Reliability Engineering Challenges in Aerospace Industry

Hamilton Sundstrand
A United Technologies Company

Dr. Vladimir Crk
HS Fellow
Hamilton Sundstrand
a United Technologies Company

Agenda

- My Short Bio
- Introduction – HS systems (Rockford, IL)
- Design for Reliability
- Reliability Engineering Tools in Design for Reliability Process
- Reliability Engineering Tools Applicability
- Questions

My Short Bio

- Hamilton Sundstrand 02/2006 – Current
  - HS Fellow
- University of Phoenix faculty 07/2002 – Current
  - MBA program: Statistics for managerial decision making, Research and evaluation methodologies
- WebSourced – Internet Marketing 07/2005 – 2/2006
  - Director of Quality Assurance and Market Research
- Honeywell International 08/1996 – 07/2005
  - Engineering Fellow & Senior Manager
- University of Arizona 08/1989 – 08/1996
  - Graduate Student and Research Associate

Electric Systems - Rockford

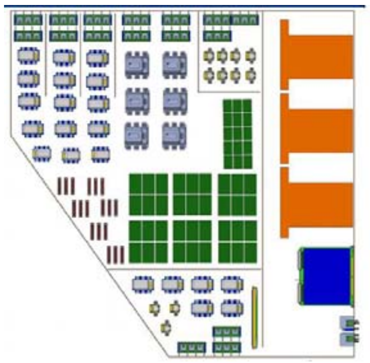
- Main Power Generation Systems
- Emergency Power Generation Systems
- Power Distribution Systems

RAT

Examples of major programs:

- Boeing 787
- Airbus A350
- C919
- Regional Jets: MRJ, CRJ, ERJ, ARJ

POWER DISTRIBUTION



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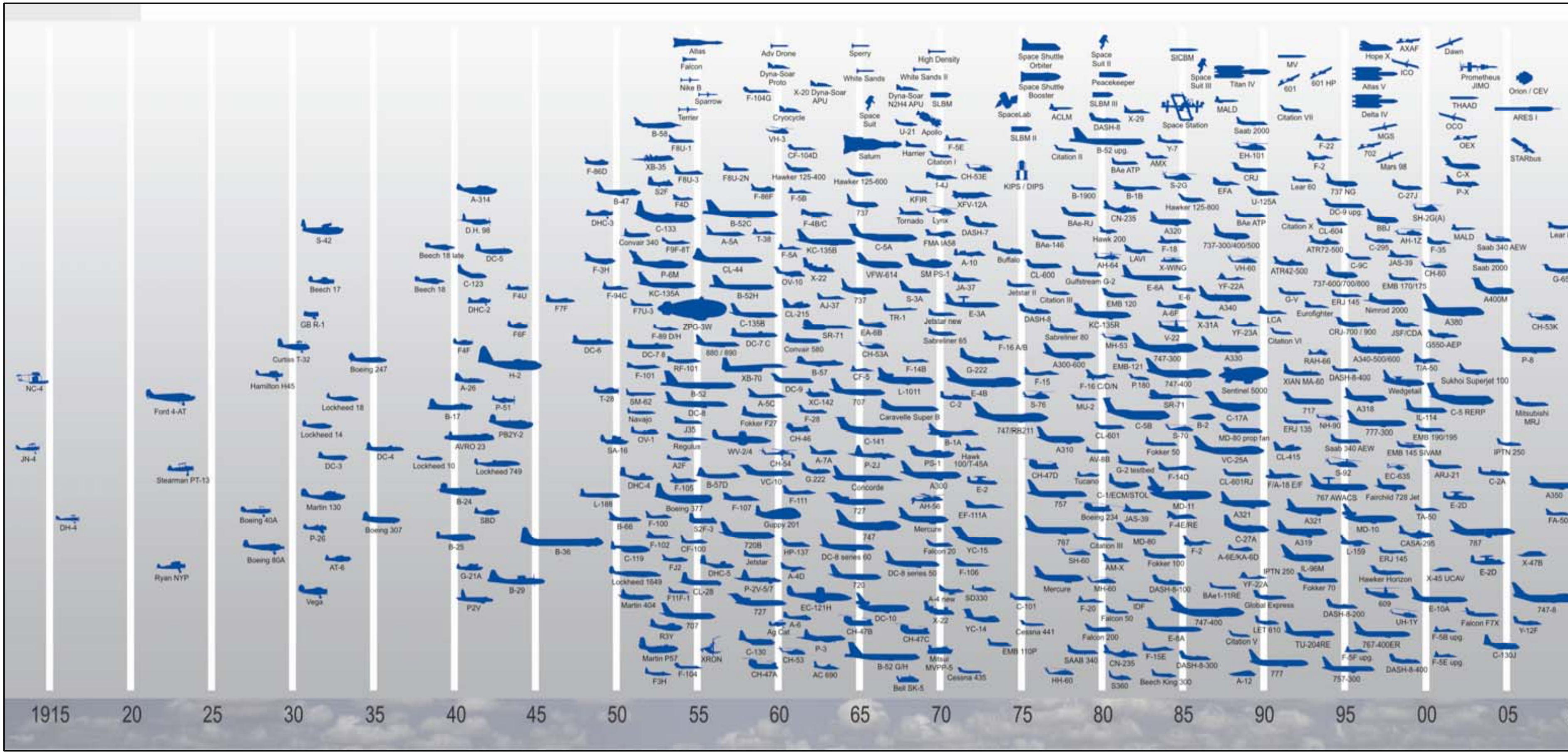
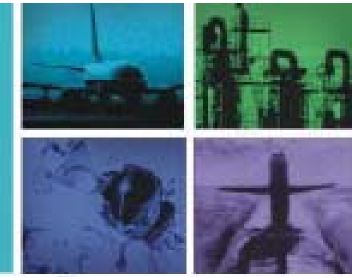
HAMILTON SUNDSTRAND
Aerospace Experience

