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Procedural Terrain Generation Standards

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Presentation Objective

- Procedural terrain generation is used extensively in the creation of training terrain databases
- Significant investment has been made in the creation of art assets, construction scripts, and procedural tools
- Suggest the need for standards:
  - Data Model and Dictionary w/Enhanced Feature and Attributes
  - Enhanced Transportation Features
  - 3D Model and Terrain w/Art Assets, Construction Scripts
  - Imagery and Sensor Maps w/Material Definition
  - Transporting and Streaming Protocols


SE CORE

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Background

- U.S. Army's SE Core program generates terrain databases for live, virtual, constructive and gaming training systems
- Objective is to reduce terrain database production costs by consolidating production into a single program
- Additionally, required to reduced the cost per square kilometer of terrain production every year
- Efficiencies enabled through procedural technologies
  - Create Vegetation Models
  - Create 3D Building Models
  - Paint Synthetic Aerial Imagery
  - Sculpt Elevation Data

Create Vegetation Models

- Creator, Maya and 3D Studio Max tools are used in hand constructed vegetation models - these tools have procedural methods to accelerate model creation
- Silvador is used to procedurally create tree models for the US Army Games-For-Training (GFT) VBS3 databases
- Speed Tree and Houdini are used to procedurally create vegetation models for other runtime systems
- Additionally, in game-based systems, grass and bush models are procedurally generated in real-time using unique material systems

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Create Vegetation Models – Example 1

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Create Vegetation Models – Example 2

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Create 3D Building Models

- Landmark features and training site buildings
  - Created by hand by highly skilled 3D modelers
  - Use procedural methods to accelerate model creation
  - Costly and time consuming
- Majority of 3D building models
  - Created using automated procedural model generation
  - Investment in art assets and construction scripts
  - Less expensive and faster
- All models produced (manual or procedural) include:
  - Multiple levels-of-detail (LODs)
  - Multiple health-states, cleared and temporally repaired states
  - Special geometry for engine unique needs
  - Interiors with functioning windows and doors

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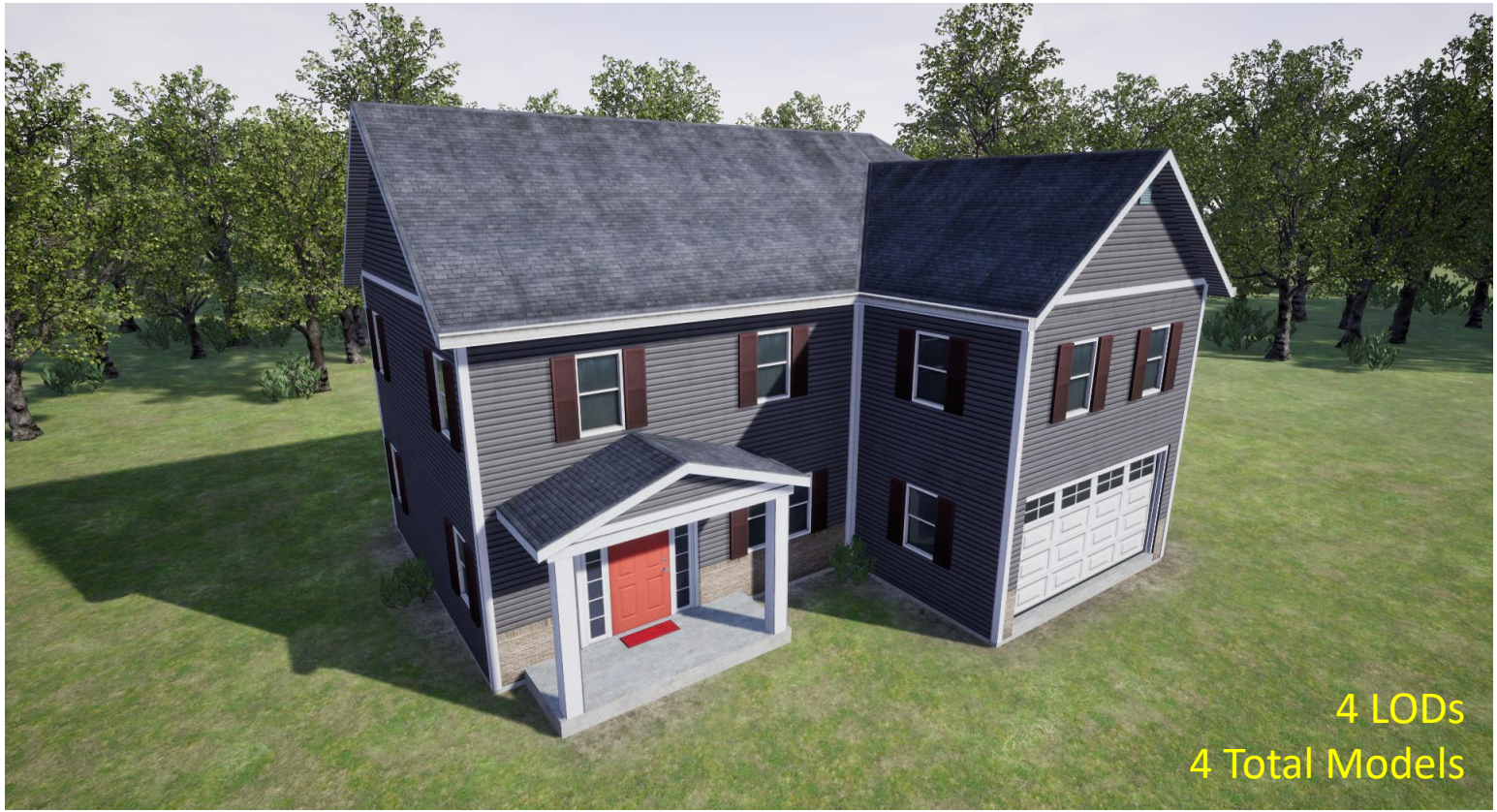
3D Building – Example Healthily



