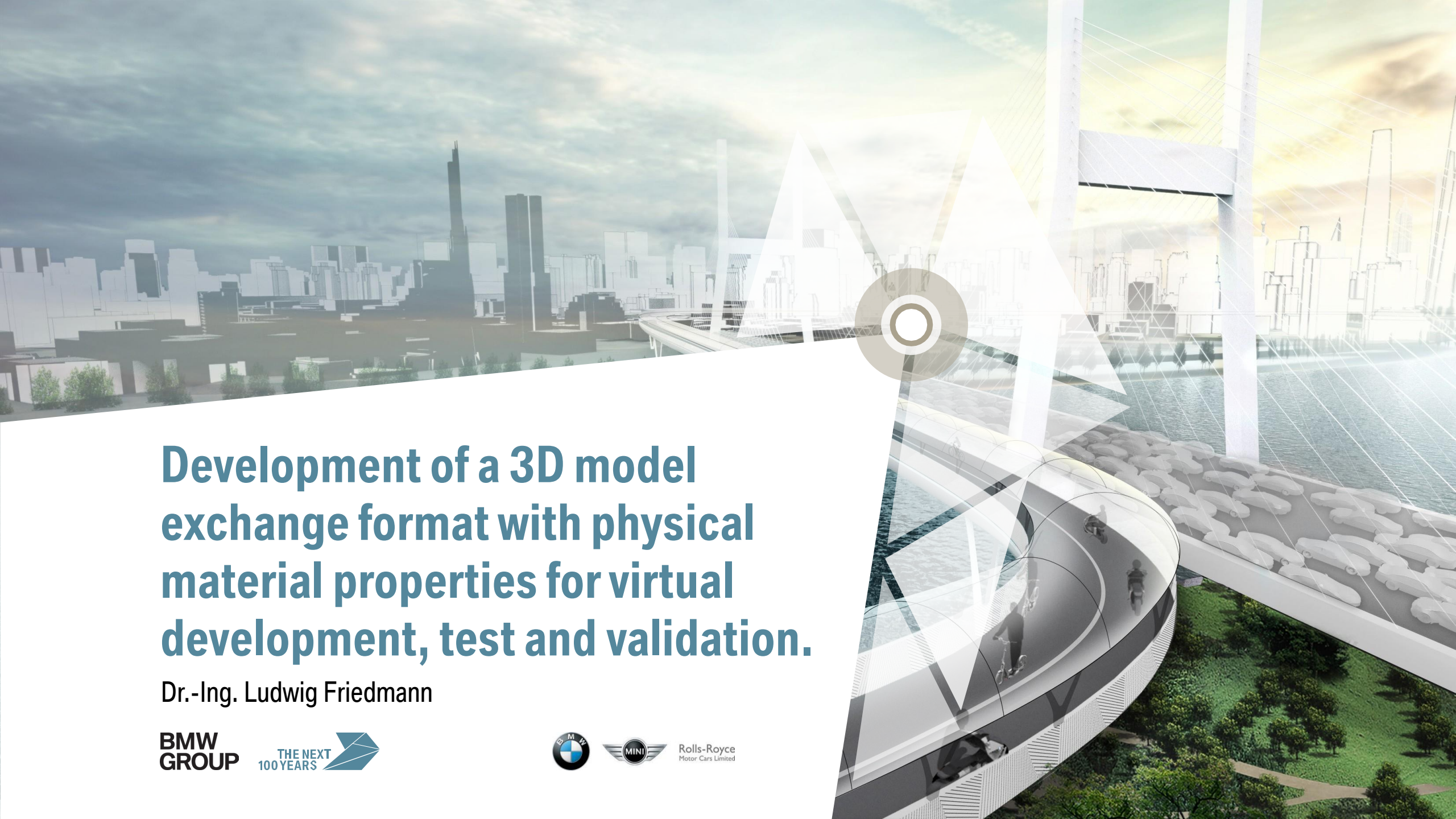


# Development of a 3D model exchange format with physical material properties for virtual development, test and validation.