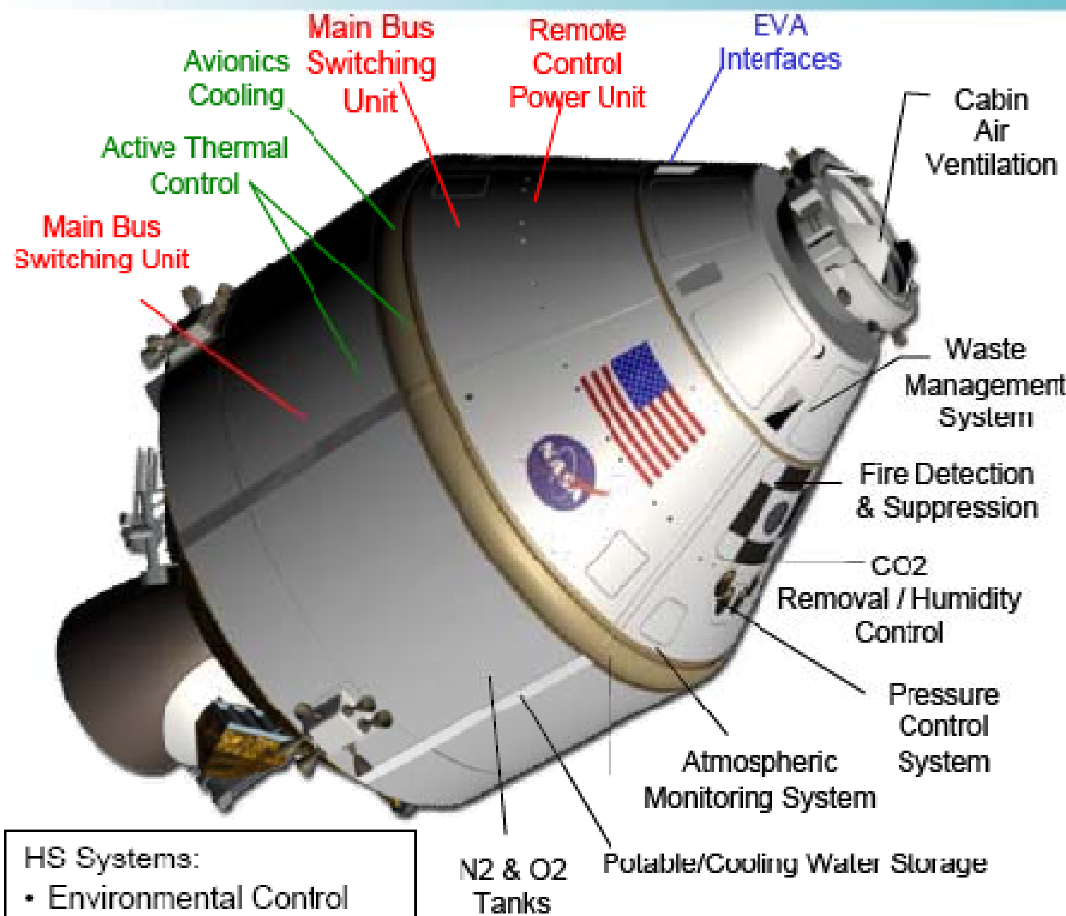


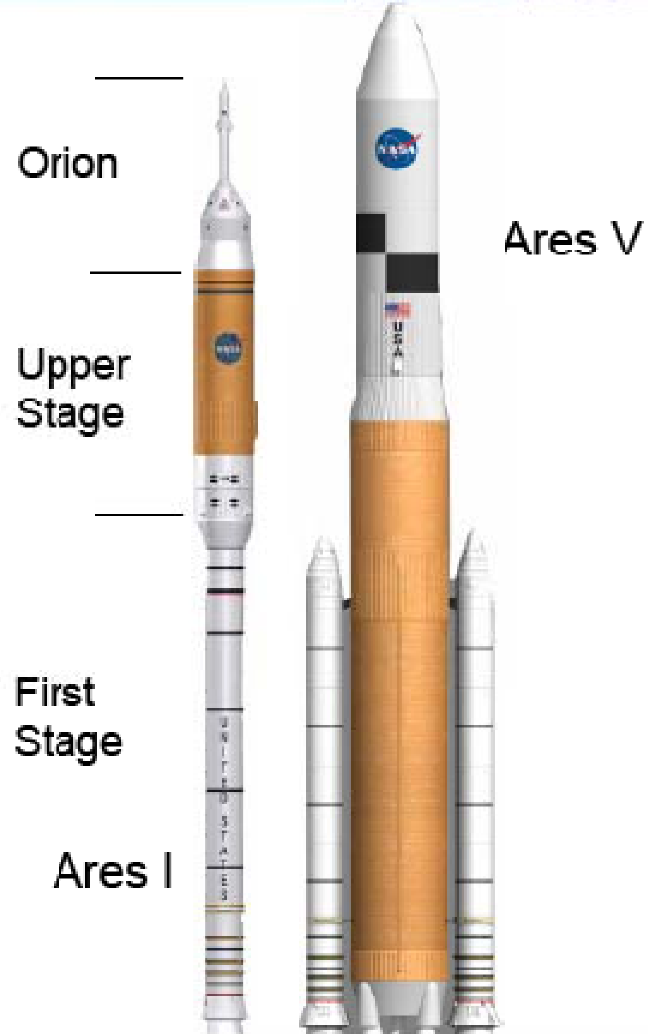
Built on a strong foundation of success, HS is leading the aerospace industry into the future on the momentum of decades of expertise in engineering and manufacturing innovative, high-quality, low-cost aircraft solutions. HS provides content on just about everything that flies and continues to expand its presence.

Space, Land & Sea

Orion







HS Systems:

- Environmental Control & Life Support
- Extra Vehicular Activity (EVA)
- Power Management and Distribution
- Thermal Management

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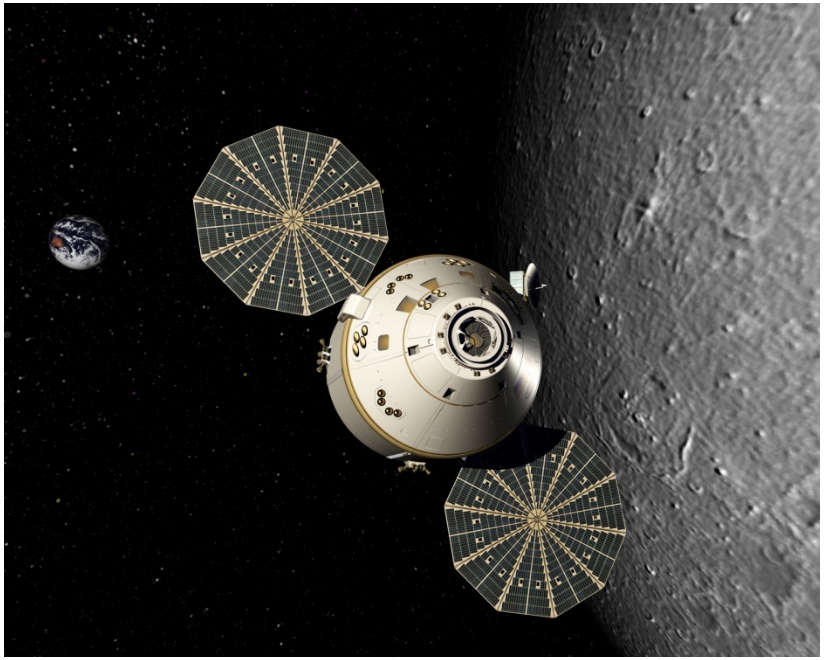
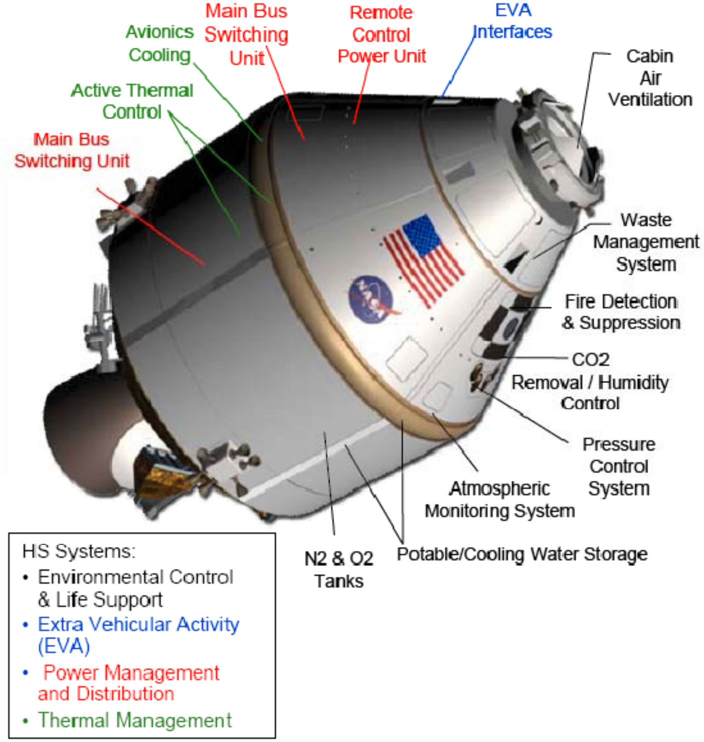
Orion – Next Generation Crew Piloted Spacecraft



