GAMA RTK ENGINE

Technology White Paper

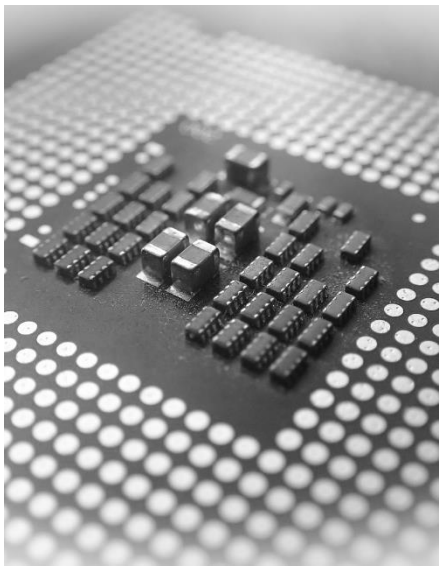
JAN 2023

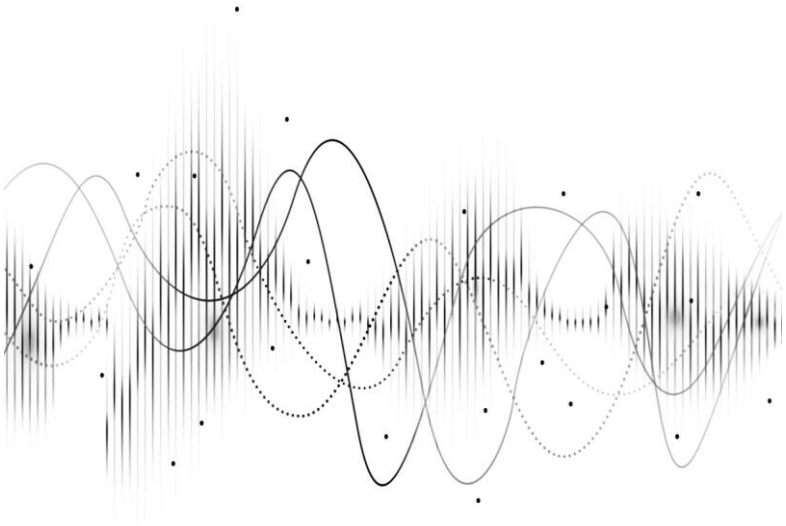
Carlson
BREAK NEW GROUND

ABSTRACT

Carlson Software's Navigation Division is proud to present its next generation RTK engine, the Gama RTK Engine (named after famous explorer Vasco da Gama).

This paper provides an overview of the main technologies deployed in the new Carlson Gama RTK engine to deliver best-in-class performance as tested in the field. This paper also includes a summary report on competitive RTK performance testing of the Gama RTK engine.





FOR NEXT-GEN CPUs

Modern CPU architectures enable powerful multi-core computations in embedded and handheld devices.

Gama was designed to take full advantage of multi-threaded computation routines, unlocking new possibilities and computational performance.

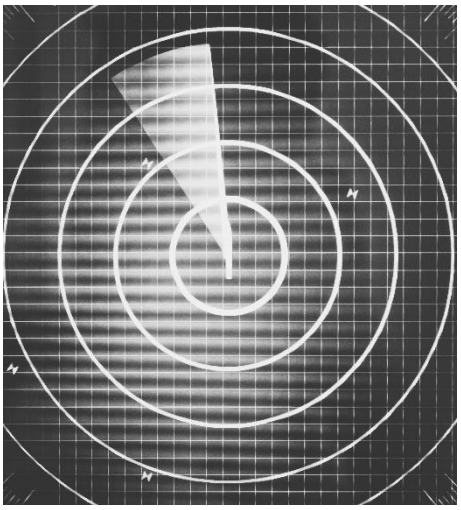
NEXT-GEN FILTERS

At its core Gama relies on multiple Extended Kalman Filters that estimate individual error components, for each individual GNSS signal. New CPU architectures enable, for the first time, to deploy extended mathematical models eliminating approximations that were a necessity of the past. Gama can estimate more than 1000 parameters per second to ensure the highest accuracy in every environment.

GNSS SIGNAL AND FREQUENCY DIVERSITY

Gama was designed from the ground up to take maximum advantage of all GNSS signals available today as well as those that may become available in the future.