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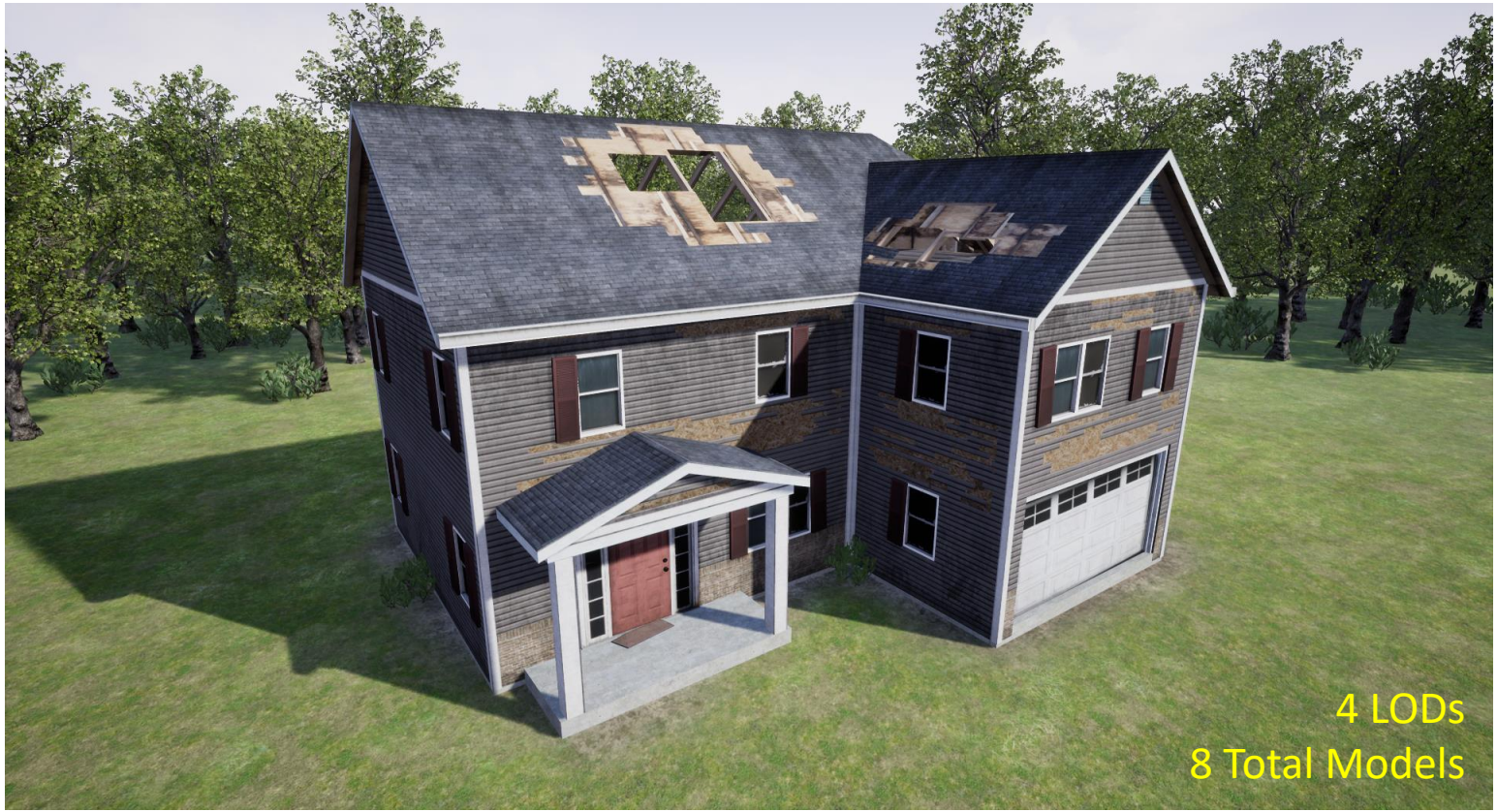
3D Building – Example Damaged



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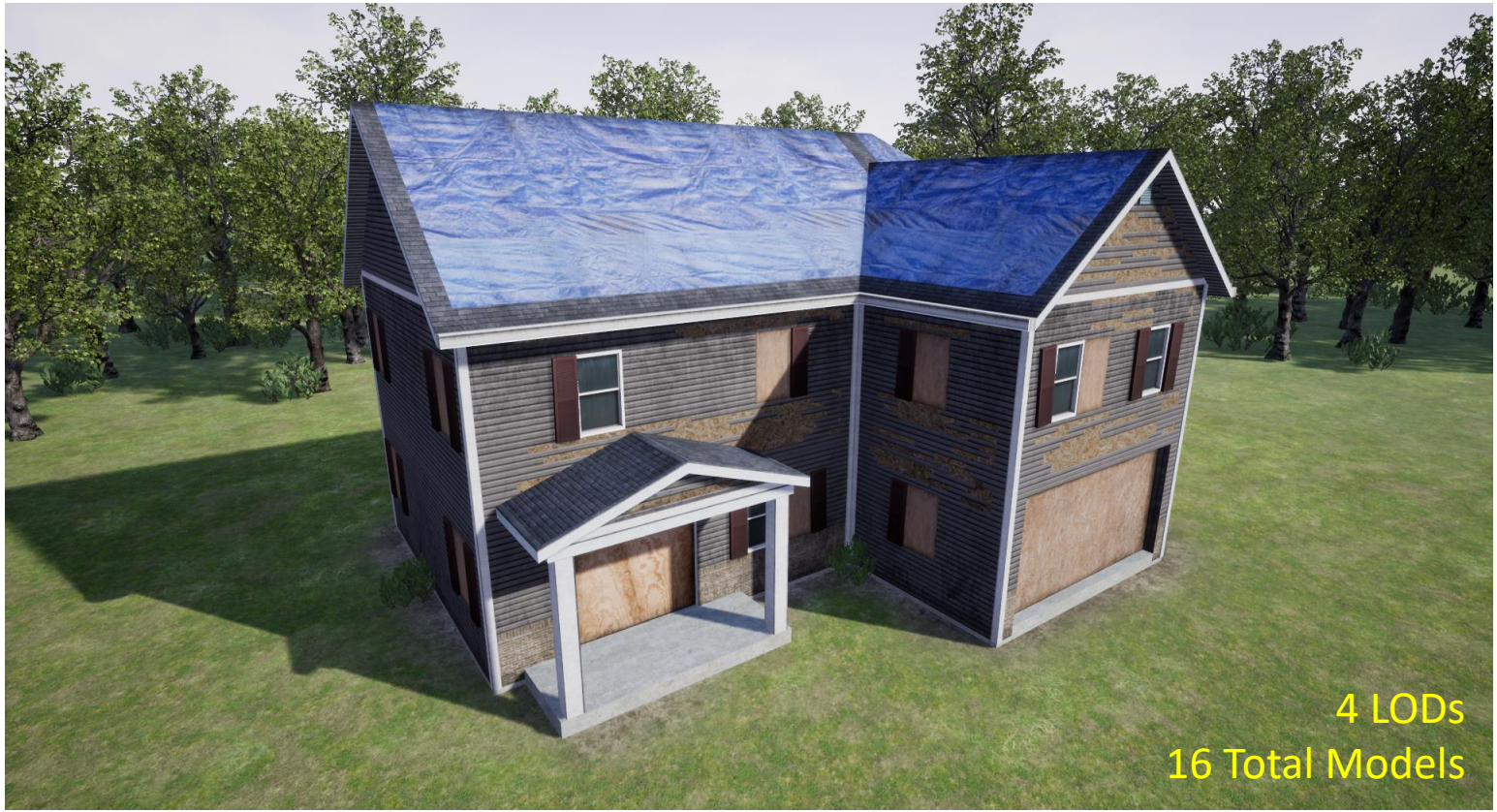
3D Building – Example Temporary Repair



