Repairable unit data — is one repaired machine getting worse, better or staying the same?

Menu: Life Data ▸ Estimate Failure Function ▸ Repairable unit data...

Part 1 — What the function does

What it calculates. One repairable machine is repaired and put back to work after each failure, and its log is a list of failure times on one running clock. ReliaEn first asks whether the failures are coming faster, slower or at a steady rate: the Laplace test and the MIL-HDBK-189 test, with the verdict IMPROVING, NO-TREND or DETERIORATING. It fits the Crow-AMSAA power law, in which the expected number of failures by time t is λ·t^β, and gives the mean time between failures (MTBF) as the machine is now. When both tests accept a constant rate, it adds a renewal card: one constant failure rate and its MTBF with a confidence interval.

What ReliaEn prints	What it tells you
Trend verdict	Whether the machine is getting worse, better, or staying the same
Laplace U and **MIL-HDBK-189** rows, each with its p-value	How strong the trend is; a p-value below the significance level rejects a constant rate
Crow-AMSAA β̂ and **λ̂**	β̂ above 1: failures bunching up (wear-out); below 1: spacing out; about 1: steady
Instantaneous MTBF at end	The mean time to the next failure as the machine is now
Cumulative MTBF	The naive average, observation time / failures - honest only without a trend
The **renewal** rows (no trend only)	One constant rate, its MTBF and the MTBF's confidence interval

From which data. One worksheet column of failure times, each the cumulative operating time from the start of the log - never the time since the previous repair - and how the watch ended: at a time T after the last failure, or at the last failure. At least two failures.

When an engineer uses it. When one machine's failure log is in hand and the question is whether a single MTBF describes it honestly, or whether it is wearing out and needs an overhaul.

When not to use it.

Situation	Use instead
The logs of several machines of one type	Life Data ▸ Repairable Fleet... (chapter 3.3)
How much a repair restores the machine is the question	Life Data ▸ Repairable Systems ▸ GRP / Kijima... (chapter 3.5)
Each failed item is replaced by a new one, and its age at failure is known	Life Data ▸ Time Dependence ▸ Weibull (2P) distribution... (chapter 2.6)

Part 2 — The example's input data

Setting. A gearbox on a conveyor drive has failed 20 times in 1,000 operating hours, and the crew feels the failures are coming faster. The reliability engineer wants to know whether the gearbox is wearing out, and what MTBF to plan with.

Input	Value
Failure times, cumulative hours (20)	292.7, 306.8, 337.2, 399.7, 486.6, 533.1, 541.0, 625.5, 656.2, 658.1, 692.1, 718.8, 763.0, 766.0, 805.3, 834.4, 857.1, 859.0, 895.1, 977.9
Truncation / T — observation end time	Time-truncated (observed to time T) / 1000
Trend-test significance α %	5
File in the worked-example zip	3-Repairable-Unit-Data/Example-2.csv — column Event time, 20 rows

	A	B
1	292.7	
2	306.8	
3	337.2	
4	399.7	
5	486.6	
6	533.1	
7	541.0	
8	625.5	
9	656.2	
10	658.1	
11	692.1	
12	718.8	
13	763.0	
14	766.0	
15	805.3	
16	834.4	
17	857.1	
18	859.0	
19	895.1	
20	977.9	
21		

The example data in the worksheet

- ① Column A: the 20 failure times, in operating hours from the start of the log.

