

Availability

- Concepts and Principles for the Practitioner -

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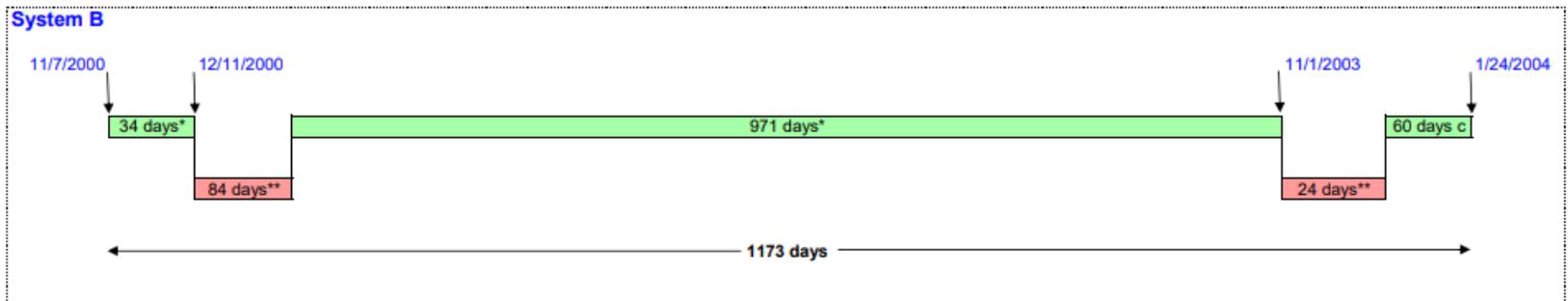
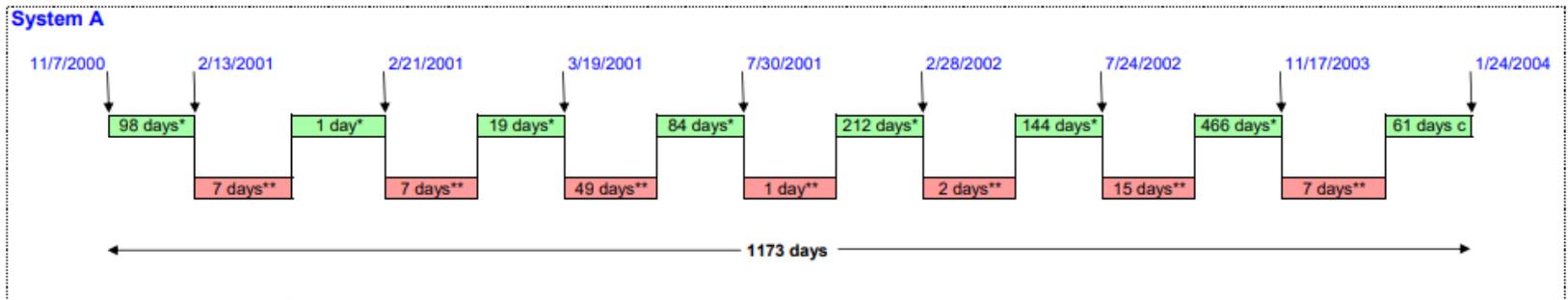
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Ideal input data to measure Availability

Uptime-Downtime Charts for Actual Hardware



Notes:

* denotes Uptime or operated ** denotes Downtime or under repair c denotes still operating Charts are not to the scale

Defining **RMA**

- 3 of the 9 Dimensions of Engineering Assurance -

- ◆ **Reliability** (R) is the probability an item will be in an uptime state (i.e., fully operational or ready) to perform its intended function **without failure** for a stated mission time under stated conditions.
- ◆ **Maintainability** (M) is the probability an item in a downtime state will be **returned to an uptime state** within a given period of time.
- ◆ **Availability** (A) is a mathematical function of Reliability and Maintainability (R&M) and is the probability a repairable item will perform its intended function at a given point in time (or over a specified period of time) when operated and maintained in a prescribed manner. Other words, availability is the probability of an item's mission readiness, an uptime state with the likelihood of **recovering from a downtime state**.

