NATIONAL LABORATORY OF THE ROCKIES

Technoeconomic Analysis of the Miba Segmented Journal Bearing

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Drivetrain Reliability Collaborative Workshop
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Photo by Josh Bauer / Bryan Bechtold, National Laboratory of the Rockies 2026

Agenda

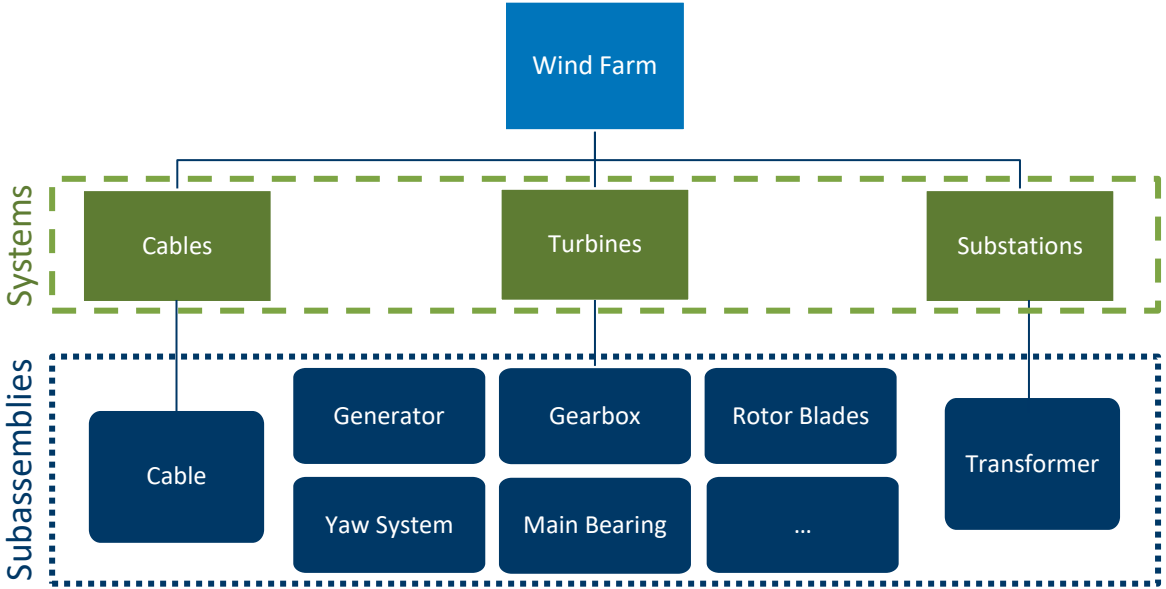
1. **Wind Operations and Maintenance cost-Benefit Analysis Tool (WOMBAT)**
2. Miba Segmented Journal Bearing (SJB)
3. Technoeconomic Analysis (TEA) Results
4. Summary and Next Steps

What is WOMBAT?

Windfarm Operations & Maintenance cost-Benefit Analysis Tool (WOMBAT)

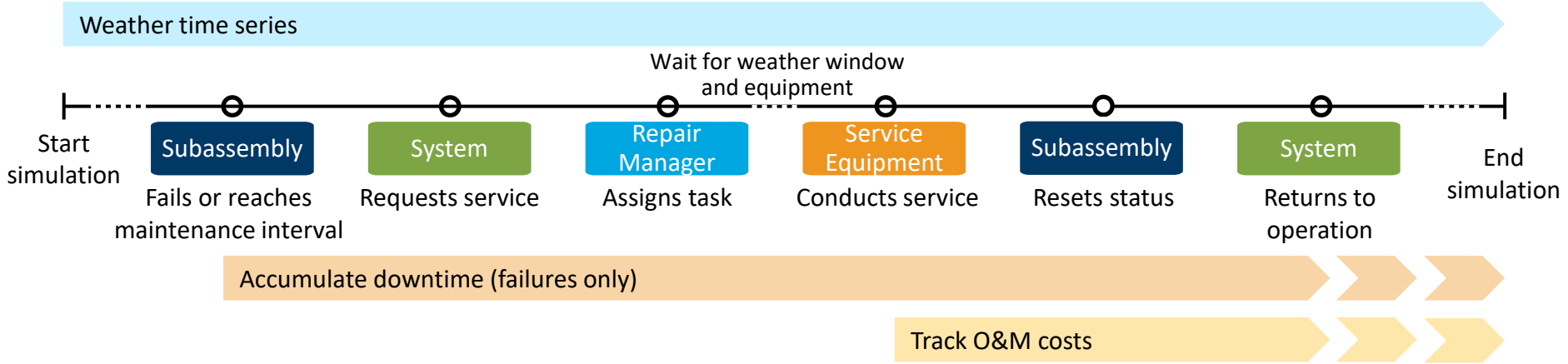
Available to download at https://github.com/NLRWindSystems/WOMBAT

