Test Effectiveness (QT)
- Mission Assurance Project Application (QT)
- Flight Performance (QT)

Reliability
- Risk Assessment (QS)
- Process Verification & Countermeasures (QS)
- Mechanical Parts (QS)

④ Mission Assurance
G. Faris (PEM)

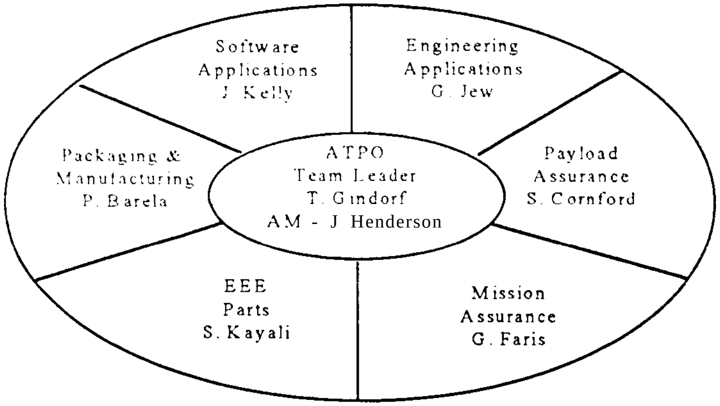
- Cost Benefit/Mgmt. Studies (QT)
- Systems Safety (QS)
- Operational Safety (QS)

⑤ Software Applications
J. Kelly (PEM) - LCR

- IV&V Projects & Grants (ARC)
- S/W Engineering (ARC)

⑥ Engineering Applications
G. Jew (PEM)

| | LCR |
|---|---|
| • Eng. Standards (M SFC) | Shinbrot |
| · 1S0 9000 (QM) - Jones | |
| • Systems Eng. (JSC) | TJ3D |
| · Structural Design-Test-Verification (M SFC) | Lou |
| • Batt & Pwr Sys. (Le RC) Applied Tech (AE) | Di Stefano |



PEM Program Element Manager
LCR - Led Center Representative
AM - Administrative Management

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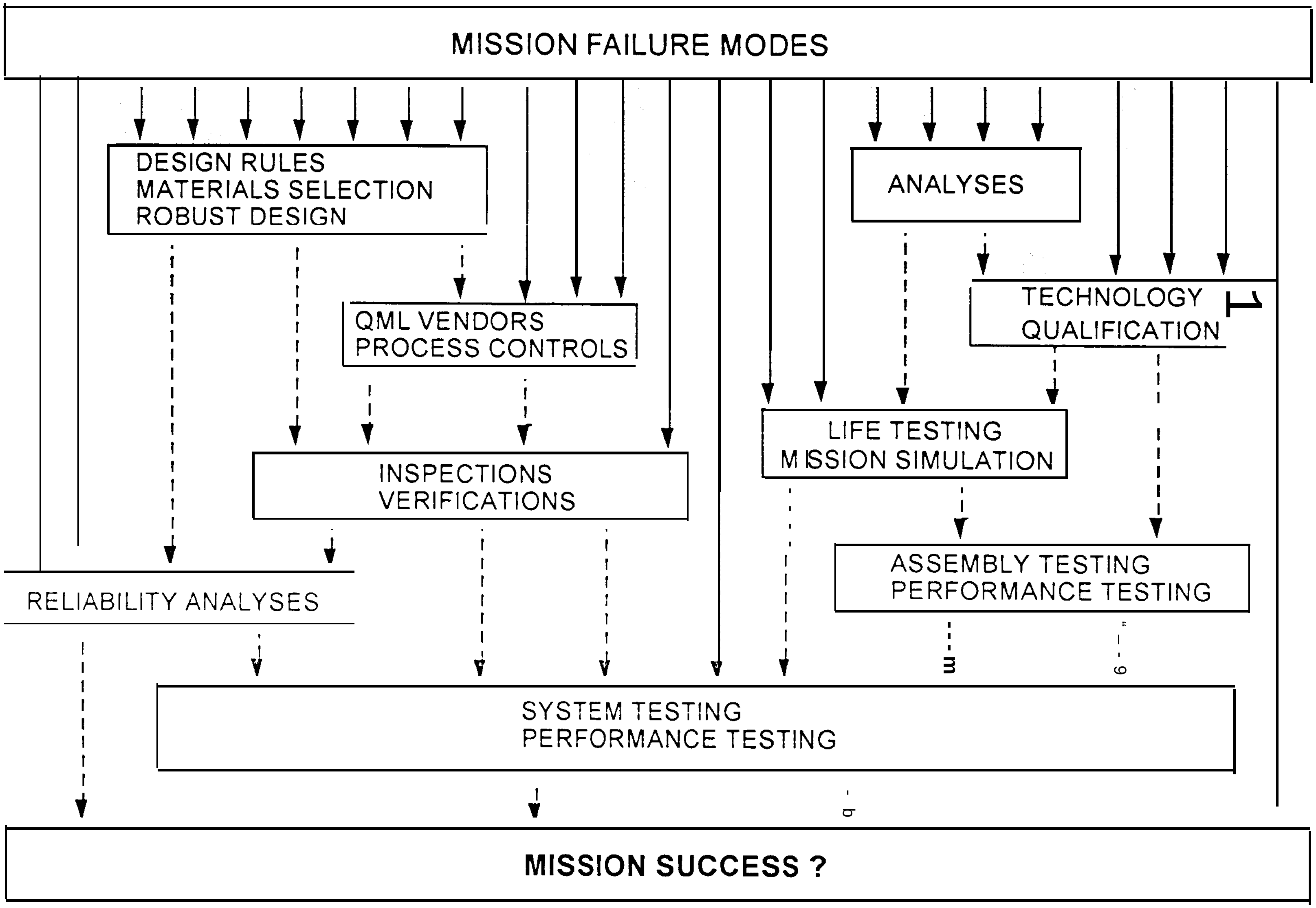
# TE TASK DRIVERS

- NASA IS ASKING US TO DO MORE WITH LESS MONEY AND TO DO IT WELL
- GET NEW TECHNOLOGY INTO PRODUCTS SOONER
- PROJECT PERSONNEL ARE ASKING US TO HELP THEM IDENTIFY THE LOW VALUE ADDED ASSURANCE TASKS AND THE OVERLY REDUNDANT TASKS
- ALL WANT PROOF (I. E.. METRICS) OF THE EFFECTIVENESS OF WHAT REMAINS AFTER TAILORING
- NEED A SYSTEMATIC APPROACH TO ACHIEVE THE ABOVE

# RAINFALL CHART



Notes: 1) Each box is a collection of PACTs
2) Dotted lines represent "escapes" - Undetected/unprevented failure modes
3) Illustrative diagram only - nothing is "to scale"

5/2/97

# TE TASK OBJECTIVES

- IMPROVE NASA/JPL's OVERALL EFFECTIVENESS BY ADVANCING THE FIELD OF DEFECT DETECTION AND PREVENTION
- SHARE EXPERIENCES, KNOWLEDGE AND AVAILABLE DATA IN THE PACT EFFECTIVENESS ARENA
- LEVERAGE INDUSTRY AND OTHER GOVERNMENT AGENCIES EXPERIENCE, KNOWLEDGE AND AVAILABLE DATA
- DEVELOPMENT& IMPLEMENT TOOLS & METRICS FOR TECHNICAL & PROGRAMMATIC RISK MANAGEMENT
- DISSEMINATE RESULTS AND FINDINGS

# NASA/JPL TEST EFFECTIVENESS PROGRAM

DATA SOURCES AND SYSTEMS

- **DATABASES**
  - **NASA/JPL FLIGHT AND GROUND ANOMALIES AND SSED**
  - **COMMERCIAL SCREENING DATA**
- **WORKING GROUPS, SEMINARS, SURVEYS, STANDARDS**

METRICS DEVELOPMENT **AND** IMPLEMENTATION

- **RELATIVE TEST AND COST EFFECTIVENESS VERSUS FAILURE MODES**
- **ROLE OF MARGINS AND INTERPLAY BETWEEN PACTS ANALYSIS VERSUS TESTING, INSPECTIONS VERSUS TESTING, TESTING COMBINATIONS, LEVEL OF ASSEMBLY, DESIGN AND FABRICATION (DESIGNING FOR AND TESTING FOR THE "ILITIES")**

METHODOLOGY DEVELOPMENT AND IMPLEMENTATION

- **SYNERGISTIC AND PHYSICS OF FAILURE BASED TESTING**
- **QUALIFICATION METHODOLOGIES FOR ADVANCED TECHNOLOGIES**
- **DEFECT DETECTION AND PREVENTION RISK IDENTIFICATION AND MITIGATION STRATEGIES MIXING AND MATCHING PACTS**

# Value Added Screening Effectiveness

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# VASE OVERVIEW

- VASE Concept
- RAINFALL CHART
- VASE Process
- Data Collection and Analyses
  - Level 1 Analysis (all HASS failures)
  - Level 2 Analysis (initial HASS failures)
  - HASS Data Analysis Examples
- Results
  - HASS Process
  - LESS Process
  - HASS/LESS Comparison
- Conclusions

