Angebot

AB-250731.9-51606.9

SEW-EURODRIVE GmbH & Co KG
23.12.2025 11:07 (0536ec2)

Agile Time & Material Contract

Zwischen den Vertragsparteien

SEW-EURODRIVE GmbH & Co KG
Ernst-Blickle-Str. 42
76646 Bruchsal, DE

im Nachfolgenden Auftraggeber genannt

und

Motius GmbH
Walter-Gropius-Straße 17
80807 München, DE

im Nachfolgenden Auftragnehmer genannt.

Projektplan

Vibecheck Phase 2

Aufgrund der technischen Terminologie ist der Projektplan in Englisch verfasst.

Status Quo

Motius successfully completed a Proof of Concept (as of August 2025) of the Vibecheck acoustic end-of-line testing.

- **Structure-borne sound microphone**: Capture of sound signals during ~20s dynamic test profile (two directions & two speeds, 4-5s each)
- **ML algorithm**: Optimized classification through extended datasets and augmentation
- **Test sequence**: Dynamic profile with forward/backward rotation at various RPM, integrated into LabVIEW & TestStand
- **Simple User Interface**: Workers can confirm / correct results, with a simple green/red display in LabVIEW
- **Data processing**: .wav (10s samples) → Log-Mel spectrograms (up to 8kHz) → CNN/Autoencoder
- **K series gearbox**: PoC was validated on K series helical-bevel gear motors

Type: All Types | Status: All Statuses | Faulty: All | Prediction: All

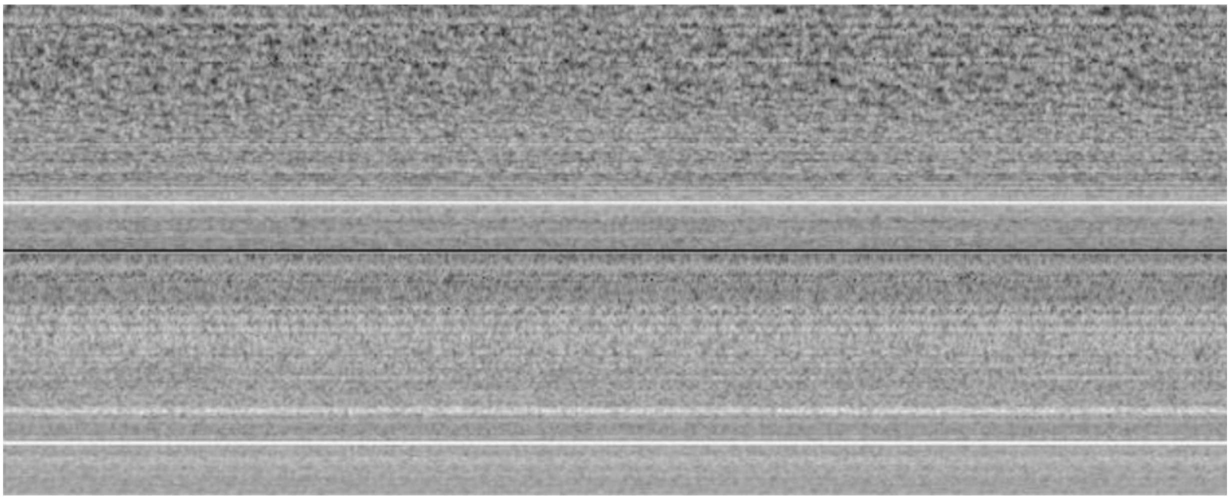
ID	Motor ID	Type	Created At ↓	Faulty	Prediction	Status
20250808134519	8562929201010001	K019 [4.5]	08/08/2025, 13:45:19	Faulty	Faulty	Completed
20250808133229	8568328601010002	K037 [20.19]	08/08/2025, 13:32:30	Good	Good	Completed
20250807154109	8562898302010001	K019 [6.91]	07/08/2025, 15:41:09	Good		Completed
20250807153744	8543533103010001	K019 [10.32]	07/08/2025, 15:37:44	Good	Good	Completed
20250807153353	8557620601010001	K029 [16.29]	07/08/2025, 15:33:53	Good		Completed
20250807152057	8567666904010002	K029 [6.95]	07/08/2025, 15:20:57	Good		Completed
20250807143853	8571718703010001	K019 [34.29]	07/08/2025, 14:38:54	Good	Good	Completed
20250807141424	8571718703010002	K019 [34.29]	07/08/2025, 14:14:24	Good		Completed

Based on 650+ experiments, as of August 2025, we achieved a reliable OK/Not OK classification with >90% accuracy (Confusion Matrix validated).