- Open-source code for wind O&M cost modeling
- Modular definition of maintenance and repair processes for each component
- Scenario-based comparisons across maintenance strategies or component technologies
- Incorporates weather and equipment availability limits
- Probabilistic failure modeling



What does WOMBAT do?

- WOMBAT evaluates O&M costs using discrete event simulation – a series of events in sequential order where no changes occur between events.
- Each subassembly has user-defined repair and maintenance tasks with their own timing.



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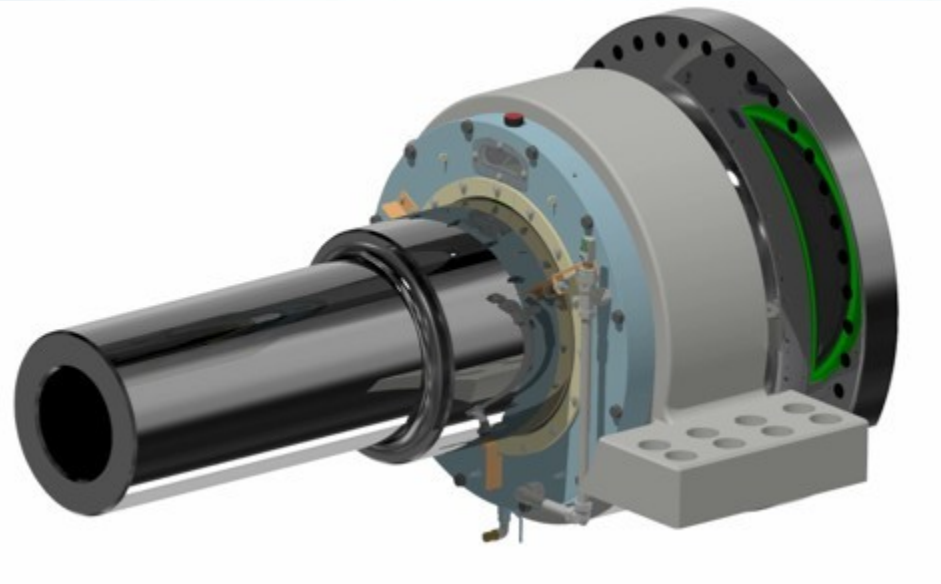
Miba SJB - Segmented Journal Bearing

Robust Journal Bearing Technology – Engineered for Easy Integration & Up-Tower Service

Innovation in Motion



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Miba SJB Value Proposition

Comparison with existing solutions

Innovation in Motion

KPI	Description	Description	KPI
Future potential	Enabling lighter/ compact drivetrain or higher power in existing space	Neutral impact on turbine system costs - enabled by compact design	CapEx
OpEx	Far lower service efforts and partial bearing costs if needed	Less number of components and low failure modes lowering failure probabilities.	Reliability
Predictive maintenance	Through accumulated load data for relevant failure modes & oil condition monitoring	Easy inspection, and faster replacement of segments independent of weather conditions	Downtime
Durability	Wear is distributed over exchangeable parts leading to higher lifetime expectancy.	Does not produce noise and additionally Hydrodynamic contact acts as damper	NVH
Sustainable	Less energy production, low service equipment, fully recyclable materials	Exchangeable segments make handling and spare part stock easier	Supply chain

