# US Army Corps of Engineers – Power Reliability Enhancement Program (PREP)

## Applying availability methodology to resilient power system design

# PREP Overview

- Mission is to promote resiliency in mechanical and electrical utility systems that support C4ISR missions
  - Serve as a focal point for reliability
  - Establish criteria for Reliable Critical Facilities, 16 Army Technical Manuals
  - Assess facilities, remove vulnerabilities, specialized engineering studies
  - Sponsor research, maintain the Reliability Database
- Created in 1981 with DoD Executive Agent (EA) status
- EA status ended in 1997 but direct funding continues
- Budget is $1.6M Direct, $3-6M reimbursable funding annually
- PREP (9 Engineers) leverages other COE work centers
- Stakeholders: National Leadership Command Capabilities (NLCC) Program
  - Primary focus is Nuclear Forces Command, Control and Communications (NC3)
  - Any DoD customer with a critical mission
  - Includes HEMP mission
  - Includes support to classified programs (all engineers have TS/SCI clearances)

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# PREP Database

- The US Army Corps of Engineers database contains nameplate, failure, and maintenance information on a wide range of power system and facility equipment. Representing 280 distinct component types, the database includes 134 categories of electric power distribution equipment.
- Data collection efforts for the database began in the early 1990s and continued through 2005, with upcoming new data collection effort
- The resulting data represent over 60 years of equipment records
- Facilities are wide ranging in purpose and location, including a variety of hospitals, universities, commercial facilities, and military installations in North America, Europe, Asia, and Africa. The diversity of facilities ensures the database represents a wide range of equipment operating conditions
- The PREP database has been published in several iterations through US Army technical manuals and IEEE (Gold Book and std. 3006.8)
- PREP uses database information as a direct input to specialized availability assessments for critical facilities

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# PREP Database Example

| *CATEGORY* | *CLASS* | *Reliability* | *Inherent Availability* | *Operational Availability* | *Unit Years* | *Failures* | *Failure Rate (Failures/Year)* | *MTBF* | *MTTR* | *MTTM* | *MDT* | *MTBM* | *Hrdt/ Year* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Diesel Engine** | | 0.651452638 | 0.999057435 | 0.994845543 | 3045.1 | 1305 | 0.428550581 | 20441 | 19.29 | 2.02 | 3.08 | 594 | 45.15 |
| E18-111 | Generator, Diesel Engine, Packaged, < 250 KW, Continuous | 0.345225121 | | | 15.0 | 16 | 1.063558550 | 8237 | | | | 6589 | |
| E18-112 | Generator, Diesel Engine, Packaged, < 250 KW, Standby | 0.720658027 | 0.999542626 | 0.994522572 | 857.8 | 281 | 0.327590557 | 26741 | 12.24 | 1.69 | 4.88 | 886 | 47.98 |
| E18-121 | Generator, Diesel Engine, Packaged, 250 KW - 1.5 MW, Continuous | 0.558396351 | 0.998290551 | 0.996936663 | 266.0 | 155 | 0.582686262 | 15034 | 25.74 | 0.52 | 1.15 | 374 | 26.83 |
| E18-122 | Generator, Diesel Engine, Packaged, 250 KW - 1.5 MW, Standby | 0.779850883 | 0.999632636 | 0.996242682 | 1439.8 | 358 | 0.248652553 | 35230 | 12.95 | 1.72 | 2.63 | 698 | 32.91 |
| E18-211 | Generator, Diesel Engine, Unpackaged, 750 KW - 7 MW, Continuous | 0.162719469 | 0.994827956 | 0.981103812 | 180.6 | 328 | 1.815727610 | 4825 | 25.08 | 3.86 | 5.00 | 259 | 165.53 |
| E18-212 | Generator, Diesel Engine, Unpackaged, 750 KW - 7 MW, Standby | 0.557610976 | 0.998408415 | 0.992627628 | 285.9 | 167 | 0.584093735 | 14998 | 23.91 | 2.57 | 3.11 | 418 | 64.58 |
| **Gas Turbine** | | 0.610781174 | 0.998591901 | 0.990150892 | 983.7 | 485 | 0.493016528 | 17768 | 25.05 | 2.39 | 2.72 | 274 | 86.28 |
| E19-111 | Generator, Gas Turbine, Packaged, 750 KW - 7 MW, Continuous | 0.203786146 | 0.995065207 | 0.985283382 | 185.5 | 295 | 1.590684138 | 5507 | 27.31 | 0.83 | 1.23 | 82 | 128.92 |
| E19-112 | Generator, Gas Turbine, Packaged, 750 KW - 7 MW, Standby | 0.831497912 | 0.999872596 | 0.991118015 | 612.4 | 113 | 0.184526491 | 47473 | 6.05 | 4.40 | 4.42 | 493 | 77.81 |
| E19-211 | Generator, Gas Turbine, Unpackaged, 750 KW - 7 MW, Continuous | 0.660878067 | 0.997626147 | 0.991756384 | 185.9 | 77 | 0.414185923 | 21150 | 50.33 | 13.26 | 15.87 | 1909 | 72.21 |