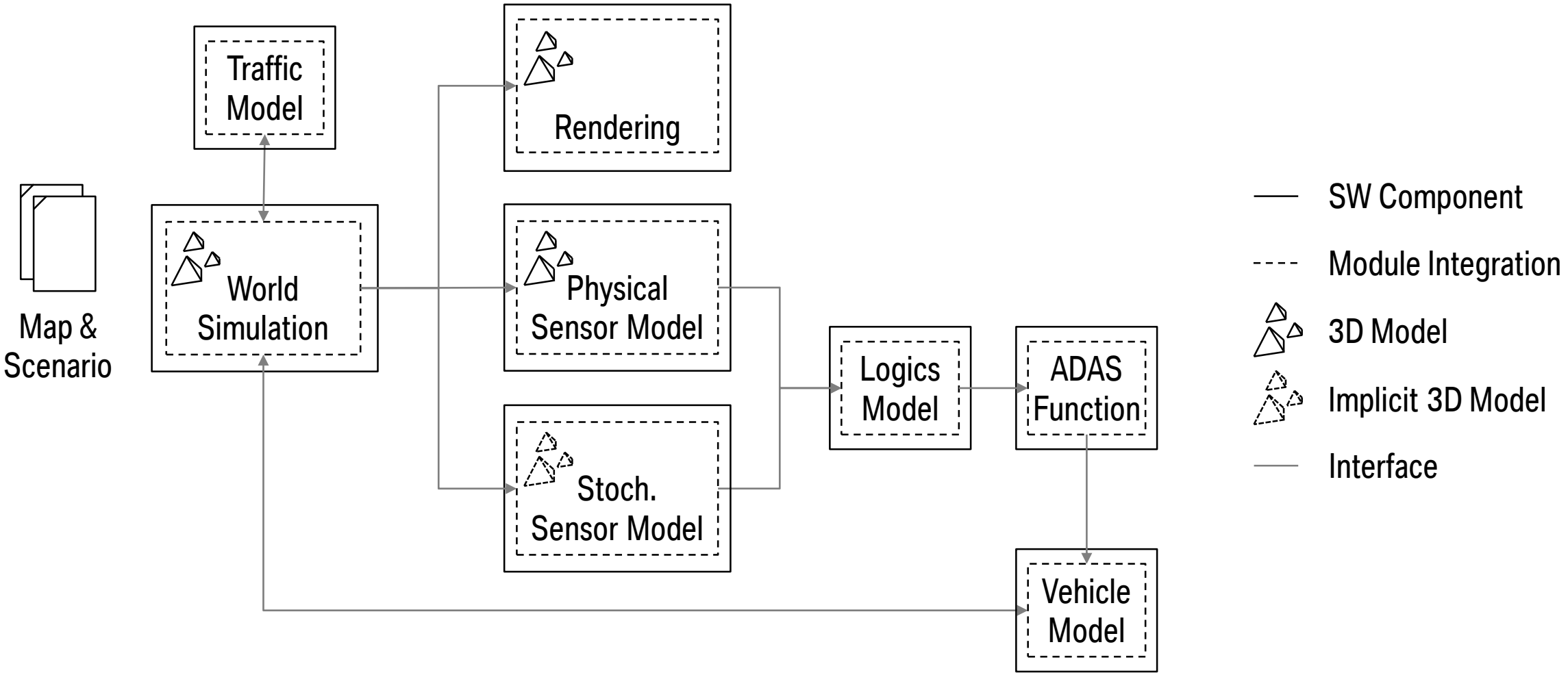
Dr.-Ing. Ludwig Friedmann

BMW GROUP THE NEXT 100 YEARS

Rolls-Royce Motor Cars Limited

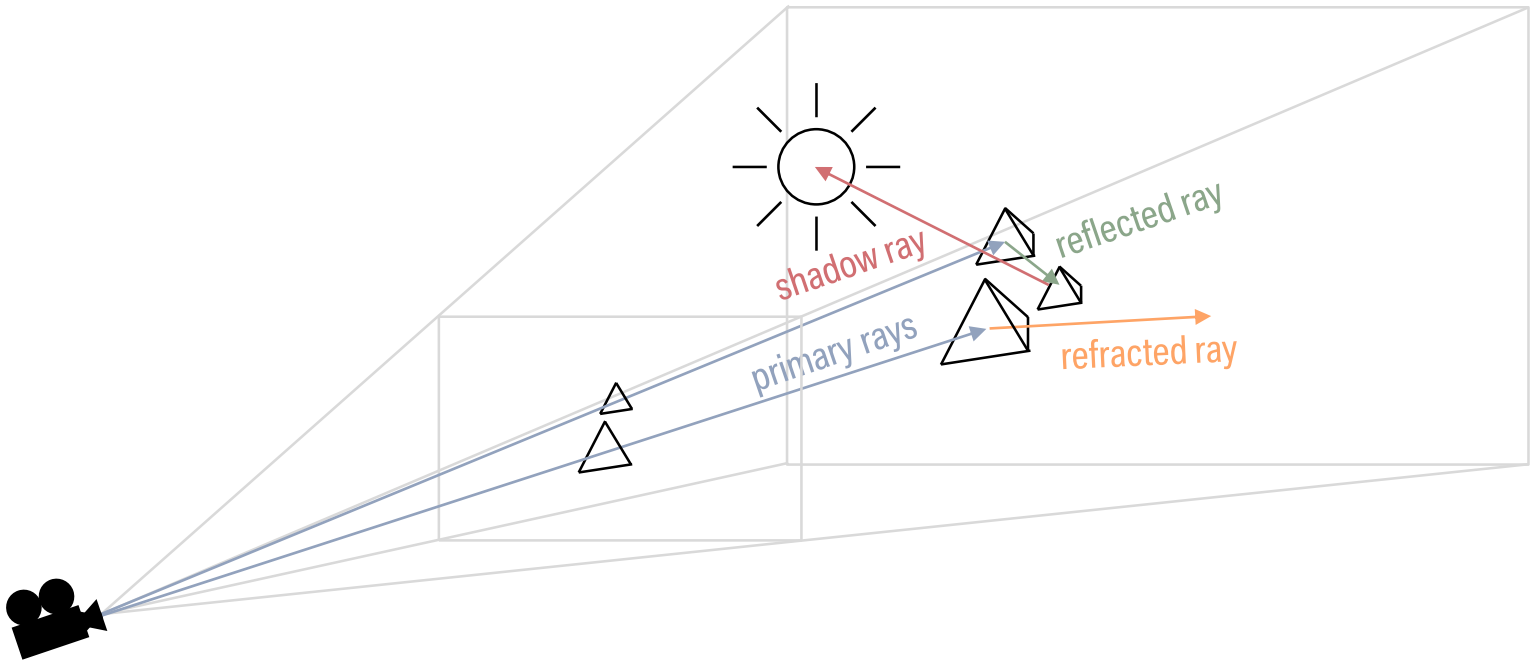
# REQUIREMENTS.

## MODERN SOFTWARE ARCHITECTURE.



# REQUIREMENTS.