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System Testing & Validation Status

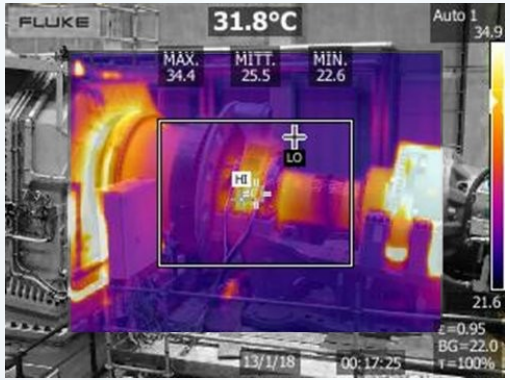
TRL5+ successfully completed

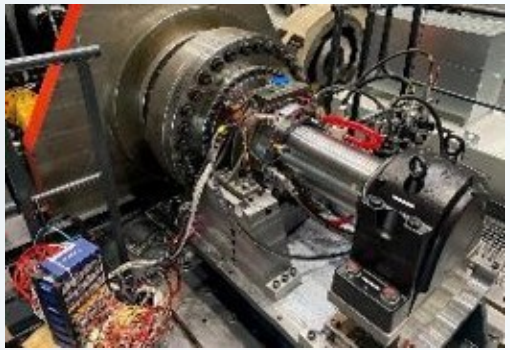
Innovation in Motion

- **Full-Scale Tests:**
  Full load envelope verified at 20C ambient & oil inlet temperature
  Critical subsets tested up to 50C oil inlet temperature.

- **Scaled Testing:**
  Full load envelope at 20C ambient & oil inlet temperature
  Critical subsets tested down to **-40C** with sump lubrication, no active supply)

- **Performance Metrics:** Validated for Efficiency, Wear, Breakaway Torque, and Shock Loads.





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Miba SJB
Program Overview & Milestones

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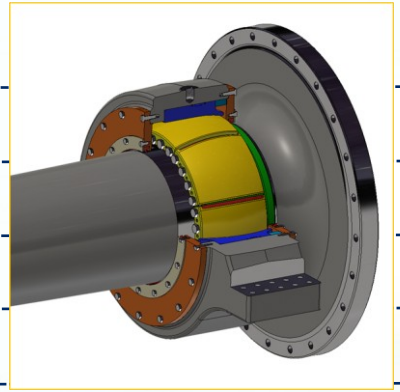
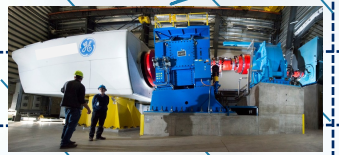


GE-Miba uptower test and new technology/new product integration (NTI/NPI) project. Testing at TBD location.

3 MW technology development and validation research GE-Miba-NLR shared resources CRADA project. Testing at NLR in 5 MW dyno.

Scaled and 3 MW technology research and demonstration Miba- and EU-funded projects. Testing at RWTH Aachen.



GE-Miba-NLR CRADA goals:

- Advancement of the segmented journal bearing (SJB) from component to full system level to achieve technology readiness level (TRL) 6 by retiring identified risks related to dynamic mechanical and electrical loads.
- Research and validation of system simulations to understand and resolve effects of full system environment and installation.
- Technoeconomic analysis of SJB value propositions.

TRL

9 8 7 6 5 4 3 2 1

21 22 23 24 25 26 27 28 29 30

Year 20xx

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Main Bearing TEA Summary

- Conduct a TEA of standard SRB and Miba SJB using WOMBAT:
  - IEC Class I-like wind resource
  - 200 MW land-based plant of 3.3-148 reference “ATB” wind turbines
  - Defined turbine CapEx and key financial model parameters
  - Defined turbine O&M parameters over plant life
    - Scheduled and/or unscheduled maintenance *for all components*
    - Repair/replacement materials cost, downtime, and frequency
    - Crane and lubrication service cost assumptions are key
  - Calculate Availability, AEP, OpEx, and LCOE
  - Examine sensitivity to main bearing failure rates and service schedules

Audience Poll

In your experience, what are typical crawler or uptower crane costs (mobilization + day rate) for a drivetrain component replacement on a 3.X MW turbine?