# Availability Concepts

- The high cost associated with operational downtime increases the importance of understanding the reliability, availability, and maintainability of systems.
- Due to the complexity of electrical and mechanical cooling systems, empirical methods have been widely applied to system reliability prediction. The empirical prediction technique attempts to quantify failure prediction.
- Availability is defined as the ability of a product (or service) to be ready for use when the customer wants to use it – it is available if it is in customer possession and it works whenever it is turned on or used.
- If the product is "in the shop" for repair, or it is in customer possession, but doesn't work, then it is unavailable.

# Availability Concepts

- This results in the same level of availability can be achieved with different values of reliability and maintainability because reliability is a measure of how often a product fails and maintainability is a measure of how quickly it can be restored.

  **Inherent availability:** When only reliability and corrective maintenance or repair (i.e., design) effects are considered, we are dealing with inherent availability. This level of availability is solely a function of the inherent design characteristics of the system.

  **Operational availability:** Availability is determined not only by reliability and repair, but also by other factors related to preventative maintenance and logistics. When these effects of preventative maintenance and logistics are included, we are dealing with operational availability. Operational availability is a "real-world" measure of availability and accounts for delays such as those incurred when spares or maintenance personnel are not immediately at hand to support maintenance.

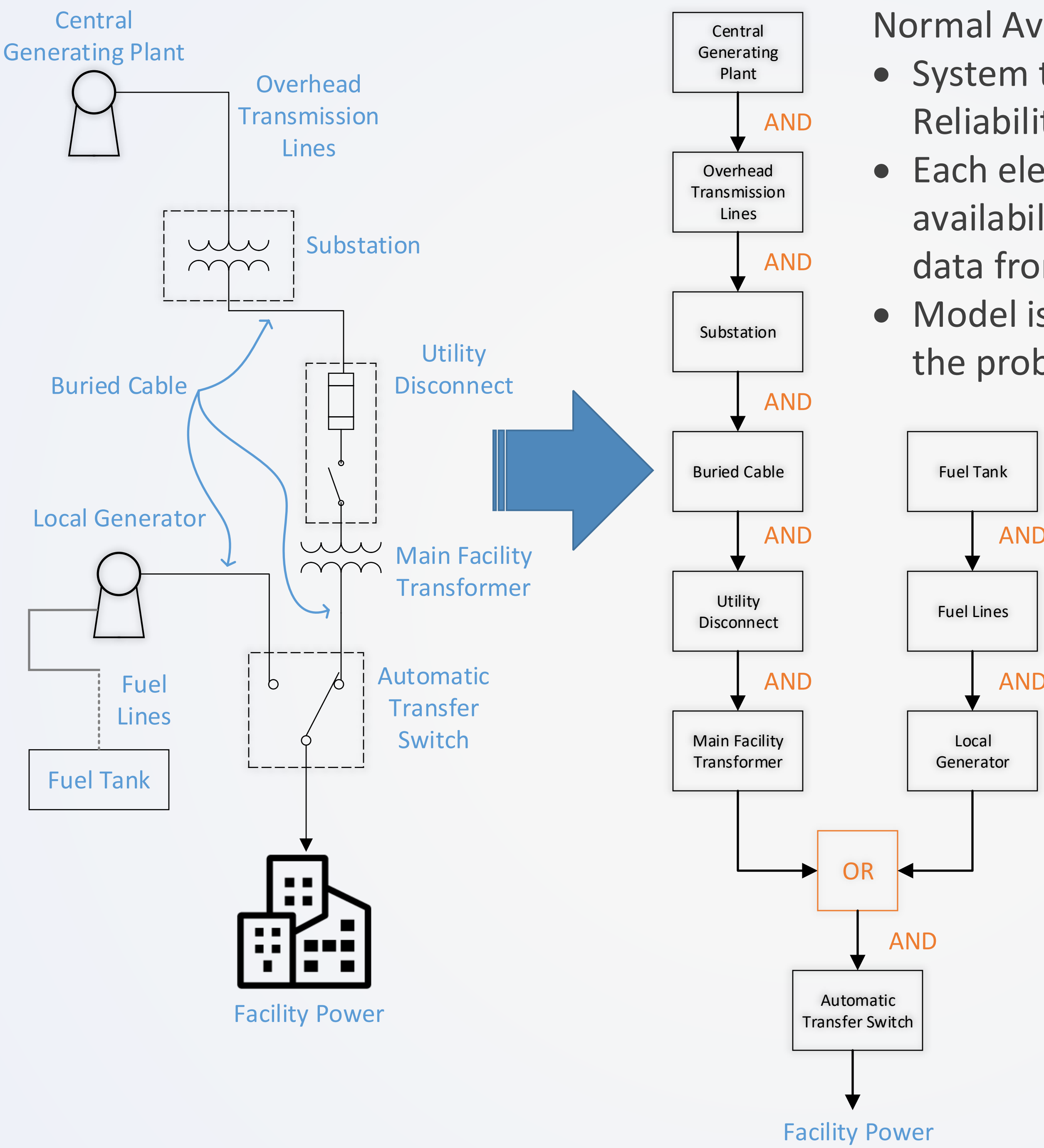
# Availability Concepts

- Availability predictions are conducted for several reasons, most notably to assess the likelihood of the current design configuration to perform its function over key intervals of time.

- Availability predictions will assess progress in meeting design goals, achieving component or part de-rating levels, controlling critical items and determining end-of-life failure mechanisms. Prediction results can be used to rank design problem areas and assist in value-engineering decisions.

- Predictions should be an ongoing activity that start with the initial design concept and the selection of parts and materials, and continue through the evaluation of alternate design approaches, redesigns, and corrective actions.

- Successive iterations provide a better estimate of product reliability, availability, and maintainability as better information on the product design approach becomes available.




## Normal Availability Study

- System topology translated into Reliability block diagram
- Each element in the model is assigned an availability probability based on summary data from component failure database
- Model is solved using GO to determine the probability of mission success

Using data from its own component failure database, PREP conducts availability studies to evaluate the inherent availability of a given system design. This can be a good starting point for evaluating the resistance of the system to various contingencies.

