2012 ARS, Europe: Warsaw, Poland

Track 1, Session 2

Begins at 10:30 AM, Wednesday, March 28th

Prerequisites for a Comprehensive and Successful FMEA

Amnon Ganot, CRE

Gertron Ltd. CTO

RAMS Consulting Services

PRESENTATION SLIDES

The following presentation was delivered at the:

International Applied Reliability Symposium, Europe
March 28 - 30, 2012: Warsaw, Poland
http://www.ARSymposium.org/europe/2012/

The International Applied Reliability Symposium (ARS) is intended to be a forum for reliability and maintainability practitioners within industry and government to discuss their success stories and lessons learned regarding the application of reliability techniques to meet real world challenges. Each year, the ARS issues an open "Call for Presentations" at http://www.ARSymposium.org/europe/presenters/index.htm and the presentations delivered at the Symposium are selected on the basis of the presentation proposals received.

Although the ARS may edit the presentation materials as needed to make them ready to print, the content of the presentation is solely the responsibility of the author. Publication of these presentation materials in the *ARS Proceedings* does not imply that the information and methods described in the presentation have been verified or endorsed by the ARS and/or its organizers.

Vocabulary

ALT	Accelerated Life Test
ATM	Automatic Teller Machine
CFMEA	Concept FMEA
DFM	Design For Maintainability
DFMEA	Design FMEA
DFR	Design For Reliability
EMI	Electromagnetic Interference
FFMEA	Functional FMEA
FMEA	Failure Mode & Effect Analysis
FRU	Field Replicable Unit
HALT	Highly Accelerated Life Test
I/O	Input / Output
IFMEA	Interface FMEA
PFMEA	Process FMEA
PIN	personal identification number
RAMS	Reliability, Availability, Maintainability & Safety

Agenda

Topic	Time (Min)
Motivation	8
FMEA Definition	
FMEA Types	
FMEA – The “Lean” Way	
System Engineering	40
System Mission(s)	
System Boundaries	
Functional Structure Diagram	
Functional Analysis	
Components Function	
Interface Diagram	
Operation Modes	
State Diagrams	
Functions & Parameters	
FMEA Tips	2
Summary	
Questions	10

Motivation

- Reliability goals become more and more demanding…
- Development cycles become shorter…
- …As a result, we have to implement more comprehensive & lean reliability methodologies….>

FMEA Definition

- An FMEA (Failure Mode and Effect Analysis) is a systematic method of identifying and preventing product and process problems before they occur.

FMEA Types

Function/ Purpose/ Parameters	Potential Failure Modes	Potential Failure Mechanisms	Potential Effects of Failure [Local, Next, System levels]	Sev (1)	Occ (2)	Dtc (3)	RPN (4)	Recommended Actions		Responsibility
								Corrective (5)	POD / Testing (6)	
FU: Data Processing										
PU: Data integrity	Erroneous data received	Bad connection	N: Wrong drop params S: Bad printing	8	3	1	24	Data integrity Inspection: Input and output (digital & Analog, Pulse?)		
		Bad input	N: Wrong drop params S: Bad printing	8	3	1	24	Data integrity Inspection: Input and output (digital & Analog, Pulse?)		
	Data corrupted	Bad processing	N: Wrong drop params S: Bad printing	8	2	1	16	Data integrity Inspection: Input and output (digital & Analog, Pulse?)		

- *Concept FMEA*
  - CFMEA is used to analyze concepts in the early stages before hardware is defined (most often at system and subsystem).
  - It focuses on potential failure modes associated with the proposed functions of a concept proposal.
  - This type of FMEA includes the interaction of multiple systems and interaction between the elements of a system at the concept stages.

FMEA Types (cont)

Function/ Purpose/ Parameters	Potential Failure Modes	Potential Failure Mechanisms	Potential Effects of Failure [Local, Next, System levels]	Sev (1)	Occ (2)	Dtc (3)	RPN (4)	Recommended Actions		Responsibility
								Corrective (5)	POD / Testing (6)	
FU: Data Processing										
PU: Data integrity	Erroneous data received	Bad connection	N: Wrong drop params S: Bad printing	8	3	1	24	Data integrity Inspection: Input and output (digital & Analog, Pulse?)		
		Bad input	N: Wrong drop params S: Bad printing	8	3	1	24	Data integrity Inspection: Input and output (digital & Analog, Pulse?)		
	Data corrupted	Bad processing	N: Wrong drop params S: Bad printing	8	2	1	16	Data integrity Inspection: Input and output (digital & Analog, Pulse?)		

- *Functional FMEA*
  - FFMEA examines the intended functions that a product, process or service is to perform rather than the characteristics of the specific implementation.
  - When a functional FMEA is developed, a functional block diagram is typically used to identify the top-level failures for each block in the diagram.
- *Interface FMEA*
  - An IFMEA analysis focuses on determining the characteristics of failures in the interconnections between subsystem elements. Cables, plumbing, fiber optic links, mechanical linkages and other interconnections between subsystem modules provide the basis for the postulated failure modes.

FMEA Types (cont)

Function/ Purpose/ Parameters	Potential Failure Modes	Potential Failure Mechanisms	Potential Effects of Failure [Local, Next, System levels]	Sev (1)	Occ (2)	Dtc (3)	RPN (4)	Recommended Actions		Responsibility
								Corrective (5)	POD / Testing (6)	
FU: Data Processing										
PU: Data integrity	Erroneous data received	Bad connection	N: Wrong drop params S: Bad printing	8	3	1	24	Data integrity Inspection: Input and output (digital & Analog, Pulse?)		
		Bad input	N: Wrong drop params S: Bad printing	8	3	1	24	Data integrity Inspection: Input and output (digital & Analog, Pulse?)		
	Data corrupted	Bad processing	N: Wrong drop params S: Bad printing	8	2	1	16	Data integrity Inspection: Input and output (digital & Analog, Pulse?)		

- *Design (Parts) FMEA*
  - DFMEA is used to analyze product detailed designs before they are released to production. DFMEA focuses on potential failure modes associated with the parts of product and caused by the design deficiencies.
- *Process FMEA*
  - PFMEA is used to analyze the already developed or existing processes. PFMEA focuses on potential failure modes associated with both the process safety/effectiveness/efficiency, and the functions of a product caused by the process problems.

FMEA – The “Lean” Way

“The art of being wise is the art of knowing what to overlook.”