Gama implements a strict independent handling of all GNSS signals available in multiple frequencies, including different modulations that signals have available in common GNSS frequency bands. This means, for instance, Gama can fully use the legacy GPS L2P and the new L2C simultaneously, for RTK, side by side with GPS L1 and L5. Gama can also operate in single-frequency mode, or with any sub-set of frequencies, in case some signals are not available or become jammed. A similar logic applies to all GNSS constellations.



Outlier Detection and Handling

Multiple protection layers apply a variety of techniques for outlier detection and handling that protect the main estimation process responsible for the high-accuracy PVT computations.

Iterative Robust Statistics and strict statistical analysis is employed to identify measurements that do not fit in the predefined model.

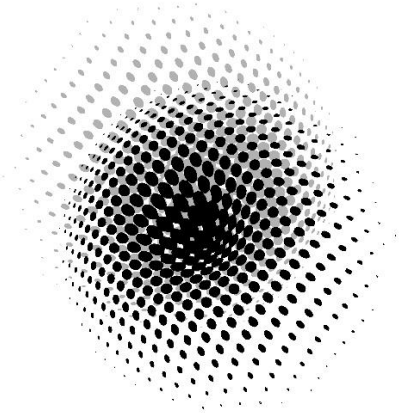
Outlier handling mechanisms respond by either adapting the error models in real-time, and still use the affected observation, or by fully rejecting faulty observations if the error is too large to be useful. This logic is applied in the multiple Extended Kalman Filters that comprise Gama, as well as at the level of a range of pre-processing filters.

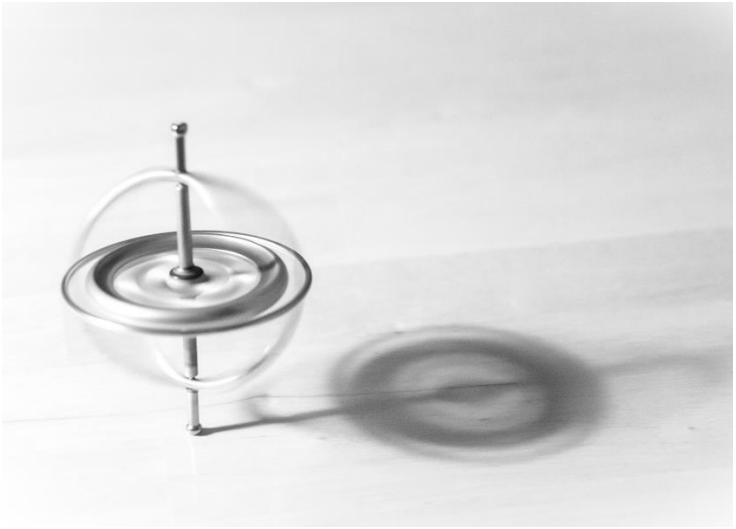
Real-Time Adaptive Filtering

Gama employs multiple techniques to ensure all GNSS error models are as accurate as possible, regardless of the environmental conditions and dynamics.

Data-driven error models were carefully derived from a broad pool of real environment data, collected under controlled conditions, and provide a strong basis for all estimation processes within the Gama Engine.
To cope with changing conditions of the surrounding environment, a collection of pre-processing filters are used to monitor GNSS signal quality, not only in terms of magnitude of the errors but also its temporal behavior (how effects change over time windows), together with other signal characteristics such as the GNSS signal strength.

Different multi-frequency signal combinations are computed, and filtered, to isolate different error sources (e.g., multipath, non-LOS signals, ionosphere) and interpret their magnitude and time behavioral characteristics.
All these metrics are combined to adjust in real-time the GNSS observation models of the main Extended Kalman Filters.





RTK FIXED+

A higher accuracy and integrity status for immediate assurance even in the most challenging conditions. Gama reports RTK Fixed+, as a user status, when additional integrity criteria are met.

Built-in real-time validation mechanism evaluates consistency of solutions computed by independent engines running in parallel.

Individual RTK engines based on truly independent implementations dramatically reduce the probability of an incorrect RTK Fix.

IMU TIGHT-COUPLING

Gama can process data from six-axis IMU sensors to provide high accuracy position, velocity, tilt and heading information.

State-of-the-art tightly-coupled hybridization engine provides capability to operate Gama in challenging environments and is immune to magnetic interference.

An advanced integration technique combines high accuracy GNSS measurements and high-rate IMU data to provide high accuracy and high-rate navigation solutions, ensuring continuous operation even during GNSS outages.