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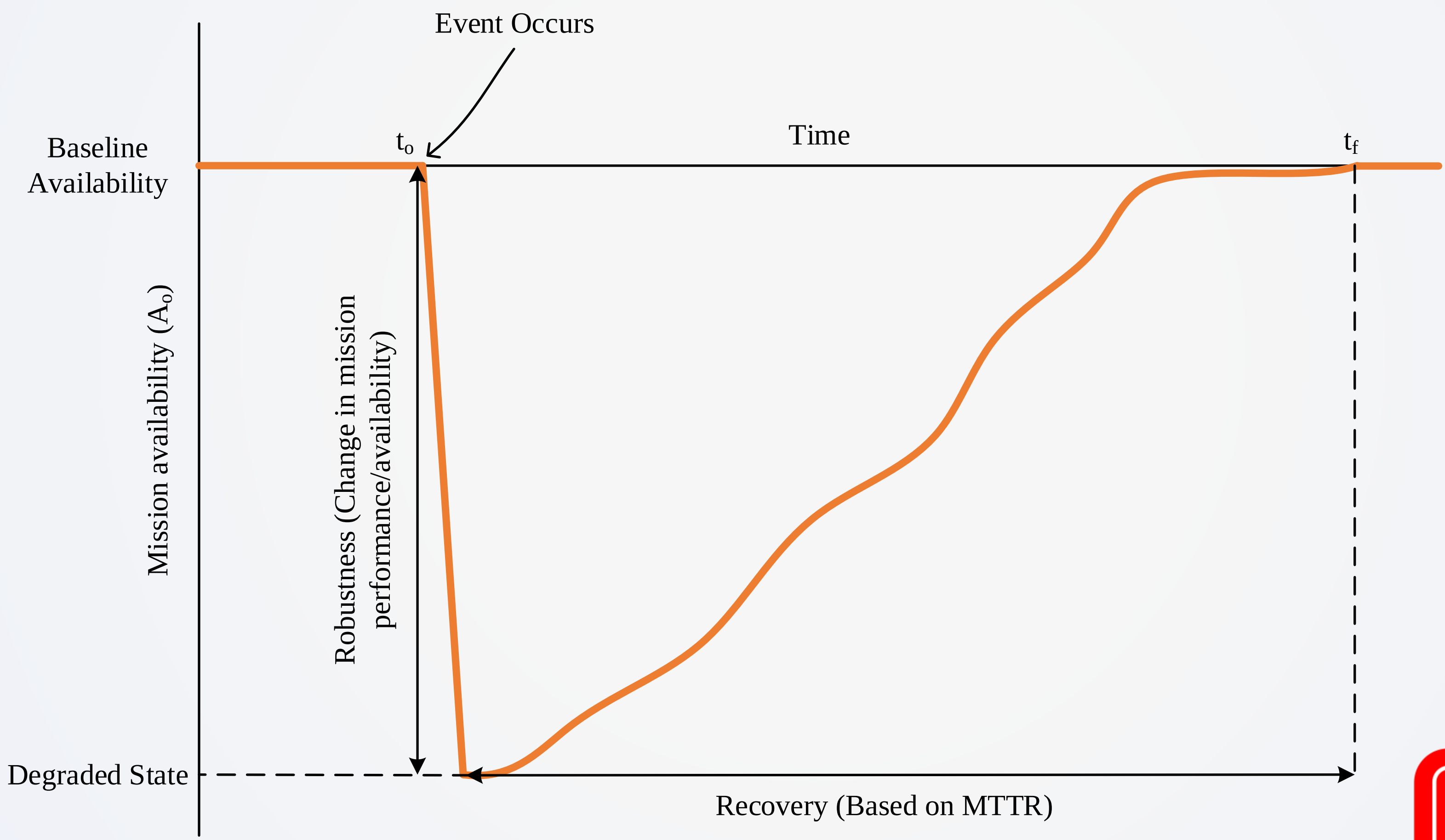
# Using Availability Metrics to Evaluate Resilience

- USACE has divided resilience into four key principles: **prepare, absorb, recover, and adapt.** Using a quantitative approach, we can evaluate both the ability of a system to **absorb** the impact of a disruption, and its ability to **recover**.
- **Robustness:** The ability of a system to absorb the impact of a disruptive event. Measured as the difference in availability between baseline and degraded state operations.
- **Recovery:** Following a disruptive event, the time required to return the system to baseline operations. Measured by evaluating MTTR data for key system assets.
- Quantitative analysis is site-specific and event-specific.