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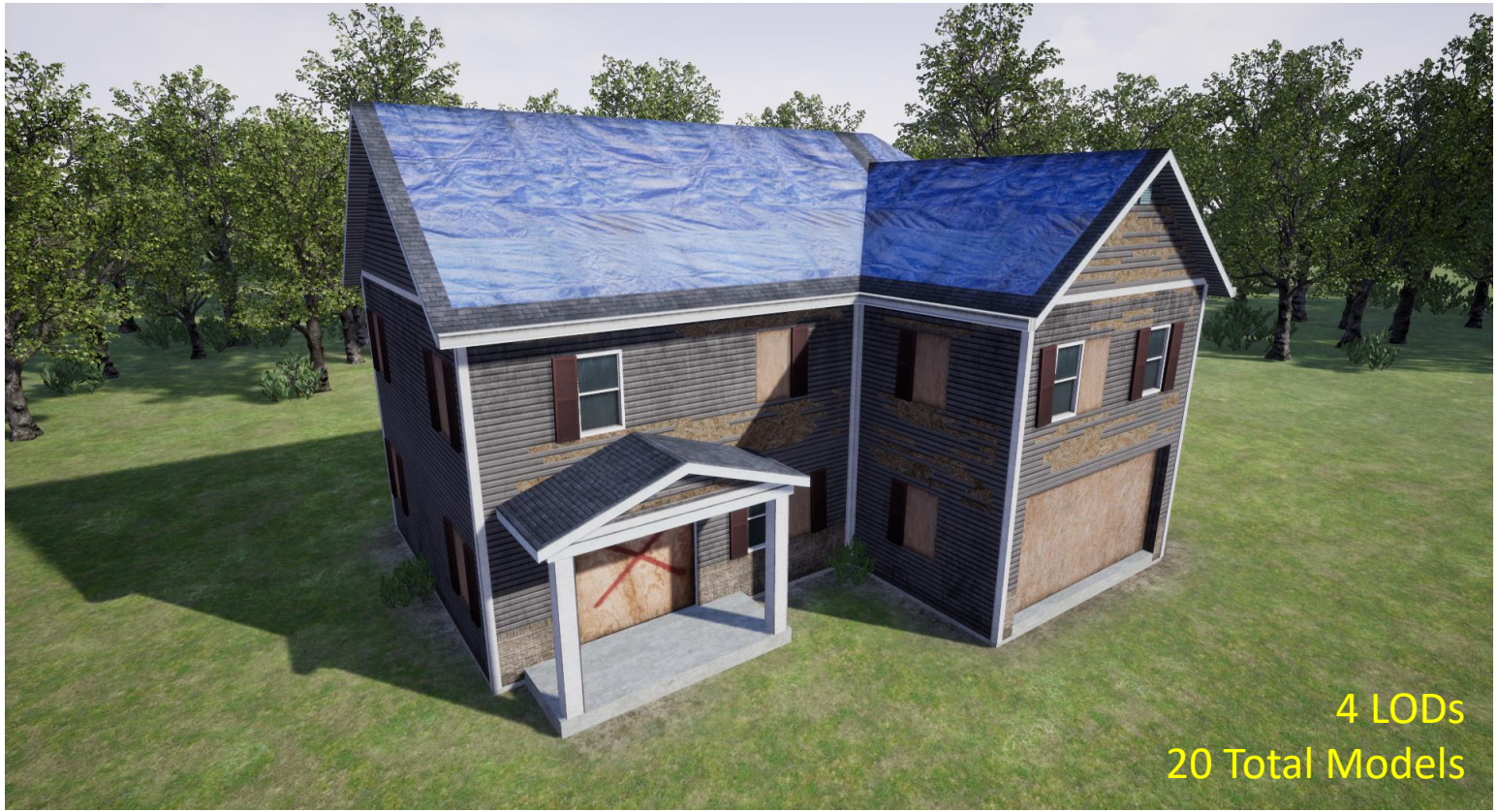
3D Building – Example Cleared



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3D Building – Example Destroyed

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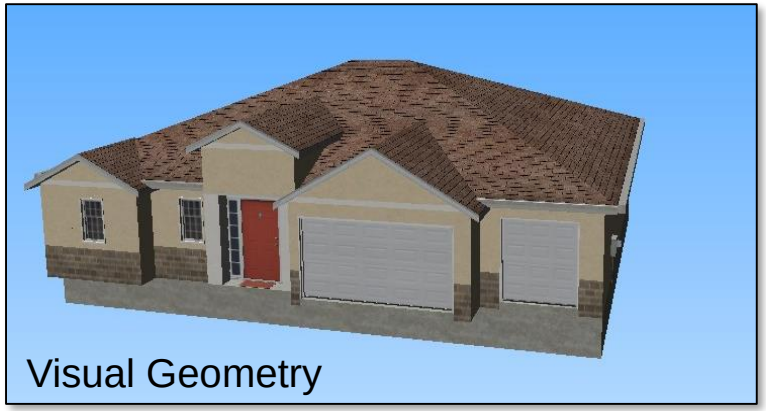
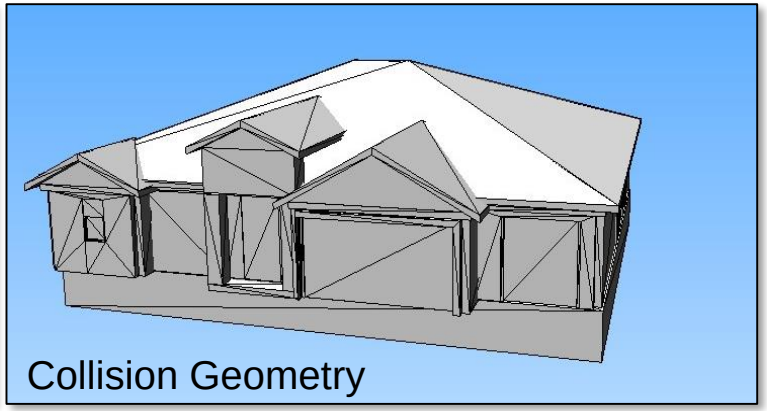
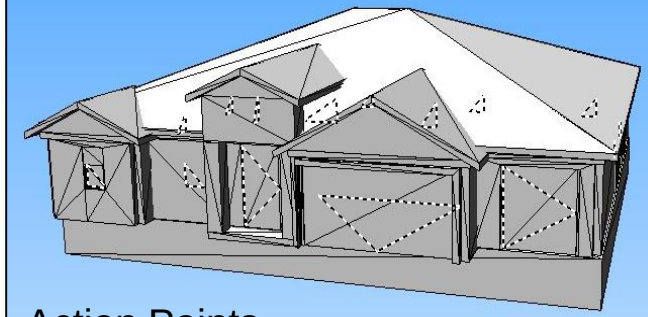
3D Building – Example Special Geometries