Main Bearing Service Model

- Evaluated range of costs and replacement rates
- Main bearing crane operation separated from other crane operations (e.g., blade, gearbox) for comparison purposes
- Downtime can be extended due to weather delays

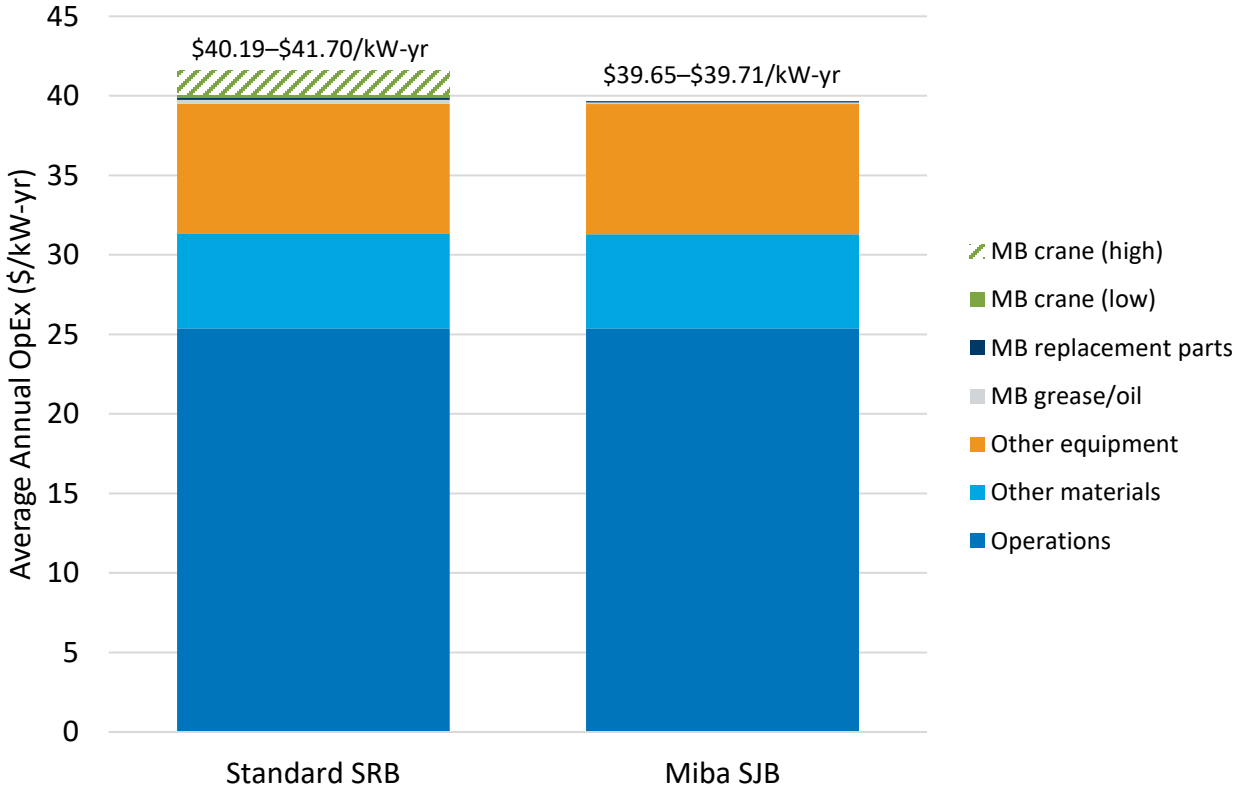
		Standard SRB	Miba SJB
Minor scheduled maintenance	Materials	$400 regrease	$2.5k oil change
	Downtime	½ workday	½ workday
	Frequency	6 months	6 years
Unscheduled uptower repair	Materials	-	New SJB segments + oil
	Downtime	-	1 workday
	Frequency	-	15% and 24% by 30 years
Unscheduled crane replacement	Crane	$140k and $840k	-
	Materials	New SRB + grease	-
	Downtime	5 and 12 weeks (avg.)	-
	Frequency	24% by 30 years[†]	-