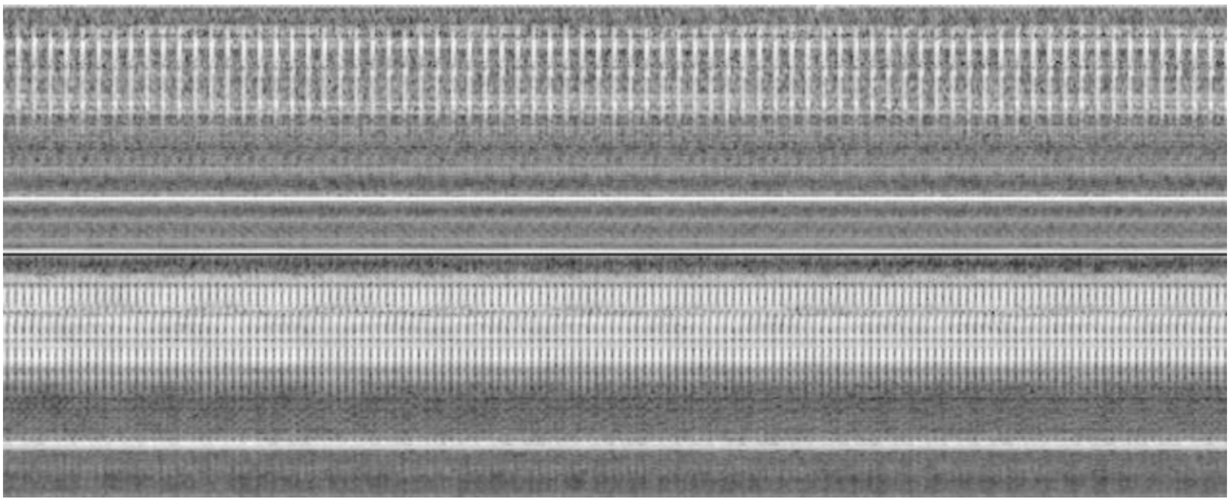
Defect Types

Classification	Description	Frequency
OK	No audible damage	90.29%
Ticks	Gear damage, scratches on tooth surfaces	4.05%
General noise	Bearing damage, dirt in the gearbox	5.66%

- **Input**: .wav recordings from 20s dynamic motor test sequences
- **Preprocessing**: 5s sample extraction with overlap
- **Feature Extraction**: Log-Mel spectrograms (max frequency: 8kHz)
- **Normalization**: Per-sample spectrogram normalization
- **Time-Frequency Representation**: Horizontal time axis, vertical frequency axis



Normal sample



Sample with ticks

Dataset Characteristics

Category	Count	Percentage	Notes
Valid Experiments	577	76.63%	Clean, properly labeled data
Microphone Issues	122	16.20%	RMS threshold filtering
Mislabeled Cases	54	7.17%	Manual expert correction

The comparatively low percentage of valid experiments points to a need for automation.

Defect vs. Normal	Count	Percentage	Notes
Defect	56	9.71%	Limits the data that can be used
Normal	521	90.29%	

The model training required a balanced dataset, which means that roughly the same amount of defect samples should be used.

Training Set	Count	Percentage	Notes
Defect Samples Used	67	50.38%	All valid defect experiments
Normal Samples Used	66	49.62%	Similar number of samples for balance

Performance Metrics on Test Set

Performance metrics are only calculated for valid experiments:

- **Sensitivity (Recall)**: ~89-94% - Critical for catching defects
- **Specificity**: ~81-100% - Important to minimize false alarms
- **F1-Score**: ~84-97% - Balanced performance indicator

Best Test Results			
LABEL / PRED	Faulty	Good	SUM
Faulty	64 50.79%	4 3.17%	68 94.12% 5.88%
Good	0 0.00%	58 46.03%	58 100.00% 0.00%
SUM	64 100.00% 0.00%	62 93.55% 6.45%	122 / 126 96.83% 3.17%