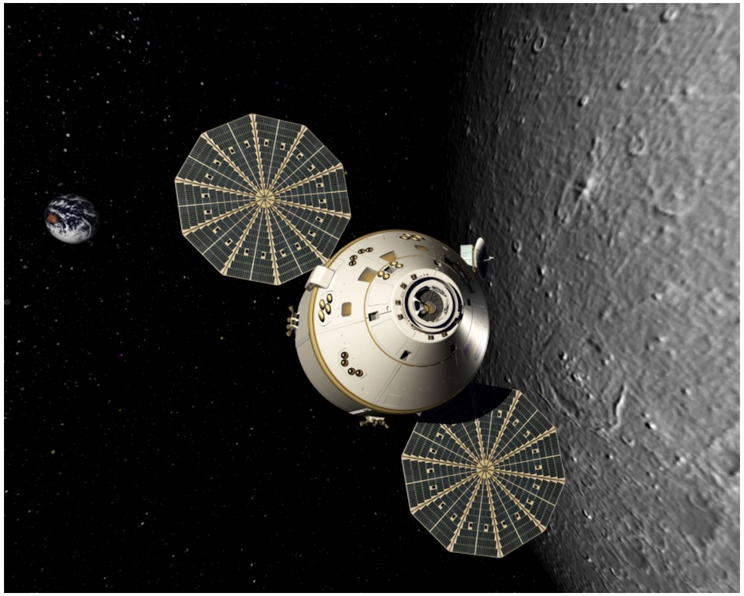


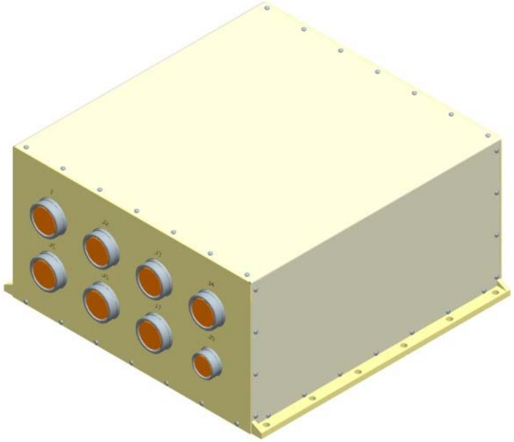
Solar Arrays are used as Primary source of power deployed in the Low Earth Orbit after separation from ARES I

Batteries are used as secondary source of power and to maintain a desired voltage level on the bus.

Electric Power System – Power Generation and Distribution System

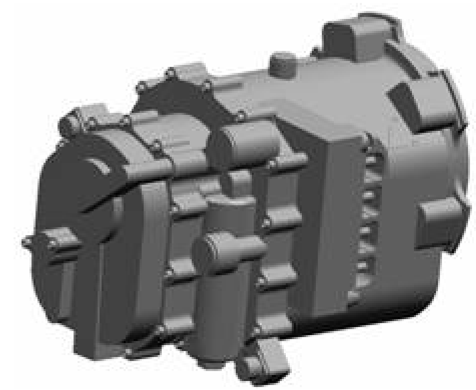
- Power Generation: IDG , VFG
- Power Distribution:
  - distributes electric power from the source to loads
  - manages power distribution:
    - detects system and component faults
    - identifies, isolates and mitigates component faults
- Redundant – multiple fault tolerant systems
  - 2 – 4 power generation channels, with cross-ties to mitigate faults
- High reliability, safety and availability requirements





Reliability Engineering Challenges

- Complexity of systems, missions and mission profiles, environments
- New technologies
- High reliability & safety requirements
- Failure data for components may not be available for given environments
- Reducing cost of development and testing
- Sample size for life testing may be very small
- Tight schedules – no room for error



Why are Reliability and Safety Important ?

- Increased awareness of reliability and safety implications
  - loss of aircraft, loss of crew, loss of mission, loss of revenue
- Customers expect HIGH REL and they demand it
- High reliability saves customers money –

  - high AC availability

  – low downtime

  – low failure frequency
- Lower maintenance cost
  - It brings customers back
- Competitive environment - reliability is a differentiator

What is Design For Reliability?

Design for reliability is a collection of methodologies and best practices performed during design phase intended to minimize the risk that a product will not meet its reliability goals.

- **Physics of Failure (PoF):**

  Physics-of-Failure (POF) is a methodology based on root-cause failure mechanism analysis and the impact of materials, defects, and stresses on product reliability.
- **Advanced statistical tools:**
  - Regression,
  - DoE,
  - Monte Carlo simulation,
  - Accelerated Life Testing, HALT/HASS

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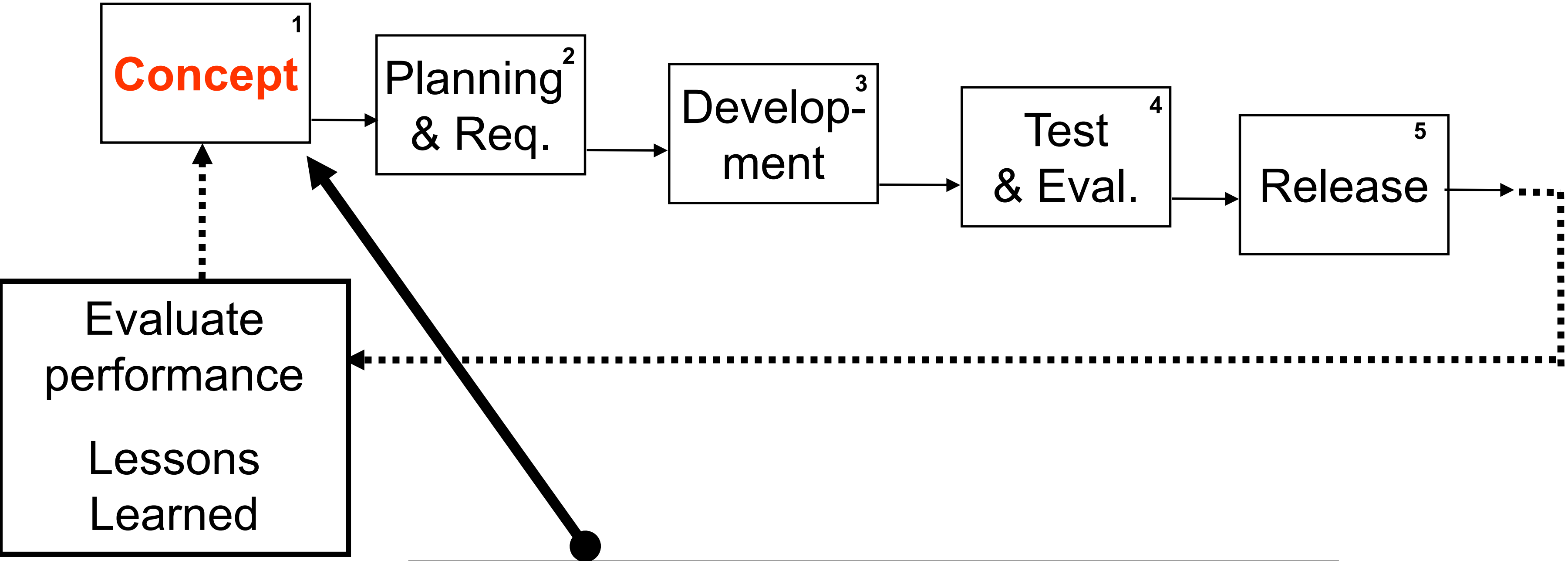
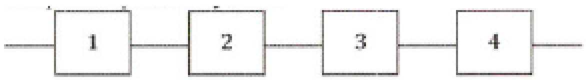
Reliability Tools in Design Process