Part 3 — How to use it, step by step

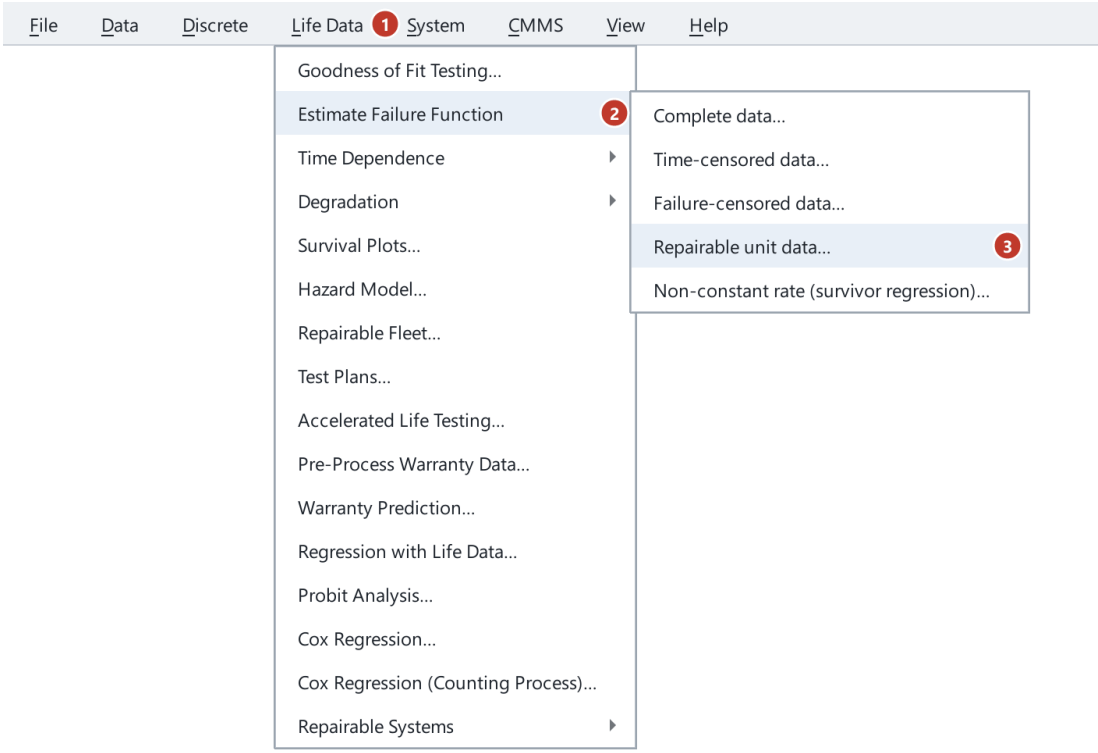
1. **Put the failure times in column A.** Copy the 20 values of Example-2.csv that stand under its heading Event time into column A of the worksheet, starting at row 1.

	① A	B
1	292.7	
2	306.8	
3	337.2	
4	399.7	
5	486.6	
6	533.1	
7	541.0	
8	625.5	
9	656.2	
10	658.1	
11	692.1	
12	718.8	
13	763.0	
14	766.0	
15	805.3	
16	834.4	
17	857.1	
18	859.0	
19	895.1	
20	977.9	
21		

Step 1 — the failure times in column A

- ① Column A: the 20 failure times, 292.7 to 977.9 hours.

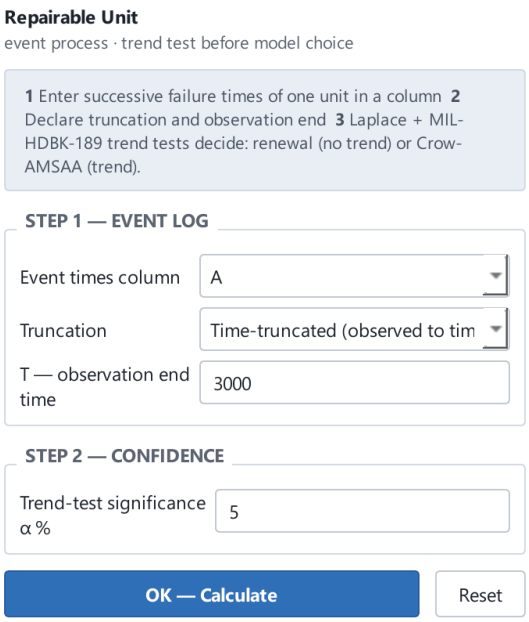
2. **Choose Life Data ▸ Estimate Failure Function ▸ Repairable unit data...** in the menu bar. The form Repairable Unit opens in the left panel.