--William James, American Philosopher

FFMEA vs. DFMEA

Attributes	Parts Approach	Functional Approach
Prerequisites	Detailed drawing	Functional diagram
Completeness criterion	Based on parts list	Difficult to establish
Knowledge of failure modes	Past experience	Examination of function
Failure mode probability	Compiled sources	Must be estimated
Usual progression	Bottom-up	**Top-down**
Relative cost	High / Long	**Low / Short**
Project stage	Late (detailed design)	**Early (system level)**
Software Analysis	Not Possible	**Can be done**

System Engineering

- There are two main approaches in engineering design: the bottom-up and top-down approaches.
- The most common methodology to engineering design is provided using the systems approach, which is actually based on a *top-down* approach to the design.
- The process is applicable to any part of the system.
- The process is self-consistent.

System Missions

- The **mission** is a concise statement outlining the primary function or purpose of the unit. A **mission** is a brief description of the unit's purpose, answering the basic question:

"Why do we need the unit?"

E.g.: Washing Machine Mission

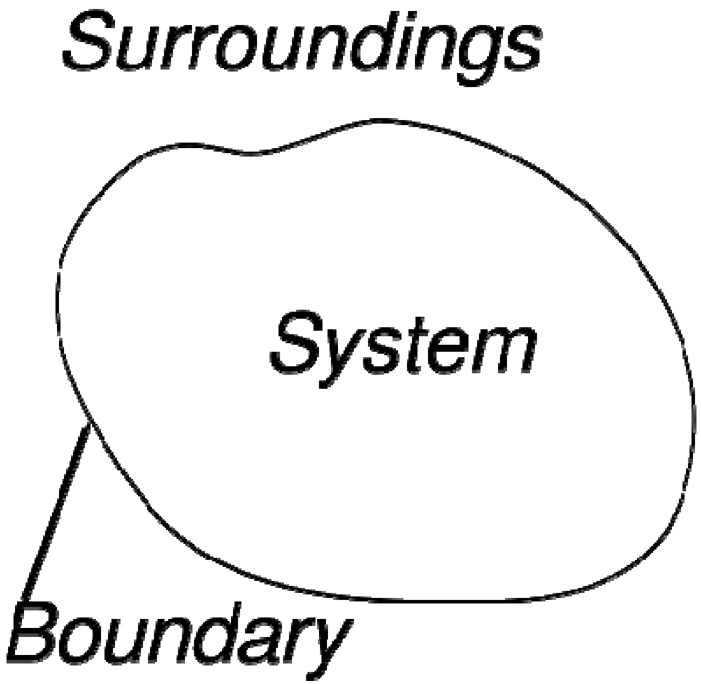
- To wash laundry…
  - Rinsing
  - Spinning
  - ….

1910 advertisement

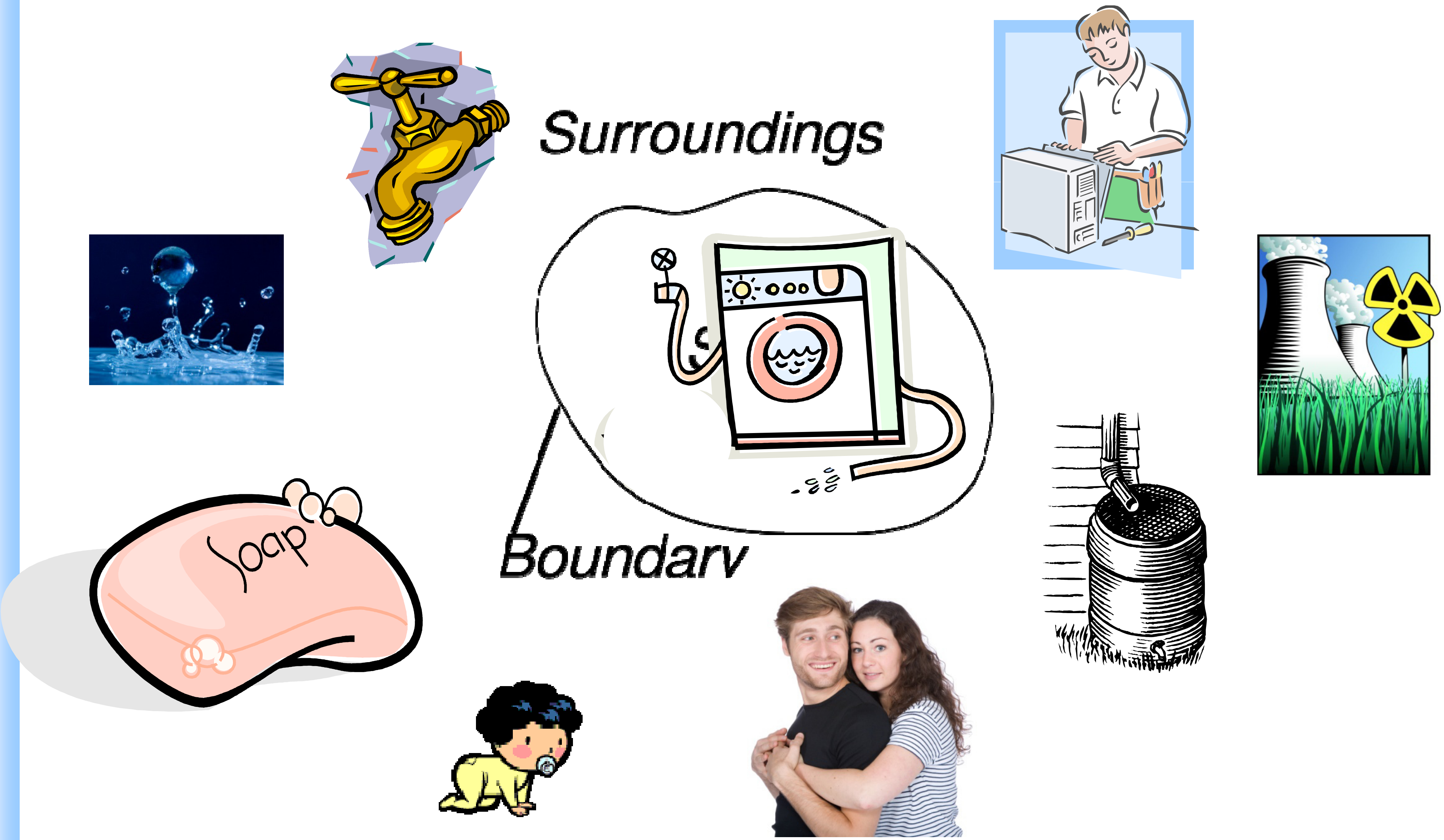
System Boundaries

- A system boundary is a boundary that separates the internal components of a system from external entities.
- Those external entities can also be thought and be called as actors.
- In a use case diagram, a system boundary is represented by a rectangle that is drawn to enclosed the internal components of a system. Any entities outside the rectangle (i.e., the system boundary) are hence the actors.