Worst Test Results			
LABEL / PRED	Faulty	Good	SUM
Faulty	51 40.48%	6 4.76%	57 89.47% 10.53%
Good	13 10.32%	56 44.44%	69 81.16% 18.84%
SUM	64 79.69% 20.31%	62 90.32% 9.68%	107 / 126 84.92% 15.08%

Current IT Integration

- **Connectivity & Deployment**: Direct network connection to backend running in Motius AWS infrastructure
- **Test bench integration**: Custom Python module is called in the test process
- **UI**: Labelling interface, display of results with green/red status, allow marking experiments as irrelevant, and highlight important information (such as spectrograms that lead to not-OK classifications)
- **Workflow**:
  - 20s total data recording time, ~30s in total (including processing times)
  - Additional reminder pop-up for attaching the body sound sensor reduced the number of invalid experiments from 25% to 5%
- **Laser vibrometer**: Comparative studies show equivalent results to structure-borne sound microphone

- **Analysis App**: VibeCheck Web App for manually analyzing, re-labelling datapoints, and marking experiments as invalid (thereby excluding them from training)

Laser Vibrometer

We benchmarked a Polytec laser vibrometer with auto-focus against the structure-borne sound microphone. The vibrometer provided similar sensor readings, without contact to the motor.

Phase 2

Extending VibeCheck Algorithm

The successfully validated PoC algorithm currently supports one gearbox type (bevel gear motors). In Phase 2, we want to support a larger variety of products, and roll out to multiple quality cells:

- **Extended datasets**: Further training with additional experiments for bevel gear transmissions
- **Data augmentation**: Audio augmentation (Pitch, Time Stretch) + spectrogram augmentation (Zoom, Brightness, Mixup, Erasing)
    - The augmentation can improve the model generalization capability and can also enforce that the model learns features instead of memorizing training data features
    - Data augmentation will be especially helpful for training new model versions for new gearbox types, which initially only have a small dataset
- **Continuous learning**: Automatic model updates based on new production data
- **Performance monitoring**: Continuous monitoring of classification accuracy
    - **Explainable AI**: Feature importance and decision visualization for experts
    - **Historic data**: Show history of experiments and model performance
- **Invalid experiment detection**: Additional script or model for detecting faulty experiments
    - **RMS Threshold**: Detect microphone disconnect (sound intensity too low)
    - **Spectral Analysis**: Identify unusual frequency patterns
    - **Future Enhancement**: Dedicated ML model for experiment validation
- **Advanced Architectures**: Research transformer models for sequence modeling

Data Augmentation Strategy

Audio-level Augmentation

- Pitch shifting (±0-20%)
- Time stretching (±0-30%)
- Noise injection (SNR: 20-40dB)

Spectrogram-level Augmentation

- Zoom augmentation (random cropping/erasing/scaling)
- Brightness/contrast variation
- MixUp: Linear interpolation between samples

Model Architecture

Before scaling to more cells, the team needs to decide whether to extend a single model or train multiple gearbox-specific models.

Approach	Advantages	Disadvantages
Extended Single Model	✓ Less training effort ✓ Simpler maintenance ✓ Faster rollout	✕ Possibly lower precision ✕ More complex feature engineering
Motor-Specific Models	✓ Higher precision per motor type ✓ Specialized features ✓ Better scalability	✕ More training effort ✕ More complex pipeline ✕ More data required

The team will likely train multiple models and test their performance compared to a single, bigger model.

