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OSA® Product Reliability and MTBF/MTTF Data

Bedrock Technical Paper BRTP001_02

Table of Contents

Revision History

Revision	Date	Description
1.0	22-Feb-2021	Initial release
1.1	06-Apr-2021	Minor content changes were made in this release. The data in the last row (BRSCS010) of Table 2 in Section 7.2 was also updated.

Abbreviations and Acronyms

Acronym	Meaning
ALT	Accelerated Life Testing
AF	Acceleration Factor
BMI	Backplane Magnetic Interface
CL	Confidence Level or Confidence Limit
E	Activation Energy Per Molecule
EPSMA	European Power Supply Manufacturers' Association
FEMA	Failure Mode and Effects Analysis
FIT	Failure in Time
FRACAS	Failure Reporting, Analysis and Corrective Action System
IC	Integrated Circuit
IO or I/O	Input / Output
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
MTBF	Mean Time Between Failures
MTTF	Mean Time to Failure
MTTR	Mean Time to Repair
SIO	Secure Input/Output Module
RBD	Reliability Block Diagram
SCC	Secure Control & Communication Module
SPM	Secure Power Module

1 Introduction

The industrial automation world is preoccupied with quality and reliability and rightly so, since these factors determine the efficacy of our processes and, ultimately, the availability, safety, and profitability of our enterprises.

Quality and reliability are closely related. Quality normally focuses on the lack of defects, whereas reliability relates to whether something is suitable or dependable for its intended use. Combined, these two factors relate directly to the value we perceive for a given product or service. Our business-related activities depend on extracting the highest value from the things we acquire and use to maximize efficiency, safety, and profitability. Therefore, we seek the highest quality and greatest reliability.

Since these requirements are fundamental, we are left with the difficult issue of how to quantify quality and dependability. The most assured approach would be to look at a historical database of performance and reach a conclusion from the perspective of hindsight. Unfortunately, the exigencies of modern life do not allow for such protracted and stale analysis and consequently we must look at other methods to assess a product and its value to us.

One method is to model the product performance mathematically, to project the anticipated dependability and, relatedly, the quality of the supply. This paper details the methods of Mean Time Between Failures (MTBF) and Mean Time to Failure (MTTF) as assessments of quality and reliability for the Bedrock Automation OSA® products.

2 Objective

This technical paper will explore the results of calculations that were performed to determine the MTBF and MTTF of the Bedrock OSA® Secure Controllers, Power, I/O, and Gateway Modules and associated Backplane Assemblies. Calculations were performed using the Relyence Studio suite of reliability and quality softwareanalysis with integrated Failure Mode and Effects Analysis (FMEA), Failure Reporting, Analysis and Corrective Action System (FRACAS), Fault Tree, Reliability Prediction, Maintainability Prediction, Reliability Block Diagrams (RBD), Weibull Analysis, and Accelerated Life Testing (ALT) Analysis. The Bedrock OSA® products that were analyzed as well as the calculation methods used are described in further detail in the following sections.

3 Reliability Concepts and Terminology

This section provides an overview of concepts and terminology used in the reliability predictions and calculations presented in this paper. Information from Guidelines to Understanding Reliability Prediction (European Power Supply Manufacturers' Association, 24 June 2005) is used for this purpose.

3.1 Reliability Definition

A practical definition of reliability is "the probability that a piece of equipment operating under specified conditions shall perform satisfactorily for a given period of time." The reliability is a number between 0 and 1.

3.2 Failure Rate

Every product has a failure rate, λ, which is the number of units failing per unit of time. This failure rate changes throughout the life of the product. That gives us the curve, shown below, that shows the failure rate to operating time for a population of any product. It is the manufacturer's aim to ensure that product in the early failure period never reaches the customer, leaving a product with a useful life period where failures occur randomly and λ is constant followed by a wear-out failure period, usually beyond the product's useful life, where λ begins to increase.