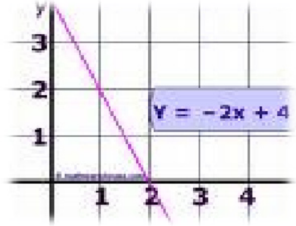
System Boundaries



E.g.: Washing Machine Boundaries

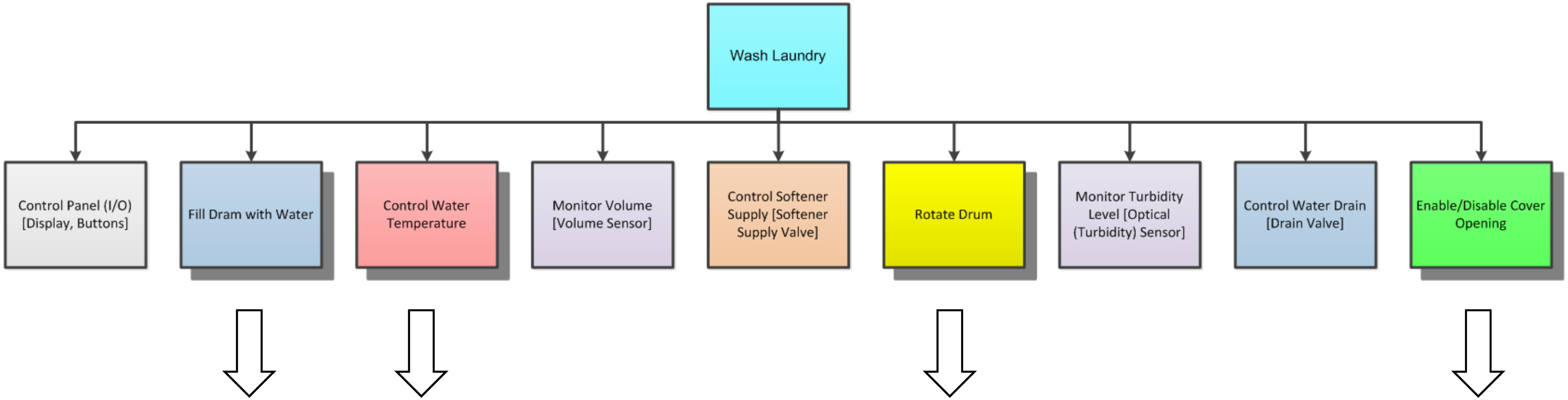


Functional Structure Diagram

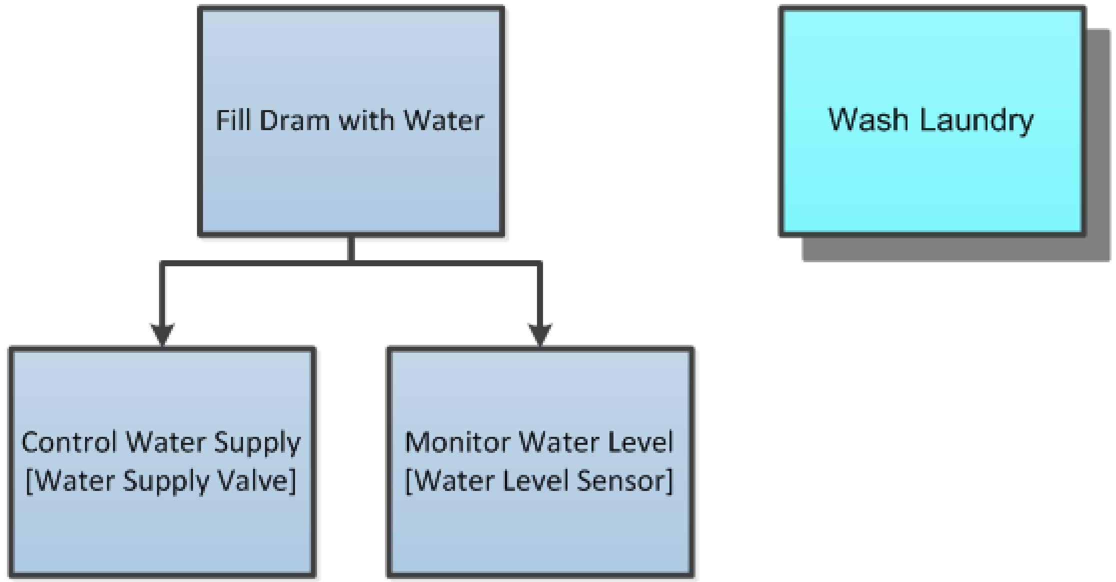


- The Functional Structure Diagram is a technique for analyzing the functional structure of a system.
- The establishment of the Functional Structure Diagram usually comes after the elaboration of the specification and before the search for alternatives.
- It presents the design solution independent of the specific technical methods to be involved.
- The functions should be in the form a **verb-noun** combination. The **verb** should be an action verb (*hold, protect, rotate, move, control, direct* etc.). The **noun** should be descriptive and general; it is the "operant" on which the operation takes place (*density, noise, color*, etc.). For example: *generate color*, *reduce noise* etc.