MULTI-SENSOR ENGINE

A new future proof platform capable of integrating and processing measurements from a wide range of sensors such as odometers, camera, and lidar. A multi-sensor engine capable of providing navigation solutions even in challenging GNSS denied environments.

More Accuracy

Higher Availability

Fixed+ Assurance

Carlson

COMPETITIVE TESTING RESULTS

As part of the internal RTK R&D processes, Carlson's internal test team continuously tests the latest version of the Gama RTK engine in a variety of diverse environments.

Overall statistics shown in the next sections were directly pulled from the Carlson Test Database which aggregates test results gathered over the last 2 years from the Gama RTK engine and real-time results produced by competitors.

Position error statistics were computed versus independent references constructed using a hybrid technique combining robotic total station and GNSS RTK, ensuring an accurate and independent reference even in the most challenging locations near wall and in dense foliage.

PERFORMANCE METRICS

Well defined performance metrics to objectively measure all main quality parameters.

CONTINUSLY TEST AND REPORT

Regular in-field testing to qualitatively test the system from a user perspective and collect data for our test database.

TEST STATISTICS DATABASE

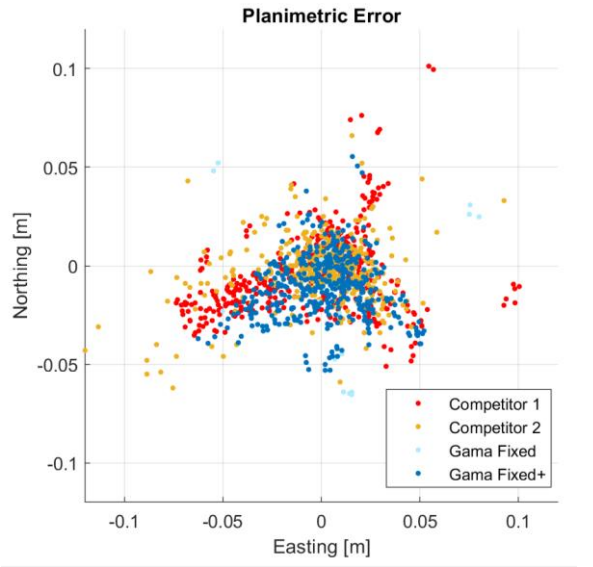
Compile all test results in a single database to monitor evaluation of performance and objectively measure and compare performance.

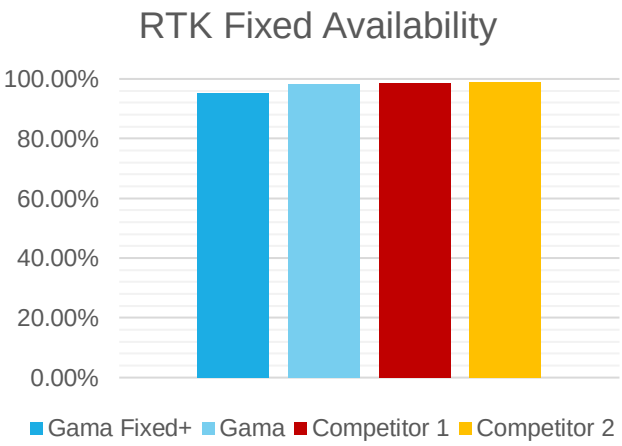
STOP-AND-GO TEST

Competitive testing vs RTK industry leaders in stop-and-go test dynamics within semi-urban environment.

12 control points were sequentially surveyed multiple times in stop and go dynamics.
2 hours test duration.

Test track features a wide range of GNSS challenges with different level of difficulty.
Control points were pre-surveyed using hybrid robotic total station and RTK.