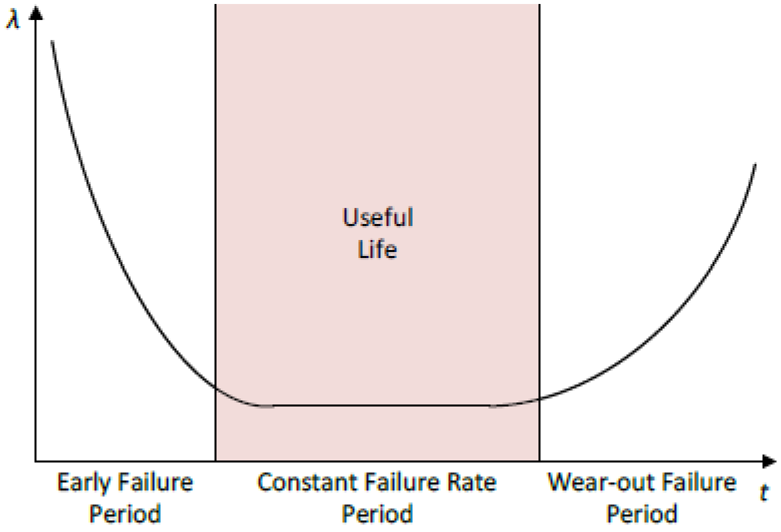


Figure 1 Failure Rate vs. Time

3.3 Definition of MTBF and MTTF

Mean time between failures (MTBF) and mean time to failure (MTTF) are defined as:

> Mean time between failures (MTBF) is the predicted elapsed time between inherent failures of a mechanical or electronic system, during normal system operation. MTBF can be calculated as the arithmetic mean (average) time between failures of a system. The term is used for repairable systems, while mean time to failure (MTTF) denotes the expected time to failure for a non-repairable system.

MTBF is a crucial maintenance metric to measure performance, safety, and equipment design, especially for critical or complex assets, like industrial controllers.

It is also used to determine the reliability of an asset. A desired MTBF can be used as a quantifiable objective when designing a new product. The MTBF figure can be developed as a result of intensive testing, based on actual product experience, or predicted by analyzing known factors. The latter being the approach taken in this paper.

The manufacturer may provide it as an index of a product’s or component’s reliability and in some cases, to give customers an idea of how much service to plan for. Most sources define this term to mean “average time between failures.”

As the definition implies, MTBF applies to equipment that is going to be repaired and returned to service while MTTF applies to parts that will be thrown away upon failing. During the “useful life period,” assuming a constant failure rate, MTBF is the inverse of the failure rate and we can use the terms interchangeably:

$$MTBF = \frac{1}{\lambda}$$

Many people misunderstand MTBF and wrongly assume that the MTBF figure indicates a minimum, guaranteed time between failures. If failures occur randomly, then they can be described by an exponential distribution:

$$R(t) = e^{-\lambda t} = e^{\frac{-t}{MTBF}}$$

After a certain time, t which is equal to the MTBF reliability, R(t) becomes:

$$R(t) = e^{-1} = 0.37$$

This value can be interpreted several ways:

- For a large number of units, only 37% of their operating times will be longer than the MTBF figure.
- For a single unit, the probability that it will work for as long as its MTBF figure, is only about 37%.
- We can say that the unit will work for as long as its MTBF figure with a 37% confidence level.

To put these numbers into context, let us consider a power supply with an MTBF of 500,000 hours, (a failure rate of 0.2%/1,000 hours), or in advertising terms, an MTBF of 57 years.

From the equation for R(t), we calculate that at 3 years (26,280 hours) the reliability is approximately 0.95, assuming the unit is used 24 hours a day for 3 years, so the probability of it surviving that time is about 95%. The same calculation for a 10-year period will give an R(t) of about 84%.

Now let us consider a customer who has 700 such units. Since we can expect, on average, 0.2% of units to fail per 1,000 hours, the number of failures per year is:

$$\frac{0.2}{100} \times \frac{1}{1000} \times 700 \ \times 24 \ \times 365 \ = 12.26$$

3.4 Definition of FIT

Failure in Time (FIT) is another way of reporting MTBF. FIT reports the number of expected failures per one billion hours of operation for a device. This term is commonly used by the semiconductor industry but is also used by component manufacturers.

FIT can be quantified several ways:

- 1,000 devices for 1 million hours each
- 1 million devices for 1,000 hours each
- As well as other combinations

FIT and Confidence Limits (CL) are often provided together. In common usage, a claim to 95% confidence in something is normally taken as indicating virtual certainty. In statistics, a claim to 95% confidence simply means that the researcher has seen something occur that only happens one time in twenty or less.

For example, component manufacturers will take a small sampling of a component, test *x* number of hours, and then determine if there were any failures in the sample run. Based on the number of failures that occur, the CL will then be provided as well.