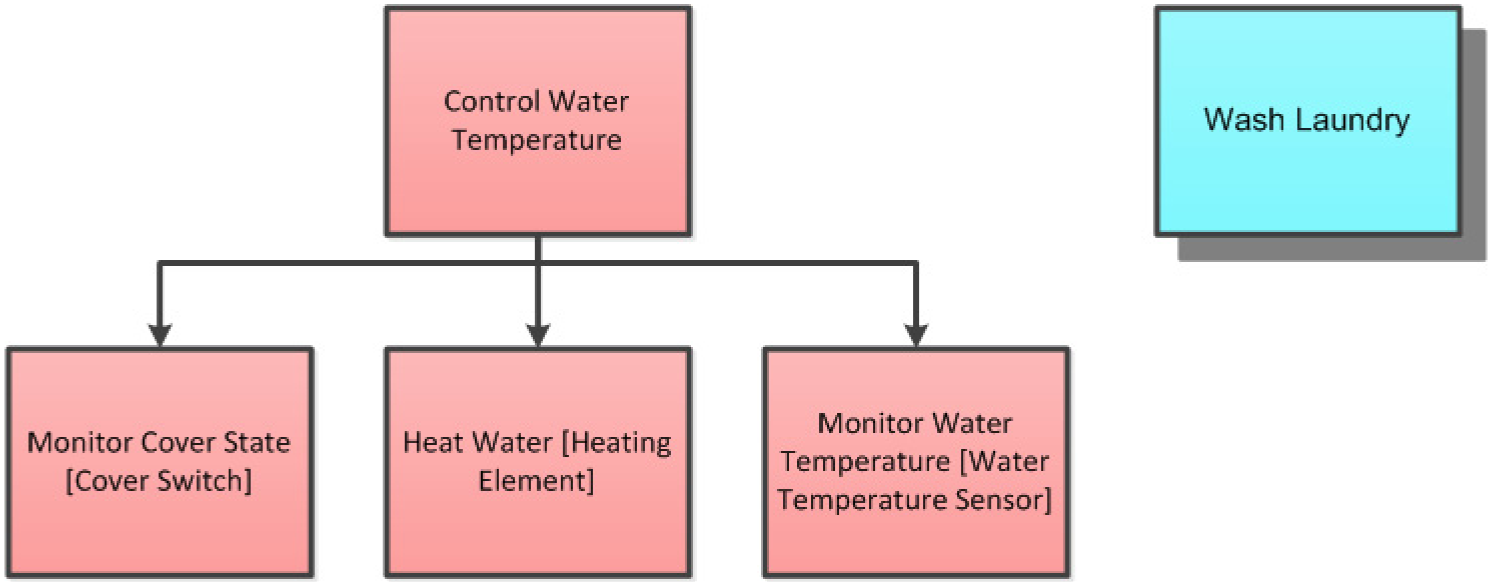
E.g.: Washing Machine Functional Structure Diagram



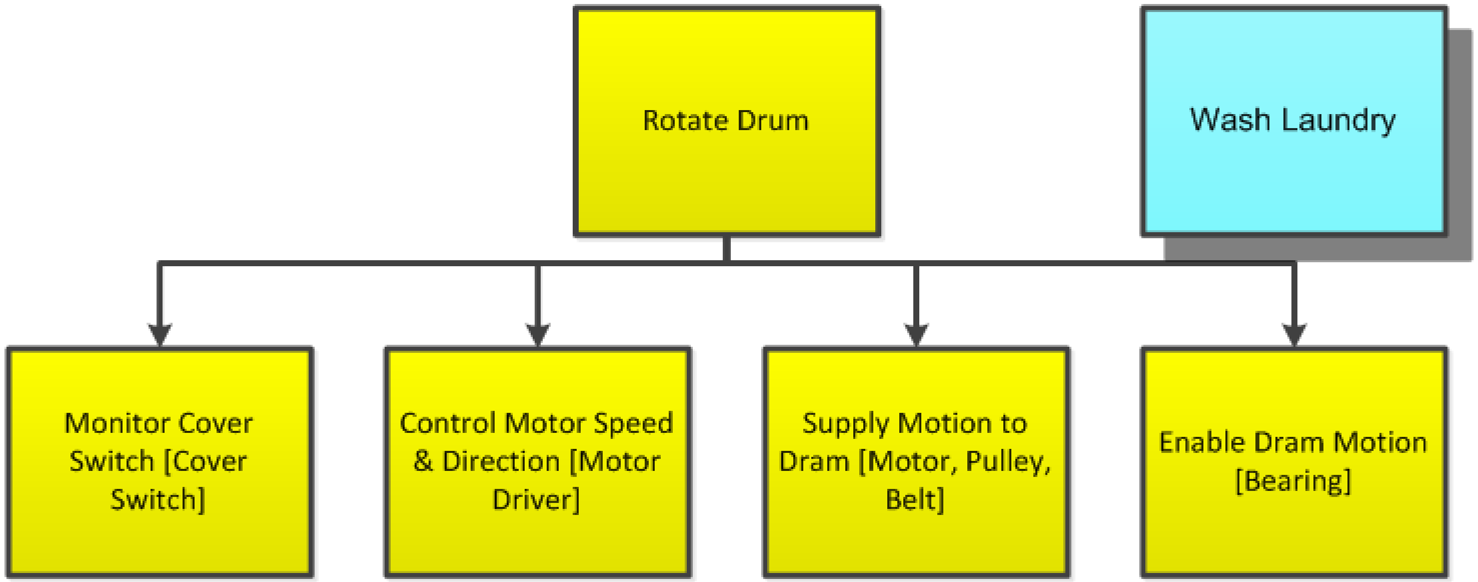
E.g.: Washing Machine Functional Structure Diagram



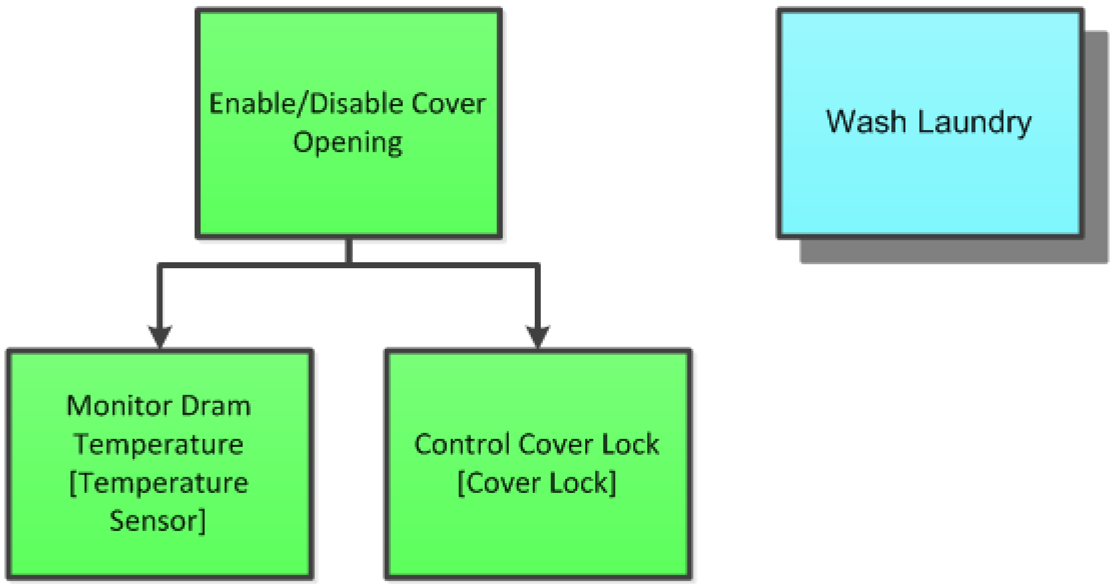
E.g.: Washing Machine Functional Structure Diagram