## MODERN RENDERING: RAY TRACING, PHYSICALLY BASED RENDERING.




**Visibility**
Primary rays (raycasts)

**Lighting & Shadows (Light Distribution)**
Shadow rays

**Reflections**
Reflected rays

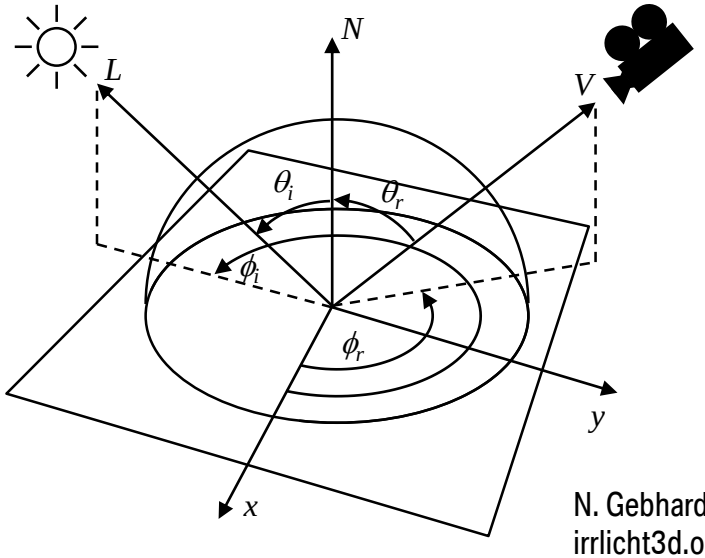
**Opacity/Translucent Objects**
Refracted rays