The formula to calculate FIT from MTBF is:

$$FIT = \frac{1}{MTBF\ Hours} \times 10^9$$

3.5 What is Service Life, Useful Life, Mission Life?

Note that there is no direct connection or correlation between service life and failure rate. It is possible to design a very reliable product with a short life. For example, a rocket must be extremely reliable (MTBF of several million hours), but it has a service life of only 4 minutes. Another example, 25-year-old humans have an MTBF of about 800 years (λ about 0.1%/year), but not many have a comparable service life. Just because something has a good MTBF does not necessarily mean that it has a long service life as well. The figure below shows some examples of service life versus MTBF.

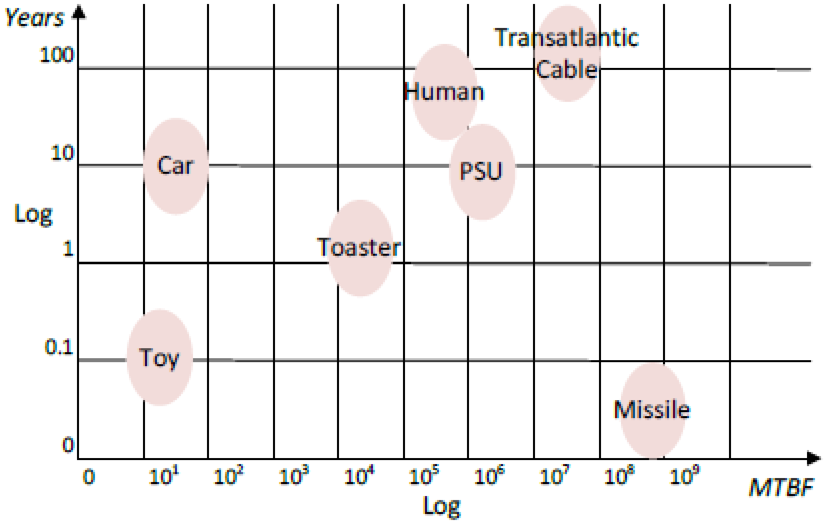


Figure 2 Service Life vs. MTBF

3.6 Reliability Prediction

A reliability prediction is the analysis of parts and components of a module to predict the rate at which an item fails. The prediction describes the process used to estimate the constant failure rate during the useful life of a product. This, however, is not possible because predictions assume that:

- The design is perfect, the stresses are known, and everything is always within ratings so that only random failures occur.
- Every failure of every part will cause the equipment to fail.
- The database is valid.

These assumptions are sometimes wrong. The design can be less than perfect, not every failure of every part will cause the equipment to fail, and the database is likely to be years out-of-date. However, none of these matters much if the predictions are used to compare different topologies or approaches rather than to establish an absolute figure for reliability. These are what predictions were originally designed for.

Some prediction manuals allow the substitution and use of vendor reliability data where such data is known instead of the recommended database data. Such data is very dependent on the environment under which it was measured and so, predictions based on such data could no longer be depended upon for comparison purposes.

A reliability prediction is usually based on an established model for electronic and mechanical components. These models provide procedures for calculating failure rates for components.

An overall system reliability prediction can be made by looking at the reliabilities of the components that make up the whole system or product. The prediction model used in this paper is MIL-HDBK-217F(N2).

3.7 Reliability Tests – Accelerated Life Testing

Life testing can be used to provide evidence to support predictions calculated from reliability models. This testing can be performed either by testing a quantity of units at their normal operating conditions, say 25°C, or under more extreme conditions to accelerate the failure mechanism. The latter method is known as accelerated life testing (ALT) and it is based on failures being attributed to chemical reactions within electronic components. This mechanism was described by physicist and chemist Svante Arrhenius at the turn of the twentieth century, and it can be used to predict how much MTTF will be reduced from its value at our example of 25°C and how tests at higher temperatures can accelerate failure and reduce the test time.

This section will look briefly at life testing at 25°C using the principles of Arrhenius to predict MTTF at other temperatures and to accelerate life testing.

To test the reliability of a product at 25°C, a reasonable number of about 100 units would be subjected to continuous, not cycled, testing in accordance with MIL-HDBK-781, Test Plan VIII-D at nominal input and maximum load for about 1 year. Test parameters include a discrimination ratio of 2 and a decision risk of 30% for each.