E.g.: Washing Machine Functional Structure Diagram



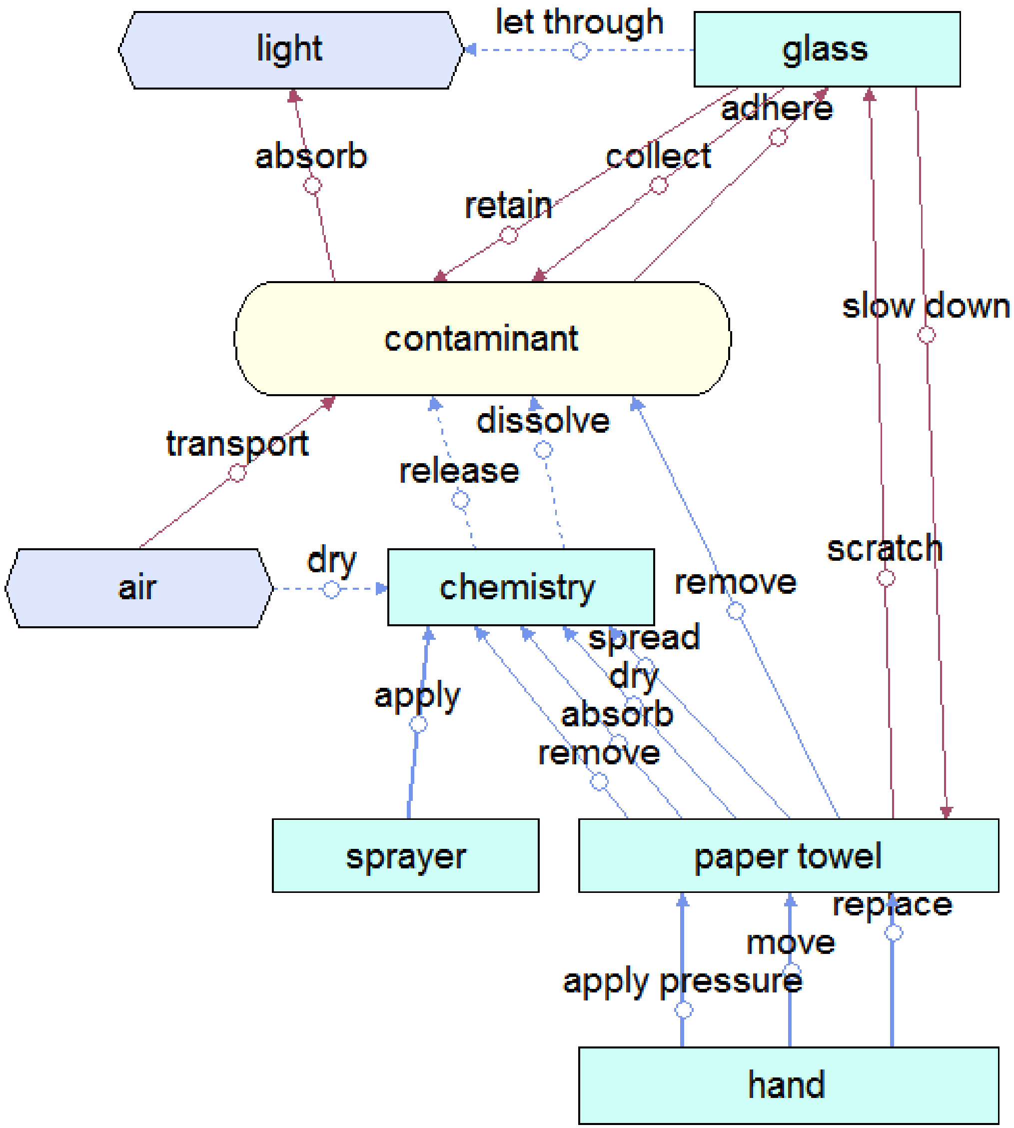
E.g.: Washing Machine Functional Structure Diagram



Functional Analysis

- A Functional Analysis is needed to be able to evaluate the interconnections between the parts. This will be used to light up the functions of the parts.

E.g.: Window Cleaning Functional Analysis



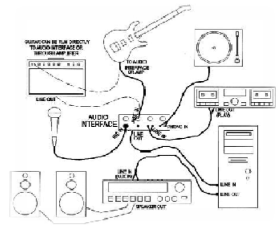
Components Functions

- To be able to analyze all the potential failure that might cause a component failure, one has to analyze each of the components failures composing the sub-system.
- The list should include all hardware components as well as software modules. In case a human is controlling the sub-system (e.g., operating panel), the human is a sub-system.
- For example: a flashlight is composed of the following sub-assemblies: lamp, batteries, switch, case and user.
- The case can further be decomposed into its sub-assemblies/components and it is the decision of the FMEA performer to decide down to what level the sub-system should be decomposed.
- **In any case, the decomposition should be at least down to the FRU (Spare Part) level.**