Additionally, the architecture of the models could be adapted, after the first tests:

❶ Convolutional Neural Network (CNN)

- Input: Log-Mel spectrograms as 2D images
- Architecture: Multi-layer CNN with attention mechanisms
- Output: Binary classification (OK/Not OK)

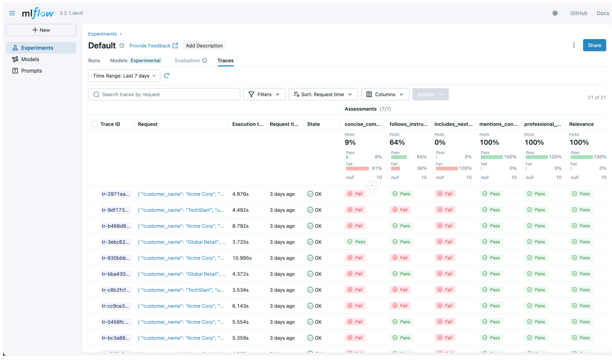
❷ Autoencoder Approach

- Unsupervised pre-training for anomaly detection

- Reconstruction error as anomaly score
- Especially useful for rare defect types

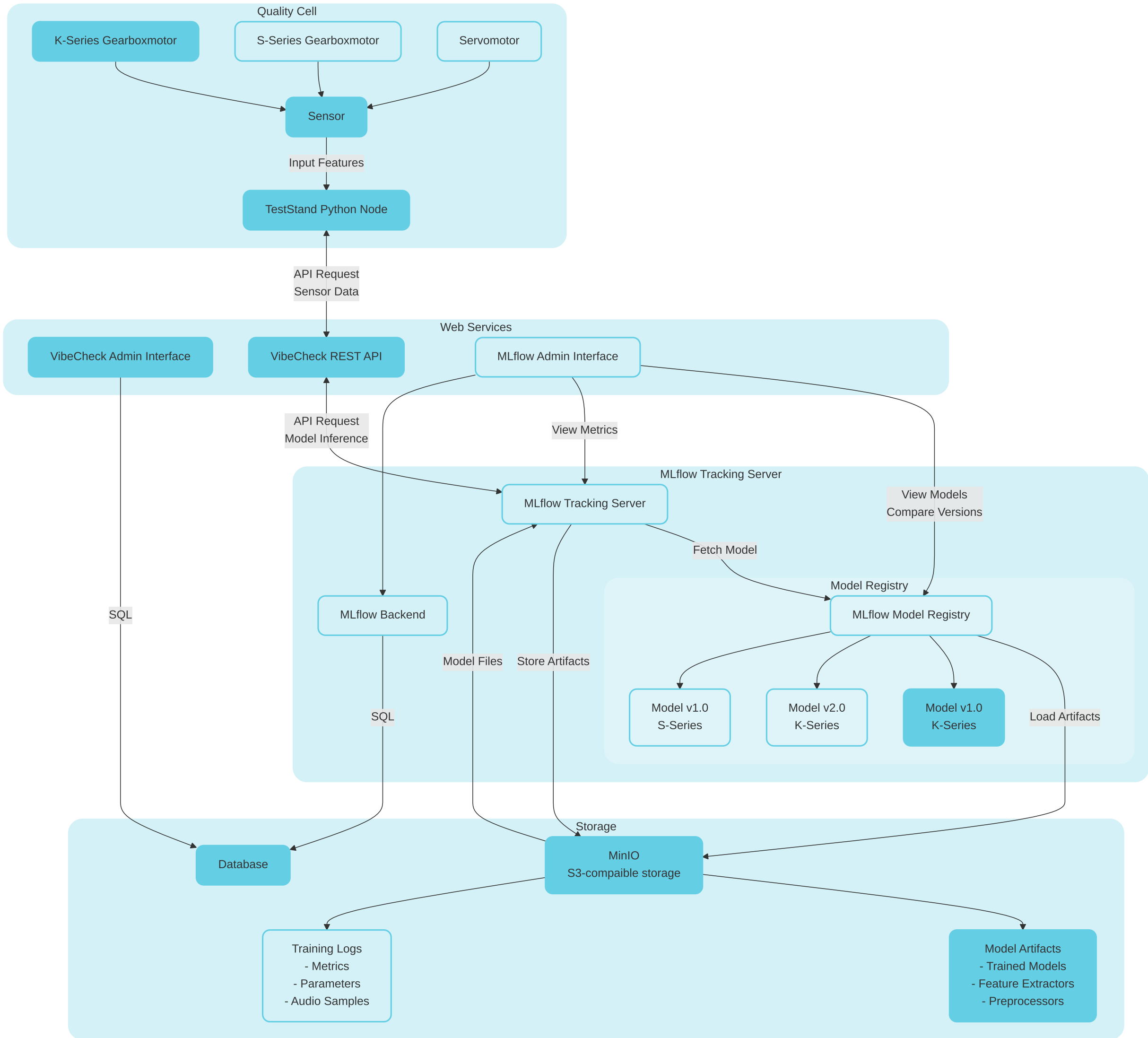
Model Training Infrastructure

Even if the team decides to only train one model, a production deployment requires more infrastructure than the current PoC.