single render loop

- Ray tracing forms the basis of modern rendering and sensor simulation
- Key concept: Bidirectional Reflection Distribution Function (BRDF)
- Physically based rendering (PBR) approximates BRDFs

# REQUIREMENTS.

## BIDIRECTIONAL REFLECTION DISTRIBUTION FUNCTION (BRDF).



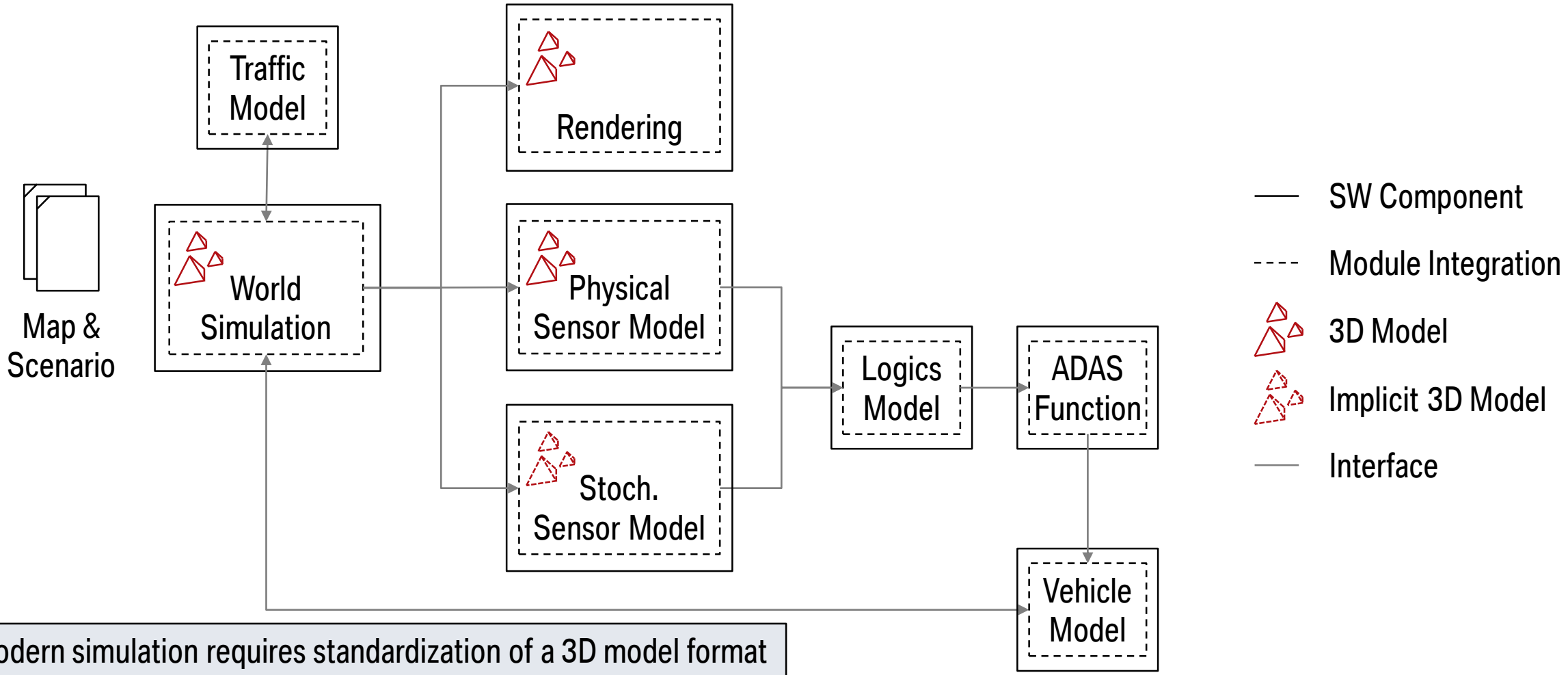

$$BRDF = f(\theta_i, \phi_i, \theta_r, \phi_r) = f(\boldsymbol{L}, \boldsymbol{V})$$