E.g.: Washing Machine Components Functions

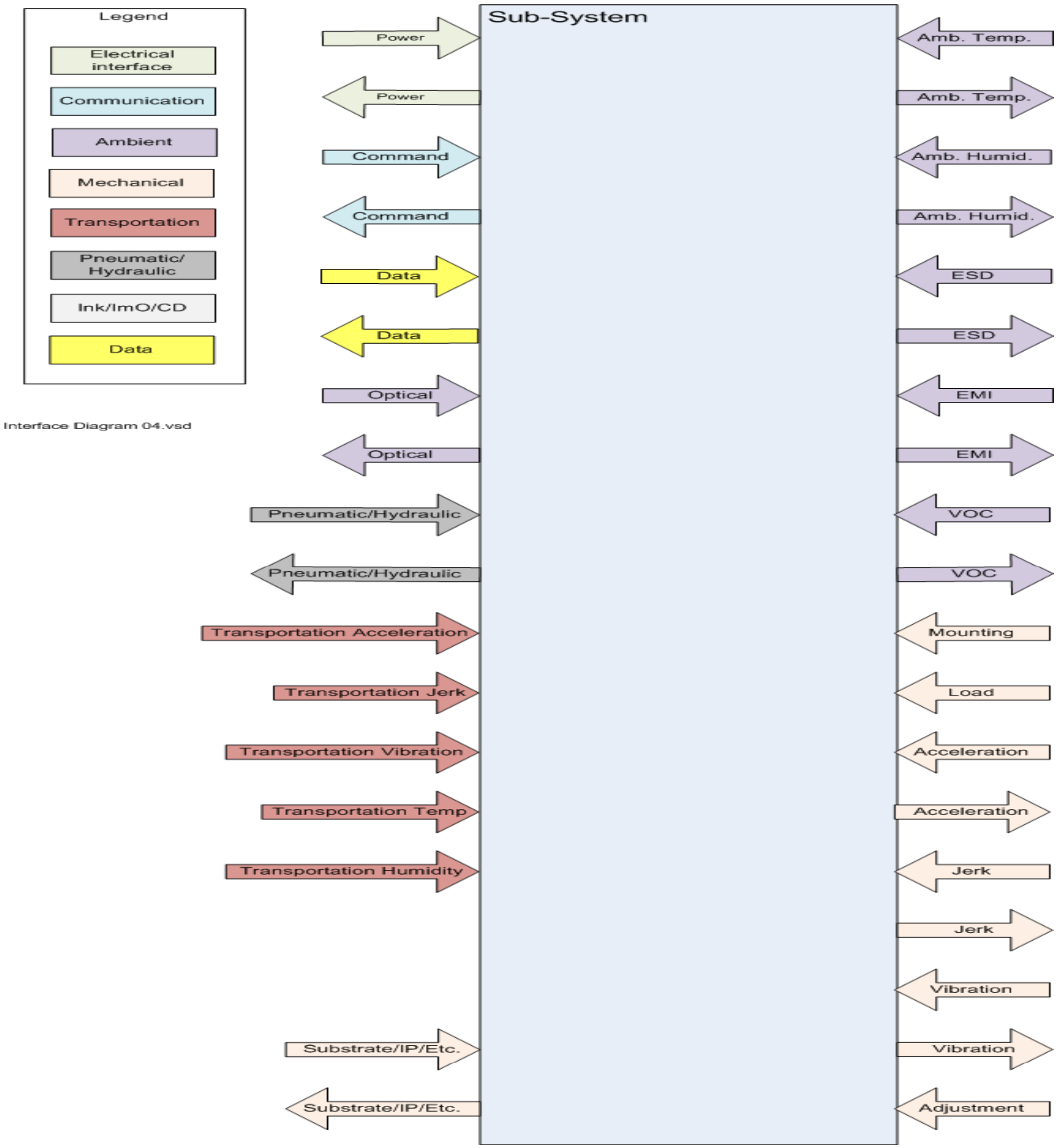
Sub-Assy	Function	Component	FRU
	????	EMI Filter	Yes
	Control Water Supply	Water Supply Valve	Yes
	Control Water Drain	Drain Valve	Yes
	Control Softener Supply	Softener Supply Valve	Yes
	????	Power Factor Correction Assy	Yes
	Supply Motion to Drum	Motor	Yes
		Pulley	No
		Belt	Yes
	????	Drum	No
	????	Front Panel	Yes
	Monitor Water Level	Water Level Sensor	Yes
	…	…	…