Visual Geometry



Collision Geometry



Action Points

Roadway Geometry

~3 LODs
25 Total Models

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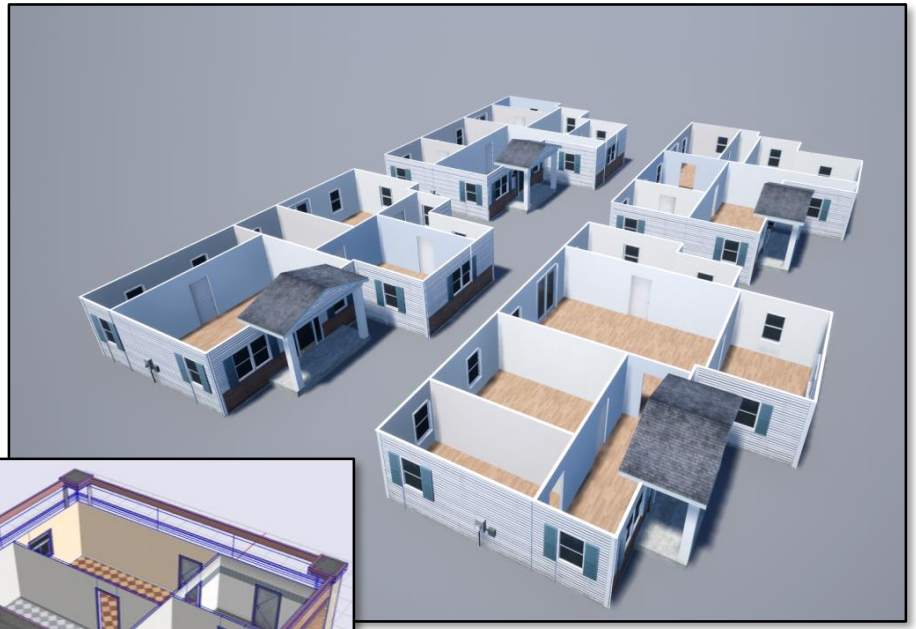
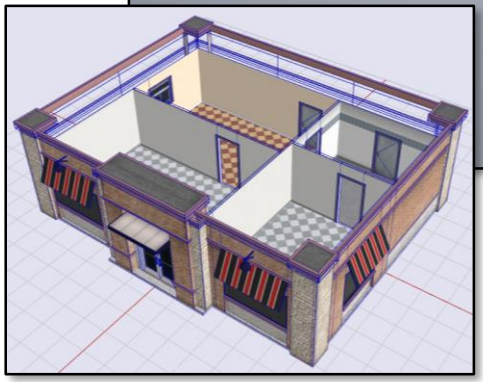
3D Building – Example 1 Interiors





Procedural Generation of interiors is still maturing

~2 LODs
27 Total Models

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Procedural Model Game Engine Example

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3D Building – Example 2 Interiors

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3D Building – Example 3 Interiors

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Paint Synthetic Aerial Imagery

- Real imagery has limitations with high preparation costs
  - Artifacts from capture, like cloud cover, snow cover, and seasons are undesirable
  - Artifacts like tree tops, cast shadows, cars on roads/in parking lots, and unwanted transitory cultural clutter must be removed
- Procedural aerial imagery is used to avoid the collection limitation and negative visual artifacts of real imagery
  - Generated based on feature data, art assets and painting rules
  - Correlated 100% to feature data
  - Supports generation of ground surface imagery
  - Supports automatic generation of correlated material maps

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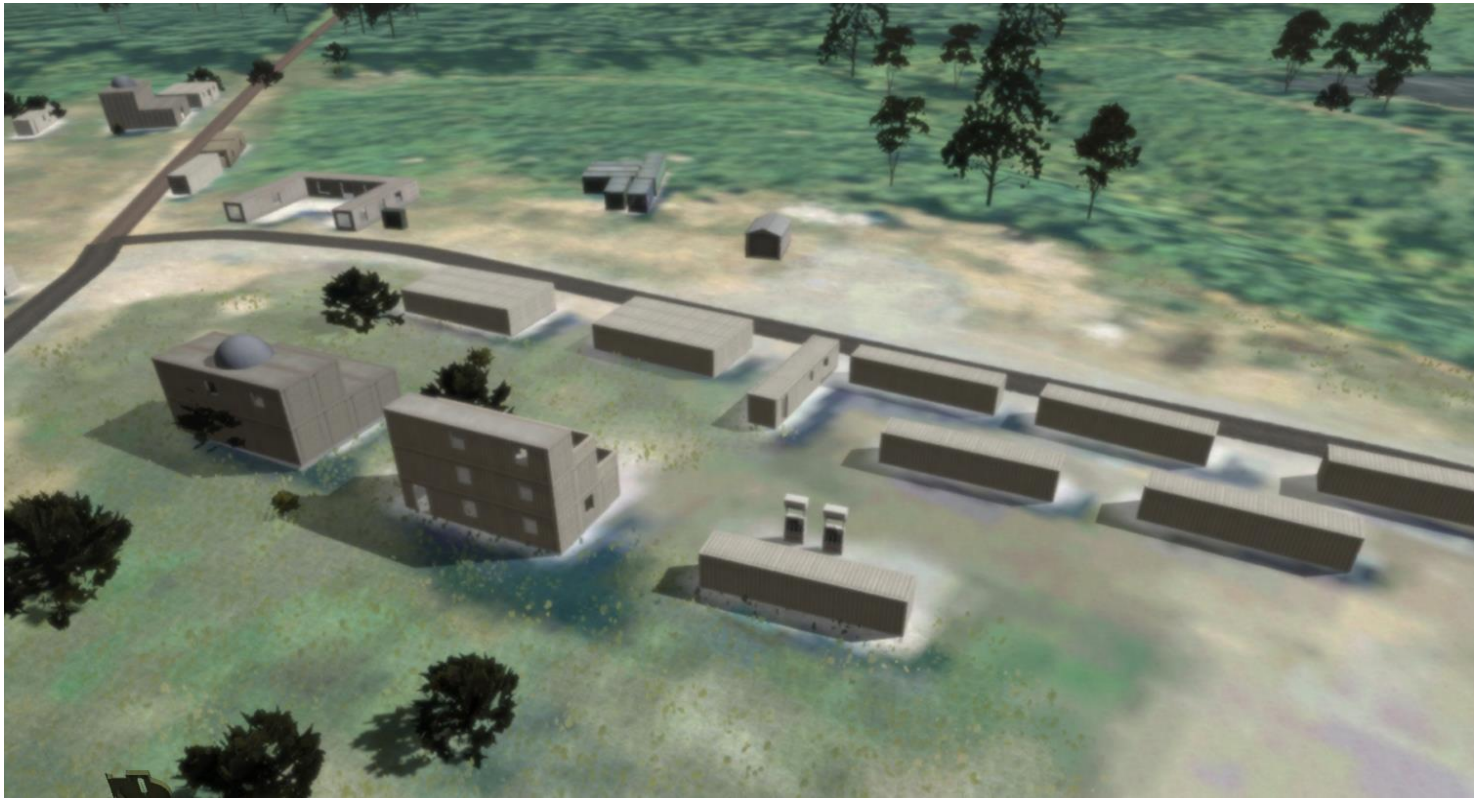
Example 1 Real Aerial Imagery