If there are any failures, the test time is extended. For example, with two failures, the test is continued to twice the minimum length of time. Preferably, the test would be continued indefinitely even if there were no failures, until the space is needed for another product. Every failure would be analyzed for the root cause and if that resulted in a component or design change, all the test subjects would be modified to incorporate the change and the test would be restarted.

One real-world example came from the experience of a power supply manufacturer. Over eight years, only two products failed during life testing. These were due to a MOSFET chip and a capacitor not meeting specification. The MOSFET chip increased temperature after several months and was found to be from a faulty batch that had voids under the chip. The capacitors were found to have microfractures that led to short circuits over time.

The MTTF demonstrated by life tests under representative operating conditions is often found to be many times longer than the calculated value, and it has the benefit of providing operational evidence of reliability.

If predictions are required for higher temperatures, then the tests at 25°C can be used with an acceleration factor to predict the reduced MTTF at elevated temperature. Alternatively, if units are tested at temperatures higher than 25°C, then an acceleration factor again applies. In this situation, the time to failure is accelerated by the increased stress of higher temperatures and the test time to calculate MTTF at 25°C can be reduced.

The Acceleration Factor (AF) is calculated from the formula below. In practice, an assumption must be made on a value for *E*, the activation energy per molecule. This depends on the failure mechanism and can vary. Different data sources show *E* from less than 0.3eV, the gate oxide defect in a semiconductor, to more than 1.1eV, the contact electro-migration.

$$AF = \frac{tf_1}{tf_2} = exp\left(\frac{\mathrm{E}}{k}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right)$$

where:

tf_1 = time to failure at temperature T_1
tf_2 = time to failure at temperature T_2
T_1, T_2 = temperature in Kelvins
E = activation energy per molecule (eV)
k = Boltzman's constant (8.617×10^{-5} (eV/K))

3.8 Reliability Block Diagram (RBD)

An RBD is a diagrammatic method for showing how component reliability contributes to the success or failure of a complex system.

An RBD is drawn as a series of blocks connected in a parallel or series configuration. Each block represents a component of the system with a failure rate. Parallel paths are redundant meaning all the parallel paths must fail for the system to fail. By contrast, any failure along a series path causes the entire series path to fail.

To construct an RBD, the reliability prediction of each module in the system must be determined first. Each module's reliability prediction model is then added to the RBD as a block of the system.

Each block of the system can then be set in one of the following configurations:

- Nonredundant series configuration
- Redundant parallel configuration
- Redundant cold standby configuration
- Redundant hot standby configuration

3.9 MTBF/MTTF Analysis Process

The MTBF/MTTF analysis process is summarized below.