Interface Diagram

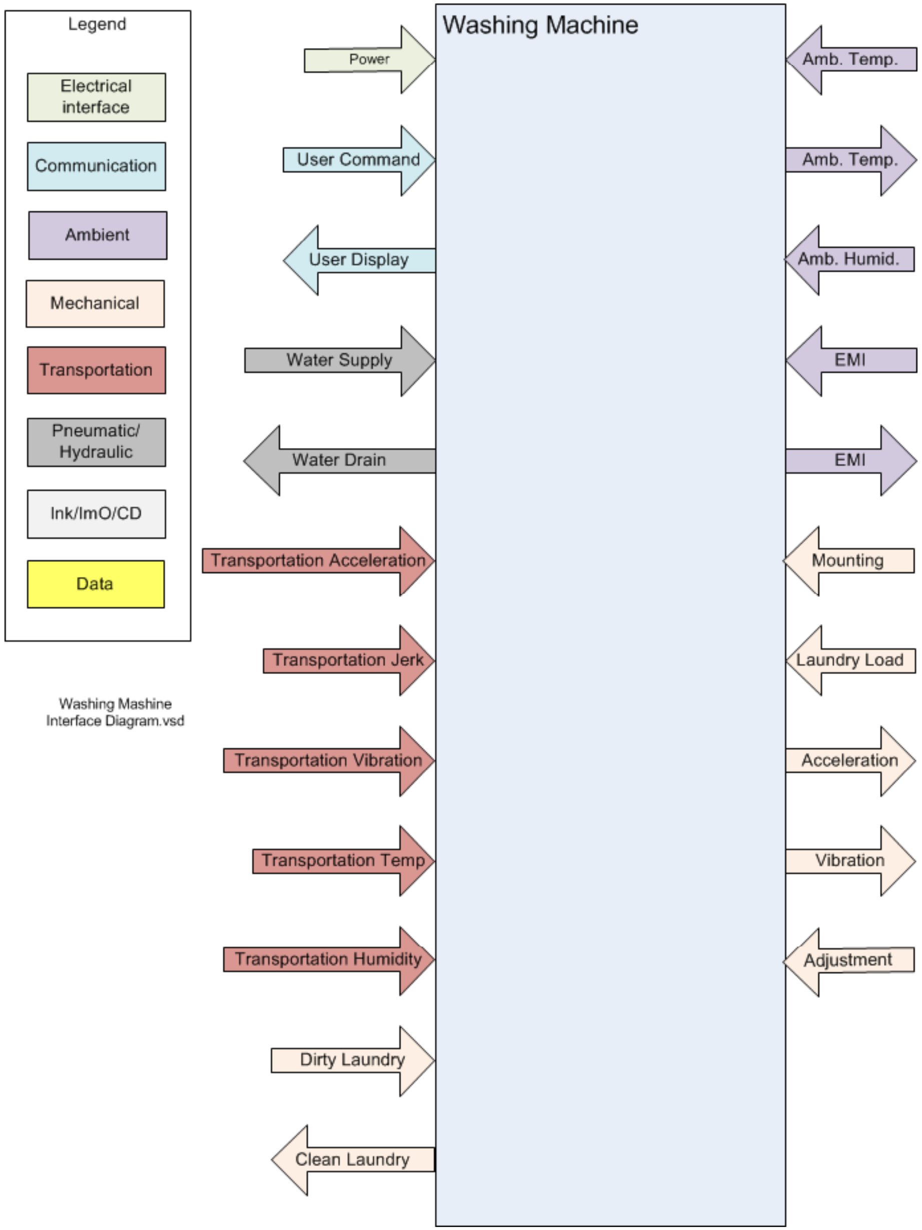


- Interface Diagram is an important data as it is composed of the relation between the system/sub-system/sub-assemblies to the next level entity.
- It always includes the missions of the unit as well as the influences of the unit on the environment and vice versa.
- Called also “Boundary Diagram.”

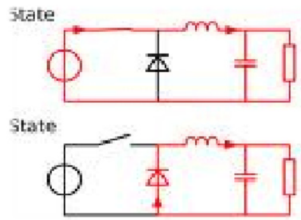
Interface Diagram – Check List



E.g.: Washing Machine Interfaces Diagram



Operating Modes

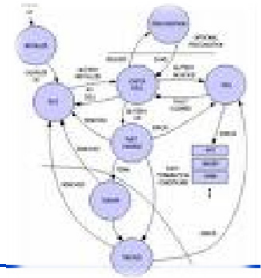


- In different operational modes, a unit might be exposed to different stress levels which lead to different failure modes due to different failure mechanisms.
- It is important to determine all the operational modes of each unit.
- Modes of operation that dominant most of the time will have the highest priority in analyzing. Examples of operating modes are: *Off, Startup, Shutdown, Standby, Setup, Active, Maintenance*, etc.

E.g.: ATM Operating Modes

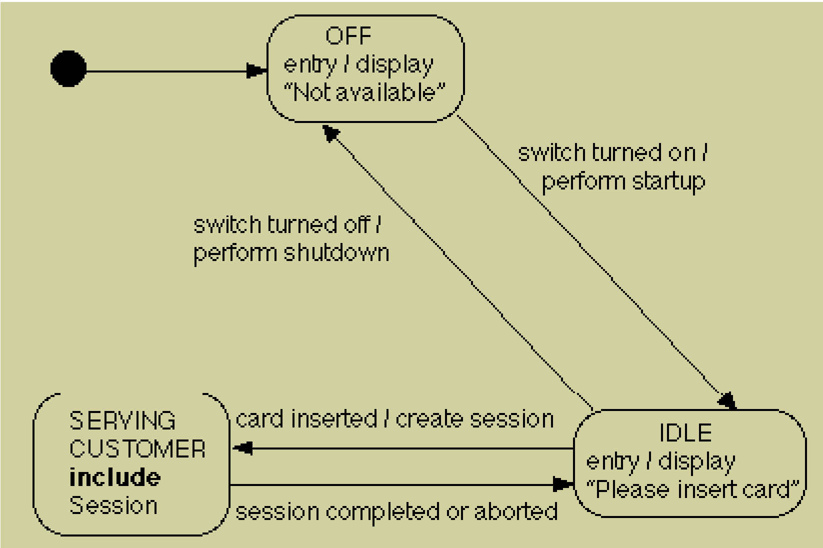
- **Off** – Display “Not Available”
- **Idle** – Display “Please Insert Card”
- **Serving Customer**
  - Reading Card
  - Reading PIN
  - Choosing Transaction
  - Performing Transaction
  - Eject Card

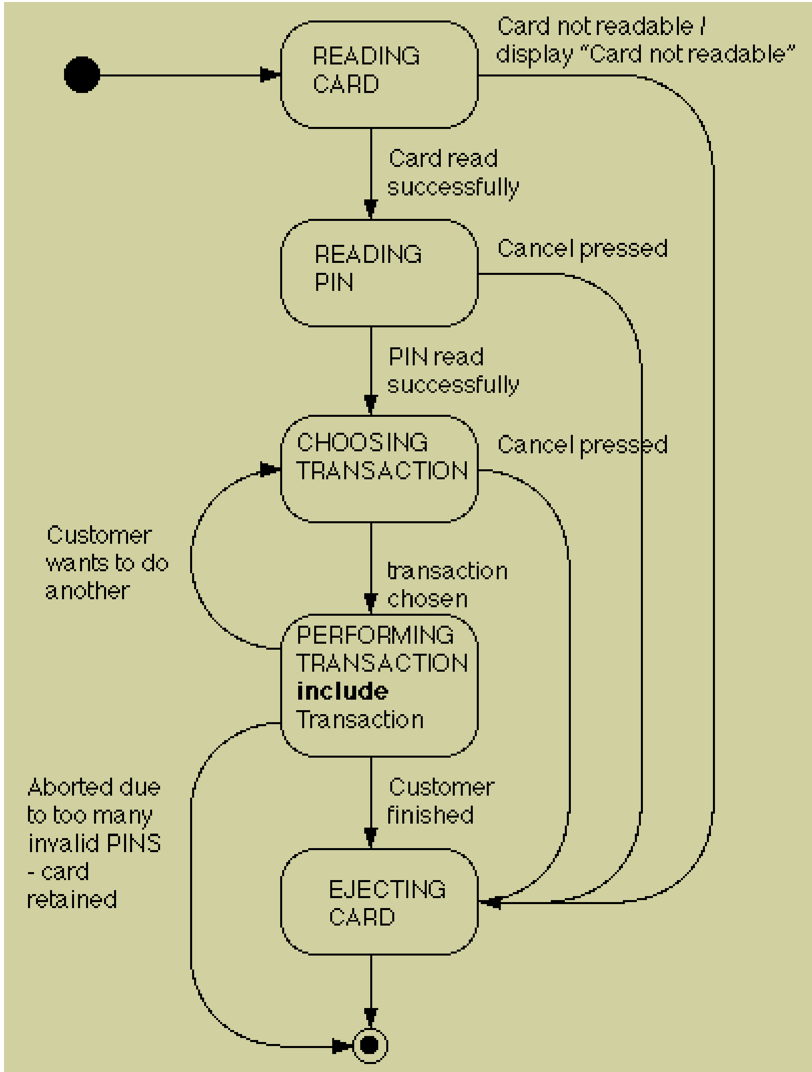
State Diagram



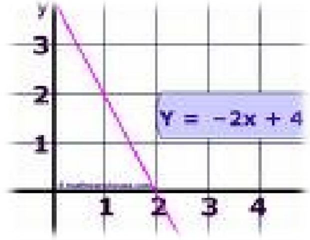
- A state diagram is a type of diagram used in computer science and related fields to describe the behavior of systems.
- State diagrams require that the system described is composed of a finite number of states; sometimes, this is indeed the case, while at other times this is a reasonable abstraction.
- In some cases, system states and operating modes are coincident, while in other cases one operating mode has several states.