# Using Availability Metrics to Evaluate Resilience




The resilience index can be evaluated as the area under the recovery curve. The lower the area under the curve, the more resilient the system. A perfectly resilient system would have a resilience index of zero.

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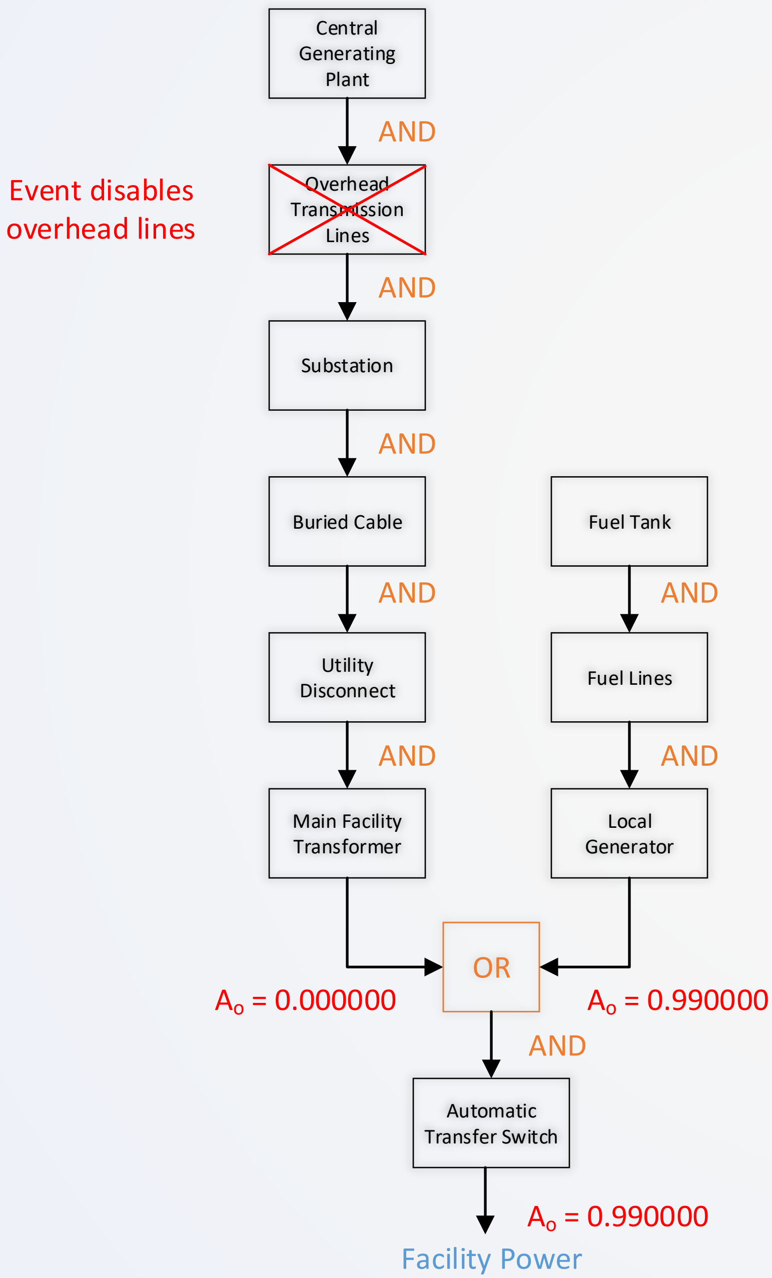
# Evaluating Robustness




1. Determine events for which the robustness of the system should be assessed
2. Determine what components are likely to fail as a result of the event
3. Analyze the degraded system state

Advantages of using Availability Metrics:

- Supported by existing datasets
- For evaluating truly random events, availability provides a useful “snapshot” of the likelihood each asset will be functional.
- Applicable to a wide range analytical tools.
- Very useful when applying deterministic methods.

