The Journal of Open Source Software

# openBURST: Real-time air surveillance simulation and analysis for active and passive sensors

**Zenon Mathews** [1¶] **and Romain Chessex** [1]

**1** Data Science and Modelling, Swiss Armed Forces Staff, Swiss Army, Switzerland ¶ Corresponding author

**DOI:** 10.21105/joss.07052

**Software**

- Review
- Repository
- Archive

**Editor:** Daniel S. Katz

**Reviewers:**

- @rvg296
- @hasantahir

**Submitted:** 14 July 2024
**Published:** 28 November 2024



## Summary

openBURST[1] is intended to provide the air surveillance sensor community with a framework for the development and testing of sensor coverage and real-time target detection analysis. openBURST focuses on the overall performance assessment of a sensor network. Besides static coverage diagram computations, openBURST facilitates real-time computation of sensor detections for simulated targets. This allows the statistical performance analysis of air picture generation in a given scenario. By providing a flexible and extendable framework to model and simulate active, passive, monostatic, and multistatic sensors, openBURST provides the implementation of optimization and machine learning approaches for sensor portfolio performance optimization in air surveillance.

## Statement of need

openBURST is a software project to design, deploy, and test active/passive radar system networks for detecting simulated or recorded real world air traffic. It consists of decoupled software modules that can be replaced, extended, or deployed independently for air surveillance sensor coverage and real-time detection computations. openBURST uses real-time communication between the distributed modules of the simulation framework, allowing for concurrent updates of target movements and sensor detections. Currently, openBURST supports coverage computation and real-time simulation of active radar and passive radar sensors (range-Doppler maps) using FM transmitters. The RF signal propagation, loss, and terrain analysis tool Splat! is extended for EM signal propagation computations with multi-core parallel processing and graphical user interfacing. openBURST uses openstreetmap data with openlayers for the interactive map. Terrain digital elevation data provided by GMTED10 is used for line-of-sight and propagation loss computations. By implementing a client-server architecture, openBURST enables browser-based clients to remain data- and implementation-agnostic.

Sensor simulation for air surveillance is of considerable interest both in the civilian and military fields as it allows for performance assessments of arbitrary sensor networks in diverse scenarios of interest. Such a simulation tool should be seen as the combination of three subparts: air traffic simulation, sensor detection simulation, and sensor data fusion.

In the open-source domain, several tools exist for the subpart of air traffic simulation. For example, BlueSky (Hoekstra & Ellerbroek, 2016) presents a fully open-source and open-data approach to air traffic simulation, whereas the OpenSky network (Schäfer et al., 2014) is a non-profit community-based receiver network that collects air traffic surveillance data and makes it accessible to academic and institutional researchers. In the domain of air surveillance sensor

[1] BURST is an acronym for "Base Units Readiness Simulation Tool". Burst 1969 mASL is a mountain peak in the Emmentaler Alps of canton Berne, Switzerland. The open-sourced version of the original BURST tool was named openBURST.

The Journal of Open Source Software

detection simulation, open-source tools for passive radar simulation such as PassiveRadarSim and for active radar simulation such as radarsimpy have been published. In the active radar domain, sophisticated open-source tools for very specific use cases such as for Synthetic Aperture Radar (SAR) RaySAR, or variants of generic wave propagation tools such as gprMAX also exist. Diverse data fusion, tracking, and state estimation tools have also been open-sourced such as Stone Soup (Thomas et al., 2017). However, currently no extendable real-time simulation suite for air traffic simulation and sensor detection for active/passive sensors that incorporates wave propagation modelling is available to the open-source community. openBURST is an attempt to fill this gap, proving the research and air surveillance simulation community with a general-purpose and modular tool, that provides a user-friendly browser-based interface.