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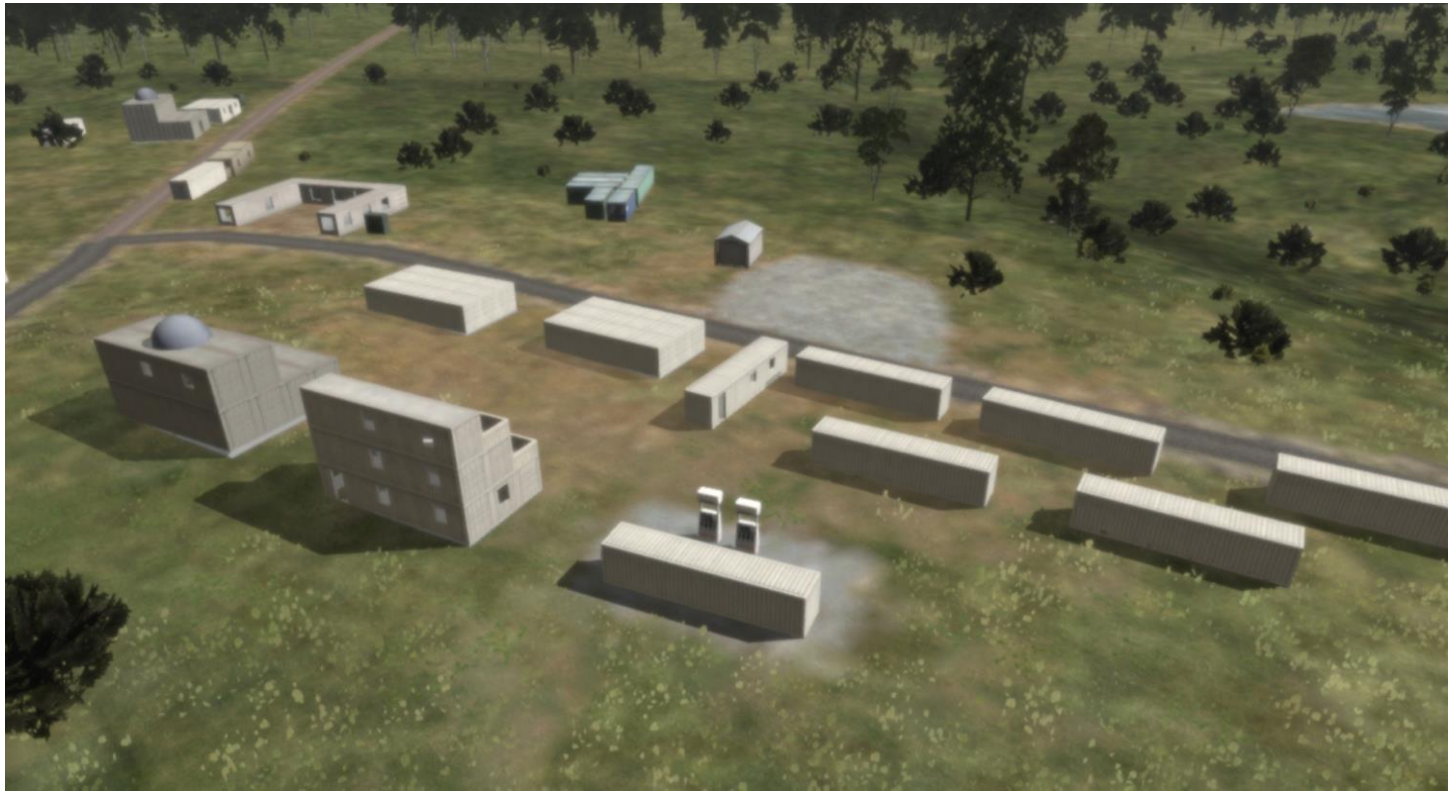
Example 1 Simulated Ground Surface Imagery



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Example 2 Real Aerial Imagery

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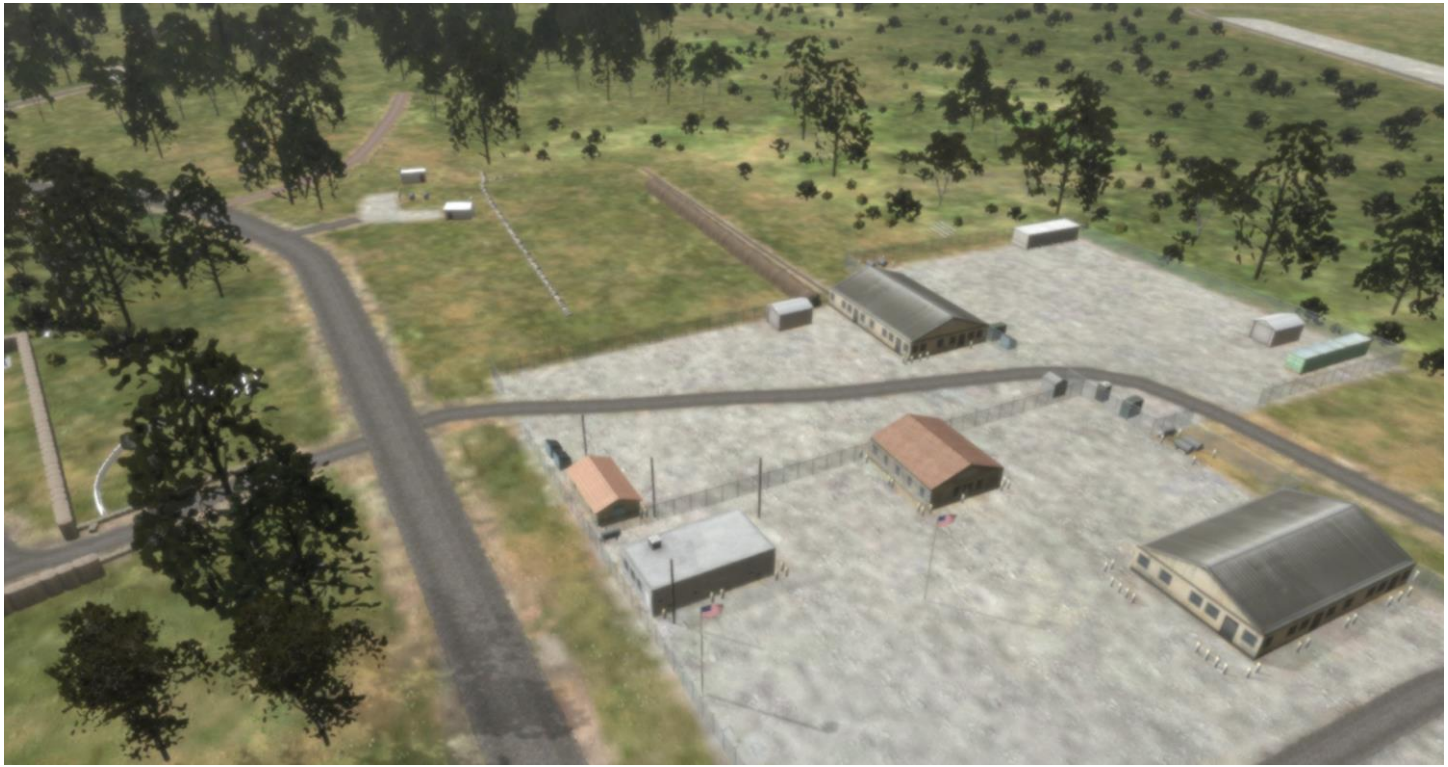
Example 2 Simulated Ground Surface Imagery



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Example 3 Simulated Ground Surface Imagery