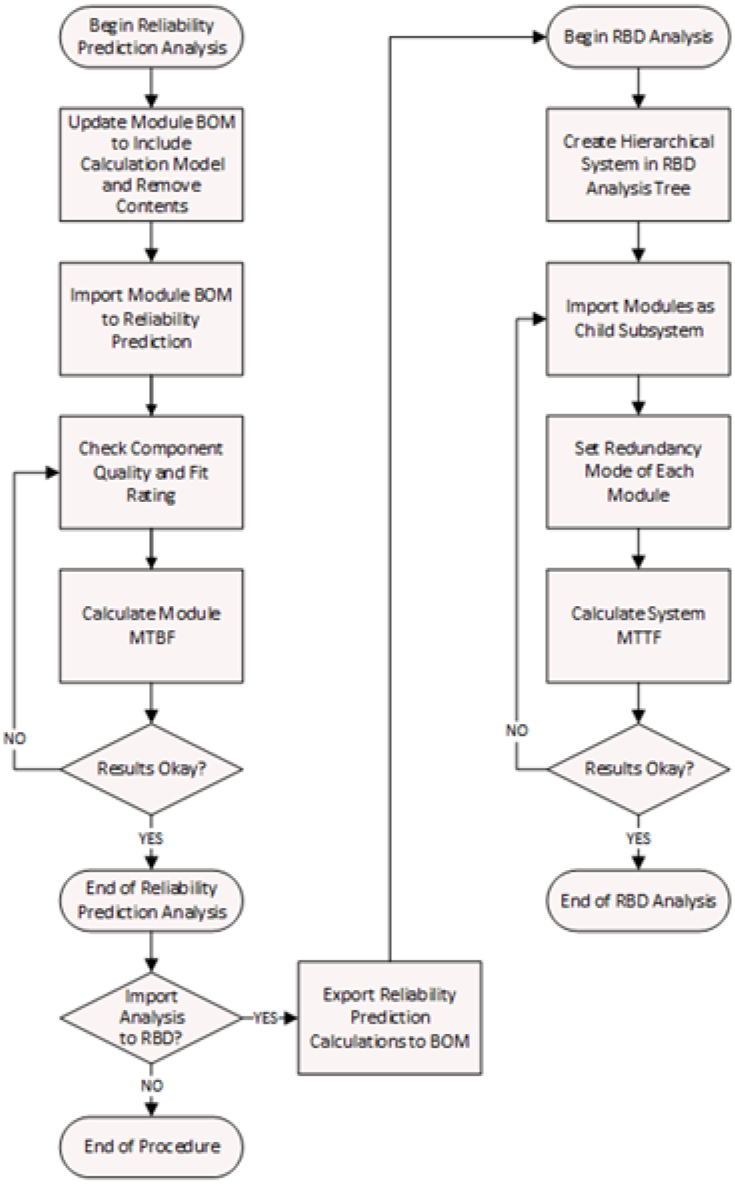


Figure 3 The MTBF/MTTF Analysis Process

4 MIL-HDBK-217

MIL-HDBK-217, Military Handbook, Reliability Prediction of Electronic Equipment, is published by the Department of Defense, based on work done by the Reliability Analysis Center and the Rome Laboratory at Griffiss AFB, NY. It is the original reliability prediction handbook and it provided guidance for performing the calculations in this paper.

The handbook contains failure rate models for the various part types used in electronic systems, such as ICs, transistors, diodes, resistors, capacitors, relays, switches, and connectors. These failure rate models are based on the best field data that could be obtained for a wide variety of parts and systems. This data is then analyzed and adjusted, with many simplifying assumptions applied, to create usable models.

The latest version of the handbook is MIL-HDBK-217F, Notice 2 also referred to as MIL-HDBK-217 F(N2).

5 Relyence Software

The Relyence Studio integrated platform with reliability prediction and RDB was used to configure the Bedrock Automation OSA® product for MTBF and MTTF analysis and to report the calculated results.

The Relyence Studio includes the following features:

- Reliability prediction
- Support for MIL-HDBK-217F
- Reliability block diagrams for creating models incorporating series, parallel, and hot and cold standby redundancy configurations.
- Calculation of metrics including reliability, availability, downtime, failure frequency, MTTR, MTBF, and path sets with a calculation engine supporting analytical calculations and Monte Carlo simulation.
- Sub-diagrams for diagram organization and reusability

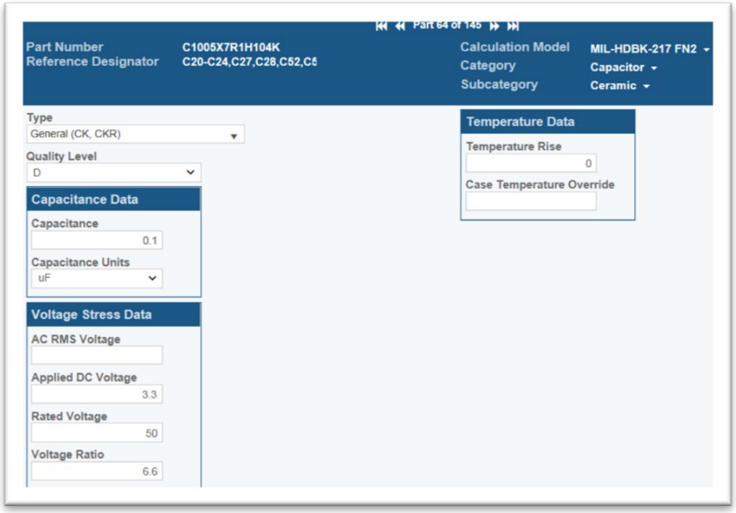
5.1 Settings

This section covers some of the Relyence Software settings used in analysis of the Bedrock Automation OSA® product. Shown below are the settings for an electrolytic capacitor with an FIT rating.