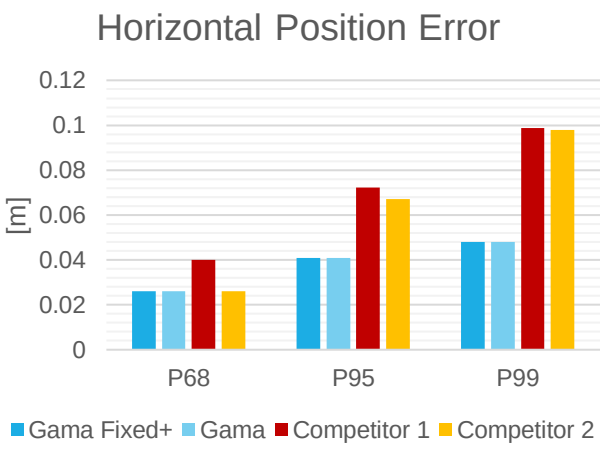


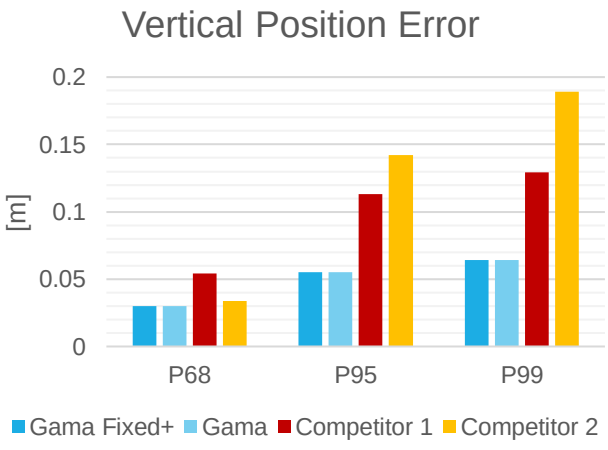


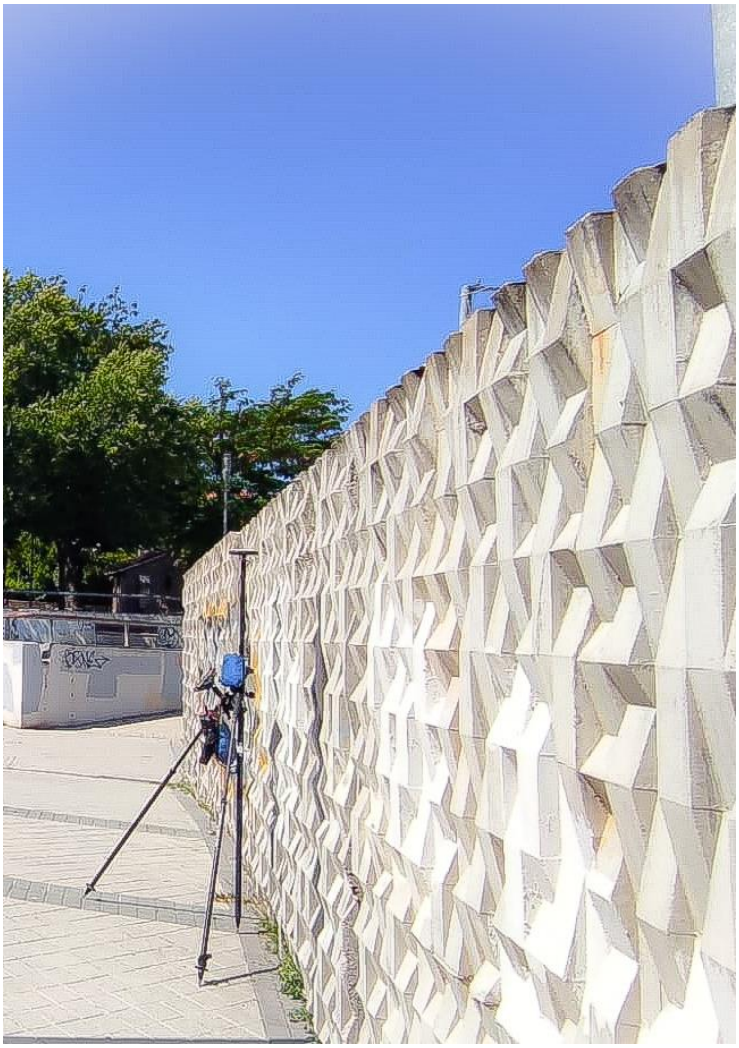
POSITION ERROR STATISTICS

Gama outperforms competitors in all error percentiles, both for horizontal and vertical domains:

- P68: 68 percentile (1-sigma confidence)
- P95: 95 percentile (2-sigma confidence)
- P99: 99 percentile (3-sigma confidence)