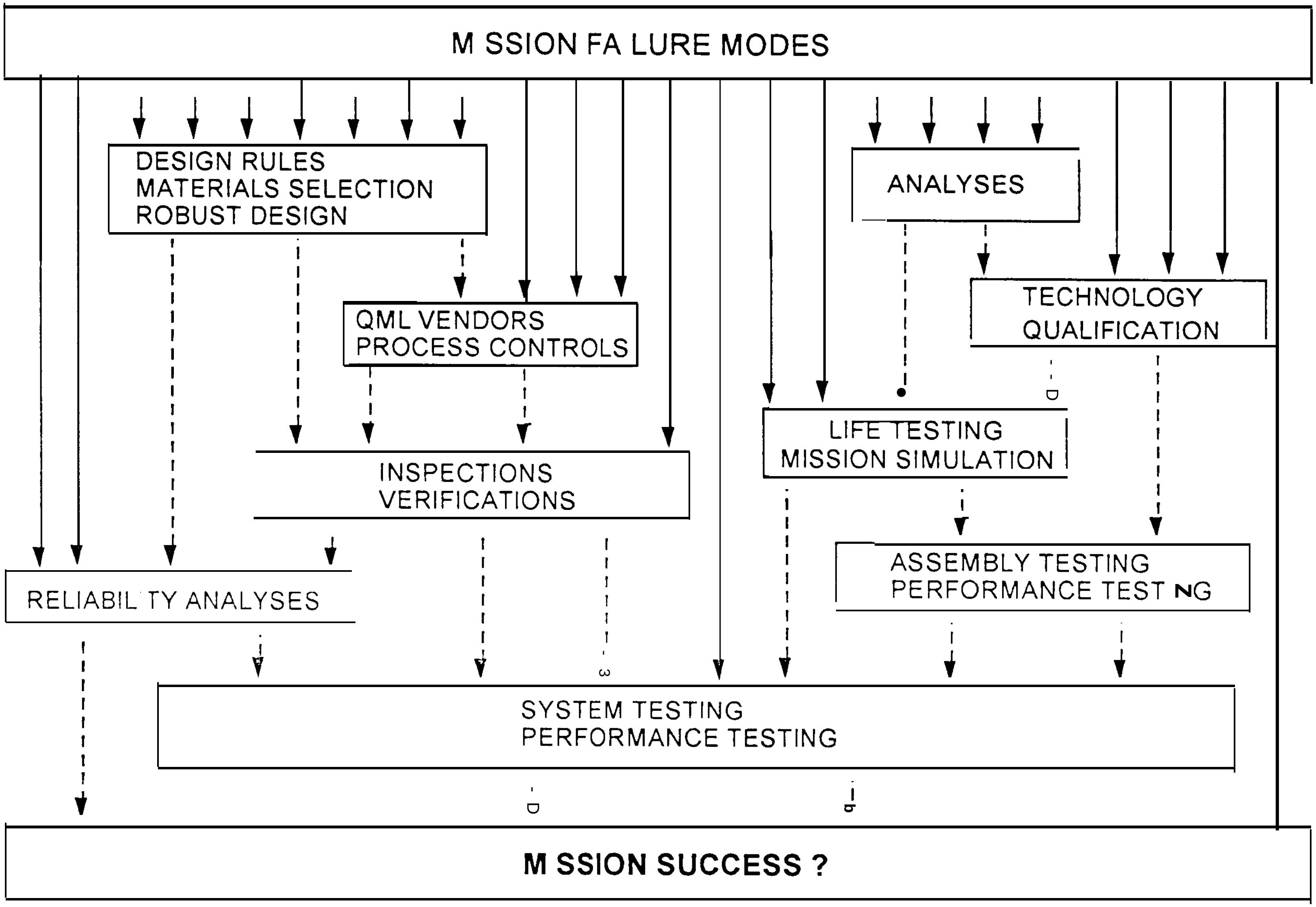
# VASE CONCEPT

Value Added Screening Effectiveness (VASE)

- NCMS ESS 2000 Project Scope: Optimize ESS process
- Process which assesses the value added by various steps in a process or all processes used in delivering a reliable product to market
  - Developed jointly between National Center for Manufacturing Sciences (NCMS) & JPL/NASA's test effectiveness program, a derivative of JPL's Defect Detection & Prevention (DDP) methodology
  - Captures failure mode/mechanism prevention, detection and/or precipitation data Vs. process parameter data Vs. design capabilities
  - Ranks the effectiveness of various screening stresses Vs. failure mode/mechanism categories

ENABLES OPTIMIZATION TRADE-OFFS BASED ON FAILURE ENGINEERING/PHYSICS

# RAINFALL CHART



Notes: 1) Each box is a collection of PACTs
2) Dotted lines represent "escapes" - Undetected/unprevented failure modes
3) Illustrative diagram only - nothing is "to scale"

# VASE PROCESS

Capture snapshots of data for a given set of processes:

- Failure classification (by process)
  - Failure mode/mechanism
  - Identification of responsible stress and/or combination of stresses
- Cost determination
  - Identify appropriate cost metric(s) and weighings:
    - (In this case cost per defect detected)
  - Allocate costs to each test step
    - ESS cost model (run for all three organizations specific cost conditions)
- Optimization
  - Rank the effectiveness of various stress/stress-combinations based on cost metric

USE THE SNAPSHOTS TO CREATE A “VIDEO IMAGE” OF THE EFFECTIVENESS TO CLOSE THE FEEDBACK LOOP AS PROCESSES CHANGE DUE TO NEW INFORMATION

# DATA COLLECTION & ANALYSES

Collect as much data as possible in the beginning

- Typically the more detailed the data the more meaningful the conclusion
- VASE process helps avoid “getting lost in the data”
- Use as much detailed data as necessary but no more.

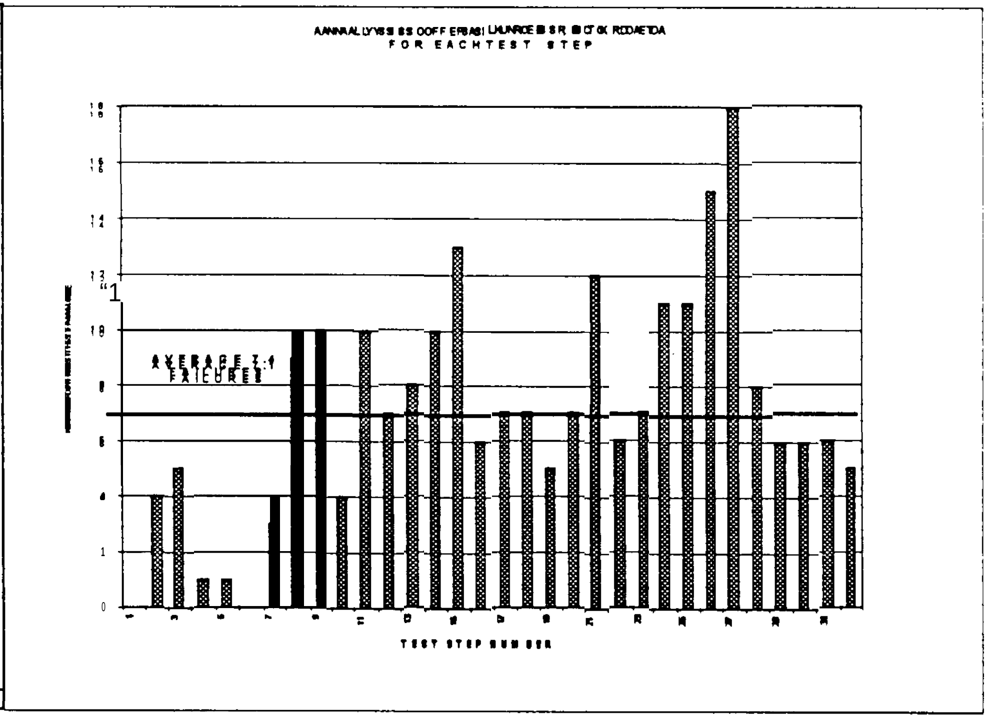
- Match level of detail for each type data collected to level of detail regarding process step

E.g.

- Screens and Workmanship
- Vibration and Lose fastners
- Duration and wire bond

# LEVEL 1 ANALYSIS (all HASS failures)

| TEP | OUNT | TE | P (C)/RAMPRATE | VIB | Voltage |
|---|---|---|---|---|---|
| 1 | 0 | 28 | Ambient | | |
| 2 | 4 | 49 | Positiveramp | | |
| 3 | 5 | 66 | Hot Level | | |
| 4 | 1 | 70 | HotLevel/Dwell | | |
| 5 | | 71 | HotLevel/Dwell | | |
| 6 | 0 | 15 | Negativeramp | | |
| 7 | 3 | -14 | Cold/(-Ramp) | | |
| 8 | 9 | -21 | Cold Dwell | | |
| 9 | 10 | -21 | Cold Dwell | | |
| 10 | 4 | 52 | Hot level | 0 . | |
| 11 | 10 | 67 | HotLevel/Dwell | 0 “ | |
| 12 | 7 | 70 | HotLevel/Dwell | 0 . | |
| 13 | 8 | .21 | Cold/(-Ramp) | 0 . | |
| 14 | 10 | -21 | Cold L. ".! | 0 . | |
| 15 | 13 | .?0 | Cold Level | 0 . | |
| 16 | 6 | 25 | Ambient/(+Ramp) | | |
| 17 | 7 | 56 | HotLevel/Dwell | | |
| 18 | 7 | 59 | HotLevel/Dwell | | |
| 19 | 5 | 70 | HotLevel/Dwell | | |
| 20 | 7 | 71 | HotDwell | | Low |
| 21 | 12 | 71 | HotDwell | | High |
| 22 | 6 | 13 | Negativeramp | | |
| 23 | 7 | .2? | Cold L. ".! | | |
| 24 | 11 | .21 | Cold L. .,! | | |
| 25 | 11 | -21 | Cold Dwell | | |
| 26 | 15 | -21 | Cold Dwell | | Low |
| 27 | 18 | .?0 | Cold Dwell | | High |
| 28 | 8 | 8 | Ambient/(+Ramp) | | |
| 29 | 6 | 23 | Ambient | | |
| 30 | 6 | 29 | Ambient | | |
| 31 | 6 | 30 | Ambient | | |
| 32 | 5 | 30 | Ambient | | Ver" high |
| :UM | 228 | | AVG. | 7.4 | |



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- High Level data Analysis can be misleading
- Wrong conclusions
  - Al l these steps are necseeasry
  - May need more steps
  - Cold Vib. more effective than Hot Vib.