Step 2 — the menu path

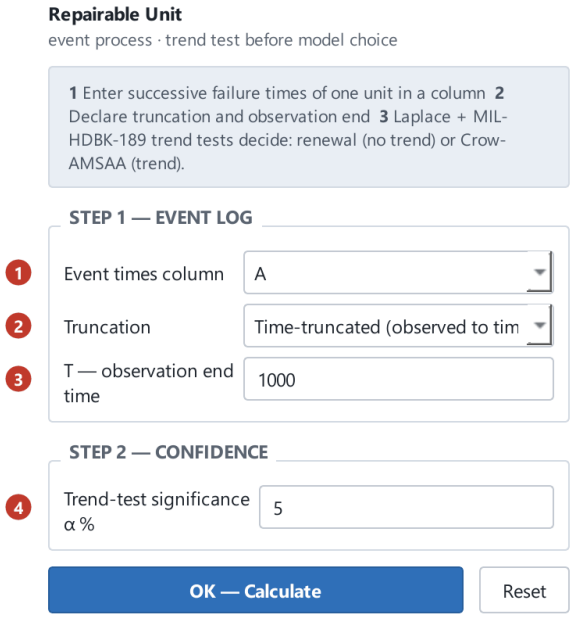
- ① Life Data: the menu.
- ② Estimate Failure Function: the submenu.
- ③ Repairable unit data...: the entry to click.

The form as it opens, before any box is set:



Step 2 — the form as it opens

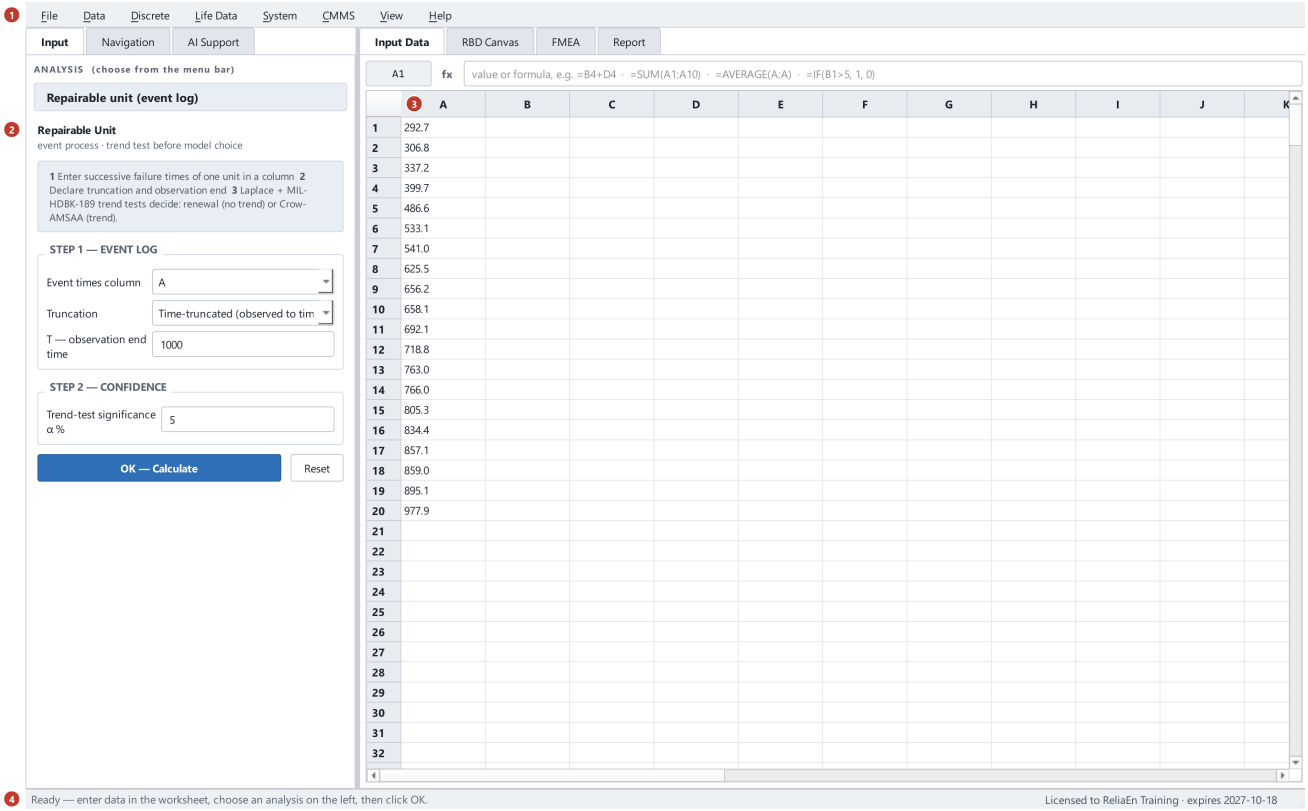
Steps 3 to 6 set or check the form's four boxes, marked ① to ④ in the picture:



Steps 3 to 6 — the form set for this example

3. ① **Check that Event times column reads A.**
4. ② **Check that Truncation reads Time-truncated (observed to time T).** The gearbox was watched to a time after its last failure; the box shows the start of the text.
5. ③ **In T — observation end time, type 1000.** It opens at 3000; the watch ended at 1,000 hours.
6. ④ **Check that Trend-test significance α % reads 5.**

7. **Click OK — Calculate** at the foot of the form (② in the picture below). ReliaEn calculates and shows the report.



Step 7 — the window just before OK

- ① The menu bar: File, Data, Discrete, Life Data, System, CMMS, View, Help.
- ② The form, set as in steps 3 to 6; OK — Calculate at its foot.
- ③ Column A: the 20 failure times.
- ④ The status bar: Ready — enter data in the worksheet, choose an analysis on the left, then click OK. and Licensed to ReliaEn Training · expires 2027-10-18.

Part 4 — The report, card by card

Repairable Unit — Trend Test + Crow-AMSAA

```
2026-11-04 08:11:00
ρ(t) = λβt^(β−1) ; Laplace & MIL-HDBK-189 trend tests first
```

The report's head

- The title Repairable Unit — Trend Test + Crow-AMSAA, the date and time of the run, and the model in one line: ρ(t) = λβt^(β−1); Laplace & MIL-HDBK-189 trend tests first.

INPUT DATA

1	Data situation	`Repairable unit (event process)`
2	Events observed	`20`
3	Observation end	`1000`
4	Truncation	`time-truncated`

Input data

- ① Data situation Repairable unit (event process).
- ② Events observed 20: the gearbox's failures.
- ③ Observation end 1000.
- ④ Truncation time-truncated.

RESULTS

1	Trend verdict	`DETERIORATING`
2	Laplace U (p-value)	`2.32813 (p = 0.0199053)`
3	MIL-HDBK-189 $\tilde{\beta}$ / χ^2, 40 dof (p-value)	`2.04937 / 19.5182 (p = 0.00529481)`
4	Crow-AMSAA $\hat{\beta}$	`2.04937`
5	Crow-AMSAA $\hat{\lambda}$	`1.42203e-05`
6	Model E[N(t)] = $\hat{\lambda} \cdot t^{\hat{\beta}}$	`1.42203e-05 · t^2.04937`
7	Model check E[N(T/5)] = E[N(200)]	`0.738889`
8	Instantaneous MTBF at end	`24.3977`
9	Cumulative MTBF	`50`