Example user interface for viewing experiments in MLflow

MLflow is an open-source platform for managing machine learning models. It can tie into existing PoC infrastructure (storage, database) and add model versioning, training with new data, and monitoring performance.



Highlighted components in blue are already in place from the PoC, the other components will be added in Phase 2.

Deploying to SEW IT Infrastructure

Next, the algorithm needs to be deployed in SEW's IT infrastructure:

- **VM vs Cloud**: Decide with an expert from SEW's IT whether we deploy to Azure or into a VM
- **Database & Storage Migration**: Database and *.wav file storage needs to move to either Azure or a VM
- **Model Versioning**: Traceable versioning with rollback functionality

For the deployment, SEW needs to provide infrastructure with these parameters:

Resource	Requirement	Comment
Memory Usage	16GB RAM	Required for model loading and preprocessing pipeline in memory
CPU Requirements	4 CPU cores	Models run without GPU, which means multiple cores help run multiple tests in parallel
Disk Usage	1TB	Mostly for storing historical data and model versions
GPU	16GB VRAM	Training a model with 650+ samples (PoC scope) takes ~30min on a GPU, >5h without it

Azure

On Azure, the resources can be split into training & inference. Training only happens infrequently, in batches. Therefore, we can run training on separate resources that are billed by hour.

On-Premise VM

For training & inference on-premise we propose one bigger VM with enough resources to do both tasks.

Test Strategy

The deployed algorithm then needs to be tested on new product types and in new quality cells:

- **Iterative Testing**: Multiple test cycles with SEW experts
- **Model validation**: Confusion Matrix validation against SEW expert classifications
- **False Negative Prevention**: Testing & model validation need to ensure that false negatives are very unlikely
- **False Positive Minimization**: Too many false positives lead to additional manual work
- **Performance Benchmarks**: At least 90% classification accuracy
- **Integration Testing**: Complete LabVIEW pipeline validation

To structure this testing, the team will create an updated test strategy for a production-ready rollout.

Rollout to new Quality Cells and Product Types

An improved ML algorithm, hosted on SEW infrastructure, after proper testing enables SEW to roll out VibeCheck on their own:

1. A **process owner** at SEW installs the required sensor and TestStand software in a new quality cell
2. In the VibeCheck admin interface, they assign a model to the new quality cell, or create a new model version in MLflow (for example for a new gearbox type)
3. During training, the TestStand user interface in the new quality cell **shows the worker the normal manual acoustic testing routine**, but starts recording data and creating a training data set
4. Gearbox motors marked as defective go to a repair cell, where **repair technicians** diagnose & repair the problem
5. Data from these diagnoses is imported into the VibeCheck dataset as well, to correct possible mislabeling by workers, and to increase the number of samples of defective motors
6. When enough data is available (at least 50 defective samples), a model is trained automatically in MLflow and the TestStand **user interface begins showing prediction results**
7. After some more validation with the worker, the **model can work autonomously** and only call in workers for defective or low-confidence results

Documentation and training materials will be created by the team for the first rollout, and improved during the first run by SEW.

Documentation includes:

Documentation Type	Target Audience	Description
Admin Guide	Process owners	Step by step guide for creating new quality cell deployments, including creating new ML model variants in MLFlow
User Guide	Workers	Accessible from TestStand, probably in a web interface or as a PDF
Troubleshooting Guide	Workers and process owners	Common issues such as microphone disconnects and how to fix them

Integration Requirements & Success Criteria

The MoSCoW method is a prioritization technique for requirements:

- **Must have**: Critical requirements that are non-negotiable for project success
- **Should have**: Important features that are highly desirable but not absolutely critical
- **Could have**: Nice-to-have features that would add value but can be deferred if necessary
- **Won't have**: Items explicitly excluded from the current scope but may be considered in future iterations