# LEVEL 2 ANALYSIS (initial HASS failures)

| STEP NO. | Failure Count | CONDITIONS |  |  |  |
|---|---|---|---|---|---|
|  |  | Temp (c)/Ramp Rate |  | Vib | Volt. |
| 1 | 0 | 24 | Ambient |  |  |
| 2 | 4 | 50 | Positive ramp |  |  |
| 3 | 4 | 66 | Hot Level |  |  |
| 4 | 0 | 70 | Hot Level/Owen |  |  |
| 5 | 0 | 71 | Hot Level/Dwell |  |  |
| 6 | 0 | 17 | Negative ramp |  |  |
| 7 | 3 | -19 | Cold/(-rr amp) |  |  |
| 8 | 6 | -21 | Cold Owen |  |  |
| 9 | 3 | -21 | Cold Owen |  |  |
| 10 | 2 | 54 | Hotlevel | On |  |
| 11 | 5 | 67 | Hot Level/Dwell | On |  |
| 12 | 0 | 70 | Hot Level/Dwell | On |  |
| 13 | 0 | -20 | Cold/(-rramp) | On |  |
| 14 | 1 | -21 | Cold Level | On |  |
| 15 | 0 | -21 | Cold Level | On |  |
| 16 | 0 | 26 | Ambient/(+ramp) |  |  |
| 17 | 1 | 56 | Hot Level/Dwell |  |  |
| 18 | 0 | 66 | Hot Level/Dwell |  |  |
| 19 | 1 | 69 | Hot Level/Owen |  |  |
| 20 | 3 | 71 | Hot Dwell |  | 45 |
| 21 | 4 | 71 | Hot Dwell |  | 55 |
| 22 | 0 | 14 | Negative ramp |  |  |
| 23 | 0 | -21 | Cold Level |  |  |
| 24 | 0 | -21 | Cold Level |  |  |
| 25 | 0 | -21 | Cold Dwell |  |  |
| 26 | 5 | -21 | Cold Dwell |  | 45 |
| 27 | 3 | -20 | Cold Dwell |  | 55 |
| 26 | 1 | 8 | Ambient/(+ramp |  |  |
| 29 | 0 | 24 | Ambient |  |  |
| 30 | 1 | 30 | Ambient |  |  |
| 31 | 0 | 30 | Ambient |  |  |
| 32 | 0 | 30 | Ambient |  | 5.8 |
| Sum | 47 |  | Avg. 15 |  |  |

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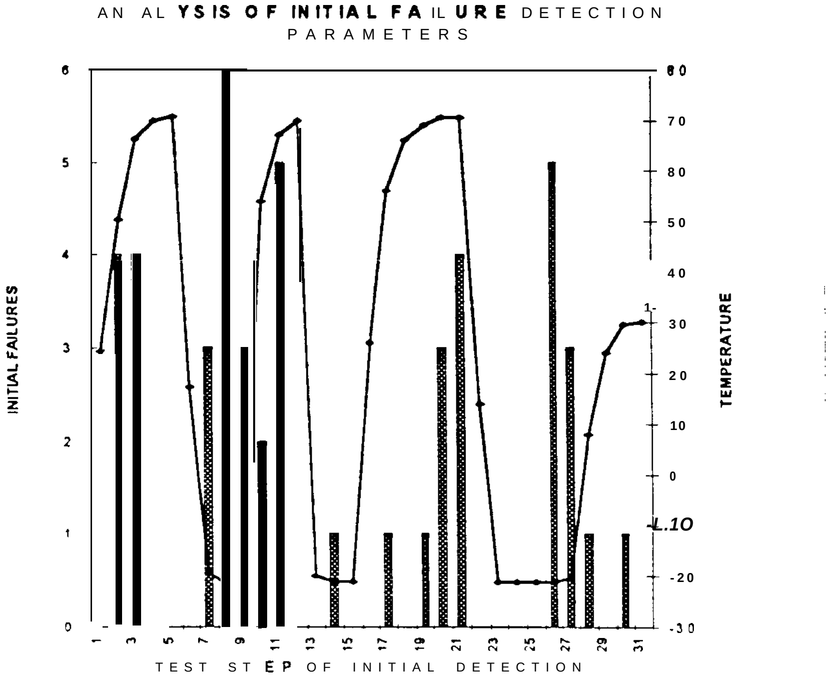
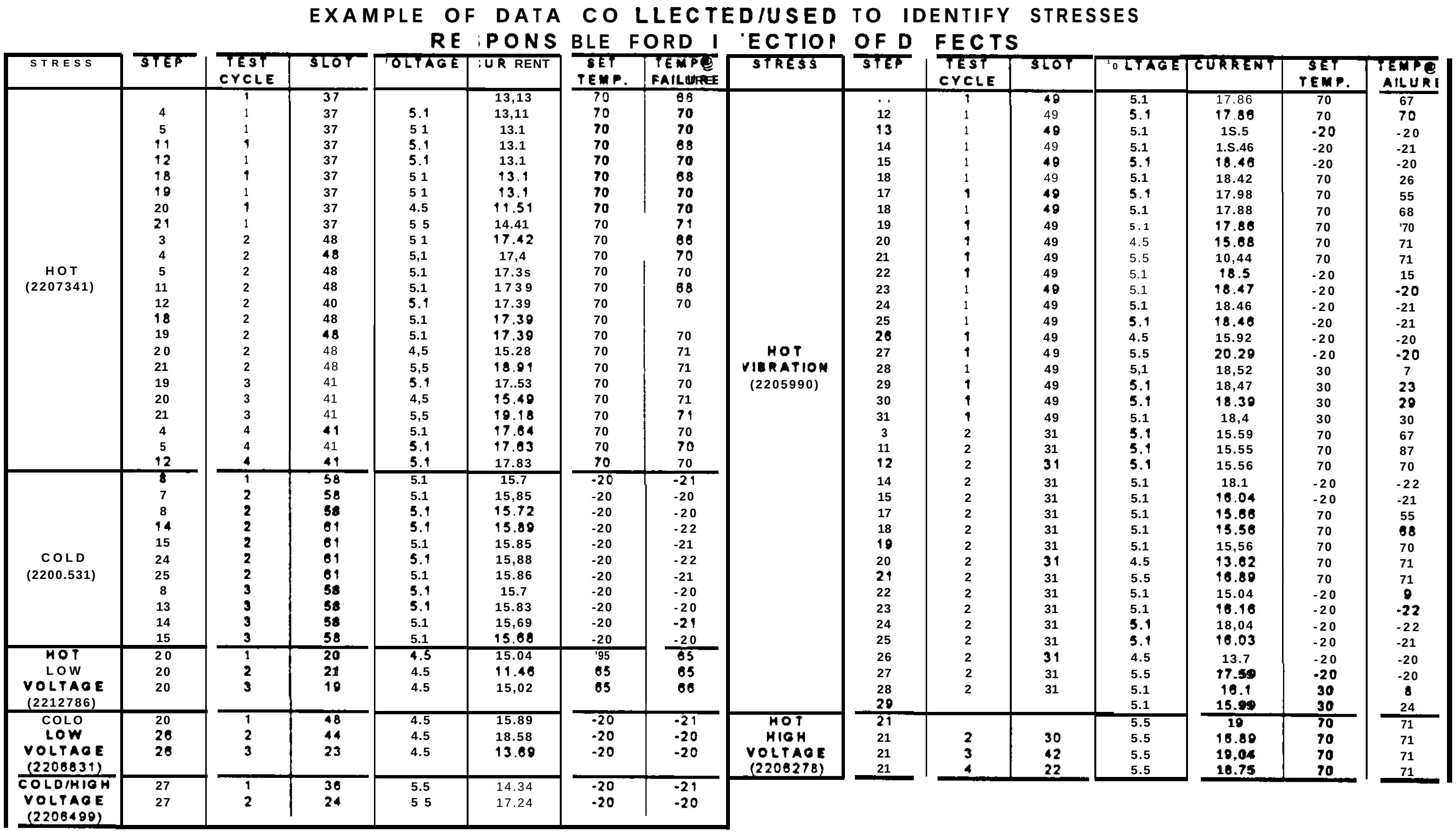


- Shows first occurance of failures
  - Different Conclusions than before:
    - Hot Vib more effective than Cold Vib.

# HASS Data Analysis: Examples



EXAMPLE OF DATA COLLECTED/USED TO IDENTIFY STRESSES
RESPONSIBLE FOR DETECTION OF DEFECTS

| STRESS | STEP | TEST CYCLE | SLOT | VOLTAGE | CURRENT | SET TEMP. | TEMP@ FAILURE |
|---|---|---|---|---|---|---|---|
| HOT (2207341) |  | 1 | 37 |  | 13,13 | 70 | 68 |
|  | 4 | 1 | 37 | 5.1 | 13,11 | 70 | 70 |
|  | 5 | 1 | 37 | 5 1 | 13.1 | 70 | 70 |
|  | 11 | 1 | 37 | 5.1 | 13.1 | 70 | 68 |
|  | 12 | 1 | 37 | 5.1 | 13.1 | 70 | 70 |
|  | 18 | 1 | 37 | 5 1 | 13.1 | 70 | 68 |
|  | 19 | 1 | 37 | 5 1 | 13.1 | 70 | 70 |
|  | 20 | 1 | 37 | 4.5 | 11.51 | 70 | 70 |
|  | 21 | 1 | 37 | 5 5 | 14.41 | 70 | 71 |
|  | 3 | 2 | 48 | 5 1 | 17.42 | 70 | 68 |
|  | 4 | 2 | 48 | 5,1 | 17,4 | 70 | 70 |
|  | 5 | 2 | 48 | 5.1 | 17.3s | 70 | 70 |
|  | 11 | 2 | 48 | 5.1 | 1739 | 70 | 68 |
|  | 12 | 2 | 40 | 5.1 | 17.39 | 70 | 70 |
|  | 18 | 2 | 48 | 5.1 | 17.39 | 70 |  |
|  | 19 | 2 | 48 | 5.1 | 17.39 | 70 | 70 |
|  | 20 | 2 | 48 | 4,5 | 15.28 | 70 | 71 |
|  | 21 | 2 | 48 | 5,5 | 18.91 | 70 | 71 |
|  | 19 | 3 | 41 | 5.1 | 17..53 | 70 | 70 |
|  | 20 | 3 | 41 | 4,5 | 15.49 | 70 | 71 |
|  | 21 | 3 | 41 | 5,5 | 19.18 | 70 | 71 |
|  | 4 | 4 | 41 | 5.1 | 17.64 | 70 | 70 |
|  | 5 | 4 | 41 | 5.1 | 17.63 | 70 | 70 |
|  | 12 | 4 | 41 | 5.1 | 17.83 | 70 | 70 |
| COLD (2200.531) | 8 | 1 | 58 | 5.1 | 15.7 | -20 | -21 |
|  | 7 | 2 | 58 | 5.1 | 15,85 | -20 | -20 |
|  | 8 | 2 | 58 | 5.1 | 15.72 | -20 | -20 |
|  | 14 | 2 | 61 | 5.1 | 15.89 | -20 | -22 |
|  | 15 | 2 | 61 | 5.1 | 15.85 | -20 | -21 |
|  | 24 | 2 | 61 | 5.1 | 15,88 | -20 | -22 |
|  | 25 | 2 | 61 | 5.1 | 15.86 | -20 | -21 |
|  | 8 | 3 | 58 | 5.1 | 15.7 | -20 | -20 |
|  | 13 | 3 | 58 | 5.1 | 15.83 | -20 | -20 |
|  | 14 | 3 | 58 | 5.1 | 15,69 | -20 | -21 |
|  | 15 | 3 | 58 | 5.1 | 15.68 | -20 | -20 |
| HOT LOW VOLTAGE (2212786) | 20 | 1 | 20 | 4.5 | 15.04 | '95 | 65 |
|  | 20 | 2 | 21 | 4.5 | 11.46 | 65 | 65 |
|  | 20 | 3 | 19 | 4.5 | 15,02 | 65 | 66 |
| COLO LOW VOLTAGE (2206831) | 20 | 1 | 48 | 4.5 | 15.89 | -20 | -21 |
|  | 26 | 2 | 44 | 4.5 | 18.58 | -20 | -20 |
|  | 26 | 3 | 23 | 4.5 | 13.69 | -20 | -20 |
| COLD/HIGH VOLTAGE (2206499) | 27 | 1 | 36 | 5.5 | 14.34 | -20 | -21 |
|  | 27 | 2 | 24 | 5 5 | 17.24 | -20 | -20 |

