

Accelerating High-Fidelity End-to-End Image Simulation with Stand-Alone Workflows

Using Lens Performance Data (LPD)

Image simulation workflows are often constrained by fragmented tool chains, manual data transfer, and limited access to optical design expertise. These challenges slow iteration cycles and restrict collaboration across multidisciplinary teams.

This application note introduces a stand-alone approach to high-fidelity end-to-end image simulation using Lens Performance Data (LPD). By capturing lens behavior in a compact, shareable format, LPD enables fast, accurate simulations without requiring direct access to optical design tools. This approach simplifies workflows, accelerates iteration, and enables collaboration across teams while preserving proprietary design information.

The Challenge of Image Simulation Workflows

Modern imaging system development requires coordination across multiple domains, including optics, sensors, and image processing. Traditionally, simulating these systems involves a combination of specialized tools and custom integrations.

Typical workflows include:

- Optical simulation to model lens behavior
- Transfer of optical results to sensor simulation tools
- Integration with image signal processing (ISP) models
- Use of custom scripts to connect each stage

These workflows introduce several challenges:

- **Slow iteration cycles** due to repeated simulation across disconnected tools
- **Complex tool dependencies**, requiring access to multiple specialized environments
- **Limited accessibility**, preventing non-optical experts from running full simulations
- **Maintenance burden** associated with custom scripts and data pipelines

As imaging systems become more complex — especially in AI-driven applications — these limitations directly impact development efficiency and system-level insight.

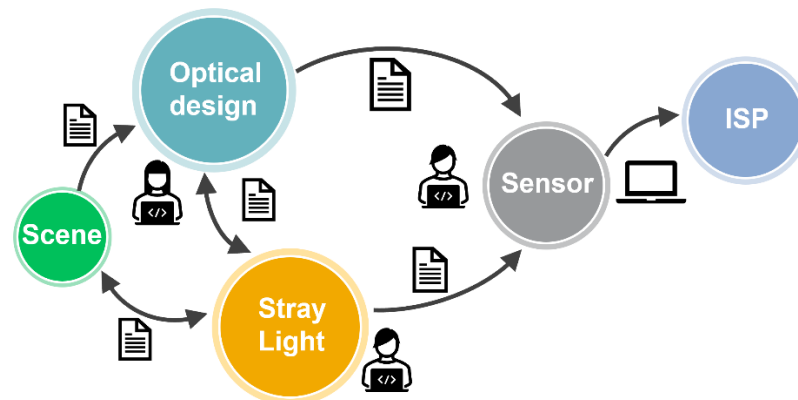


Figure 1. Data handoffs between optical, sensor, and ISP tools.

Rethinking Image Simulation: A Stand-Alone Approach

A stand-alone image simulation workflow addresses these constraints by consolidating the imaging pipeline into a single environment.

In this approach, image simulation operates independently of real-time connections to optical design tools. Instead of repeatedly accessing lens design data, simulations rely on precomputed representations of lens performance.

This enables:

- Faster iteration when modifying scenes, sensors, or processing steps
- Reduced dependency on specialized tools
- Broader accessibility for cross-functional teams
- Simplified workflow management

The result is a more flexible and efficient framework for evaluating imaging systems at the system level.

Key benefit

Stand-alone simulation allows iteration on scenes, sensors, and processing without re-running optical simulations.

Lens Performance Data (LPD): Capturing Lens Behavior

At the core of this approach is the **Lens Performance Data (LPD) file**, a self-contained representation of lens imaging behavior.

Rather than describing the physical construction of a lens, the LPD file captures the **optical performance characteristics** required for simulation, including:

- Point Spread Function (PSF) data
- Distortion characteristics
- Field-dependent performance
- Wavelength-dependent behavior
- Polarization effects

This file allows image simulation tools to accurately model lens effects without requiring access to the underlying design.

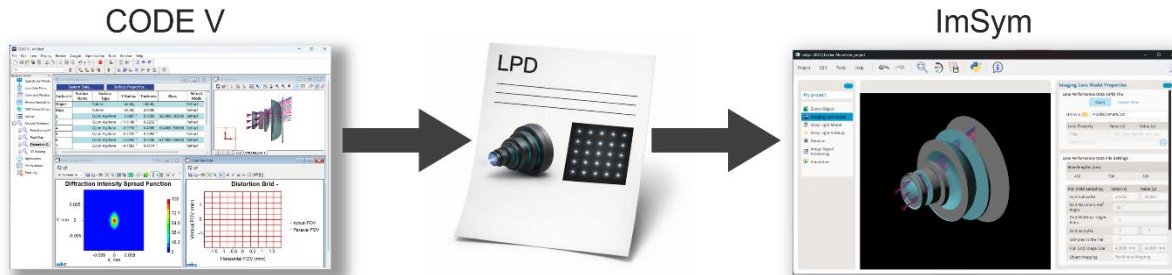


Figure 2. Save LPD from CODE V to import into ImSym

LPD separates lens performance from lens design.

This separation enables:

- Faster reuse across simulation scenarios
- Simplified collaboration between teams
- Protection of proprietary lens design data

Generating and Using LPD Files

LPD files can be created through two primary workflows:

Generation from CODE V

An optical designer generates the LPD file using CODE V and shares it with downstream users.