Part Number	Calculation Model	Category	Subcategory	Type	Quantity	Reference Designator	Description	Failure Rate, Override
TLJP107M006R540	MIL-HDBK-217 FN2	Capacitor	Electrolytic	Tantalum, Solid (CSR)	14	C2,C3,C58,C62,C69 ,C84,C93,C94,C108	CAP TANT 100UF 6.3V 20% 0805	7.60000

Figure 4 Example of a Relyence Software component with an FIT Rating

Similarly, below are the settings for a ceramic capacitor with no FIT rating.



Part Number C1005X7R1H104K
Reference Designator C20-C24,C27,C28,C52,C5
Calculation Model MIL-HDBK-217 FN2
Category Capacitor
Subcategory Ceramic

Type General (CK, CKR)
Quality Level D

Capacitance Data
Capacitance 0.1
Capacitance Units uF

Voltage Stress Data
AC RMS Voltage
Applied DC Voltage 3.3
Rated Voltage 50
Voltage Ratio 6.6

Temperature Data
Temperature Rise 0
Case Temperature Override

Figure 5 Example of a Relyence Software component without an FIT Rating

A Relyence Parts Library was created that contained all the components used on every Bedrock Automation OSA® product. Once a component has been entered into a board specific analysis, the operating voltage and temperatures can be modified to the specific board operating environment.

The analysis required the following Library parameters to be entered for each component:

- Manufacturer Part Number
- Calculation model, i.e., MIL-HDBK-217 F(N2)
- Component Category, i.e., Semiconductor
- Component Subcategory, i.e., Diode
- Type, i.e., General Purpose
- Quantity of that component on the board
- Schematic Reference Designator of the component, i.e., CR113
- Part Description

If a FIT rating for a component is available, the above parameters will be overridden by the entered FIT rating.

6 Standalone and Redundant Configurations

MTBF and MTTF analysis was performed on Bedrock OSA® products in the configurations listed in the following sections.

6.1 Standalone

A standalone configuration is one in which the unit being evaluated is not placed in a redundant or series configuration with other units. The MTBF value is based on the components contained within the units being analyzed.

6.2 Series

A series configuration has no redundancy. Units are connected in sequence. All units must be operating for the system to successfully function.

For Bedrock OSA® products, this applies to discrete output modules.

6.3 Cold Standby

In cold standby, identical units are placed in a redundant configuration but the backup unit is not functioning. If the operational unit fails, the backup will become operational.

No evaluation was performed on Bedrock OSA® products in a cold standby configuration.

6.4 Hot Standby

Hot standby is similar to cold standby except the redundant unit is active. When a failure occurs, the backup unit keeps the system operating.

6.5 Parallel Redundancy

In a parallel configuration, all units are operating all the time. A designated quantity is required to keep the system operating.

7 Summary

Results of MTBF/MTTF analysis of Bedrock Automation OSA® products are present in the following sections. Results are grouped by type of configuration. The temperature indicated in the column headings is the ambient temperature of the module. A rise of 15°C occurs inside the module. This was determined during UL testing.

7.1 Bedrock Automation OSA® Product Descriptions

Below is a list of each Bedrock Automation OSA® product analyzed along with a simple description.

Table 1 List of Bedrock Automation OSA® products analyzed.

Bedrock Product No.	Description
BRBMI010	Backplane Module Interconnect, 2 SPM, 2 SCC, 10 pin-less SIO, Black Fabric® electromagnetic coupling to every I/O slot
BRSCC100	Secure Control & Communication Module, Single/Dual Redundant, cyber secure multi-core processor w adv RTOS
BRSCCF00	Secure Control & Communication Module w Flow Computing, Single/Dual Redundant, cyber secure processor w adv RTOS
BRSCS010	Secure Control & Communication Module, Single, Cyber secure, multi-core processor w adv RTOS
BRSCS050	Secure Control & Communication Module, Single, Cyber secure, multi-core processor w adv RTOS
BRSPM024	Secure Power Module, 24 V dc Power Input, BMI Mounted, Single/Dual Redundant, secure 24 V dc output up to 5 A
BRSPM100	Secure Power Module, Universal Power Input, BMI Mounted, Single/Dual Redundant, secure 24 V dc output up to 5 A
BRSIO105	Secure I/O Module, Universal 5 Channel, Analog Input/Output, Channel Isolated, soft-selectable universal analog I/O
BRSIO210	Secure I/O Module, Universal 10 Channel, Discrete Input, Channel Isolated, soft-selectable universal discrete input
BRSIO310	Secure I/O Module, Universal 10 Channel, Discrete Output, Channel Isolated, soft-selectable universal discrete output
BRSIO510	Secure I/O Module, High-Speed 10 Channel, Discrete Input, Group Isolated, soft-selectable high-speed discrete input
BRSIO620	Secure I/O Module, 20 Channel, Analog Input, Group Isolated, high density analog input