- System Architecture development – fault tolerance
- QFD (Requirements Flow-down)
- Lessons learned
- Contract MTBF / reliability requirements
- MTBF / MTBUR inputs
- Technology selection
- Use environment
- Risk assessment tools

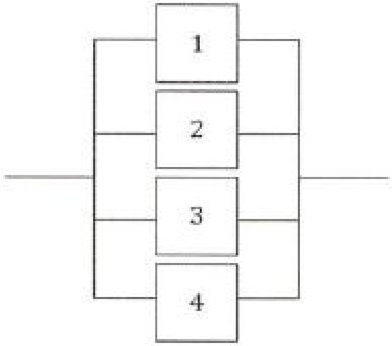
Reliability Tools in Design Process - Concept

- Probabilistic Modeling – Fault Tolerance & System Architecture



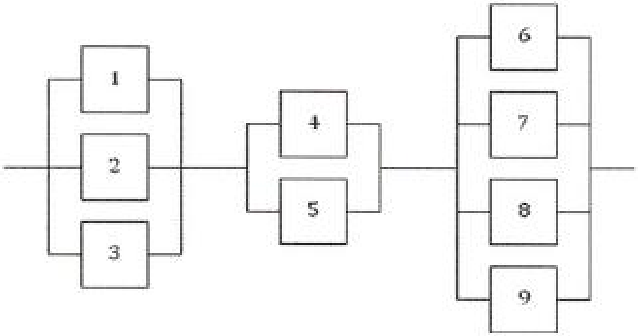
Series system architecture

– Zero fault tolerance



Parallel system architecture

– Desired fault tolerance



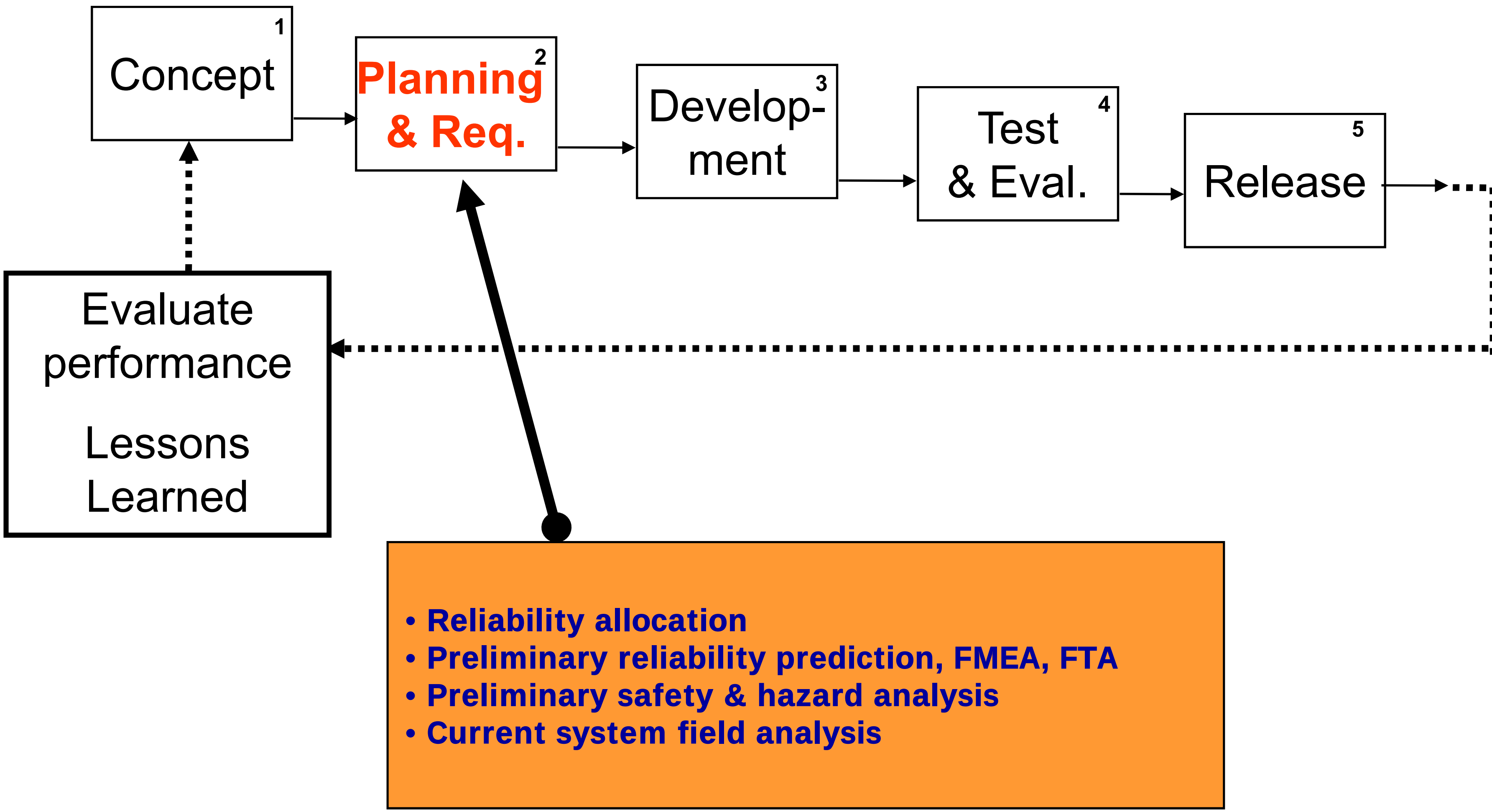
Complex system architecture

- complex system functions with fault tolerance

Architecture design with fault tolerance:

- Provides high system redundancy
- Provides high system reliability
- Provides high system safety
- Provides high system availability

Reliability Tools in Design Process



Reliability Tools in Design Process –

Preliminary design (planning & requirements development)