Requirement	Priority	Description	Success Criteria
Existing HTTP Integration	Must	Use of already implemented MES-HTTP interface	Integration working
Python Integration	Must	Use of already implemented TestStand Python integration	Python calls successful
Data Flow	Must	Sensor → TestStand → HTTP → ML-Service → Result back	End-to-end data flow
Recording duration	Must	Less than 30s run time for the audio analysis	< 30s analysis time
NI Measurement Hardware	Must	Integration with existing NI DAQmx infrastructure	Hardware integration
Model accuracy	Must	Classification accuracy target	> 90% accuracy
False positive rate	Must	Minimize incorrect failure classifications	< 2% false negative rate
CI/CD Pipeline	Must	Continuous integration & deployment in SEW infrastructure	Automated deployments
Model Versioning	Must	Support for different gearbox types with version management	Multiple models managed

Tracing	Must	Comprehensive logging system for debugging and monitoring	All errors tracked
Multi-cell Support	Must	Infrastructure supporting continuous learning across multiple quality cells	3+ cells operational
Functional Safety	Must	Safety concept for production deployment	Safety approval obtained
Laser Vibrometer	Must	Could replace body sound sensors with laser vibrometer, if easier to automate	Alternative sensor option
Performance	Should	Inference time target	< 1s inference time
System availability	Should	System uptime target	> 99% uptime
Body-Sound Microphone	Should	Contact-based sensors (already validated in EOL Cell 2)	Sensor validation
User Interface	Should	Green/Red display in LabVIEW with correction workflow for false positives	UI functionality
Order-XML Integration	Should	Automatic parameter extraction for dynamic profiles	Auto parameter extraction
Standardization	Should	Uniform setup based on EOL Cell 2 pilot experiences	Consistent setup
Data Augmentation	Should	Improved data augmentation for better model training	Enhanced model robustness
Performance Metrics	Should	Established metrics for model validation and monitoring	KPIs defined & tracked
Data Acquisition Monitor	Should	Detect issues with data acquisition and warning workers	Alert system operational

		procedures for SEW process owners	Complete documentation
Integration Testing	Should	Complete testing in office environment before production	Tests passed
Minimal Rollout Effort	Could	TestStand setup + DAQ + body sound sensor or vibrometer installation per cell	TBD rollout time per cell
Worker Integration	Could	Inspector interface with pop-up labeling implemented on EOL PCs	Worker interface active
Production Monitoring	Could	One week monitoring period for all deployed cells	7-day stability verified
Automation	Won't	Automating data acquisition is not part of this project	-