Bedrock Product No.	Description
BRSIO720	Secure I/O Module, 20 Channel, Discrete Input, Channel Isolated, high density discrete input
BRSIO820	Secure I/O Module, 20 Channel, Discrete Output, Channel Isolated, high density discrete output
BRSIOU10	Secure I/O Module, Universal 10 Channel, Input/Output, Channel Isolated, soft-selectable universal I/O
BRUCG100	Universal Control Gateway Module, 5 Channel, Ethernet, Channel Isolated, 10/100 Mbps, PoE on all channels
BROSAR20 BROSAR2H	Secure Remote Controller, Universal Input/Output, 20 Channel, 8 or 32 GB flash, cyber secure, multi-core processor w. adv. RTOS
BROSAR10 BROSAR1H	Secure Remote Controller, Universal Input/Output, 10 Channel, 8 or 32 GB flash, cyber secure, multi-core processor w. adv. RTOS
BROSAF20	Secure Remote Controller w Flow Computing, 20 Universal I/O, 64 GB flash, cyber secure, multi-core processor w. adv. RTOS
BROSAF10	Secure Remote Controller w Flow Computing, 10 Universal I/O, 64 GB flash, cyber secure, multi-core processor w. adv. RTOS
BRUPS500	Cyber Secure Uninterruptible Power Supply, 24 V dc, 12 Ah, Lithium-Ion batteries, panel/wall/pipe mountable
BRSPS500	Cyber Secure Power Supply, 24 V dc, 500 W, Worldwide voltage & frequency, panel/wall/pipe mountable
PWARTUCPU	Printed Wiring Assembly associated with all Secure Control and Communication Modules
PWARTUIO2	Printed Wiring Assembly associated with all Secure I/O Modules
PWARTUIO1	Printed Wiring Assembly associated with all Secure I/O Modules
PWAFLOCPU	Printed Wiring Assembly associated with Secure Control and Communication Modules w Flow Computing

7.2 Standalone Summary

MTBF results for Bedrock OSA® individual modules evaluated in a standalone configuration are listed below.

Table 2 MTBF Results for Standalone Modules

Bedrock Product No.	MTBF Hours @ 25^{0}C	MTBF Years @ 25^{0}C	MTBF Hours @ 55^{0}C	MTBF Years @ 55^{0}C	MTBF Hours @ 75^{0}C	MTBF Years @ 75^{0}C
BRBMI010	3,420,373	390.45	2,095,655	239.23	1,581,730	180.56
BRSIO105	385,921	44.06	241,683	27.59	173,101	19.76
BRSIO210	702,318	80.17	422,995	48.29	286,482	32.70
BRSIO310	433,862	49.53	264,063	30.14	191,644	21.88
BRSIO510	1,071,197	122.28	615,248	70.23	425,661	48.59
BRSIO620	726,666	82.95	435,677	49.74	312,652	35.69
BRSIO720	881,442	100.62	500,366	57.12	347,689	39.69
BRSIO820	470,987	53.77	267,764	30.57	184,096	21.02
BRSIOU10	716,231	81.76	443,429	50.62	300,190	34.27
BRUCG100	503,854	57.52	265,501	30.31	169,937	19.40
BRSPM024	864,734	98.71	519,702	59.33	351,985	40.18
BRSPM100	696,707	79.53	415,315	47.41	279,171	31.87
BRSCC100	452,828	51.69	259,132	29.58	174,724	19.95

Bedrock Product No.	MTBF Hours @ 25⁰C	MTBF Years @ 25⁰C	MTBF Hours @ 55⁰C	MTBF Years @ 55⁰C	MTBF Hours @ 75⁰C	MTBF Years @ 75⁰C
BRSCCF00	410,125	46.82	241,452	27.56	163,301	18.64
PWARTUCPU	517,745	59.10	304,902	34.81	205,765	23.49
PWARTUIO2	519,876	59.35	295,204	33.70	188,047	21.47
PWARTUIO1	977,341	111.57	554,791	63.33	355,617	40.60
PWAFLOCPU	501,987	57.30	300,099	34.26	202,416	23.11
BRSCS050	534,269	60.99	332,777	37.99	235,953	26.94
BRSCS010	517,555	59.08	320,785	36.62	226,790	25.89

MTTF results for Bedrock Automation OSA® systems evaluated in a standalone configuration are listed below.