Unlike a number of existing open-source tools for detailed simulations of single sensors (either active or passive, monostatic or bistatic, etc.), openBURST provides an extendable framework for diverse sensor and target simulations. By parallelizing computationally intensive steps and by providing a user-friendly browser-based interface, openBURST considerably simplifies sensor network and target simulations. For example, openBURST can be used to dynamically change scenarios, sensor/transmitter attributes, and targets for predicting passive/active radar performance and compare with real-world test measurements as needed by recent studies (Malanowski et al., 2022). openBURST provides a modular and extendable active/passive sensor network simulation framework that can be used as the sensor model in diverse studies, such as sensor fusion performance (Fränken et al., 2022), sensor location optimization (Mathews et al., 2015; Yi et al., 2017), learning resource optimization (Mathews et al., 2022), or decision making (Mathews et al., 2008). In summary, openBURST facilitates new exciting scientific explorations of sensor network/fusion performance studies and sensor network performance benchmarking. Extensions with digital transmitters for passive radar and passive emitter tracking sensors are currently planned.

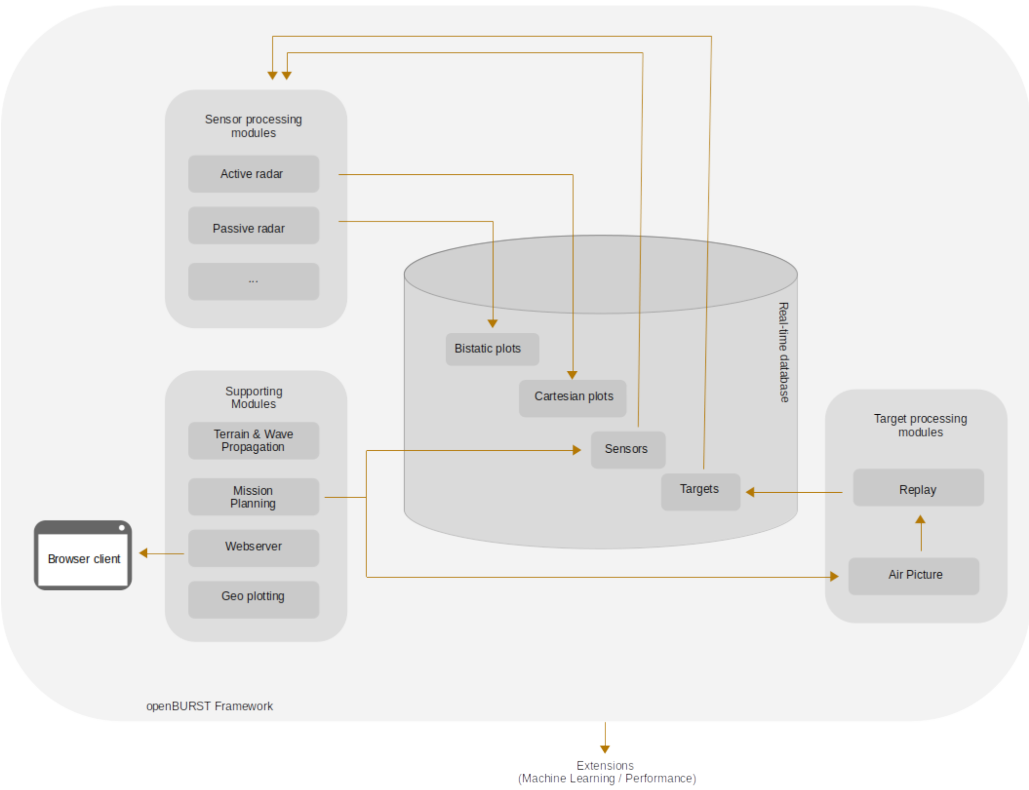


**Figure 1:** openBURST framework with its component modules and real-time database.

The Journal of Open Source Software

# Results Examples

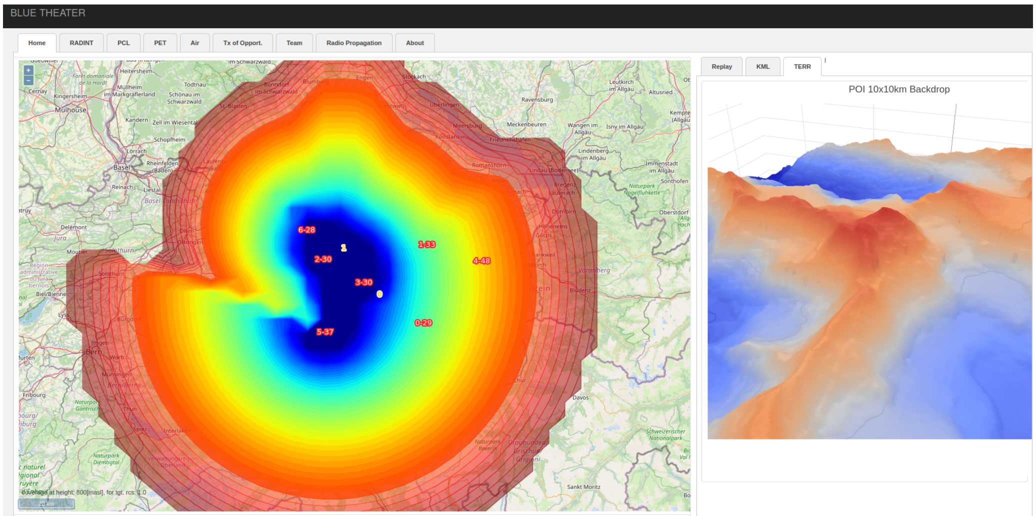


**Figure 2:** Example of passive radar coverage computation. Left: with numbered receivers and transmitters of opportunity, right: terrain backdrop of the sensor position.

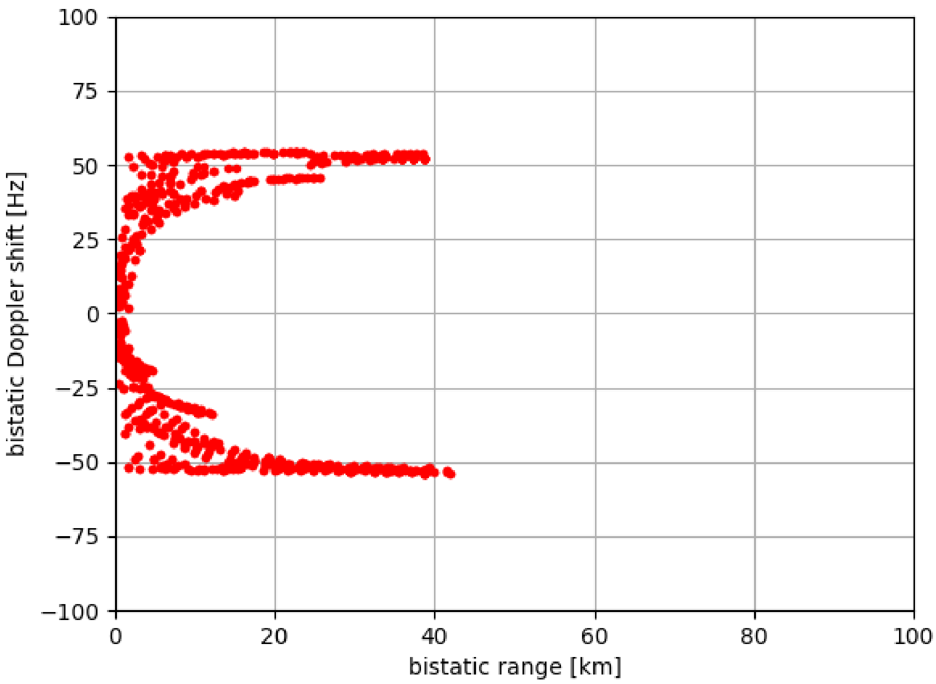


**Figure 3:** Example of passive radar real-time range-Doppler detections for a given target scenario of a closely flying formation of aerial vehicles.