| STRESS | STEP | TEST CYCLE | SLOT | VOLTAGE | CURRENT | SET TEMP. | TEMP@ FAILURE |
|---|---|---|---|---|---|---|---|
| HOT VIBRATION (2205990) | .. | 1 | 49 | 5.1 | 17.86 | 70 | 67 |
|  | 12 | 1 | 49 | 5.1 | 17.86 | 70 | 70 |
|  | 13 | 1 | 49 | 5.1 | 1S.5 | -20 | -20 |
|  | 14 | 1 | 49 | 5.1 | 1.S.46 | -20 | -21 |
|  | 15 | 1 | 49 | 5.1 | 18.46 | -20 | -20 |
|  | 18 | 1 | 49 | 5.1 | 18.42 | 70 | 26 |
|  | 17 | 1 | 49 | 5.1 | 17.98 | 70 | 55 |
|  | 18 | 1 | 49 | 5.1 | 17.88 | 70 | 68 |
|  | 19 | 1 | 49 | 5.1 | 17.86 | 70 | '70 |
|  | 20 | 1 | 49 | 4.5 | 15.68 | 70 | 71 |
|  | 21 | 1 | 49 | 5.5 | 10,44 | 70 | 71 |
|  | 22 | 1 | 49 | 5.1 | 18.5 | -20 | 15 |
|  | 23 | 1 | 49 | 5.1 | 18.47 | -20 | -20 |
|  | 24 | 1 | 49 | 5.1 | 18.46 | -20 | -21 |
|  | 25 | 1 | 49 | 5.1 | 18.46 | -20 | -21 |
|  | 26 | 1 | 49 | 4.5 | 15.92 | -20 | -20 |
|  | 27 | 1 | 49 | 5.5 | 20.29 | -20 | -20 |
|  | 28 | 1 | 49 | 5,1 | 18,52 | 30 | 7 |
|  | 29 | 1 | 49 | 5.1 | 18,47 | 30 | 23 |
|  | 30 | 1 | 49 | 5.1 | 18.39 | 30 | 29 |
|  | 31 | 1 | 49 | 5.1 | 18,4 | 30 | 30 |
|  | 3 | 2 | 31 | 5.1 | 15.59 | 70 | 67 |
|  | 11 | 2 | 31 | 5.1 | 15.55 | 70 | 87 |
|  | 12 | 2 | 31 | 5.1 | 15.56 | 70 | 70 |
|  | 14 | 2 | 31 | 5.1 | 18.1 | -20 | -22 |
|  | 15 | 2 | 31 | 5.1 | 16.04 | -20 | -21 |
|  | 17 | 2 | 31 | 5.1 | 15.66 | 70 | 55 |
|  | 18 | 2 | 31 | 5.1 | 15.56 | 70 | 68 |
|  | 19 | 2 | 31 | 5.1 | 15,56 | 70 | 70 |
|  | 20 | 2 | 31 | 4.5 | 13.62 | 70 | 71 |
|  | 21 | 2 | 31 | 5.5 | 16.89 | 70 | 71 |
|  | 22 | 2 | 31 | 5.1 | 15.04 | -20 | 9 |
|  | 23 | 2 | 31 | 5.1 | 16.16 | -20 | -22 |
|  | 24 | 2 | 31 | 5.1 | 18,04 | -20 | -22 |
|  | 25 | 2 | 31 | 5.1 | 16.03 | -20 | -21 |
|  | 26 | 2 | 31 | 4.5 | 13.7 | -20 | -20 |
|  | 27 | 2 | 31 | 5.5 | 17.59 | -20 | -20 |
|  | 28 | 2 | 31 | 5.1 | 16.1 | 30 | 8 |
|  | 29 |  |  | 5.1 | 15.99 | 30 | 24 |
| HOT HIGH VOLTAGE (2206278) | 21 |  |  | 5.5 | 19 | 70 | 71 |
|  | 21 | 2 | 30 | 5.5 | 16.89 | 70 | 71 |
|  | 21 | 3 | 42 | 5.5 | 19,04 | 70 | 71 |
|  | 21 | 4 | 22 | 5.5 | 16.75 | 70 | 71 |

- For decisions regarding effeteness of individual stresses must go deeper into data

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# HASS PROCESS RESULTS

## VASE MATRIX FOR HASS PROCESS

| HASS STRESSES PLUS FUNCTIONAL FAILURES, i.e. Dead-On-Arrivals | FAILURE MODES/MECHANISMS | | | | | | | | | | | | | | | | | | TOTALS | DEFECT COSTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIMING | FUNCTIONAL FAILURE/WRONG OUTPUT | UNKOWN | SHORT | STUCK BIT (CRACKED DIE) | NO DEFECT FOUND | INSUFICIENT SOLDER | COLD SOLDER JOINT | SOLDER BALL | SOLDER BRIDGE | SOLDER WETTING | FLUX CLEANING PROCESS FAILURE | COPLANARITY | HANDLING | ICT TEST SKIPPED | INTERRUPT | PARAMETER DRIFT | OTHERS | TOTAL FAILURES DETECTED BY KNOB | Relative Cost/Defects found (by Screening Stress) |
| FUNCTIONAL TEST (DOA) | 3 | | | 2 | 1 | | | 1 | 1 | | | 9 | 1 | 4 | 1 | 1 | | | 24 | $17 |
| COLD LEVEL | 2 | 4 | 2 | | | 1 | 1 | 2 | | | | | | | | | | | 12 | $70 |
| COLD/LOW VOLTAGE | 3 | 2 | 1 | | | | | | | | | | | | | | | | 6 | $70 |
| VIBRATION OR HOT/VIBRATION | | 1 | | 1 | | | | | | 1 | 2 | | | | | | 1 | | 6 | $559 |
| HOT LEVEL OR RAMP RATE | 1 | 2 | | | 1 | 1 | | | | | | | | | | | | | 5 | $335 |
| COLD/HIGH VOLTAGE | 1 | 2 | | | | | | | | | | | | | | | | | 3 | $140 |
| HOT LEVEL | 2 | | | | | | | | | | | | | | | | | | 2 | $419 |
| HOT/HIGH VOLTAGE | | | 2 | | | | | | | | | | | | | | | | 2 | $210 |
| COLD/NEGATIVE RAMP | 1 | | 1 | | | | | | | | | | | | | | | | 2 | $210 |
| HOT/LOW VOLTAGE | | | 2 | | | | | | | | | | | | | | | | 2 | $210 |
| RAMP RATE (?) | | | 1 | | | | | | | | | | | | | | | | 1 | $419 |
| HOT DWELL OR HOT AFTER VIB | | | | | | 1 | | | | | | | | | | | | | 1 | $839 |
| MULTIPLE THERMAL CYCLES | | | | | | 1 | | | | | | | | | | | | | 1 | $5,032 |
| OTAL FM's FOUND BY ALL KNOBS | 13 | 11 | 9 | 3 | 2 | 4 | 1 | 3 | 1 | 1 | 2 | 9 | 1 | 4 | 1 | 1 | 1 | 0 | 67 | $200 |

[illegible] VASE3 XLS//VASE 4

**Ranked** HASS **Stresses Vs. Cost per defect defected**

# LESS PROCESS RESULTS

## VASE MATRIX FOR LESS PROCESS

| LESS | FAILURE MODES MECHANISMS | | | | | | | | | | | | | | | | | | | | TOTALS | DEFECT COSTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STRESSES PLUS FUNCTIONAL FAILURES i.e. Dead-On-Arrivals | PRECIPITATED BUT NO DEFECT FOUND | NO DEFECT FOUND | TIMING | STUCK BIT | FUNCTIONAL FAILURE/WRONG OUTPUT | UNKNOWN | SHORT | SOLDER REFLOW | INSUFFICIENT SOLDER | COLD SOLDER JOINT | SOLDER BRIDGE | SOLDER WETTING | FLUX CLEANING PROCESS FAILURE | OPEN TRACE INSIDE BOARD | MISHANDLING | PART PLACEMENT | CT TEST SKIPPED OR FAULTY ICT | CONNECTOR SHORTED | “” | PARAMETER DRIFT | TOTAL FAILURES DETECTED BY KNOB | relative Cost/Defects found (by Screening Stresses) |
| FUNCTIONAL TEST DOA | | | | | | | | | | | | | | 1 | 7 | | | · | 2 | | 4 | |
| TRANS.CYCLES & COLD OR TIME COLD | | | | | | | | | | | | | | | | | | | 3 | | 6 | $75 |
| HOT LEVEL | | | | 2 | | | | | | | | | | | | | | | | | 3 | $5 |
| COLD LEVEL | | | | | · | | | | | | | | | | | | | | | | 2 | .7 |
| IN AIR & HIGH VOLTAGE TESTING | | | 2 | | | | | | | | | | | | | | | | | | 2 | $14 |
| HOT & LOW VOLTAGE | | | 1 | | | | | | | | | | | | | | | | | | 1 | $14 |
| TRANS.CYCLES | | | | | | | | | | | | | | | | | | | 2 | | 2 | $224 |
| IN AIR TESTING OR TRANS.CYCLES & HOT OR TIME HOT | | | | 1 | | | | | | | | | | | | | | | | | 1 | $448 |
| TOTAL FM's FOUND BY ALL KNOBS | | | 4 | 4 | 3 | | | 1 | | | | | | 2 | 7 | 1 | 1 | 1 | 7 | | 31 | |

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Ranked LESS Stresses Vs. Cost per defect defected

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# HASS/LESS COMPARISON

**Comparison VASE Matrix for HASS AND LESS PROCESSES**
**(BY Tall Pole FAILURE MODES)**

| **CONFIDENCE LEVEL ESTIMATE** | TIMING | FUNCTIONAL FAILURE/WRONG OUTPUT | SHORT | STUCK BIT (Cracked Die) | SOLDER DEFECTS (REFLOW + INSUFFICIENT SOLD ER + COLD JOINT + BRIDGE + WETTING) | FAILURE NOT REPRODUCIBLE OR UNKNOWN (2) | PARAMETER DRIFT | OPEN TRACE INSIDE BOARD | WIRE SHORTED | **OVERALL** INCLUDING NO DEFECT FOUND & UNKNOWN | **OVERALL** EXCLUDING NO DEFECT FOUND & UNKNOWN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ho = HASS is equal or better than LESS | 90% | 84% | 82% | | 82% | | 74% | | 74% | 32% | 82% |
| Ho = LESS is equal or better than HASS | | | | 99% | | 96% | | 94% | | 68% | 18% |

Which Process is Best?