$$BRDF = \frac{dL_r(\theta_r, \phi_r)}{dE_i(\theta_i, \phi_i)} = \frac{Radiance\ in\ direction\ \boldsymbol{V}}{Irradiance\ in\ direction\ \boldsymbol{L}}$$

N. Gebhardt. Einige BRDF Modelle.
irrlicht3d.org/papers/BrdfModelle.pdf

- Defined by National Bureau of Standards (USA, 1977)
- Models specular reflection, diffuse diffraction and refraction
- Many different models (from visually plausible to physically accurate)
- Physical modeling requires physical material properties

# REQUIREMENTS.
## NEED FOR STANDARDIZATION.

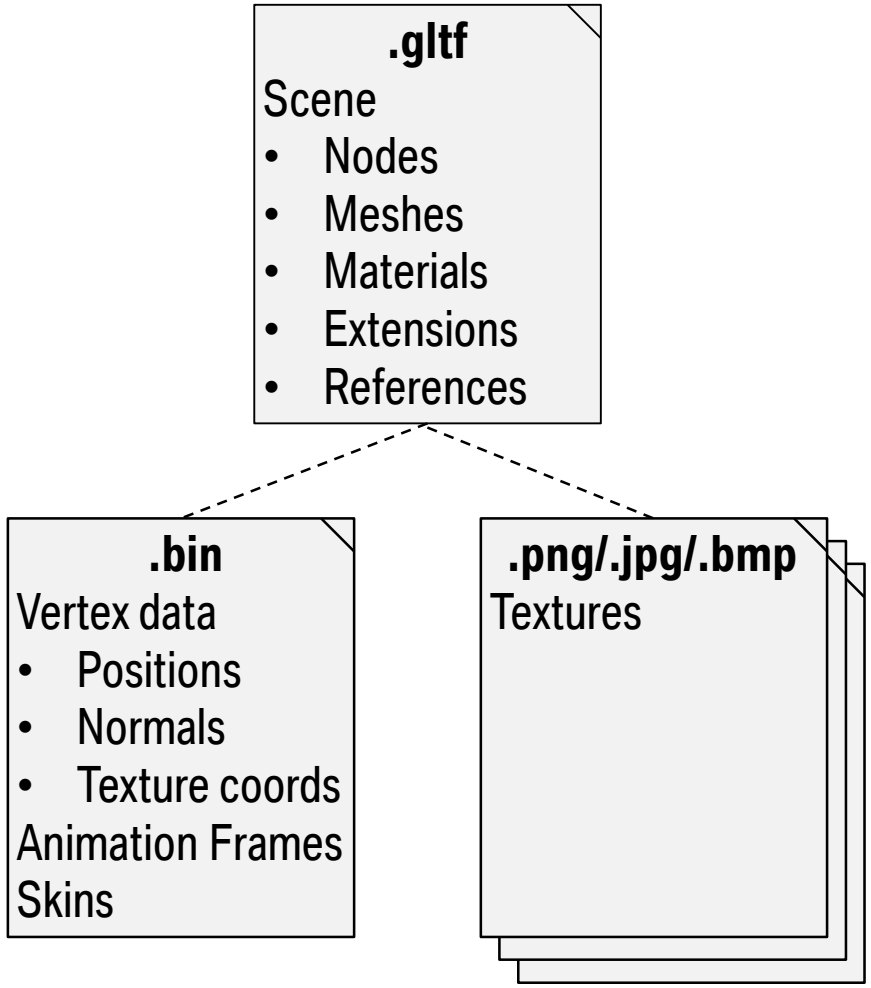



- Modern simulation requires standardization of a 3D model format
- Rendering and sensor simulation require physical materials
- BRDF material concepts can be reused