Robust against the elements

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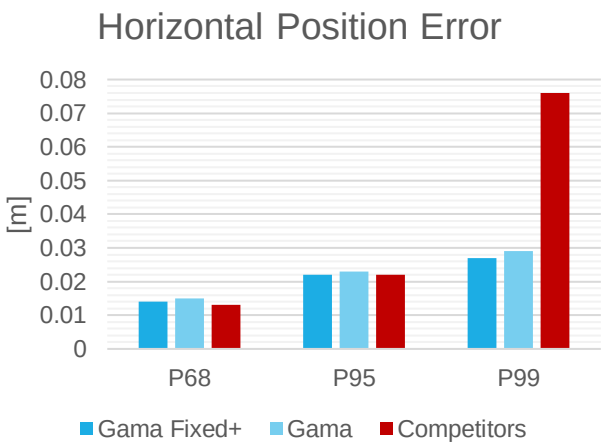
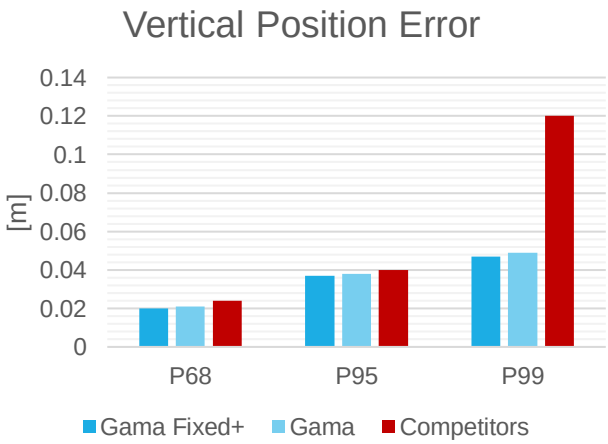
OVERALL STATISTICS

SEMI URBAN

Based on a total of 37 hours of data
from 22 different data sets recorded at different locations.

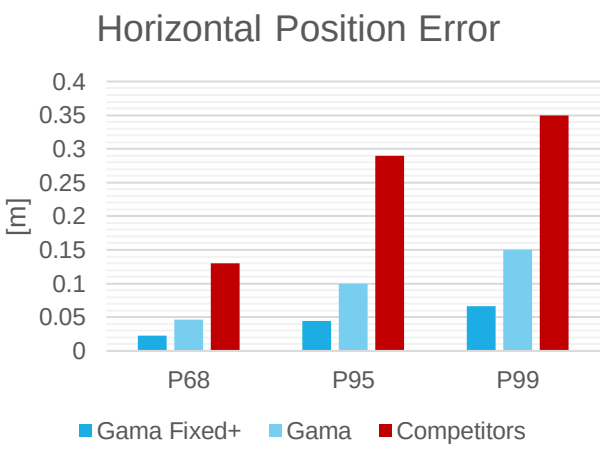


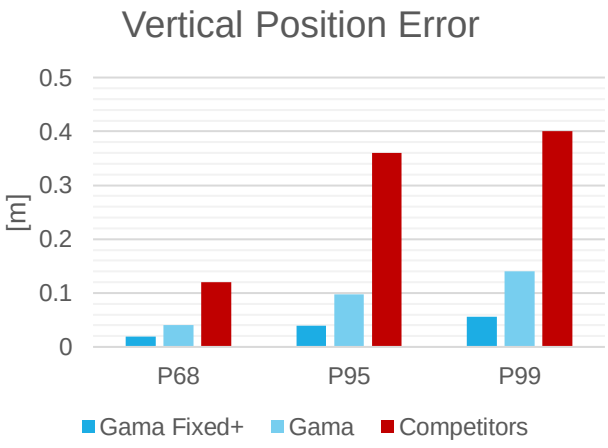


OVERALL STATISTICS

NEXT TO WALL

Based on a total of 90 hours of data
from 22 different data sets recorded at different locations.