- System and subsystem reliability goals definition
- Reliability and safety requirements specification
- Reliability requirements allocation to subsystems
- Reliability and safety requirements flow-down
- Reliability and safety requirements validation
- System reliability modeling (RBD)
- Preliminary reliability prediction
- Preliminary FMEA
- Preliminary safety analysis and FTA
- Preliminary maintainability analysis

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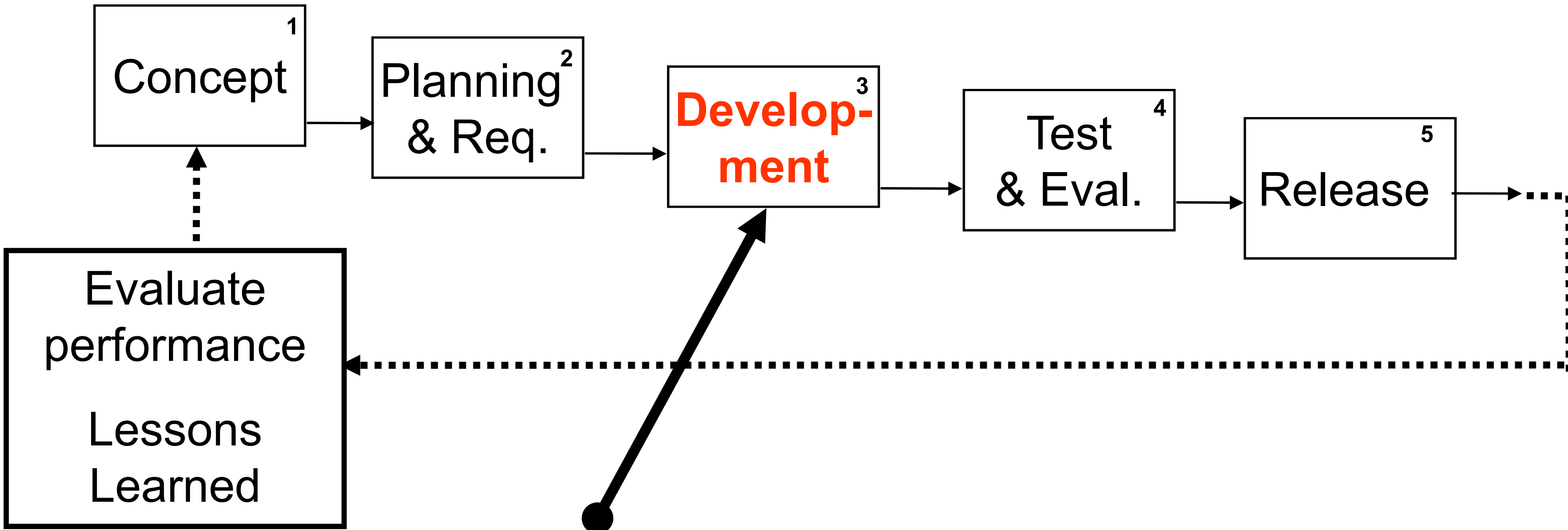
Reliability Tools in Design Process

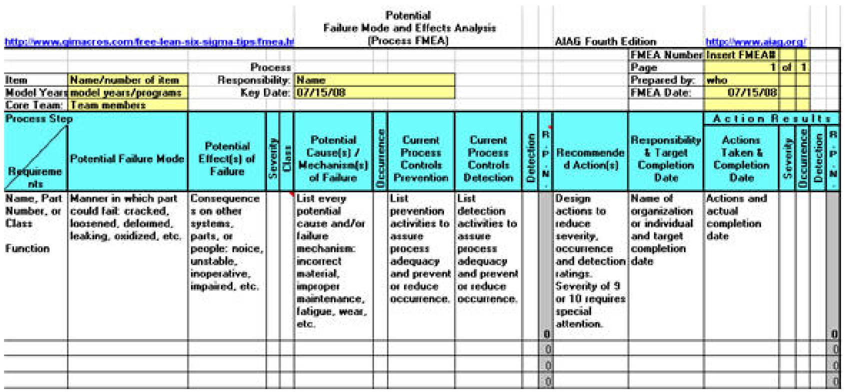


- **Parts derating analysis**
- **Worst case analysis / Monte Carlo**
- **Simulation analysis – Monte Carlo**
- **FMEA and criticality analysis**
- **FTA – Fault Tree Analysis (CAFTA, Relex)**
- **MTBF / failure rate prediction**
- **No fault found rate reduction**
- **HALT / HASS**
- **DOE**

Reliability Tools in Design Process –

Detailed design – Reliability & Safety Analyses

- Probabilistic Modeling – FMEA, FTA, Simulation, SEU/MBU analysis



http://www.qimacros.com/free-lean-six-sigma-tips/fmea.ht

Potential
Failure Mode and Effects Analysis
(Process FMEA)

AIAG Fourth Edition http://www.aiag.org/

Item	Name/number of item	Process Responsibility:	Name
Model Years	model years/programs	Key Date:	07/15/08
Core Team:	Team members		

FMEA Number	Insert FMEA#
Page	1 of 1
Prepared by:	who
FMEA Date:	07/15/08

Process Step / Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Class	Potential Cause(s) / Mechanism(s) of Failure	Occurrence	Current Process Controls Prevention	Current Process Controls Detection	Detection	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken & Completion Date	Severity	Occurrence	Detection	R.P.N.
Name, Part Number, or Class Function	Manner in which part could fail: cracked, loosened, deformed, leaking, oxidized, etc.	Consequences on other systems, parts, or people: noice, unstable, inoperative, impaired, etc.			List every potential cause and/or failure mechanism: incorrect material, improper maintenance, fatigue, wear, etc.		List prevention activities to assure process adequacy and prevent or reduce occurence.	List detection activities to assure process adequacy and prevent or reduce occurence.		0	Design actions to reduce severity, occurrence and detection ratings. Severity of 9 or 10 requires special attention.	Name of organization or individual and target completion date	Actions and actual completion date				0
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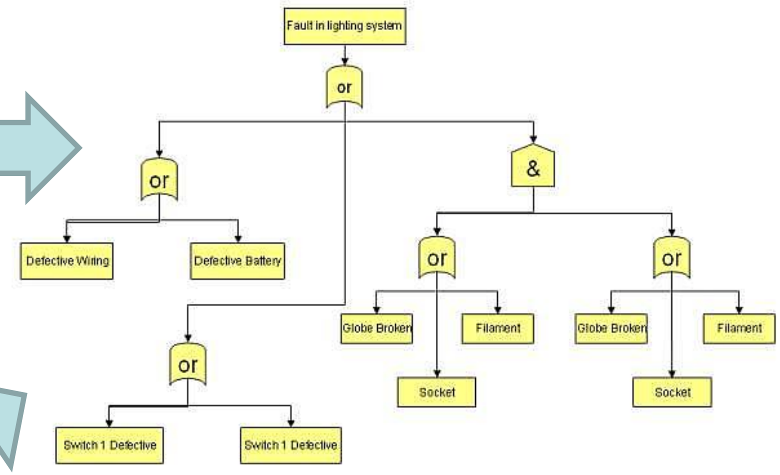
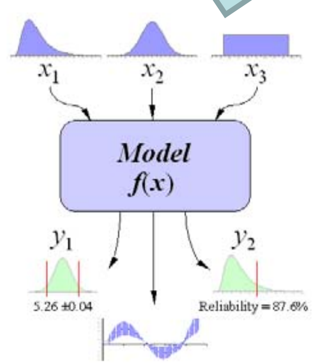