# SELECTION OF A FILE FORMAT.

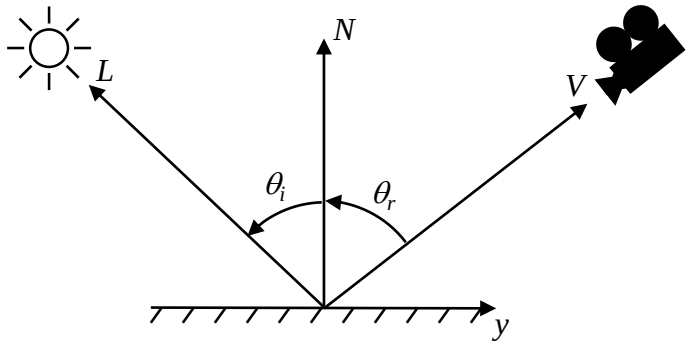
## GRAPHICS LAYER TRANSPORT FORMAT (GLTF 2.0).

- Open-source, royalty-free, maintained by Khronos Group
- Optimized for efficient transmission and loading of 3D scenes and models
- Intended as industry standard for 3D model exchange
- Wide support in computer graphics, modelling software, game engines
- Support for extensions, e.g. PBR workflows



# EXTENDING GLTF.
## MATERIAL PROPERTIES FOR AUTOMOTIVE SENSORS.

- Based on glTF extension mechanism
- 1st step: model specular reflection of optical wavelenghts using the fresnel equation

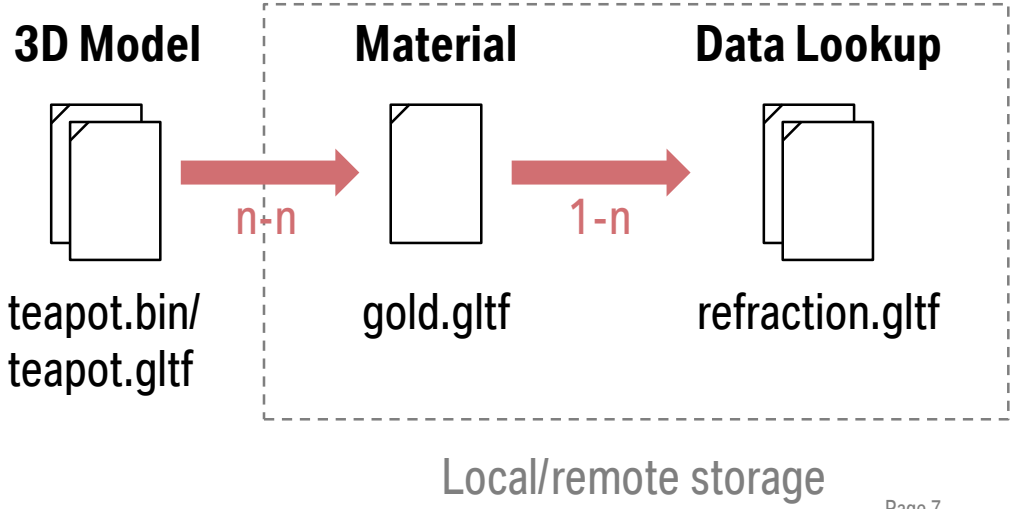



### Specification

- Vertex-/texture-based material annotation
- Parameters structured by sensor type and wavelength
- Separation of global parameters and material-specific lookup-tables

### Implementation

- Raycaster gathering result of fresnel equation as automated test
- Physically correct rendering (pathtracing) using environment map



# 3D MODEL EXCHANGE FORMAT WITH PHYSICAL MATERIAL PROPERTIES .

## RESULTS & NEXT STEPS.

### glTF extensions

- Material annotation
- Asset information
- Reference links

### Exemplary implementations

- Raycaster, pathtracer

### Materials & models

- Parameter sets for aluminum, gold, iron
- Material textures and 3D models

### Next Steps

- Extensions for other automotive sensors (radar, lidar, ultrasonic)
- Publication

# Questions & Answers

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