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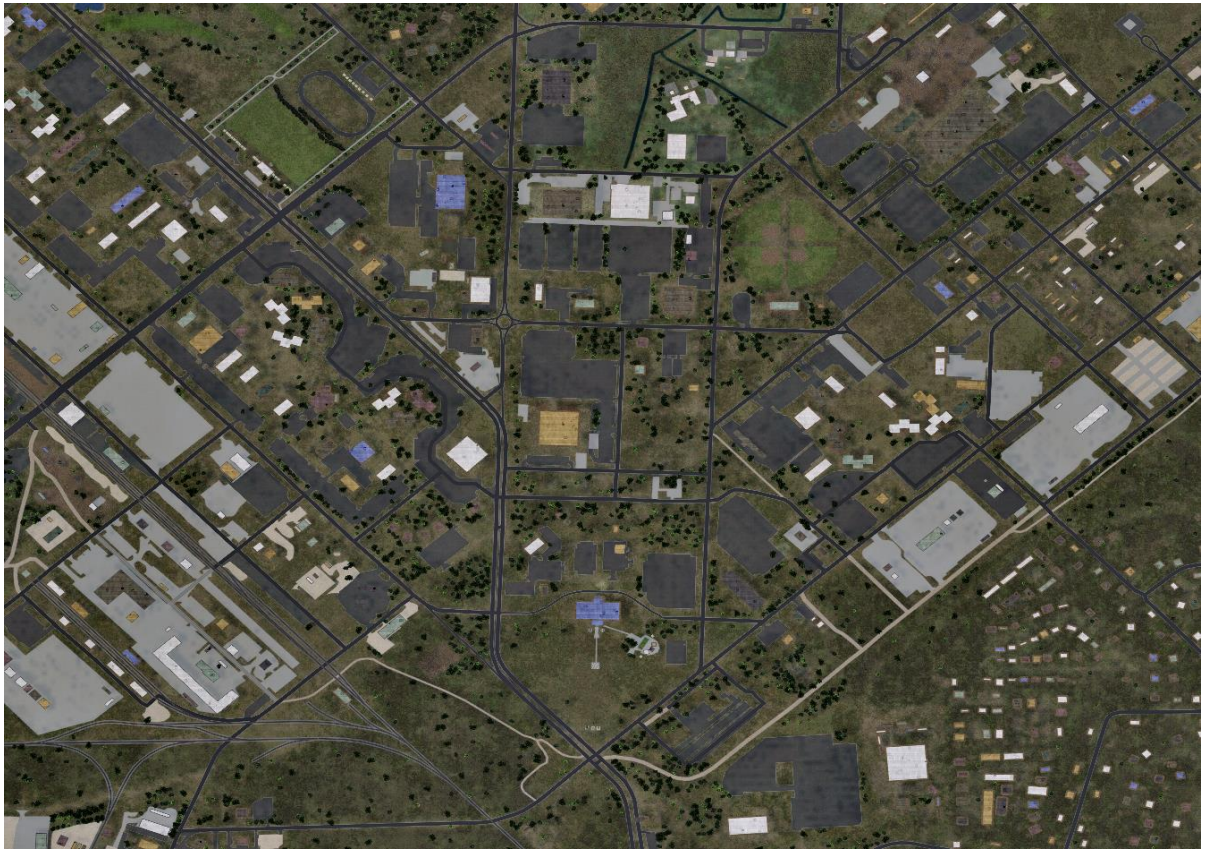
Example 1 Simulated Ground Surface Imagery



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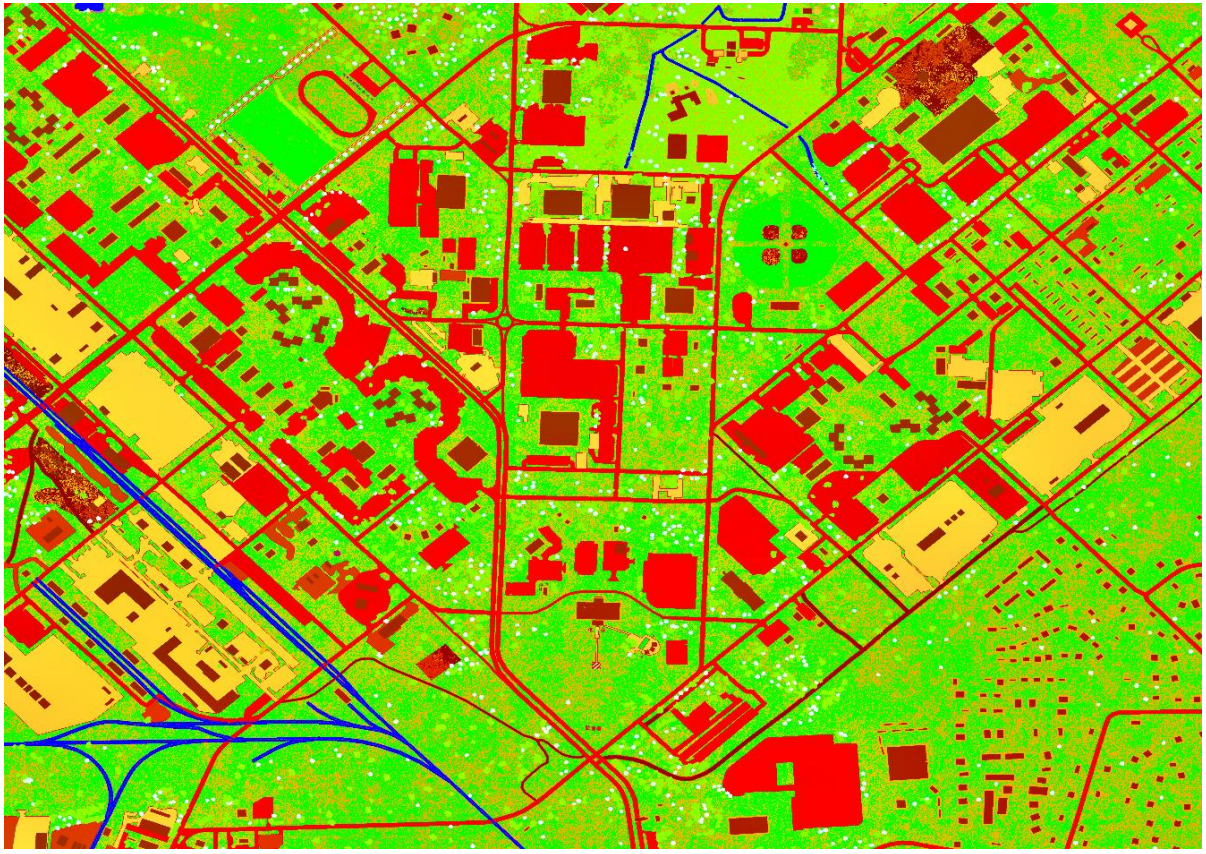
Example 1 Correlated Material Map False Color



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Example 2 Simulated Ground Surface Imagery