E.g.: ATM State Diagrams



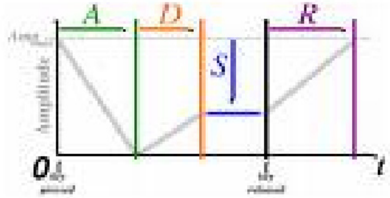


Function



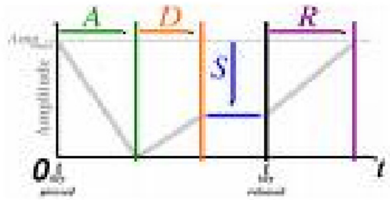
- While the mission answers the basic question "Why do we need the unit?" the functions describes the way how we are going to do it.
- While a mission is non measurable, functions have measurable results and unique definitions of failure.
- E.g., while the major car mission is transporting passengers from one place to another, one of the functions is braking.
- In some cases, functions and missions are coincident.

Function’s Parameters



- The function’s parameters are those variables that are controlled by the function .
- E.g., function = "set pressure" / parameters = pressure & rate)
  - *For each Sub-Assembly, write its Function(s).*
  - *For each Function, write its Parameter(s).*
  - *For each Parameter write if it is a Critical Parameter.*

E.g.: Washing Machine Functions & Parameters



Sub-Assy	Function	Parameters	Critical	Rel. Data
	Control Panel (I/O) [Display, Buttons]	Display Integrity	Yes	Yes
		Input Signal Integrity	Yes	Yes
	Control Water Supply [Water Supply Valve]	State Integrity	Yes	Yes
		Pressure Drop	No	No
		Line Leak Rate	Yes	No
		Out Leak Rate	Yes	No
	Monitor Water Level [Water Level Sensor]	Accuracy	Yes	Yes
	Monitor Cover State [Cover Switch]	State Integrity	Yes	Yes
	Heat Water [Heating Element]	Heating Power	No	Yes
	…….	…….		

Perform Functional FMEA Tips

- Add Failures Modes based on *Functions parameters.*
- Add Failure Modes due to *illegal transition between states.*
- Add Failure Modes due to *electrical power interruption at any state.*
- Add Failure Modes due to *interfaces issue.*
- Add Failure Modes due to *human error.*

Summary

- Reliability goals become more and more demanding…
- Development cycles become shorter…
- …As a result, we have to implement more comprehensive & lean reliability methodologies….>
- The most common methodology to engineering design is provided using the systems approach, which is actually based on a *top-down* approach to the design.
- The mission is a concise statement outlining the primary function or purpose of the unit - "Why do we need the unit?"
- A system boundary is a boundary that separates the internal components of a system from external entities.
- Functional Structure Diagram presents the design solution independent of the specific technical methods to be involved.

Summary (Cont)

- A Functional Analysis is needed to be able to evaluate the interconnections between the parts. This will be used to light up the functions of the parts.
- Make a list that includes all hardware components as well as software modules and their functions. In case a human is controlling the sub-system (e.g., operating panel), the human is a sub-system.
- Interface Diagram is an important data as it is composed of the relation between the system/sub-system/sub-assemblies to the next level entity.
- It is important to determine all the operational modes of each unit.
- State diagrams require that the system described is composed of a finite number of states; sometimes, this is indeed the case, while at other times this is a reasonable abstraction.

Where to Get More Information

- *Statcharts: A Visual Formalism for Complex Systems*. David Harel
- *Fundamentals of Failure Modes and Effects Analysis*. John B. Bowles
- *Standard for Performing a Failure Mode and Effects Analysis (FMEA) and Establishing a Critical Items List (CIL)* (DRAFT). Flight Assurance Procedure (FAP) – 322 – 209
- *Functional Clues*. Aleksey Pinyayev
- Washing machine. Wikipedia
- *System Reliability & Failure Prevention*. Herbert Hecht
- *Handbook of Performability Engineering*. Krishna B. Misra
- *Reliability Centered Maintenance*. John Moubray
- *The Basic of FMEA*. Robin E. McDermott, Raymond J. Mikulak, Michael R. Beauegard

Amnon Ganot, CRE

- RAMS Expert at ORBOTECH Ltd. & CTO at GERTRON Ltd. RAMS Consulting Services
- Amnon Ganot is the RAMS expert at Orbotech ltd. Amnon is working at Orbotech for the last 22 years. Prior to being the RAMS expert, Amnon was the RAMS & Standard Compliance manager of Orbotech.
- During his cadence as the RAMS & Standard Compliance manager, he concentrated on developing methodologies for RAMS such as ALT, FMEA (Quick & Extended), DFM, DFR, Design for Standard Compliance, HALT, etc. Prior to the former job, he was, for more than 25 years, a project manager and system engineer in multidisciplinary projects in the medical, communication and industrial field.
- In the last four years, Amnon is occupied as CTO of Gertron Ltd., performing RAMS consulting services.
- Amnon holds a B.Sc in Electrical Engineering from the Technion Israel Institute of Technology, Israel. Amnon received his MBA from the Tel-Aviv University, Israel. Amnon is an ASQ Certified Reliability Engineer (CRE) as well as ISQ Certified Reliability Engineer (CREI)
- Contact Inf.: Gertron Ltd., P.O. Box 164, Yavne, Israel 81101
Phone: +972 54 4942373 Fax: +972 3 9410685
E-Mail: amnon-g@inter.net.il

Gertron
גרטרון בע"מ

Questions

Thank you for your attention.

Do you have any questions?