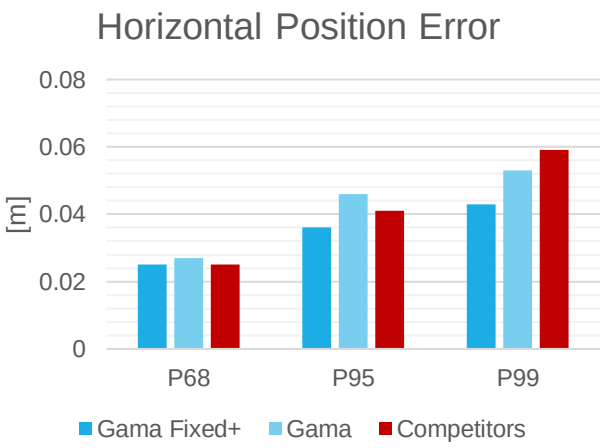


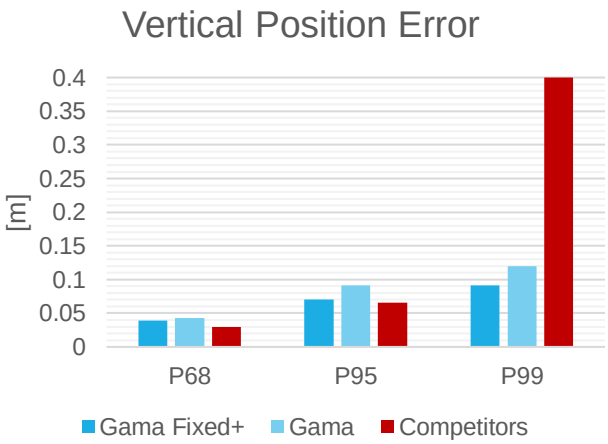


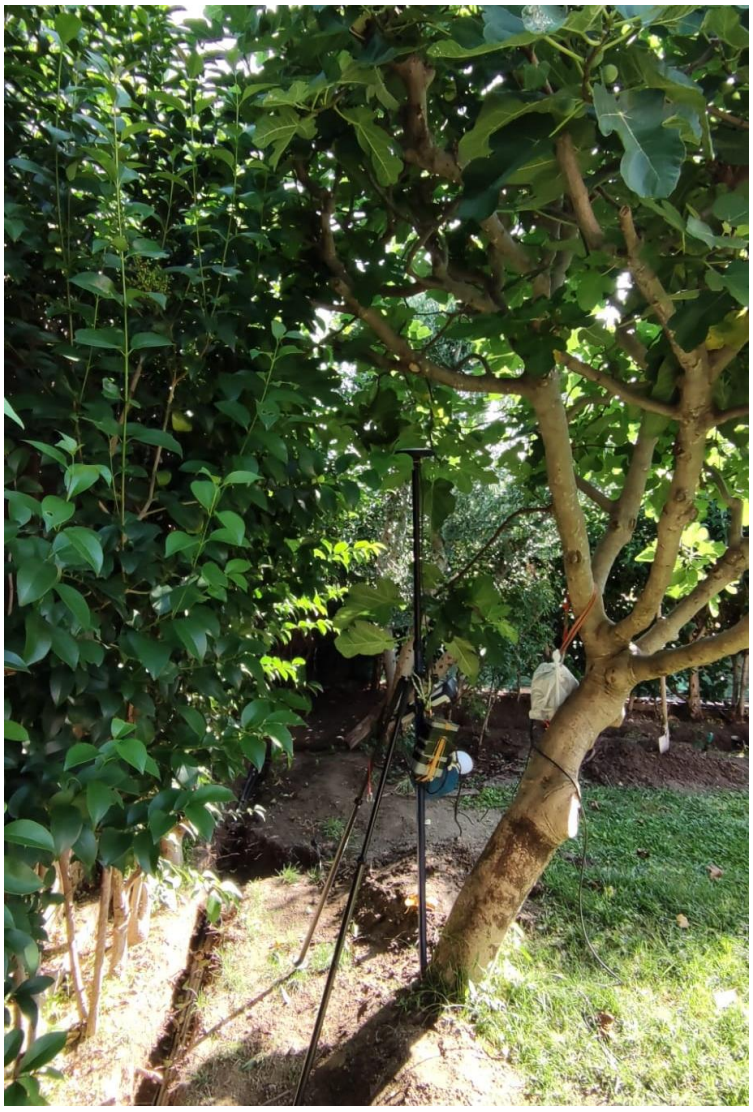
OVERALL STATISTICS

DENSE FOLIAGE

Based on a total of 56 hours of data from 13 different data sets recorded at different locations.







CONCLUSION

Carlson Software's next generation Gama RTK engine deploys a range of new technologies to deliver best-in-class performance.

The Gama RTK engine supersedes performance metrics in all environments under test when compared to established RTK industry leaders, as assessed from performance test reports gathered over the last 2 years and supported by a large statistical pool of data presented in this report.

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