FMEA, (FMES) – Failure Modes Effects (Summary) Analysis

– Bottom-up analysis

– Quantifies effects of component failures to system operation



FTA – Fault Tree Analysis

– Top-down analysis

– Quantifies probabilities for safety critical events

Monte Carlo Simulation

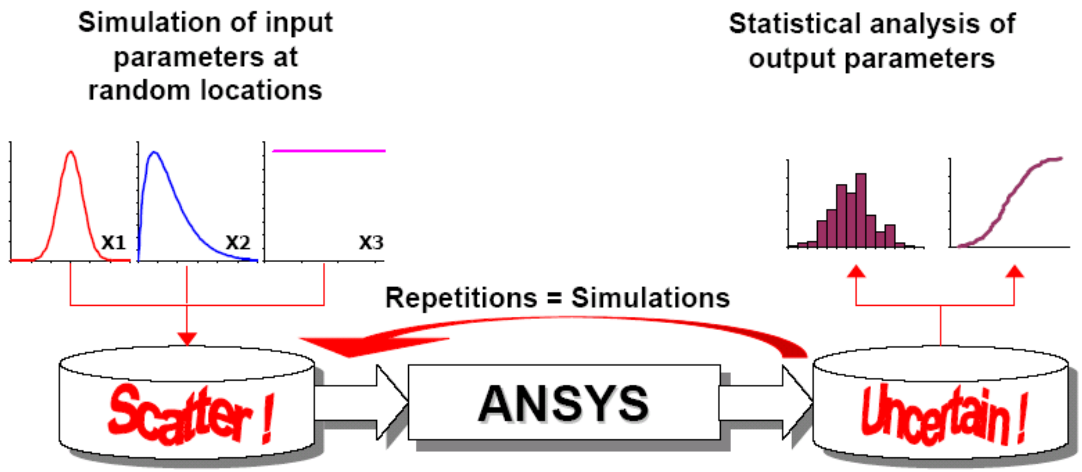
- computes probabilities for complex systems, quantifies propagation of variability from inputs to outputs

SEU/MBU Analysis
(Radiation effects)
- component upsets due to atmospheric radiation (neutrons & protons)

Reliability Tools in Design Process –

Detailed design – Monte Carlo Simulation

- **Variation in material properties: density, yield strength, modulus of elasticity, homogeneity, contamination, …**
- **Variation due to manufacturing process variability: dimensions, heat treatment, residual stresses, …**
- **Variation due to degradation with time: wear, corrosion, embrittlement.**
- **Variation due to environment: temperature, humidity, supply voltage, vibration, …**

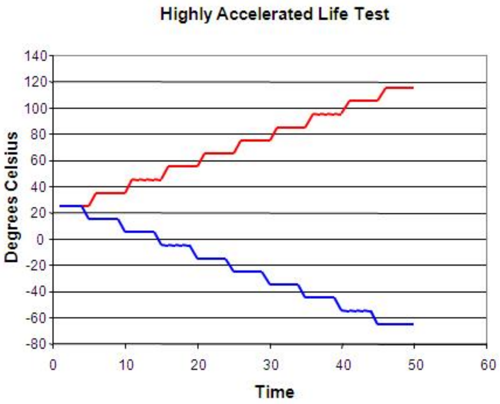


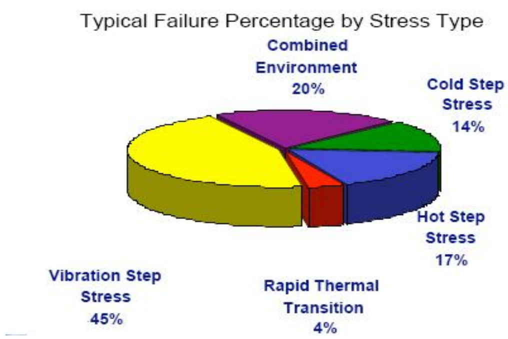
Reliability Tools in Design Process –

Detailed design – HALT/HASS, ALT

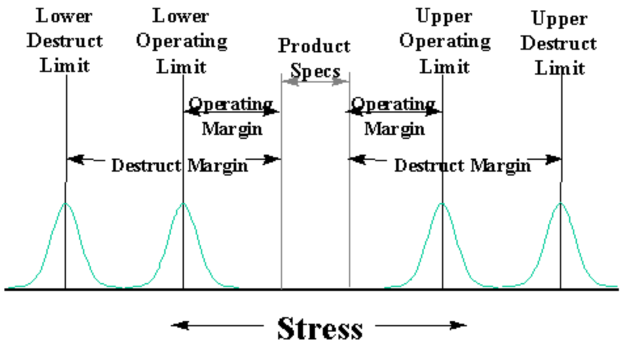
HALT is a process used during the design stage of a product, it provides a stringent environment that drives design maturity.

- **Quickly discovers design & process flaws.**
- **Evaluates & improves design margins.**
- **Reduces development time & cost.**
- **Eliminates design problems before release to manufacturing.**
- **Ship a mature product at market introduction.**
- **Use as a sustaining engineering tool to evaluate impact of product modifications and cost reductions.**