Types of Availability

- ◆ **Demonstrated availability**
 - Uses actual historical data
 - $= (\text{uptime}) / (\text{uptime} + \text{downtime}) = (\text{uptime}) / (\text{total required time})$
- ◆ **Predictive availability** has **three ways to define uptime and downtime.**
 - Inherent availability: Uses only the failure distribution and repair distribution
 - Achieved availability: Includes preventive or scheduled maintenance actions
 - Operational availability: Includes logistics and administrative delay times
- ◆ **And Predictive availability** has **three ways to treat mission time.**
 - Point (instantaneous) availability at time t
 - Average (interval, mission) availability during the time period from t_1 to t_2
 - Limiting (steady-state, asymptotic) availability as time (t_2) becomes large
- ◆ **For additional information**
 - See [Availability Types and Formulas for Inherent Availability](#)

Types of Availability (continued)

- ◆ Tip: Start with **Inherent Limiting Availability**.
 - There is much to do even with this form of availability. See [RMA Tasks](#)
- ◆ Why?
 - From a design point of view and especially in regards to collecting input data, determining inherent availability **is easier than** achieved availability, and determining achieved availability **is easier than** operational availability. Operational availability especially involves resources and trade-offs external to the design engineering organization—and **many times this data does not exist**.
- ◆ Note: Point in time vs. or Near-term time interval vs. Time is infinite:
 - Both Point and Average Availabilities in time converge to Limiting Availability
 - **Infinity sometimes is not that far away!** For example, within six-decimal places (0.995025), Point Availability equals Limiting Availability when mission time = 90 time units, MTBF = 2000, MTTR = 10, and the availability math model uses constant failure rate and constant repair rate.

Using RMA to make likelihood in a risk statement

- ◆ When risk is viewed only as potential loss, “potential” is the likelihood (probability) that a scenario and associated “loss” will occur.
 - For a brief summary on risk, see [Risk Concept & Operation](#)
- ◆ Use the complement of the R, M, or A probabilities to make the failure probability. That is,
 - $1-R$, $1-M$, or $1-A = p_f$
- ◆ Tip: To approximate $1-A$ as Limiting Unavailability:
 - $1-A \approx \text{MTTR}/\text{MTBF} = (1-A)/A = \lambda/\mu$
 - For an Excel illustration, see Worksheet 2 in [RMA Dashboard](#)

Why say RMA and not RAM?

- ◆ “Say it the way we should do it.”
 - “... the words you have at your disposal frame how you [and our decision makers] see the world.”
- ◆ That is ...
 - First, design for reliability (**DfR**).
 - Second, if reliability is not sufficient, design for maintainability (**DfM**).
 - When an item entails both R and M, the performance metric is availability (**A**) and is a mathematical function of R and M.
- ◆ Tip: If the forecasted A is less than the allocated “design to” specification, then **as a guideline**, increase R before decreasing M.

Inherent Limiting Availability as a Design Guideline

- ◆ When Inherent Limiting Availability (A_{inh}) is specified, then:
 - $MTTR = [(1 - A_{inh}) / (A_{inh})] * MTBF$
 - Or simply: $MTTR = \text{slope} * MTBF$ where slope is the **MTTR factor**
- ◆ Tip: In practice, the above equations should use \leq instead of $=$.
 - Thus, **MTTR** is an **upper-bound** value
 - And **MTBF** and **availability** are each **lower-bound** “design to” values
- ◆ Tip: Availability measures typically relate to one of four combinations of R and M (each being either high or low).
 - Two combinations provide the same availability measure; **one combination can be unsafe** when compared to the other combination
 - See next page for details

Availability and the Four Combinations of R and M

- ◆ Preferences 2 and 3 can make same availability measure
- ◆ Preference 2 has less risk than preference 3

Reliability	Maintainability	Preference
High	Low	# 1
High	High	# 2
Low	Low	# 3
Low	High	# 4

- ◆ To explore these combinations, see the [RMA Quantitative Relationships](#) and/or the [RMA Dashboard](#) Excel files

Modeling uptime (reliability) for a single repairable item

- ◆ The Weibull distribution for example can model uptime data for a single repairable item when the repair process is “as-good-as-new.” However,
- ◆ When the **renewal process** is not restored to its original condition, the average or mean time between failure (MTBF) will change (i.e., typically decrease over time due to minimal repair).
- ◆ As the result of **minimal repair**, the **intensity function** is used (or least determine if needed) instead of the **hazard rate function**.
 - When the times to failure data are not reordered from small to large, the [Laplace Test](#) can be used to test for a trend.
 - A Laplace Test score around zero means the process is stationary (defined on next page). Thus, the MTBF is constant and is not changing over time.