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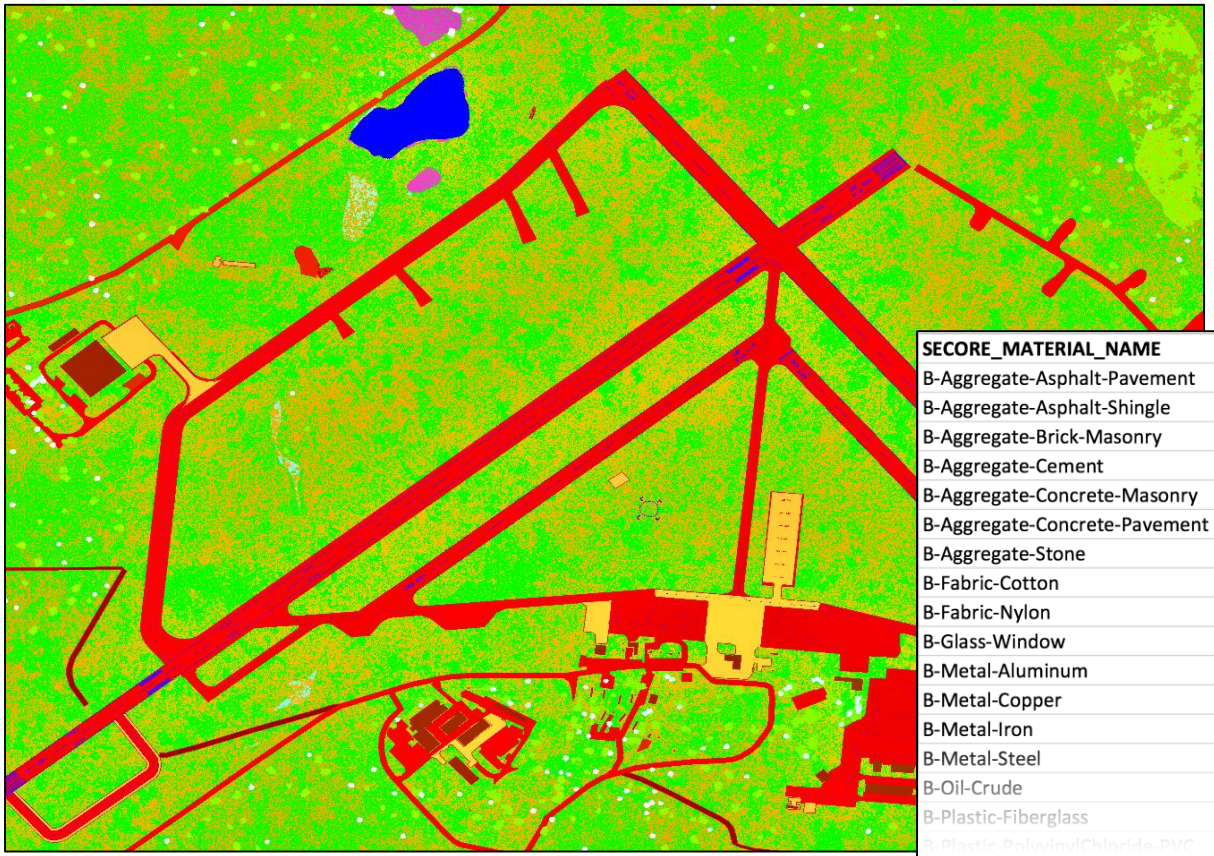
Example 2 Correlated Material Map False Color



SECORE_MATERIAL_NAME	RGB_PIXEL_VALUES	RGB_COLOR
B-Aggregate-Asphalt-Pavement	220,40,0	
B-Aggregate-Asphalt-Shingle	160,80,0	
B-Aggregate-Brick-Masonry	250,70,70	
B-Aggregate-Cement	120,140,160	
B-Aggregate-Concrete-Masonry	200,200,0	
B-Aggregate-Concrete-Pavement	255,200,40	
B-Aggregate-Stone	30,30,250	
B-Fabric-Cotton	200,50,80	
B-Fabric-Nylon	230,100,200	
B-Glass-Window	100,80,60	
B-Metal-Aluminum	140,140,140	
B-Metal-Copper	220,150,70	
B-Metal-Iron	70,70,70	
B-Metal-Steel	190,40,80	
B-Oil-Crude	100,0,100	
B-Plastic-Fiberglass	50,30,90	
B-Plastic-PolyvinylChloride-PVC	40,80,100	

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Sculpt Elevation Data

- Harmonize the spatial relationship between feature data and elevation data
- Synthetically-generated, high-resolution elevation inset describes the complex surface required to ensure vehicle traversal from road to bridge/tunnel to road
- Procedurally create:
  - Correlated high-resolution elevation data insets
  - Bridge models based on linear features
  - Tunnel models based on linear features
- No touch labor used to modify the elevation data

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Sculpt Elevation Data – Example Before

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Sculpt Elevation Data – Example After

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Recommended Standards

Procedural Standards

2 Features and Attributes
- Transportation Features
- Feature Intensification

1 3D Model
- 3D Terrain

3 Synthetic Imagery

4 Material Maps

Data Delivery Standards

- Streaming Features
- Transporting Features
- Streaming 3D Models and 3D Terrain
- Transporting Models and Terrain

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3D Model - Procedural Generation

- Construction Rules
  - Rules for procedural 3D model generation
  - Consideration
    - Adopt Esri® Computer Generated Architecture (CGA)
    - CGA's define construction grammar
    - Used in Esri's CityEngine™

Support OGC CGA Standard

Example CGA Fragment

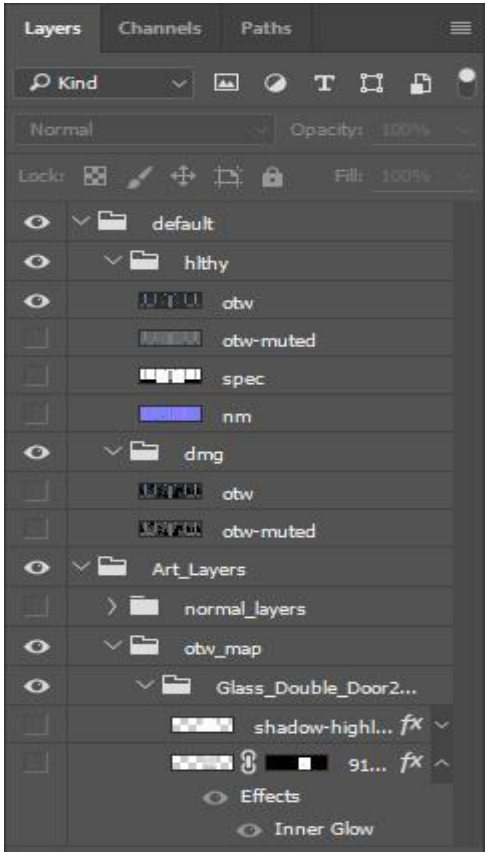
```
1  // ATTRIBUTES
2  attr building_height = 3.0
3  attr roof_angle = 20
4  attr roof_overhang = 0.3
5  attr roof_thickness = 0.2
6  attr window_width = 1.3 // Width of the window
7  attr window_length = 1.3 // Vertical length of t
8  attr window_spacing = 1.5 // Spacing between win
9  attr window_height = 0.7 // Height of the window
10 attr door_width = 2.0
11 attr door_length = 2.1
12
13 // RULES
14 Initial -->
15 extrude(building_height)
16 comp(f)
17 {
18 top: Roof |
19 bottom: Foundation |
20 front: FrontWalls |
21 side: SideWalls
22 }
23 // ROOF
24 Roof -->
25 roofGable(roof_angle, roof_overhang)
26 comp(f) { top : ExtrudeRoof | side : GableWallTe
27 ExtrudeRoof -->
28 extrude(world.y, roof_thickness)
29 comp(f) { top : RoofTex | bottom : SoffitTex | s
30 // WALLS
31 SideWalls -->
```