- Depends on ypour "Corporate Culture"
- What defects are slipping through previous process steps

# CONCLUSIONS

VASE process snapshots are most effective where product technologies are mostly evolutionary rather than revolutionary

- Use DDP & HALT process to handle the evolutionary technology pieces
- VASE tool was demonstrated to bean effective tool for process optimization
- Extension of VASE process to other processes (Software Development, ICT, system test, field failures) is straight forward and could result in significant cost savings by increasing scope to beyond just optimizing ESS Steps
  - Utilize existing SPC data
  - Provide guideance for V&V

# DEFECT DETECTION AND PREVENTION (DDP) IMPLEMENTATION*

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* From a JPL presentation originally presented by Steve Cornford on Risk Management

# INTRODUCTION

## • ACHIEVING THE FBC PARADIGM:

FASTER AND CHEAPER CAN BE EDICTED, BUT HOW TO GET BETTER? BE SMARTER. DO IT BETTER OR DO IT DIFFERENTLY.

- CONSIDER RISK AS A RESOURCE
- CONSIDER ALL “ASSURANCE” ACTIVITIES ON EQUAL FOOTING (COUNT EVERYTHING WHICH HELPS ACHIEVE SUCCESS)
  - THINK ABOUT THE “VALUE-ADDED” OF EACH ACTIVITY
- UTILIZE METHODOLOGY TO MANAGE “RISK AS A RESOURCE”, FILL HOLES AND REMOVE REDUNDANT ACTIVITIES
  - IMPLEMENTED AS PART OF DESIGN PROCESS
  - FOCUS PROJECT EFFORTS ON MEETING REQUIREMENTS
  - UTILIZES LATEST FINDINGS, DATA AND HELPS FOCUS RESEARCH EFFORTS
  - REFINED AS PROJECT MATURES, AS NECESSARY
  - SERVES AS A “KNOWLEDGE BASE” FOR SUBSEQUENT PROJECTS

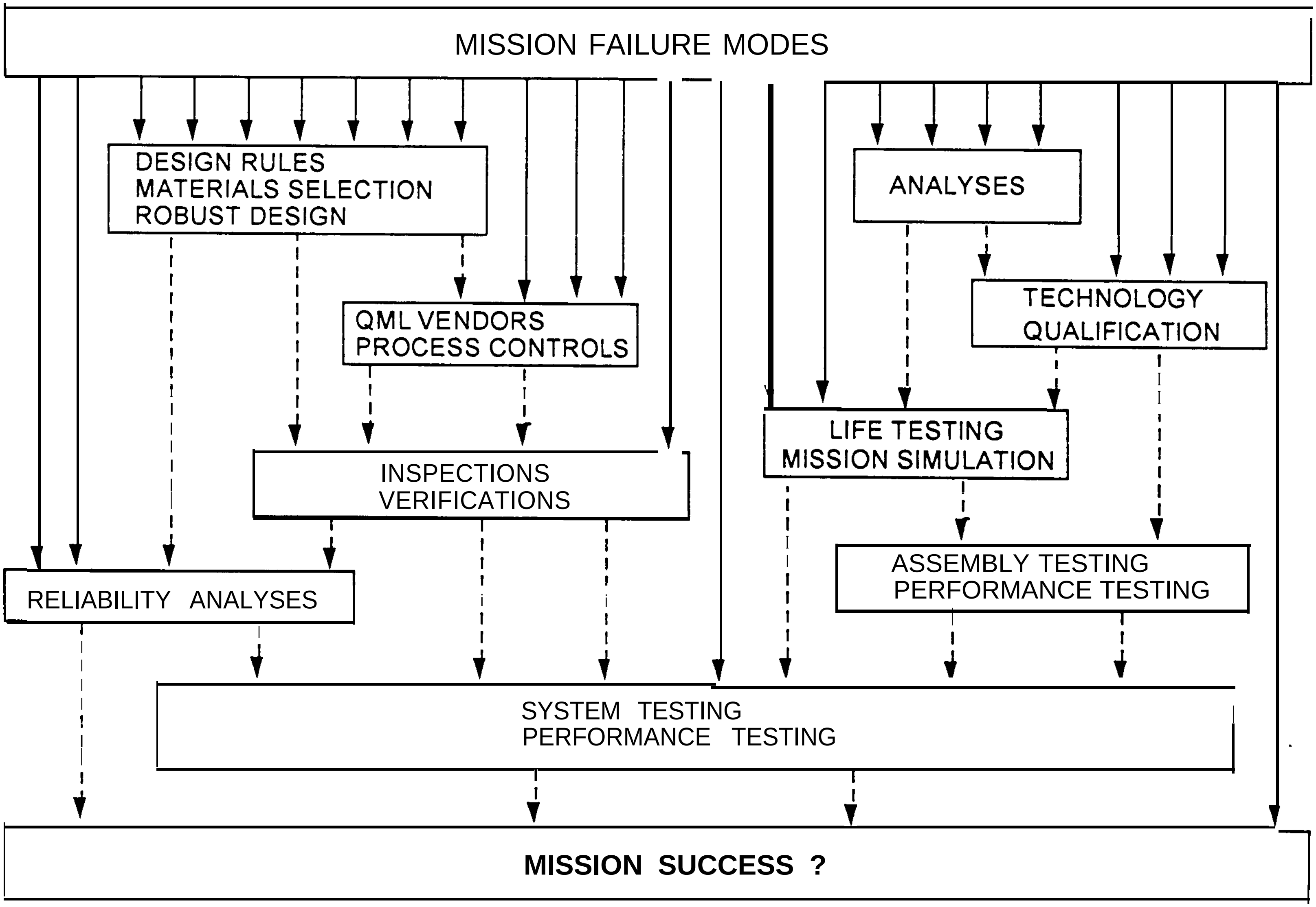
# DEFINITIONS

- PACTS - Are everything that could be done

  (toolbox of prevention/detection options)

  - Preventions (Redundancy, Design Rules, Materials Selection, Software Architecture, etc.)
  - Analyses (Reliability (Fault Tree Analyss, Failure Mode and Effects Criticality Analysis (FMECA), Worst Case Analysis), Fatigue, Structural, Performance, Electrical SPICE models, etc.)
  - process Controls (Inspections, Materials purity, QML vendors, Documentation, etc.)
  - Tests (Environmental, Life, Simulations, Performance, etc.)
- FAILURE MODES(FMs)/DEFECTS
  - "Hard" - Cracks, Explosions, Open Circuits, etc.
  - "SoEt" - Resets, Performance Degradations, etc.
  - I am using the word failure in its broadest sense: Failure to meet goals/requirements

# RAINFALL CHART



MISSION FAILURE MODES

DESIGN RULES
MATERIALS SELECTION
ROBUST DESIGN

ANALYSES

TECHNOLOGY
QUALIFICATION

QML VENDORS
PROCESS CONTROLS

LIFE TESTING
MISSION SIMULATION

INSPECTIONS
VERIFICATIONS

ASSEMBLY TESTING
PERFORMANCE TESTING

RELIABILITY ANALYSES

SYSTEM TESTING
PERFORMANCE TESTING

**MISSION SUCCESS ?**

Notes: 1) Each box is a collection of PACTS

**2) Dotted lines represent "escapes" - Undetected/unprevented failure modes**

**3) Illustrative diagram only - nothing is "to scale"**

M Gibbel- 4
EMSC 5/4/97

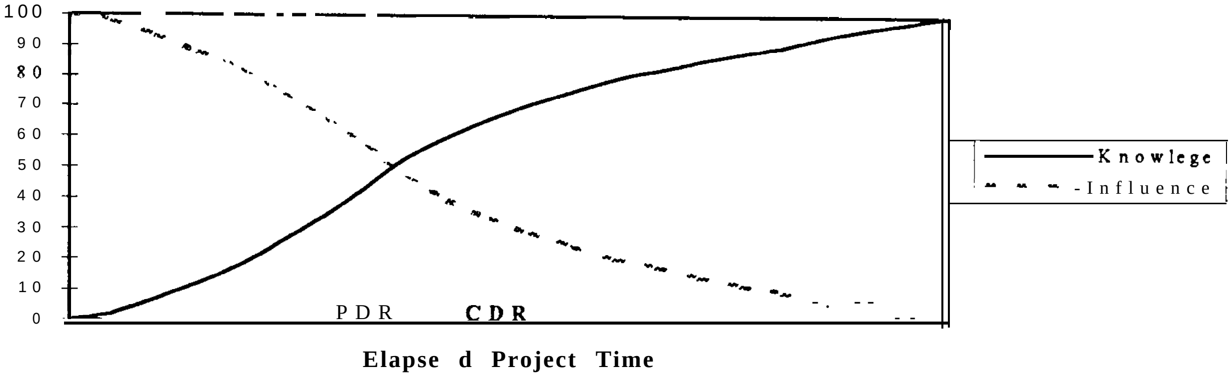
# DDP UTILIZES ACEQ "ENGINE"