Generation within ImSym

ImSym invokes CODE V in the background to generate LPD from a lens model.

Both approaches support flexibility in team structure and workflow integration

Workflow: Stand-Alone End-to-End Image Simulation

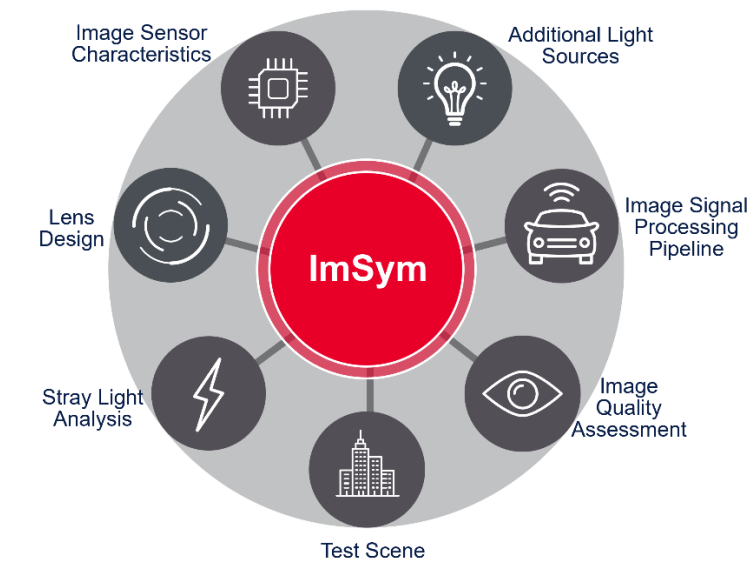


Figure 3. Full imaging chain using ImSym.

Using LPD, the image simulation workflow becomes streamlined:

Step 1: Define Scene

- Import a scene and define radiometric properties

Step 2: Apply Lens Effects via LPD

- Use LPD to simulate optical effects without direct lens model access

Step 3: Model Sensor Behavior

- Configure detector parameters such as exposure, noise, and pixel layout

Step 4: Apply Image Signal Processing

- Execute ISP steps such as demosaicing, color conversion, or distortion correction

Step 5: Iterate

- Modify scene, sensor, or processing parameters without re-running optical simulations

This workflow removes the need for repeated data transfer between tools and enables rapid experimentation.

Example Application: Simulation for Object Detection

To illustrate the workflow, consider an example involving image simulation for a car detection algorithm:

- Multiple scenes are simulated using a consistent LPD-based lens model
- Python scripting automates batch simulation across scenarios
- Simulated images are processed using an object detection algorithm
- Results are compared across variations, such as distortion correction vs. uncorrected images

In this example, a wide-angle lens introduces noticeable distortion in the simulated images. Detection results are evaluated both before and after applying a distortion correction step through a custom image signal processing (ISP) pipeline. This allows engineers to isolate the impact of distortion on detection performance and determine whether correction is necessary for the application. Simulation across multiple scenes supports scalable evaluation against expected object positions, enabling more systematic analysis.

This approach supports:

- Rapid evaluation of detection performance under different imaging conditions
- Comparison of system behavior with and without distortion correction
- System-level tradeoff analysis (e.g., optics vs. processing)
- Efficient dataset generation for AI workflows



Original scene



Car detection on
distorted image



Car detection on
distortion-corrected image

Practical insight

Batch simulation enables rapid evaluation of model performance across varied imaging conditions.

Collaboration Across Teams and Organizations

LPD enables a new model of collaboration:

- Optical designers can share lens performance without exposing design details
- Image simulation engineers can work independently of optical design tools
- External partners can evaluate system performance using shared LPD files

This is particularly valuable in scenarios involving:

- Supplier collaboration
- Cross-functional engineering teams
- Distributed development environments

Practical Benefits of the LPD-Based Approach

The stand-alone workflow provides measurable improvements:

- **Faster iteration**
Engineers can modify simulation parameters without recomputing optical models.
- **Simplified toolchain**
Fewer tool dependencies reduce setup complexity and licensing constraints.
- **Increased accessibility**
Non-specialists can perform complete image simulations.
- **Reduced script maintenance**
Integrated workflows decrease reliance on custom code.
- **IP protection**
Lens designs remain secure while performance data is shared.

These benefits directly support more efficient system-level development and earlier identification of performance issues.

When to Use this Approach

The LPD-based workflow is particularly effective for:

- System-level imaging simulation
- Algorithm development and validation
- Cross-team collaboration
- Early-stage architecture evaluation
- Scenarios requiring rapid iteration

Conclusion

Stand-alone image simulation workflows based on Lens Performance Data provide a practical solution to the limitations of traditional multi-tool pipelines.

By decoupling image simulation from direct access to optical design environments, this approach enables:

- Faster iteration cycles
- Simplified workflows
- Improved collaboration
- Broader accessibility

For engineering teams focused on system-level performance, the ability to simulate end-to-end image formation efficiently and flexibly can significantly accelerate development and improve design decisions.

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