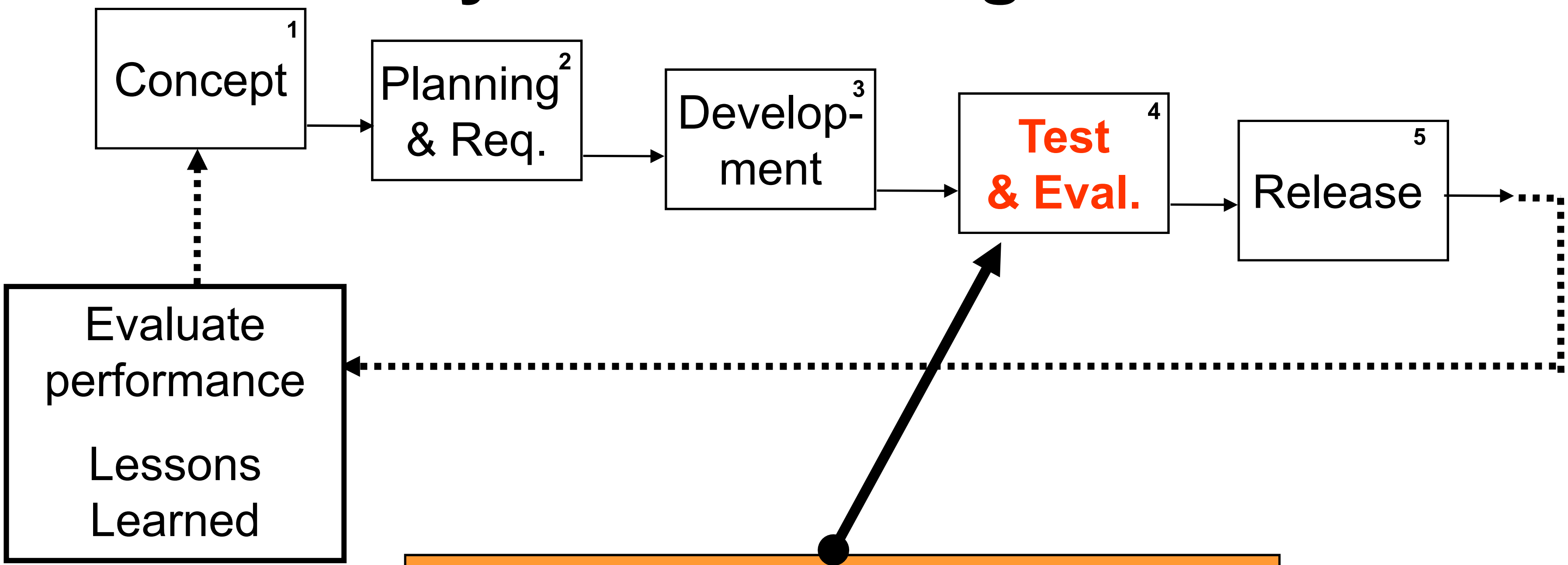


HALT Theory



ALT vs. HALT?

Reliability Tools in Design Process



- **Screening program (HASS/ESS)**
- **Reliability demonstration**
- **FMEA demonstration testing**
- **Life testing (HALT, ALT)**
- **FRACAS**

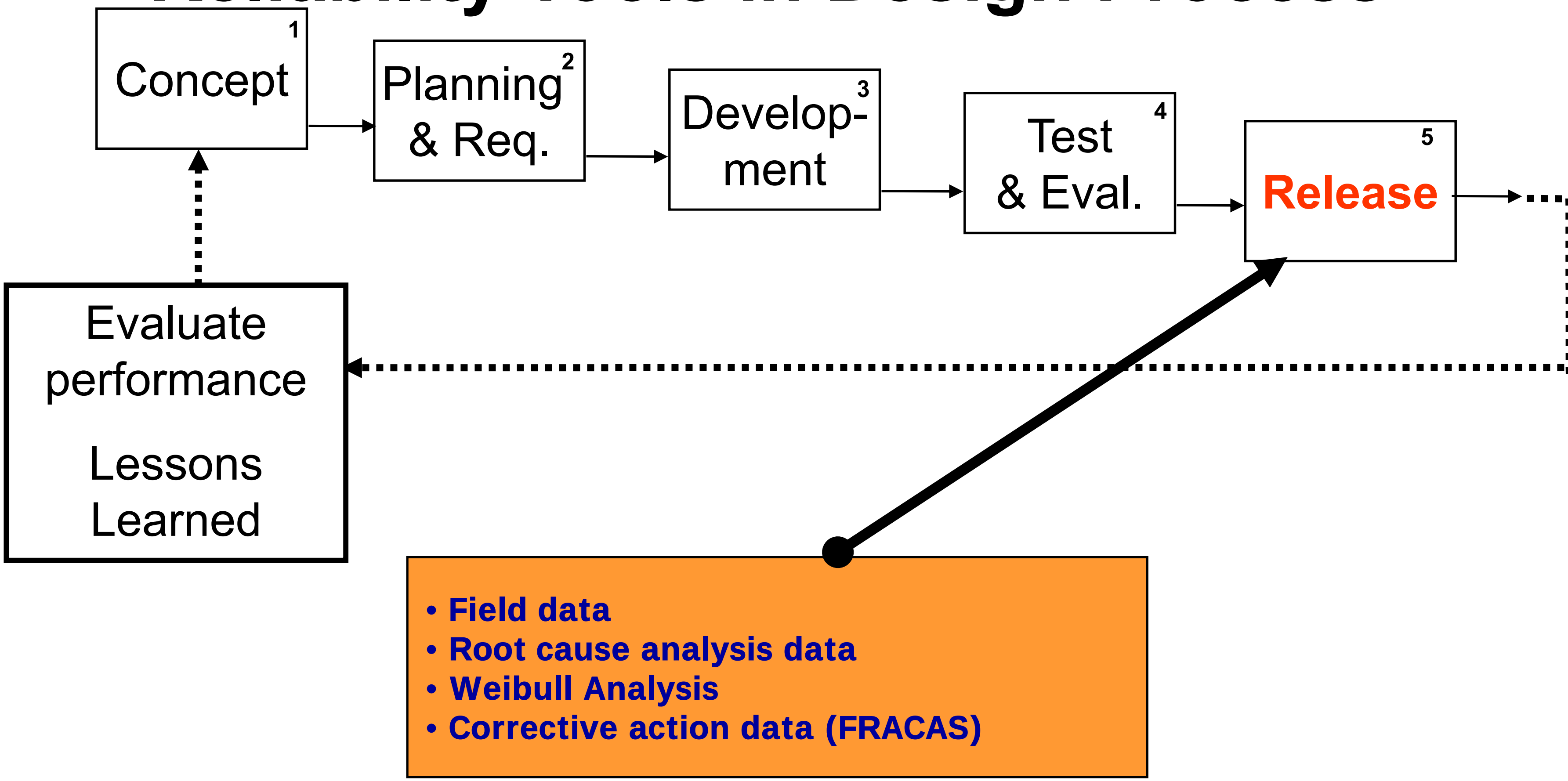
Reliability Tools in Design Process –

Detailed design

- Probabilistic Modeling – Life Testing Methodologies

  - HALT – **H**ighly **A**ccelerated **L**ife **T**ests
  - HASS – **H**ighly **A**ccelerated **S**tress **S**creening
  - ALT – **A**ccelerated **L**ife **T**est (traditional life tests)
  - ESS – **E**nvironmental **S**tress **S**creening
  - Burn – In tests
  - RDT – **R**eliability **D**emonstration **T**esting
  - ORT – **O**n-going **R**eliability **T**esting
  - RGT – **R**eliability **G**rowth **T**esting