Results

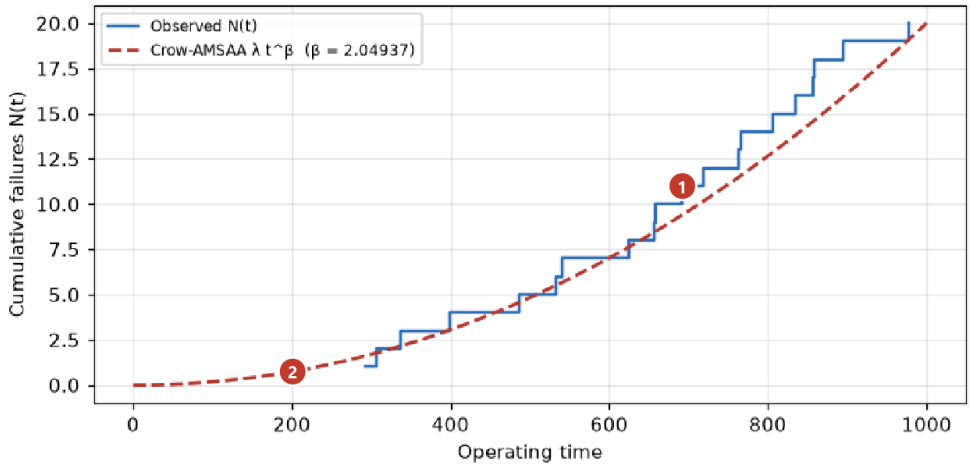
- ① Trend verdict DETERIORATING: the failures come faster.
- ② Laplace U (p-value) 2.32813 (p = 0.0199053): below the 5 % level.
- ③ MIL-HDBK-189 $\tilde{\beta}$ / χ^2, 40 dof (p-value) 2.04937 / 19.5182 (p = 0.00529481): the second test agrees.
- ④ Crow-AMSAA $\hat{\beta}$ 2.04937: well above 1, wear-out.
- ⑤ Crow-AMSAA $\hat{\lambda}$ 1.42203e-05.
- ⑥ Model E[N(t)] = $\hat{\lambda} \cdot t^{\hat{\beta}}$ 1.42203e-05 · t^2.04937: the expected failures by time t.
- ⑦ Model check E[N(T/5)] = E[N(200)] 0.738889: the model expects less than one failure in the first 200 hours - and the log has none.
- ⑧ Instantaneous MTBF at end 24.3977: as the gearbox is now.
- ⑨ Cumulative MTBF 50: the naive average.

INTERPRETATION

1 The trend tests detect a time trend (Laplace p = 0.0199053): reliability is **deteriorating** (failures arriving faster — wear-out of the repairable system). The Crow-AMSAA power-law NHPP applies: β = 2.04937, λ = 1.42203e-05. Instantaneous MTBF at the end of observation is 24.3977. A naive MTBF = T/n (50) would be misleading here.

Interpretation

- ① ReliaEn's reading: The trend tests detect a time trend (Laplace p = 0.0199053): reliability is deteriorating (failures arriving faster — wear-out of the repairable system). The Crow-AMSAA power-law NHPP applies: β = 2.04937, λ = 1.42203e-05. Instantaneous MTBF at the end of observation is 24.3977. A naive MTBF = T/n (50) would be misleading here.



Interactive Plot

Cumulative failures N(t) against operating time

- ① Observed N(t): the staircase of the 20 failures, steepening towards the end.
- ② Crow-AMSAA λ t^β (β = 2.04937): the fitted curve, bending upwards.

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The report's foot

- ① The licence line Licensed to ReliaEn Training · RL-2026-0017: the licence the report was made under.

Part 5 — How to interpret the results

Is the gearbox wearing out? Yes. The Laplace statistic is U = 2.32813 with p = 0.0199053, below the 5 % level: the failures sit late in the 1,000-hour window, and the verdict is DETERIORATING. The MIL-HDBK-189 test agrees, χ^2 = 19.5182 on 40 degrees of freedom, p = 0.00529481. The Crow-AMSAA shape $\hat{\beta}$ = 2.04937 is well above 1, so the failures come faster as the gearbox ages.

What MTBF to plan with. As the gearbox is now, it fails on average every 24.3977 hours: the instantaneous MTBF at the end of observation, T / (n·$\hat{\beta}$) = 1000 / (20 × 2.04937). The cumulative MTBF, 1000 / 20 = 50 hours, is half as long and would be misleading: with a trend, an average over the whole log describes a gearbox that no longer exists. There is no renewal card, because the tests reject a constant rate.

What to decide. Plan an overhaul or a replacement of the gearbox, not more spares at the old rate. The model $\hat{\lambda}$·t^$\hat{\beta}$ with $\hat{\lambda}$ = 1.42203e-05 forecasts the failures ahead if nothing is done.

Check the clock first. Every failure time must be cumulative from the start of the log. A list of gaps between failures typed as if it were cumulative looks like failures spacing out and gives a false IMPROVING verdict.