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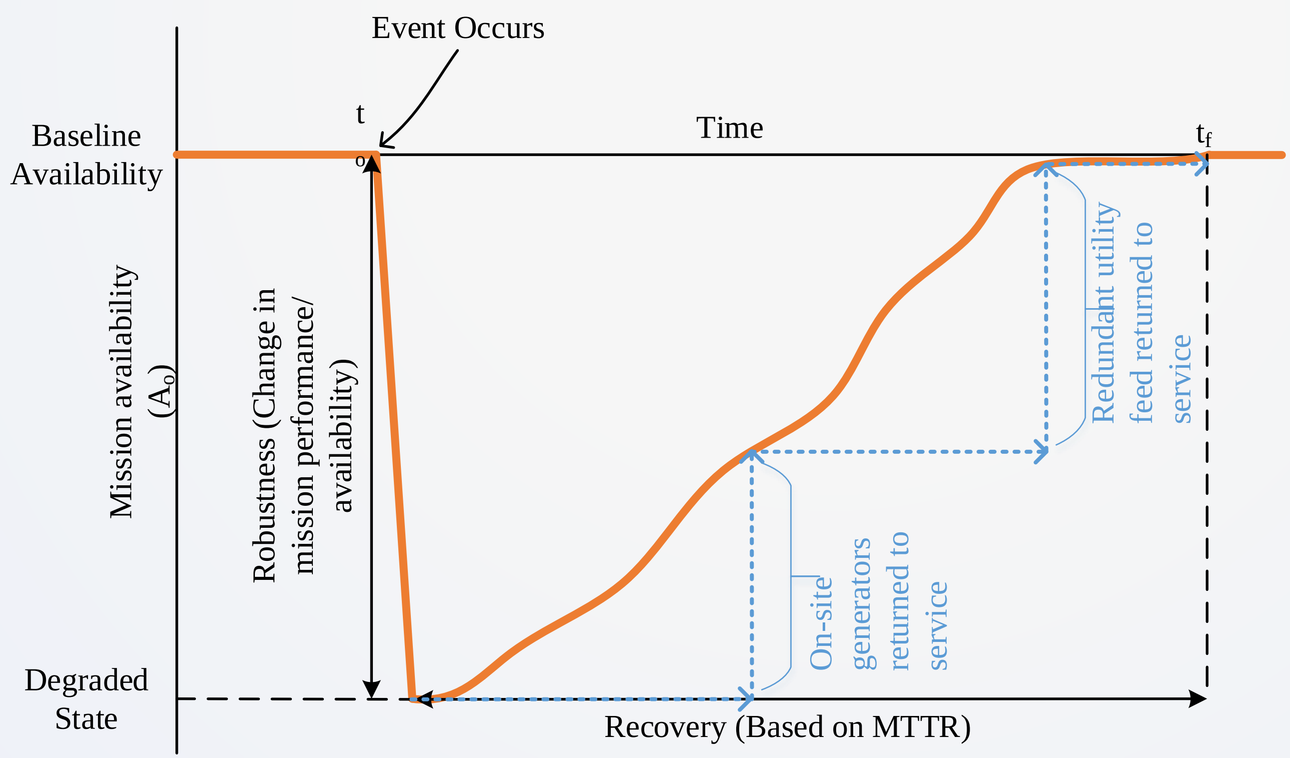
# Evaluating Recovery

Recovery time is determined by the average length of time required to return damaged components to service. Using MTTR statistics for key components, we can estimate the time required to return to baseline operations. For large or complex systems, availability during the recovery phase may change continuously. For smaller systems, or where fewer redundant paths exist, it can be more useful to consider the change in availability during the recovery phase as a step function

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# Summary

- Availability metrics provide a useful tool for quantifying power system resilience.

- Power system resilience can be evaluated according to two criteria, robustness and recovery. Robustness is a measure of a system’s ability to absorb the impact of an event (change in availability). Recovery is a measure of the time required to return to baseline operations (MTTR).

- Overall system resilience is represented by the deviation in power supply availability over the course of the recovery period.

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