Modeling an uptime state or mission readiness (availability) for a repairable system

- ◆ In general, the Boolean formulas that model system reliability also model system availability.
- ◆ Tip: The union of all failure events from numerous independent renewal processes is called a **superimposed renewal process**.
 - This process in time will become a [homogenous Poisson process](#) (HPP) ideally if each item in the system has failed at least one time.
 - The **Poisson distribution function** describes failure events that occur randomly and at a constant average rate.
 - An HPP is a **stationary point process** since the distribution of the number of events in a interval of fixed length does not vary, regardless of when (where) the interval is sampled. (Ref. O'Connor, 4th ed)
- ◆ Although each item may have a nonconstant failure rate, **eventually a steady-state failure rate for the system is observed**.

Establishing the Availability Requirement

- ◆ Availability as with any goal or specification that pertains to an **operational** (as opposed to a **physical**) characteristic of an item:
 - Is more from human judgement than engineering.
 - Is a probability value in the interval **from demonstrated** past performance (or peer performance) **to predicted** potential performance.
 - In spite of the reliance on probabilistic (as opposed to deterministic) thinking, analytical methods are used such as:
- ◆ Rule of Thumb:
 - 1 per 1,000,000 \approx 1/16-inch per one mile (actually, 98.64% of 1 mile).
 - p_f is related to a **concrete concept** instead of an abstract one (e.g., 10^{-6})!
- ◆ Tool (calculator):
 - Mission vs. Program Reliability: [Probability of x or more events](#)

What is the availability of your electricity provider?

- ◆ How much **unavailability** and associated **downtime** can you accept?

IF		THEN			
Probability electric power is ...		Expected electric power unavailability in one year is ...			
On	Off	Seconds	Minutes	Hours	Days
0	1	31,536,000.00	525,600.00	8,760.00	365.00
0.9	0.1	3,153,600.00	52,560.00	876.00	36.50
0.99	0.01	315,360.00	5,256.00	87.60	3.65
0.999	0.001	31,536.00	525.60	8.76	0.37
0.9999	0.0001	3,153.60	52.56	0.88	0.04
0.99999	0.00001	315.36	5.26	0.09	0.00
0.999999	0.000001	31.54	0.53	0.01	0.00
0.9999999	0.0000001	3.15	0.05	0.00	0.00

Tools: Allocating and Reporting Availability

- ◆ Allocate availability with or without margin:
 - The last worksheet in this Excel file [RMA Quantitative Relationships](#) equally allocates availability of a system to serial subsystems.
 - This method provides a minimum-bound “design to” availability goal for each subsystem.
 - Regardless the math models used, the reliability (availability) at **the system level is never greater than** the particular serial subsystem containing the lowest reliability (availability) .
- ◆ Rolling up, assessing, and reporting RMA from the subsystem level to the system level:
 - This Excel file [RMA Dashboard](#) provides a work process with example that enters (posts) serial subsystem MTBF and MTTR values and then calculates reliability and the three types of availability (based on constant failure and repair rates) both at the subsystem and system level levels.

Reference

Presentation Hyperlinks

[Availability Types and Formulas for Inherent Availability](#)

[RMA Tasks](#)

[Risk Concept & Operation](#)

[RMA Dashboard](#)

[RMA Quantitative Relationships](#)

[Laplace Test](#)

[homogenous Poisson process](#)

[Probability of x or more events](#)

URLs from “KSC Reliability”

<https://kscddms.ksc.nasa.gov/Reliability/Availability.html>

https://kscddms.ksc.nasa.gov/Reliability/Documents/160122_RM_A_Tasks.pdf

https://kscddms.ksc.nasa.gov/Reliability/Documents/181120_Risk_concept_and_operation.pdf

https://kscddms.ksc.nasa.gov/Reliability/Documents/170310.4_RMA_Dashboard_with_example.xlsm

https://kscddms.ksc.nasa.gov/Reliability/Documents/190910_RM_A_Quantitative_Relationships_and_Allocate_Availability.xlsm

https://kscddms.ksc.nasa.gov/Reliability/Documents/Laplace_Test.pdf

https://kscddms.ksc.nasa.gov/Reliability/Documents/160503_Poisson_Process_Prob_of_r_or_less_events_in_a_time_interval.xlsx

<https://kscddms.ksc.nasa.gov/Reliability/Documents/Binomial/reliabilityProb.xls>