Table 3 MTTF Results for Standalone Systems

Bedrock Product No.	MTTF Hours @ 25⁰C	MTTF Years @ 25⁰C	MTTF Hours @ 55⁰C	MTTF Years @ 55⁰C	MTTF Hours @ 75⁰C	MTTF Years @ 75⁰C
BROSAR20/BROSAR2H	259,638	29.64	149,987	17.12	98,254	11.22
BROSAR10/BROSAR1H	338,850	38.68	196,764	22.46	130,345	14.88
BROSAF20	255,270	29.14	148,828	16.99	97,656	11.15
BROSAF10	331,645	37.86	194,753	22.23	129,359	14.77
BRUPS500	183,479	20.95	113,621	12.97	N/A	N/A
BRSPS500	497,042	56.74	305,364	34.86	224,791	25.66

7.3 Series Summary

MTTF results for Bedrock OSA® dual modules evaluated in a series configuration are listed below.

Table 4 MTTF Series Results

Bedrock Product No.	MTTF Hours @ 25⁰C	MTTF Years@ 25⁰C	MTTF Hours @ 55⁰C	MTTF Years @ 55⁰C	MTTF Hours @ 75⁰C	MTTF Years @ 75⁰C
BRSIOU10	358,115	40.88	229,086	26.15	150,096	17.13

7.4 Redundant Hot Standby Summary

MTTF results for Bedrock OSA® dual modules evaluated in a redundant, hot standby configuration are listed below.

Table 5 Redundant Hot Standby Results

Bedrock Product No.	MTTF Hours @ 25⁰C	MTTF Years @ 25⁰C	MTTF Hours @ 55⁰C	MTTF Years @ 55⁰C	MTTF Hours @ 75⁰C	MTTF Years @ 75⁰C
BRSIO105	578,881	66.08	362,565	41.34	259,652	29.64
BRSIO210	1,053,477	120.26	634,492	72.43	429,723	49.06
BRSIO310	650,792	74.29	396,094	45.22	287,465	32.82
BRSIO510	1,606,795	183.42	922,872	105.35	638,492	72.89

Bedrock Product No.	MTTF Hours @ 25^0C	MTTF Years @ 25^0C	MTTF Hours @ 55^0C	MTTF Years @ 55^0C	MTTF Hours @ 75^0C	MTTF Years @ 75^0C
BRSIO620	1,089,999	124.43	653,515	74.60	468,978	53.54
BRSIO720	1,322,164	150.93	750,212	85.64	521,533	59.54
BRSIO820	706,480	80.65	401,646	45.85	276,144	31.52
BRSIOU10	1,074,346	122.64	665,145	75.93	450,286	51.40
BRUCG100	755,783	86.28	398,252	45.46	254,905	29.10
BRSPM024	825,522	94.24	779,5523	88.99	527,977	60.27
BRSPM100	1,045,061	119.30	622,973	71.12	418,756	47.80
BRSCC100	679,241	77.54	387,957	44.29	262,086	29.92
BRSCCF00	615,188	70.23	362,179	41.35	244,951	27.96

MTTF values were calculated for a BRUPS500 serving as a hot standby backup to a BRSPS500. The MTTF results for that configuration are listed below.

Table 6 Results for BRUPS500 as Hot Standby to BRSPS500

Bedrock Product No.	MTTF Hours @ 25^0C	MTTF Years @ 25^0C	MTTF Hours @ 55^0C	MTTF Years @ 55^0C	MTTF Hours @ 75^0C	MTTF Years @ 75^0C
BRUPS500/BRSPS500	194,375	22.19	119,701	13.66	N/A	N/A

8 Conclusion

Estimating dependability and reliability has always been a difficult and complex mathematical concept. Using the tools presented herein, it can be demonstrated that through advanced and varied testing conditions and utilizing standards-based software applications, the Bedrock OSA® products, in a multiplicity of hardware configurations, can provide the assurance of reliable performance.

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