## ACEQ = ACCURATE, COST EFFECTIVE QUALIFICATION

Developed by Steve Cornford and Phillip Barela

- REQUIREMENTS MATRIX
  - WEIGHT FMs AGAINST REQUIREMENTS
    - REQUIREMENTS WEIGHTED PER PROJECT
    - SUMMATION YIELDS IMPACT COEFFICIENTS
    - IDENTIFIES "DRIVERS" (FMs AND REQUIREMENTS)
- EFFECTIVENESS MATRIX
  - WEIGHT PACTS AGAINST FMs
    - SUMMATION YIELDS EFFECTIVENESS COEFFICIENTS
    - IDENTIFIES HOLES AND UNKNOWNS
  - LOOK TO "ROOT CAUSE" OR FAILURE PHYSICS
- WEIGHTED SUM
  - PROVIDES RELATIVE EFFECTIVENESS
  - "MIX AND MATCH" PACTs AND ASSOCIATED COSTS
  - OPTIMIZATION PROBLEM WITH COST AND SCHEDULE CONSTRAINTS

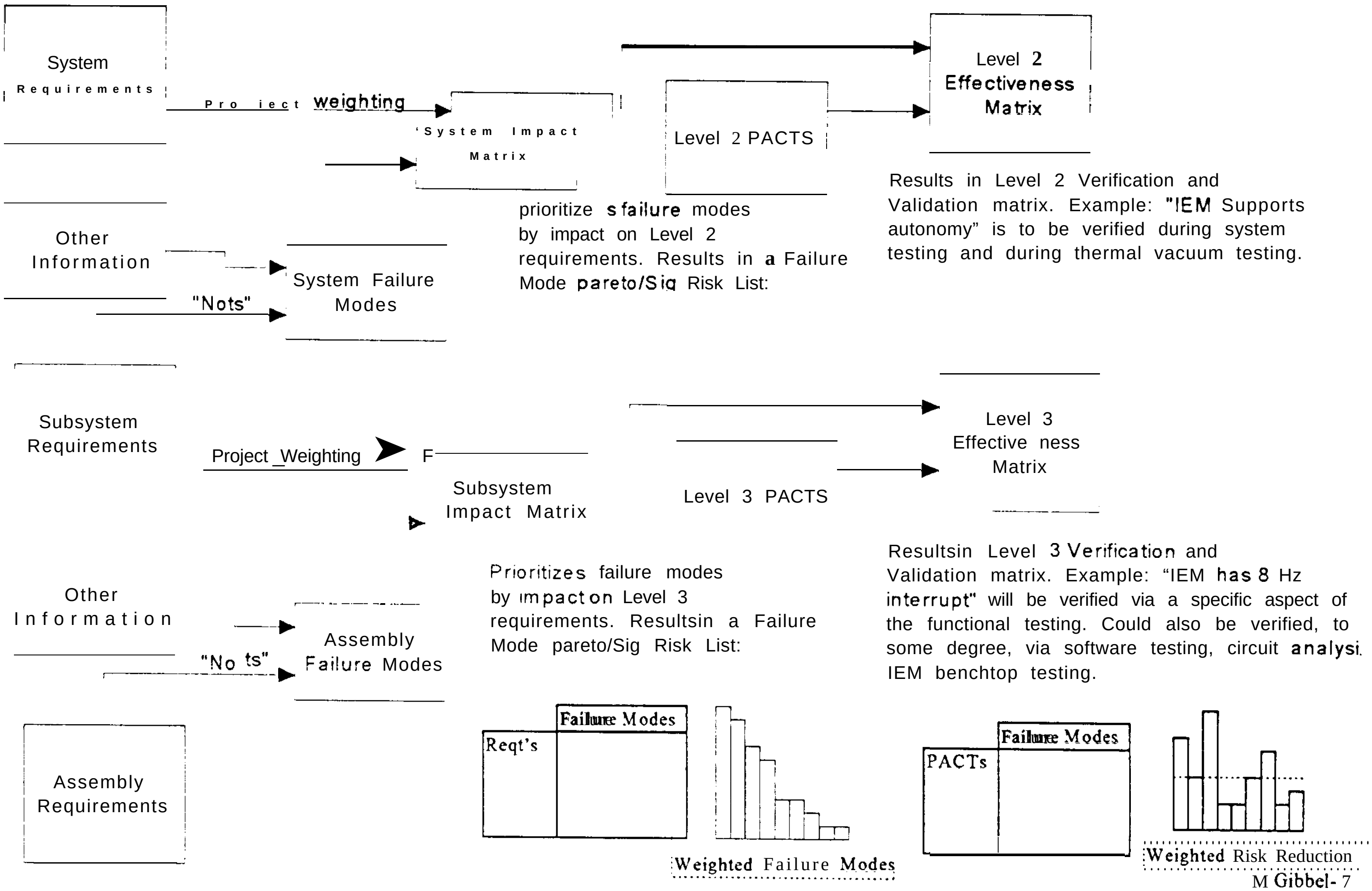
# KNOWLEDGE VS INFLUENCE



- IN OUR "ONESY" ENVIRONMENT (COMMERCIAL INDUSTRY CALL US "ULTRA-LOW VOLUME" ) THE ABILITY TO USE DETAILED KNOWLEDGE (TECHNOLOGY, RISK ELEMENTS, ETC.) IS CONSTRAINED
  - NEED TO "PHASE-LOCK" WITH PROJECT DEVELOPMENT
  - USE ITERATIVE PROCESS, REFINED VIA KNOWLEDGE AND DECISIONS IN PROJECT LIFE CYCLE
- RELATED LESSONS LEARNED (LL):
  - BUILD PROTOTYPES/EM's TO GET EARLY INFORMATION
  - GET INTO TEST AS EARLY AS POSSIBLE, LONG ENOUGH TEST SCHEDULE TO BE ABLE TO USE ANSWERS TO TAILOR/TARGET SUBSEQUENT TESTING
  - PERFORM SEPARATE TECHNOLOGY QUALIFICATION

# DDP ON DS 1 PROCESS FLOW

## Process repeats to lower levels of assembly/requirements
## “Nets” refers to not meeting lower level requirements as a failure mode



prioritizes failure modes by impact on Level 2 requirements. Results in a Failure Mode pareto/Sig Risk List:

Results in Level 2 Verification and Validation matrix. Example: "IEM Supports autonomy” is to be verified during system testing and during thermal vacuum testing.

Prioritizes failure modes by impact on Level 3 requirements. Results in a Failure Mode pareto/Sig Risk List:

Results in Level 3 Verification and Validation matrix. Example: “IEM has 8 Hz interrupt" will be verified via a specific aspect of the functional testing. Could also be verified, to some degree, via software testing, circuit analysi. IEM benchtop testing.

# Partial Information from DS 1

## Partial List, Not Project Reviewed

| | | *Navigation Failure* | *Power Failure* | *MICAS (camera) Failure* | *Other Failure Modes* |
|---|---|---|---|---|---|
| Weight | **Requirements** | | | | |
| 0.5 | Deliver to Cape | 3 | 3 | 3 | |
| 0.3 | Demo New Technology | 3 | 3 | 3 | |
| 0.2 | Asteroid/Comet Science | 9 | 9 | 9 | |
| | **Liklihood** | **1** | **1** | **1** | |
| | **Requirement Impact** | **4.2** | **4.2** | **4.2** | |
| | | | | | |
| | **PACTs** | | | | |
| | Mission Assurance Plan | 3 | 3 | 3 | |
| | Design Approach | 3 | 3 | 3 | |
| | Reserve Mgmt' | 3 | 3 | 3 | |
| | **Total Effectiveness** | **9** | **9** | **9** | |
| | **Risk Balance** | **2.1** | **2.1** | **2.1** | |

| | | *IEM not support autonomy* | *Autonomy fails function* | *HV converter degrades* | *HV converter fails to distribute* |
|---|---|---|---|---|---|
| Weight | **Sub-requirements** | | | | |
| 0.06 | Optical Star Imaging | 9 | 9 | 1 | 9 |
| 0.1 | Ion Engine Operation | 9 | 9 | 1 | 9 |
| 0.04 | Ion Engine Control | 9 | 9 | 1 | 9 |
| 0.06 | Autonomy | 9 | 9 | 3 | 9 |
| | **Liklihood** | **0.4** | **0.7** | **0.6** | **0.9** |
| | **Requirement Impact** | **1.30** | **2.27** | **0.22** | **2.92** |
| | | | | | |
| | **PACTs** | | | | |
| | Functional Test | 9 | 3 | 1 | 3 |
| | S/W Test Bed | 3 | 9 | 0 | 0 |
| | Technology Qualification | 1 | 1 | 3 | 3 |
| | Converter Inspection | 0 | 0 | 1 | 3 |
| | **Total Effectiveness** | **13** | **13** | **5** | **9** |
| | **Risk Balance** | **10.0** | **5.7** | **23.1** | **3.1** |

- Note that at higher levels it's tough to develop discriminators
- As move to lower levels and assign likelihoods, start to see separation of risk values
- At any given time, some subsystems may have more (or less) information available - Use all you got!