Reliability Tools in Design Process

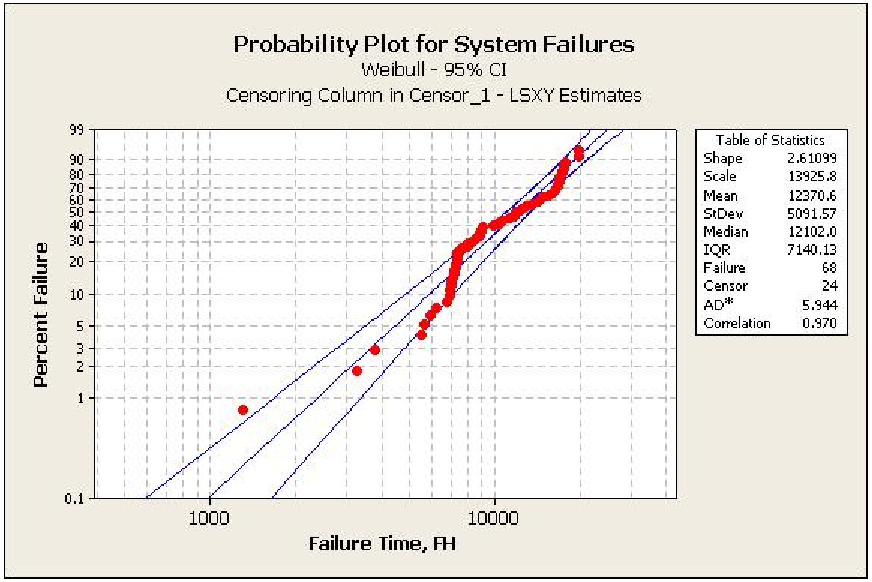


Reliability Tools in Design Process –
Field Data Analysis

- Probabilistic Modeling – Weibull Analysis

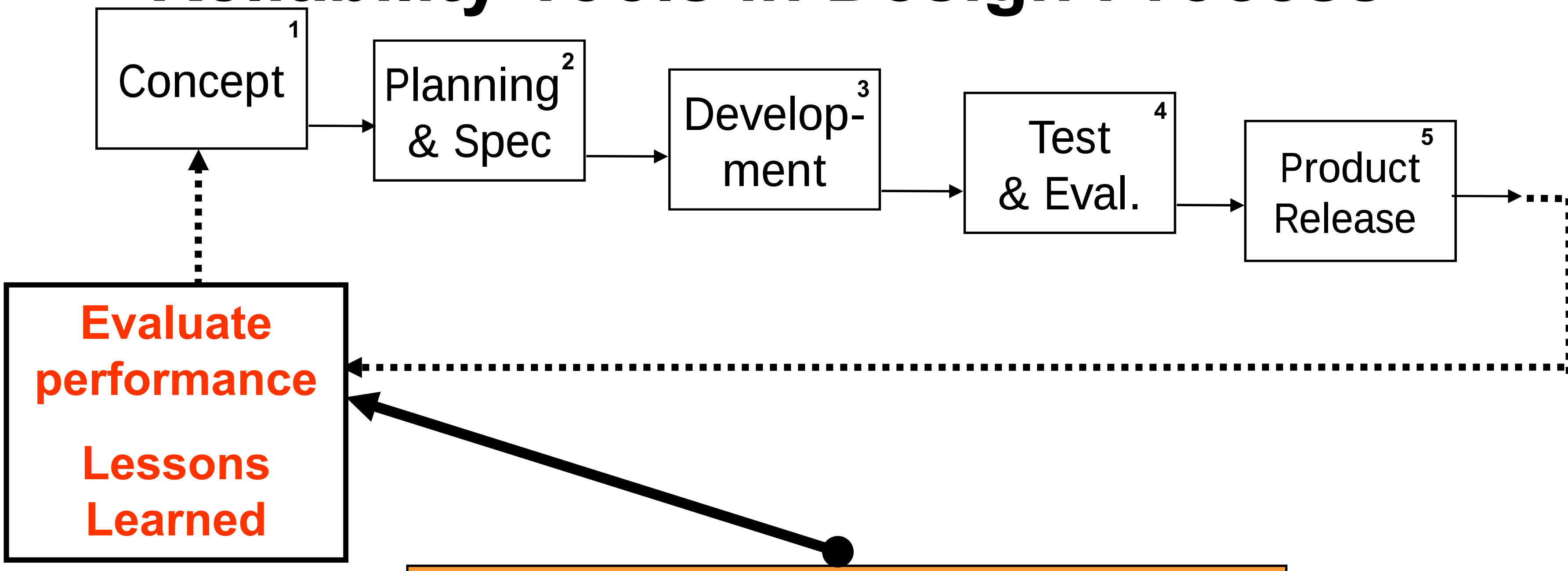
Linear regression or Maximum Likelihood Method:

- Probabilistic method for risk analysis
- Provides reliability estimation from field or test data
- Provides forecast of the field failures – returns
- Provides input to spare parts calculations
- Provides input to warranty costs modeling
- Provides input to system availability and maintainability modeling



β= 2.6
η= 13,926 hrs – characteristic life
MTBF = 12,370 hrs

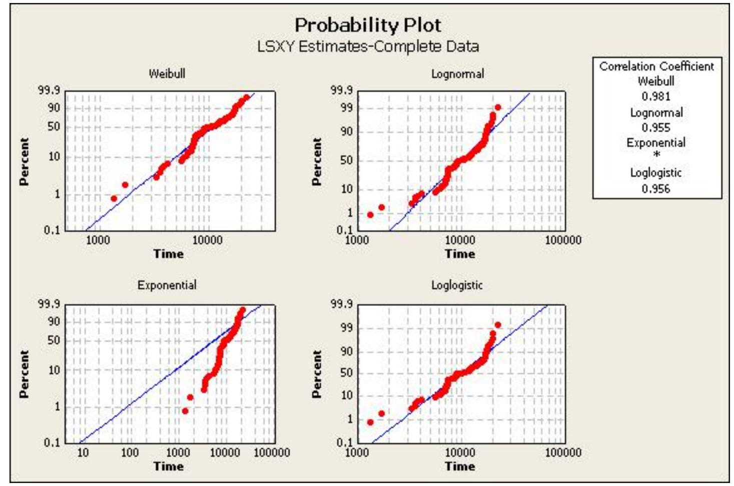
Reliability Tools in Design Process

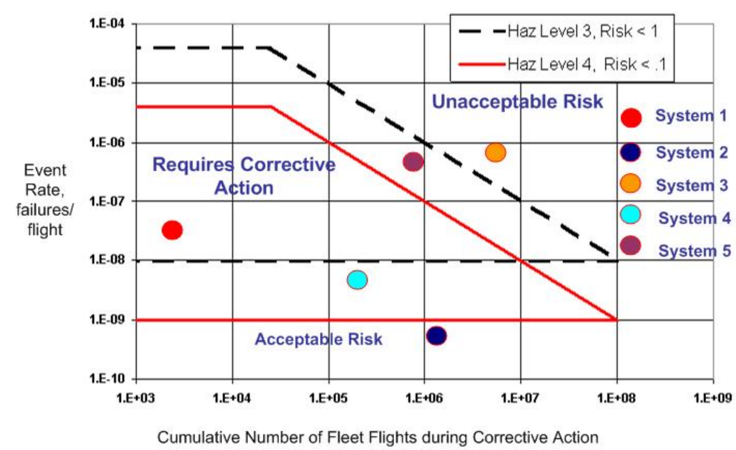


- **Weibull Analysis**
- **Lessons Learned - Knowledge Management**
- **Field Data Database**
- **CAAM Risk Analysis – retrofit plan and schedule**

Reliability Tools in Design Process

- Probabilistic Modeling – Field Data Analysis
  - Estimates of the systems' failure rates, MTBF, MTBUR – HS internal database
  - Estimates of the component failure rates – inputs to RM&S analyses
    - Systems reliability predictions
    - Fault trees for the systems safety analysis
  - Risk Analysis (CAAM – Continuous Airworthness Analysis Methodology – AC39-8)
    - Estimates hazard levels for field failures
    - Determines corrective action interval and retrofit schedule to meet required risk





Reliability Tools Applicability

- Reliability is all about cost-benefit relationship.
- More efficient reliability tasks → lower risk at the same cost.
- More reliability activities (investment) early in the design process → lower overall development , maintenance and cost of ownership.
- Selection of “appropriate” tools frequently driven by customers.
- **A comprehensive design process → Design for Reliability**

Questions?