Phase 2 Summary

Production-Ready ML Algorithm

Robust algorithm validated across multiple gearbox types with >90% accuracy

Automated Training Pipeline

Continuous learning system with automatic model updates and deployment

Performance Monitoring

Real-time accuracy tracking and anomaly detection across quality cells

Multi-Cell Operation

System successfully deployed and operational in two additional quality cells

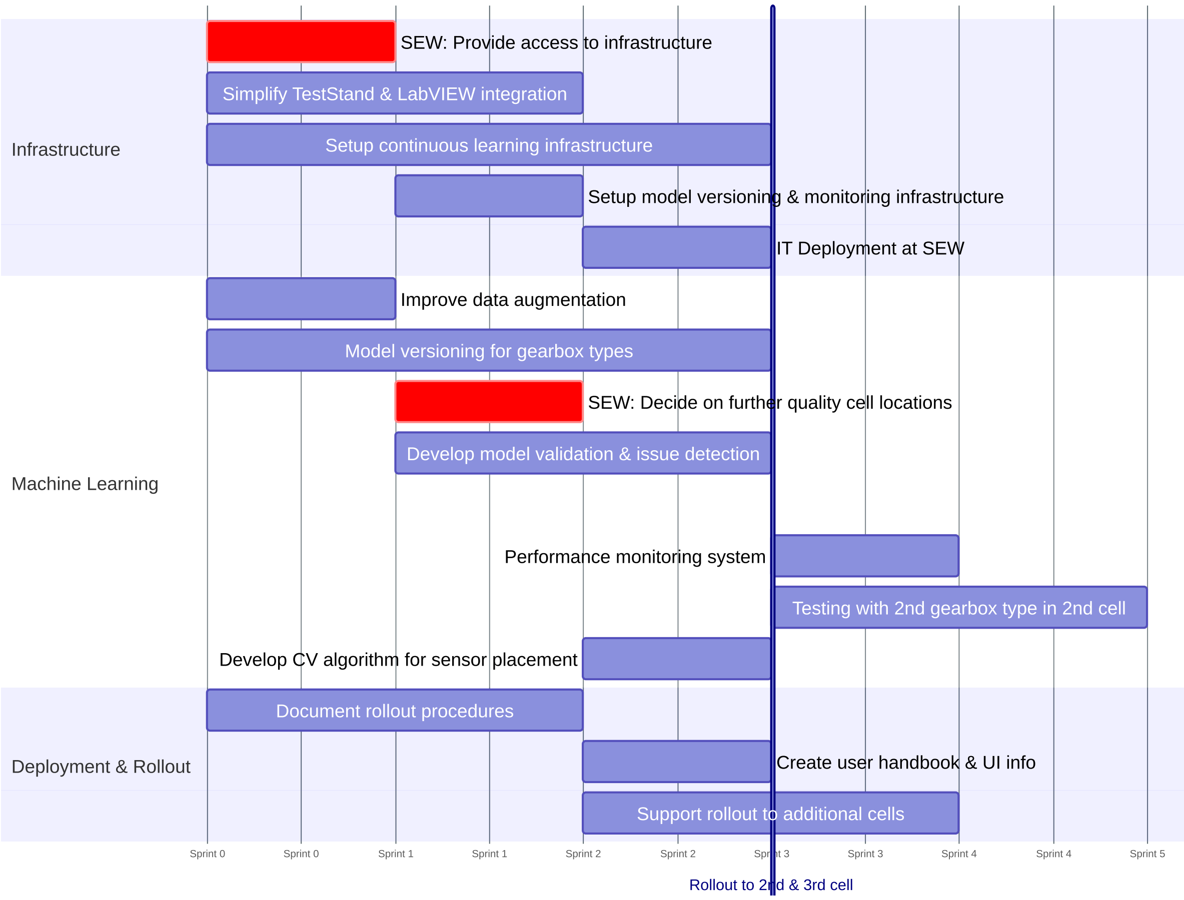
Rollout Documentation

Complete handbooks and infrastructure for future in-house expansion to additional cells

Show positive ROI

Pre-filtering & reliable classification lead to a significant reduction in manual testing time and costs

Roadmap


Infrastructure
SEW: Provide access to infrastructure
Simplify TestStand & LabVIEW integration
Setup continuous learning infrastructure
Setup model versioning & monitoring infrastructure
IT Deployment at SEW
Machine Learning
Improve data augmentation
Model versioning for gearbox types
SEW: Decide on further quality cell locations
Develop model validation & issue detection
Performance monitoring system
Testing with 2nd gearbox type in 2nd cell
Develop CV algorithm for sensor placement
Deployment & Rollout
Document rollout procedures
Create user handbook & UI info
Support rollout to additional cells
Sprint 0
Sprint 0
Sprint 1
Sprint 1
Sprint 2
Sprint 2
Sprint 3
Sprint 3
Sprint 4
Sprint 4
Sprint 5
Rollout to 2nd & 3rd cell

Red tasks in the GANTT roadmap are tasks that require input from SEW:

Task	Sprint	SEW Action Required	Impact on Timeline
Provide access to IT infrastructure	1	Grant access to SEW IT systems, provide VM or container infrastructure	Blocks all deployment activities
Decide on further quality cell locations	2	Select 2 additional quality cells for VibeCheck rollout	Blocks testing and further development of model
Support deployment in Graben-Neudorf	4 - 6	Provide support for new quality cell setups	Required for physical deployment and testing