# DDP IN THE RISK MANAGEMENT PROCESS

- RISK PLANNING
  - IMPLEMENTS SYSTEMATIC REQUIREMENT DEVELOPMENT PROCESS
  - PROCESS FOR DOCUMENTING RISK AND RISK MITIGATION (RATIONALE AND DECISIONS)
  - TOOL FOR IMPLEMENTING THE ALLOCATION PROCESS (RESOURCES, RESERVES, ETC)
  - OBVIOUS LESSON LEARNED TO DATE: THE EARLIER THE TOOL IS IMPLEMENTED> THE MORE USEFUL/COST BENEFICIAL IT IS
- RISK IDENTIFICATION AND ASSESSMENT
  - AS PROJECT REQUIREMENTS, AND PACT SELECTIONS EVOLVE, RISKS ARE IDENTIFIED IN MORE DETAIL
  - RISKS ARE IDENTIFIED AS EARLY AS POSSIBLE
  - IMPACT OF VARIOUS RISK ELEMENTS CORRELATED TO SPECIFIC PROJECT IMPLEMENTATION DECISION'S
  - WEIGHTED BASED ON PROJECT/MISSION PRIORITIES
  - PROVIDES QUANTITATIVE EVALUATION OF RELATIVE RISK
  - OBVIOUS LESSON LEARNED TO DATE: VALUE DEPENDS ON INFORMATION AVAILABLE
- RISK DECIS1ON MAKING
  - ENABLES PROJECT MANAGERS/PERSONNEL TO MAKE INFORMED DECISIONS
  - DECISION RATIONALE CAPTURED AS PART OF PROCESS
    - USES ALL AVAILABLE INFORMATION
    - IDENTIFIES "TALL POLES"
    - IDENTIFIES "BANG FOR BUCK" OPPORTUNITIES
- RISK TRACKING (ITERATION WITH PROJECT EVOLUTION/CLOSING THE LOOP)
  - CAN EASILY SEE IMPACTS OF DESIGN TRADEOFFS AND CHANGES, CONSTRAINTS
  - EARLIER DECISION AND RATIONALE NOT LOST, NOR NEED TO BE "REMEMBERED'

# DDP IMPLEMENTATION NEEDS

- REQUIRES "CRITICAL MASS" OF EXPERTISE AND SKILLS
  - CONCURRENT ENGINEERING
  - PROJECT SUPPORT IS IMPERATIVE
- REQUIRES EFFECTIVENESS INFORMATION
  - INFORMATION SOURCES, METRICS, TEAMING
- ITERATIVE PROCESS
  - START WITH GENERIC FMs/PACTs
  - REFINED AS PROJECT MATURES: GENERIC BECOMES SPECIFIC
  - KNOWLEDGE BASE UPDATED AND APPLIED TO NEXT PROJECT

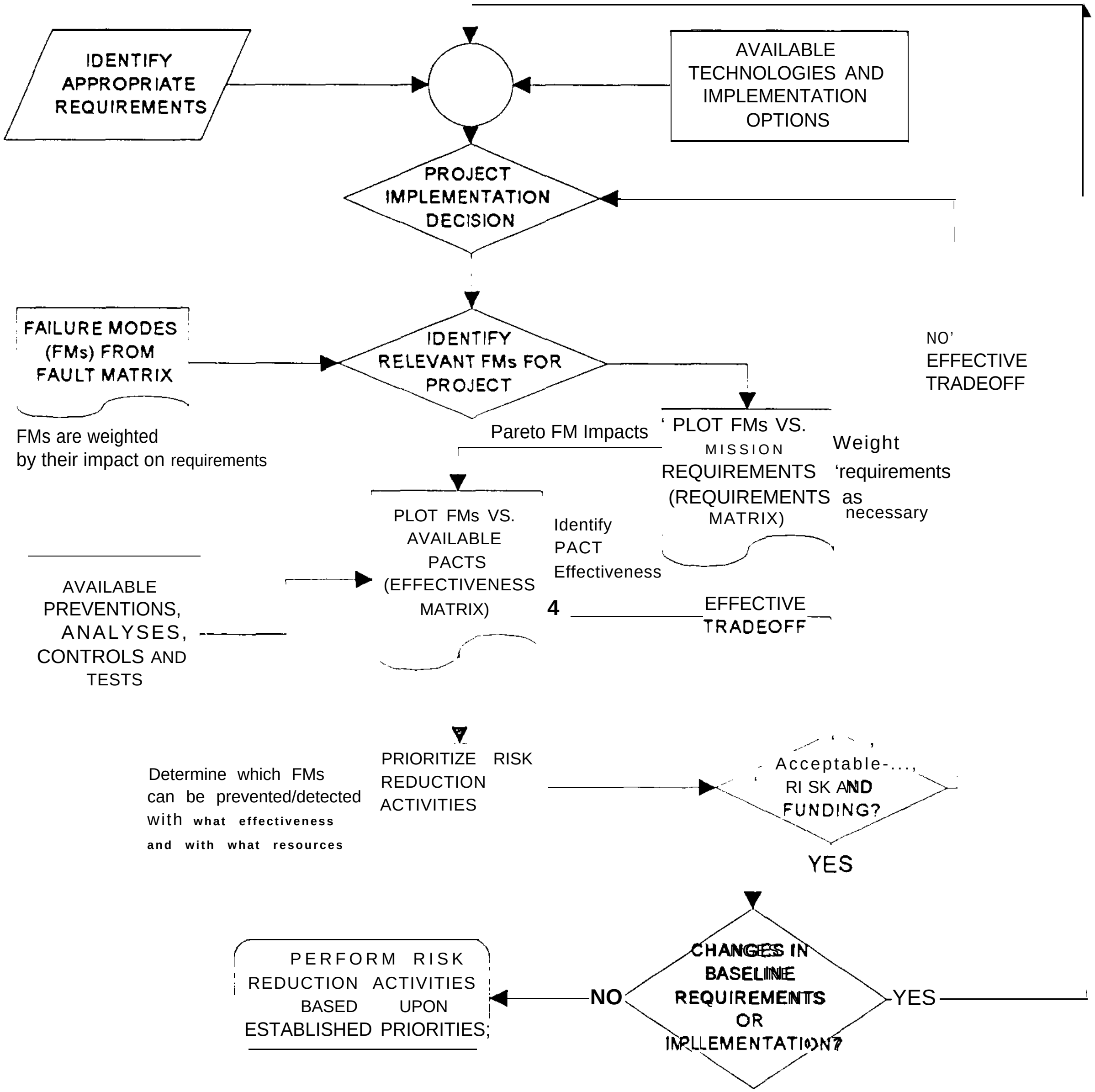
# DDP SUMMARY

- ADDITONAL RESOURCE FOR NEW PROJECT PROPOSALS, RISK MANAGMENT PLANNING
- UTILIZES A PHYSICS OF FAILURE OR "ROOT CAUSE" APPROACH
  - TRANSLATABLE FROM HARDWARE TO HARDWARE
  - CORRELATES TO OBSERVED ANOMALIES
  - REDUCES TO A SMALLER "CORE" SET OF FMs
- ISA TOOL BOX FOR PACTS
  - RELATIVE EFFECTIVENESS VERSUS FMs
  - COST VERSUS PACT PARAMETERS
- ISA TOOL BOX FOR FMs
  - ANOMALY DATABASE
  - CORRELATED WITH HARDWARE, LEVEL OF ASSY, ETC.
- CONCURRENT, TAILORED APPROACH
  - REQUIREMENTS, FMs AND PACTs ARE DEVELOPED AND TAILORED CONCURRENTLY WITH THE PROJECT LIFE CYCLE
- PROVIDES MEANS OF CAPTURING CORPORATE KNOWLEDGE IN TIMES OF "SKUNK WORKS"
- DDP IS A SYSTEM LEVEL APPROACH TO RISK MANAGEMENT, RISK PLANNING, RISK IDENTIFICATION AND ASSESSMENT, RISK DECISIONS, AND RISK TRACKING

b

# BACK-UP VIEWGRAPHS

# DDP FLOW CHART



IDENTIFY APPROPRIATE REQUIREMENTS

AVAILABLE TECHNOLOGIES AND IMPLEMENTATION OPTIONS

PROJECT IMPLEMENTATION DECISION

FAILURE MODES (FMs) FROM FAULT MATRIX

FMs are weighted
by their impact on requirements

IDENTIFY RELEVANT FMs FOR PROJECT

NO' EFFECTIVE TRADEOFF

Pareto FM Impacts

PLOT FMs VS. MISSION REQUIREMENTS (REQUIREMENTS MATRIX)

Weight 'requirements as necessary

PLOT FMs VS. AVAILABLE PACTS (EFFECTIVENESS MATRIX)

Identify PACT Effectiveness

AVAILABLE PREVENTIONS, ANALYSES, CONTROLS AND TESTS

4

EFFECTIVE TRADEOFF

PRIORITIZE RISK REDUCTION ACTIVITIES

Determine which FMs can be prevented/detected with what effectiveness and with what resources

Acceptable-...., RISK AND FUNDING?

YES

CHANGES IN BASELINE REQUIREMENTS OR IMPLEMENTATION?

NO

YES

PERFORM RISK REDUCTION ACTIVITIES BASED UPON ESTABLISHED PRIORITIES;

# KITE EXAMPLE

| Weight | | Lightning and rain | String breaks | String stretches > 10% | String weight exceeds 1 kg | Totals | Cost ( k$) |
|---|---|---|---|---|---|---|---|
| | ***REQUIREMENTS*** | | | | | | |
| **9** | Human holds kite and lives | 9 | | | | **9** | |
| **9** | Kite + string height requirement | | 9 | | 3 | **12** | |
| **1** | Maximum wind speed 100 mph | | 9 | 1 | | **10** | |
| **3** | Maximum wind speed 10 mph | | 1 | | | **1** | |
| | *Likelihood* | 0.3 | 0.1 | 0.3 | 0.3 | | |
| | **Totals** | **24.3** | **9.3** | **0.3** | **8.1** | | |
| | | | | | | | |
| | ***PACTs*** | | | | | | |
| P1 | Choose "normal string" | 1 | 3 | 3 | 9 | **16** | 1 |
| P2 | Choose "super string" | 3 | 9 | 9 | 3 | **24** | 10 |
| P3 | Human not grounded | 9 | | | | **9** | 1 |
| P4 | Avoid flying if looks like rain | 9 | | | | **9** | 1 |
| cl | Examine length of string | | 3 | 1 | | **4** | 6 |
| A1 | String strength estimation | | 3 | 3 | | **6** | 3 |
| A2 | String weight estimation | | | | 9 | **9** | 2 |
| T1 | Weigh string | | | | 9 | **9** | 1 |
| T2 | String "copy" pull test - qual | | 9 | 9 | | **18** | 6 |
| T3 | String "copy" pull test - accep | | 3 | 3 | | **6** | 6 |
| T4 | String "similar" pull test - qual | | 3 | 3 | | **6** | 1 |
| T5 | String "similar" pull test - accep | | 1 | 1 | | **2** | 1 |
| | **Effectiveness Totals (Opt 1)** | **21.0** | 18.0 | **18.0** | **12.0** | | **20** |
| | **Effectiveness Totals (Opt 2)** | **21.0** | **21.0** | **21.0** | **12.0** | | **25** |
| | **Effectiveness Totals (Opt 3)** | 1 | **12.0** | **12.0** | **9.0** | | **9’4** |
| | **Effectiveness Totals (Opt 4)** | **19.0** | 6.0 | 60 | 9.0 | | |
| | **Risk Balance (Opt 1)** | 0.9 | **1.9** | 60.0 | | | |
| | **Risk Balance (Opt 2)** | **0.9** | **2.3** | **70.0** | **1.5** | | |
| | **Risk Balance (Opt 3)** | 0.8 | 1.3 | 40.0 | 1.1 | | |
| | **Risk Balance (Opt 4)** | **0.8** | **0.6** | **20.0** | **1.1** | | |

| ***Req Impact*** | ***PACT Effectiveness*** |
|---|---|
| *9= significant loss* | *always prevents/detects* |
| *3= moderate loss* | *a few scenarios it may not* |
| *1= minimal loss* | *a few scenarios it may* |
| *0= no impact* | *will not detect/prevent* |

options

- **Opt. 1: P2+P3+P4+A2+T2**
  - **20 KS**
  - **21,18,18,12 (Effec** w/o **weight)**
  - **0.9, 1.9,60, 1.5 (Risk Reduction Balance)**
- Opt **2: P2+P3+P4+T1+T2+ T3**
  - **25 K$**
  - **21,21,21, 12 (EtTee w/o** weight)
  - 0.9,2.3,70, 1.5 (Risk Reduction Balance)
- Opt 3: P1+P3+P4+T2
  - 9 K$
  - 19, 12, 12,9 (Effec w/o weight)
  - 0.8, 1.3,40, 1.1 (Risk Reduction Balance)
- Opt 4: P1+P3+P4+T4
  - 4 K$
  - 19,6,6,9 (Effec w/o weight)
  - 0.8,0.6,20, 1.1 (Risk Reduction Balance)
- Judgement call which is best! Depends on resources and risk posture
  - When include likelihood there is a feedback loop after selection of some PACTS (i.e. super string never breaks means liklihood gets very small) . This means that the “tall pole” failure mode ranking may change.
  - Similarly, if new requirement is imposed (e.g. don’t fly if raining)