## Publications and Projects

Versions of openBURST have been used in a number of studies for passive radar location optimization, sensor fusion, and learning resource allocation in active and passive sensor networks (Mathews et al., 2015, 2022; Mousel, 2017; Studer et al., 2022).

## Acknowledgements

We thankfully acknowledge the support from the the Swiss Armed Forces Staff for open-sourcing openBURST. We also thank our colleagues at the Swiss Department of Defense, especially from the Swiss Air Force and armasuisse Science & Technology. We acknowledge the early work for passive radar coverage computation implemented by the master thesis by Mousel (2017).

## References

Fränken, D., Ott, T., Lutz, S., Hoffmann, F., Samczyński, P., Płotka, M., Dróżka, M., Schüpbach, C., Mathews, Z., Welschen, S., & Norheim-Næss, I. (2022). Integrating multiband active and passive radar for enhanced situational awareness. *IEEE Aerospace and Electronic Systems Magazine*, *37*(8), 36–49. https://doi.org/10.1109/MAES.2022.3178973

Hoekstra, J. M., & Ellerbroek, J. (2016). BlueSky ATC simulator project: An open data and open source approach. *Proceedings of the Seventh International Conference for Research on Air Transport (ICRAT)*.

Malanowski, M., Żywek, M., Płotka, M., & Kulpa, K. (2022). Passive bistatic radar detection performance prediction considering antenna patterns and propagation effects. *IEEE Transactions on Geoscience and Remote Sensing*, *602*, 1–16. https://doi.org/10.1109/TGRS.2021.3069636

Mathews, Z., Bermudez i Badia, S., & Verschure, P. (2008). Intelligent motor decision: From selective attention to a Bayesian world model. *International IEEE Conference Intelligent Systems*, *1*, 4-8-4-13. https://doi.org/10.1109/IS.2008.4670418

Mathews, Z., Quiriconi, L., Schuepbach, C., & Weber, P. (2022). Learning resource allocation in active-passive radar sensor networks. In *Frontiers in Signal Processing, Volume 2*. https://doi.org/10.3389/frsip.2022.822894

Mathews, Z., Quiriconi, L., & Weber, P. (2015). Multi-static passive receiver location optimization in alpine terrain using a parallelized genetic algorithm. *2015 IEEE Radar Conference (RadarCon)*. https://doi.org/10.1109/RADAR.2015.7131222

Mousel, P. (2017). Passive radar coverage optimization. *Master Thesis, Institute of Electromagnetic Fields (IEF), ETH Zurich*.

Schäfer, M., Strohmeier, M., Lenders, V., Martinovic, I., & Wilhelm, M. and. (2014). Bringing up OpenSky: A large-scale ADS-b sensor network for research. *13th IEEE/ACM International Symposium on Information Processing in Sensor Networks (IPSN)*, 83–94. https://doi.org/10.1109/IPSN.2014.6846743

Studer, S., Mathews, Z., Welschen, S., C., S., Leuthold, J., & Smajic, S. (2022). Maximum information fusion of passive and active radars for air surveillance. *IEEE Radar Conference (RadarConf), New York City, NY, USA,pp. 1-6*. https://doi.org/10.1109/RadarConf2248738.2022.9764225

Thomas, P. A., Barr, J., Balaji, B., & White, K. (2017). *An open source framework for tracking and state estimation ('Stone Soup')*. *10200*, 1020008. https://doi.org/10.1117/12.2266249

Yi, J., Wan, X., Leung, H., & Lü, M. (2017). Joint placement of transmitters and receivers for distributed MIMO radars. *IEEE Transactions on Aerospace and Electronic Systems*, *53*(1), 122–134. https://doi.org/10.1109/TAES.2017.2649338