Work packages

Work Package	Duration
Setup infrastructure for multiple quality cells	9 Days
Data update and analysis	1 Days
Allow multiple runs per motor, link between runs	1 Days
Highlight spectrograms that lead to not-OK classification	1 Days
Setup performance metrics & model validation	4 Days
Improve invalid experiment detection, mark as invalid and exclude from training	3 Days
Implement workflow in TestStand to repeat experiment when an invalid experiment is detected	2 Days
Data training format exploration	1 Days
Improve data augmentation	2 Days
Model training, comparison and iteration	3 Days
Setup rules for model switching	2 Days
Setup continuous-learning infrastructure	4 Days
Allow selecting laser vibrometer or body sound sensor	5 Days
Integrate laser vibrometer SDK, automate data acquisition & training	11 Days
Implement data acquisition and validation for continuous learning	4 Days
Implement model performance monitoring for continuous learning	5 Days
Continuous integration & deployment in SEW infrastructure	5 Days

ODBC	1 Days
Simplify TestStand & LabVIEW integration	4 Days
Integrate data from repair station, parse non.structured text descriptions, validate Not OK labels from workers	6 Days
Add admin interface to manage models and rules (which gearbox type goes to which model)	6 Days
Implement & test model versioning for different gearbox types	12 Days
Setup & test logging and error tracing	2 Days
Detecting issues with data acquisition and warning workers	5 Days
Support rollout to two additional quality cells	8 Days
Document rollout & deployment procedures for SEW process owners	3 Days
Create a user handbook & add information in the UI	3 Days
Testing & validation with new gearbox type in new quality cells	3 Days
Testing & monitoring of third cell over one week	8 Days
Meetings & Project Management	14 Days
Total Duration	**138 Days**

Rollen und Kosten

Rollen, Kosten, und der rechtliche Rahmen sind wieder in Deutsch verfasst.

Rolle	Level	Tagessatz	Tage	Gesamtkosten
AI Engineer	Technology Specialist III	1,008.00 €	54.00 Tage	54,432.00 €
Software Engineer	Technology Specialist IV	1,120.00 €	66.00 Tage	73,920.00 €
Mechanical Engineer	Technology Specialist III	1,008.00 €	4.00 Tage	4,032.00 €
Project Owner	Project Management IV	1,344.00 €	14.00 Tage	18,816.00 €
			Gesamtkosten Entwicklung	**151,200.00 €**
			Reisekosten	7,773.91 €
			Fixkosten	10,000.00 €
			Gesamtkosten Netto	**168,973.91 €**
			Steuer (19%)	32,105.04 €
			Gesamtkosten Brutto	**201,078.96 €**

Hardware Kosten sind nicht Teil des Angebots.

Rate Card

Es gilt die Rate Card aus dem Rahmenvertrag, Stand 2025:

Bereich	Titel	Level	Stundensatz	Tagessatz
Technology Specialist	Senior Lead Tech Specialist	Technology Specialist VI	180.00 €	1,440.00 €
	Lead Tech Specialist	Technology Specialist V	161.00 €	1,288.00 €
	Senior Tech Specialist	Technology Specialist IV	140.00 €	1,120.00 €
	Tech Specialist	Technology Specialist III	126.00 €	1,008.00 €
	Associate Tech Specialist	Technology Specialist III	112.00 €	896.00 €
	Developer	Technology Specialist I	84.00 €	672.00 €
Project Management	Partner	Project Management VI	230.00 €	1,840.00 €
	Senior Technical Executive	Project Management V	187.00 €	1,496.00 €
	Technical Executive	Project Management IV	168.00 €	1,344.00 €
	Senior Project Owner	Project Management III	149.00 €	1,192.00 €
	Project Owner	Project Management II	133.00 €	1,064.00 €

Die oben skizzierten Projektrollen stellen ein Referenzteam dar. Sollte es bei der Besetzung der Projektrollen zu Abweichungen kommen, gilt folgende Rate Card. Das Projektvolumen bleibt unberührt.

Rechtlicher Rahmen

Es gelten die rechtlichen Bedingungen des Vertrags **AB-250219.29-51606.6**

Unterschrift

AB-250731.9-51606.9

Wir bitten darum den unterzeichneten Vertrag oder Ihre Bestellung an bestellung@motius.de zu versenden.

Dieses Angebot gilt bis 2025-08-30

SEW-EURODRIVE GmbH & Co KG	Motius GmbH
Auftraggeber	Auftragnehmer
Zeichnungsberechtigter	Zeichnungsberechtigter
Ort, Datum	Ort, Datum
Unterschrift	Unterschrift