# DDP IMPLEMENTATION STATUS

- ACEQ ORIGINALLY DEVELOPED FOR QUALIFICATION OF ADVANCED TECHNOLOGIES
  - NASA, DoD, INDUSTRY QUALIFYING MCMs IN RELTECH PROGRAM
  - USUAL STANDARDS HAVE UNKNOWN RELEVANCE
  - GO TO ROOT CAUSE OR PHYSICS OF FAILURE
- DDP METHODOLOGY
  - RESOURCES OF ONGOING R&D/STUDY EFFORTS FOCUSED ON PROVIDING USEFUL DATA
  - ESTABLISHING A SOFTWARE/DATABASE TOOL (WILL LINK WITH PDC)
  - INFRASTRUCTURE FUNDS TO ESTABLISH BETTER COST NUMBERS
  - BEING APPLIED TO:
    - NMP DS2: NEW MISSION ASSURANCE APPROACH
    - QuIC: QUALIFICATION / RISK REDUCTION OF BRASSBOARD INTERFEROMETRY COMPONENTS
    - PLUTO EXPRESS: IN PROCESS FOR FLIGHT COMPUTER
- **CONTACT STEVE CORNFORD (818) 354-1701) FOR MORE INFORMATION**

# End of Life Simulation

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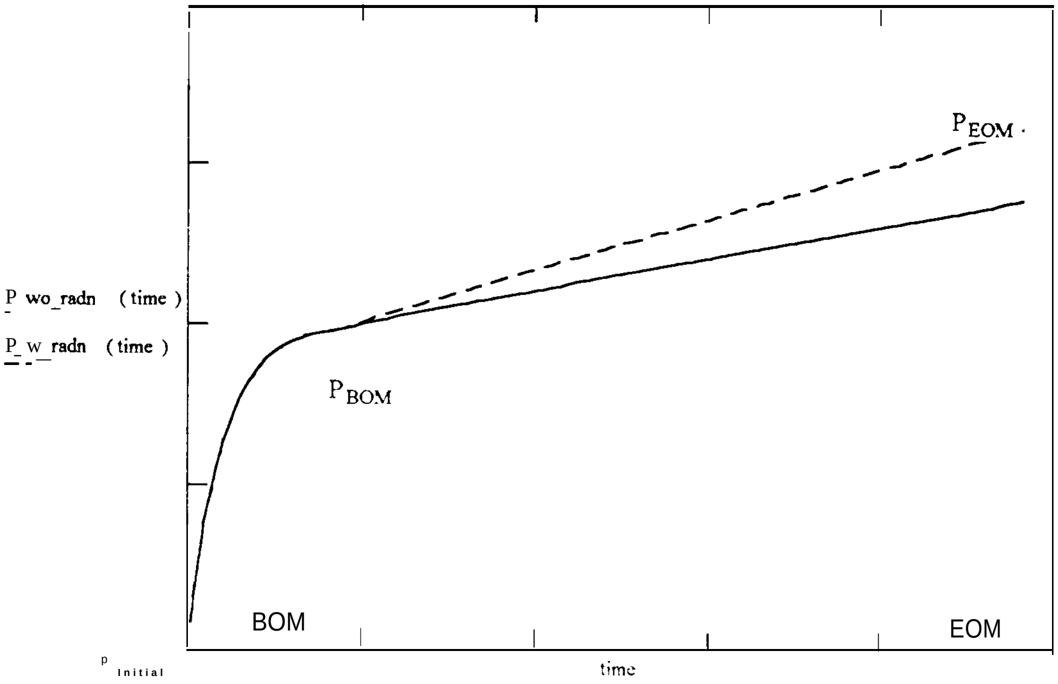
# EOL Simulation Objectives

- Develop and validate an approach to combining testing and analysis which:
  - Demonstrates functional performance throughout the mission life cycle at the beginning of the circuits life
  - Results in an Enhanced Stress Screen
- Analyze VTFMT effectiveness versus circuit block type and mission characteristics
- Develop EOL Simulation Guidelines

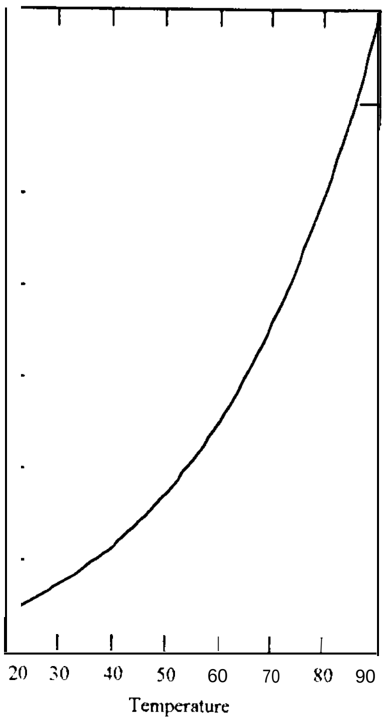
# Driving Force & Benefits

- Quantitative Verification of Design Performance and Robustness
- More Reliable, Faster, Better and Cheaper
  - Labor Intensive Analysis Traded for Relatively Benign Costs of Testing
- Concurrent Process
  - Ties the Design and Verification process together
- Can be used to Enhanced Product Screen

# EOL Electrical Performance Verification



Electrical Parameter Variation vs. Mission Timeline



Parameter Value vs. Temperature

- The “mission” is equivalent to the “desired field life”
- The Initial Parameter value may move due to initial part “bum-in” variations, but the biggest effect is typically the initial part parameter tolerance
- Radiation will not be as critical for terrestrial applications

# Electrical Parameter Variation

## Required Delta T's For Worst Case EOM Simulation

**Delta T's <30**

all DIODES

$I_{cc}$ of DIGITAL IC's

A/D CONVERTERS

VOLTAGE REGULATORS

12 of 16 TRANSISTOR TYPES

1 of 6 FET TYPES (linear)

4 of 6 FET TYPES (switch)

some RESISTORS

some VOLTAGE REGULATORS

**Delta T's >50**

some Capacitors

$T_{HL}$ of DIGITAL IC's

most OPAMP'S

D/A CONVERTERS

1 of 16 TRANSISTOR TYPES

2 of 6 FET TYPES (linear)

REFERENCE ZENER DIODES

some RESISTORS

**USE Voltage and Clock Frequency Margining where Delta T's >50C**

All of the Worst Case Analysis For This Database Assumed 17 Year Life and 100 krad @~100 rad/s Which Could Yield Extremely Pessimistic Results, Depending on Individual Device Annealing Rates. Thus , All Delta T's Required For EOM Simulation Are Upper Bounds.

# Current Funded Products of EOL

- Part Parameter Variation Databook (PPVD) (User Interactive)
- Implementation Guidelines
  - Defining Critical Parameters/Paths
  - Key Parameters of Individual Parts (Op Amps, Diodes, etc.)
  - Identification of Means for Stimulating Part Parameters (Initial Value, Aging, Radiation)
- Catalog of Typical Circuits
  - Encompass a Wide Range of "Typical" Circuits Used in NASA and JPL App.
    - Schematics,
    - Characteristic Equations,
    - Critical Parameters of Each Circuit,
    - and the Fundamental Test/Monitoring Points Associated with Each Circuit.

# Phase 1: Establish Feasibility

- **Study Interactions of Voltage and Temperature on Simple, Easily Analyzed Circuits on Perf.**
- **Study the Means by Which VTMT Can be Used to Simulate Life Environments of Radiation, % EOL Degradation and Temperature**
    - **-Use Critical Path/Critical Parameter technique**
    - **-Other Techniques?**
- **Other collaborative efforts (with parts people)**
    - **-Class S vs. Commercial grade parts**
    - **-FPGAs**
    - **-Others?**
- **Establish Link Between Expected Rad Effects and Real Rad Effects on these Test Circuits (Joint w/Parts Radiation RTOP)**
    - **-Establish Whether Superposition is a Reality**
    - **-Study Fast & Slow Dose Rate and Annealing Time Effects**

# Phase 2: EOL Simulation Study

- **Will Focus on More Advanced Circuits with Mixed Technologies Which Will Stretch Our Ability To Simulate End Of Life Of These Test Vehicles.**
- **Will Look at Galileo Telemetry Data on Certain System Circuits (Start in FY97)**
  - **-Compare WCA of these Circuits with Telemetry Data**
  - **- Using Similar (if not exact copies of these circuits) test what VTF Combinations will bring to Various States of the Galileo Mission.**
- **From The Results of The FY97 and FY98 Validation Results, End of Life Simulation Guidelines Will Be Produced. These Guidelines Will Include The Following:**
  1. **Steps For Establishing VTFMT For The Circuit Under Test**
     - **Either Critical Path/Critical Parameter Technique**
     - **Inherited/Similar Hardware Technique**
     - **Other Techniques?**
  2. **How and Whereto Find the Critical Parameters to be Used ‘**