[†] *L. Haus, S. Sheng, and R. Pulikollu. 2025. "Newer/Larger Wind Turbine Reliability Analysis & Applications." In Drivetrain Reliability Collaborative Workshop. Golden, CO. https://app.box.com/s/ahluyk9rkr4g9ji5s2t43gofd9xligho.*

Photo by Dennis Schroeder, NLR 49408

OpEx and Availability Results

- Results represent averages across 25 simulations of a 30-year plant life
- Costs of crane and grease/oil for the main bearing (MB) are the primary differences between scenarios
- Availability
  - Standard SRB: 95.6%
  - Miba SJB: 96.1%



Audience Poll

What is typical annual spending on main bearing grease for a 3.X-MW turbine?

LCOE Results

- Lower OpEx and higher availability for the Miba SJB lead to higher energy production
- 0.4–1.3% lower LCOE with Miba SJB relative to standard SRB
- Lifetime per-turbine savings are larger than initial investment

Parameter	Standard SRB	Miba SJB
Total Installed CapEx	$1,968/kW	$1,968/kW+Δ
OpEx	$40.19–41.70/kW-yr	$39.65–$39.71/kW-yr
Fixed Charge Rate	6.5%	6.5%
Availability	95.5-95.6%	96.05-96.06%
Net AEP	4,096–4,104 MWh/MW/yr	4,118 MWh/MW/yr
LCOE	$40.96–$41.38/MWh	$40.83–$40.91/MWh
LCOE Reduction wrt SRB	-	0.4–1.3%
Per-Turbine Savings Over Life wrt SRB	-	$48,000–$189,000

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Summary and Next Steps

- Uptower service and improved reliability of Miba main bearing can result in:
  - Elimination of crane and reduction of lubrication service costs
  - 1.2–4.9% reduction in OpEx and 0.5% increase in Availability and AEP
  - 0.4–1.3% LCOE reduction
- Next steps:
  - Evaluation tests on GE Sierra 3 MW machine head in NLR 5 MW dynamometer to achieve TRL 6 in late 2026

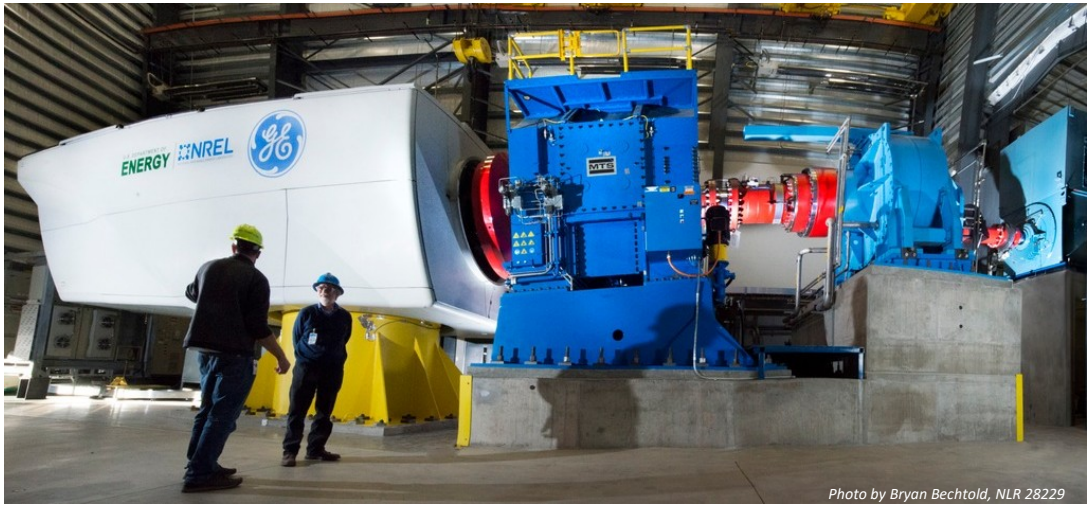

Photo by Bryan Bechtold, NLR 28229

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Thank you!

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