3D Model - Procedural Generation

- Art Assets Rules
  - Companion to CGA Specification
  - Specification for texture spatial resolution, wrapping and tiling schemes, texture map types, etc.
  - Consideration
    - Stored in Adobe Photoshop Document (PSD) format
    - Develop Content Specification

Support OGC Art Asset Standard

Example PSD Layers



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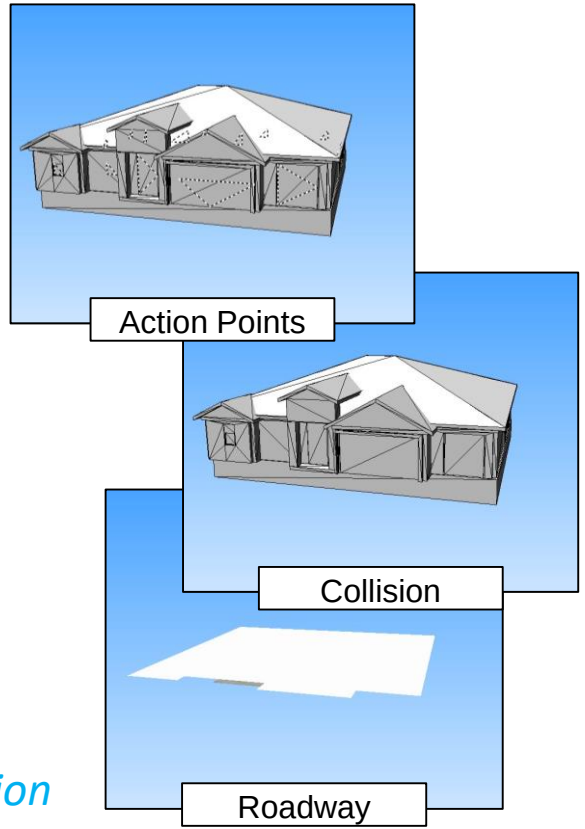
3D Model - Procedural Generation

- Model Functionality Specification
  - Specification for runtime unique needs
    - Multiple Health States
    - Encoded Mission Function Data
    - Behavior Geometry and Attributes
    - Multiple Levels-of-Fidelity
    - Multiple Levels-of-Detail
  - Consideration
    - Develop Functionality Specification

Support OGC Model Functionality Specification



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Features - Standard Data Model

- Well-defined, Content Complete, Explicit Feature Relationships
- Consideration
  - US Army Geospatial Center's (AGC) Ground-Warfighter Geospatial Data Model (GGDM)
  - Open Geospatial Consortium (OGC) CDB Features and Attributes List
  - Simulation Interoperability Standards Organization (SISO) Reuse and Interoperation of Environmental Data and Processes (RIEDP) Features and Attributes List

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Features - Standard Data Dictionary

- Agree Definitions, Common Understanding
- Consideration
  - SEDRIS Environmental Data Coding Specification (EDCS)
  - National System for Geospatial-Intelligence (NSG) Feature Data Dictionary (NFDD)
  - NSG Core Vocabulary (NCV) Standard
  - Defence Geospatial Information Working Group (DGIWG) Feature Data Dictionary (DFDD) (which NFDD is derived)
  - DGIWG Geospatial Information Framework (DGIF)
  - NCV is the most complete, adopt

Features - Enhanced Attributes Example

Desired House Recreations

Procedural House Created from Enhanced Attributes

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Features - Enhanced Attributes Example

- Building Height, Number of Stories, Height of Stories
- Exterior Wall Colors and Materials
- Roof Types and Orientations, Colors and Materials, Gables Placement
- Apertures Types, Styles, Colors and Locations (e.g. Doors and Windows)
- Appendages Types, Colors and Locations (e.g. Chimneys, A/C Units, Utility Boxes, Stand Pipes)

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Data Model and Dictionary

- Good Data Model and good Data Dictionary are required for consistent and repeatable procedural content generation
- Desire enhanced feature attributes
  - Typical building feature includes footprint geometry, height and building function type
  - Needed to enable automated creation of geo-representative 3D building models
- Include details for interiors
- Include details for entity actions

Support Data Model and Data Dictionary Standard

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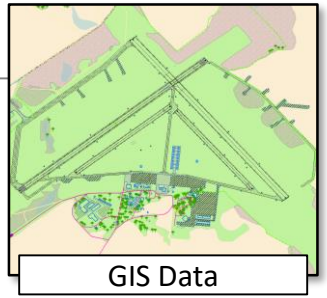
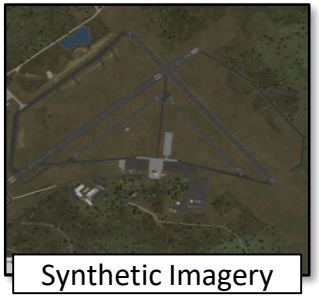
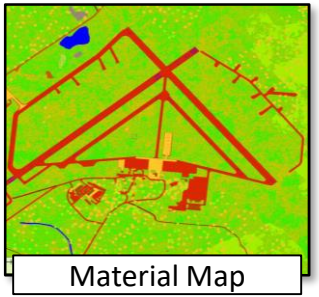
Synthetic Imagery

- Painting Rules
  - Standard rules for painting synthetic imagery
  - Similar to CGAs for 3D models
  - Include rules for ground surface, aerial imagery, and material maps
  - Consideration
    - Multiple vendors are offering commercial tools for procedural imagery
    - A number of government owned procedural imagery tools are available
    - Anyone willing to offer starting specification?

Support Synthetic Imagery Painting Rules Standard


GIS Data

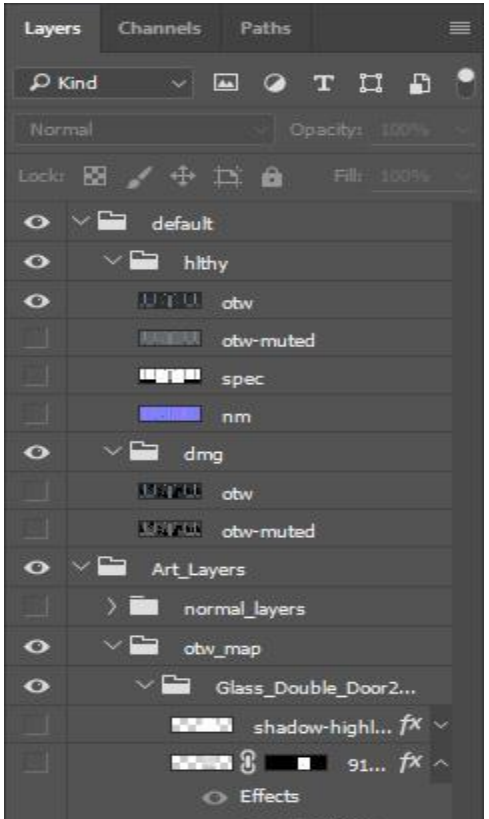

Synthetic Imagery


Material Map

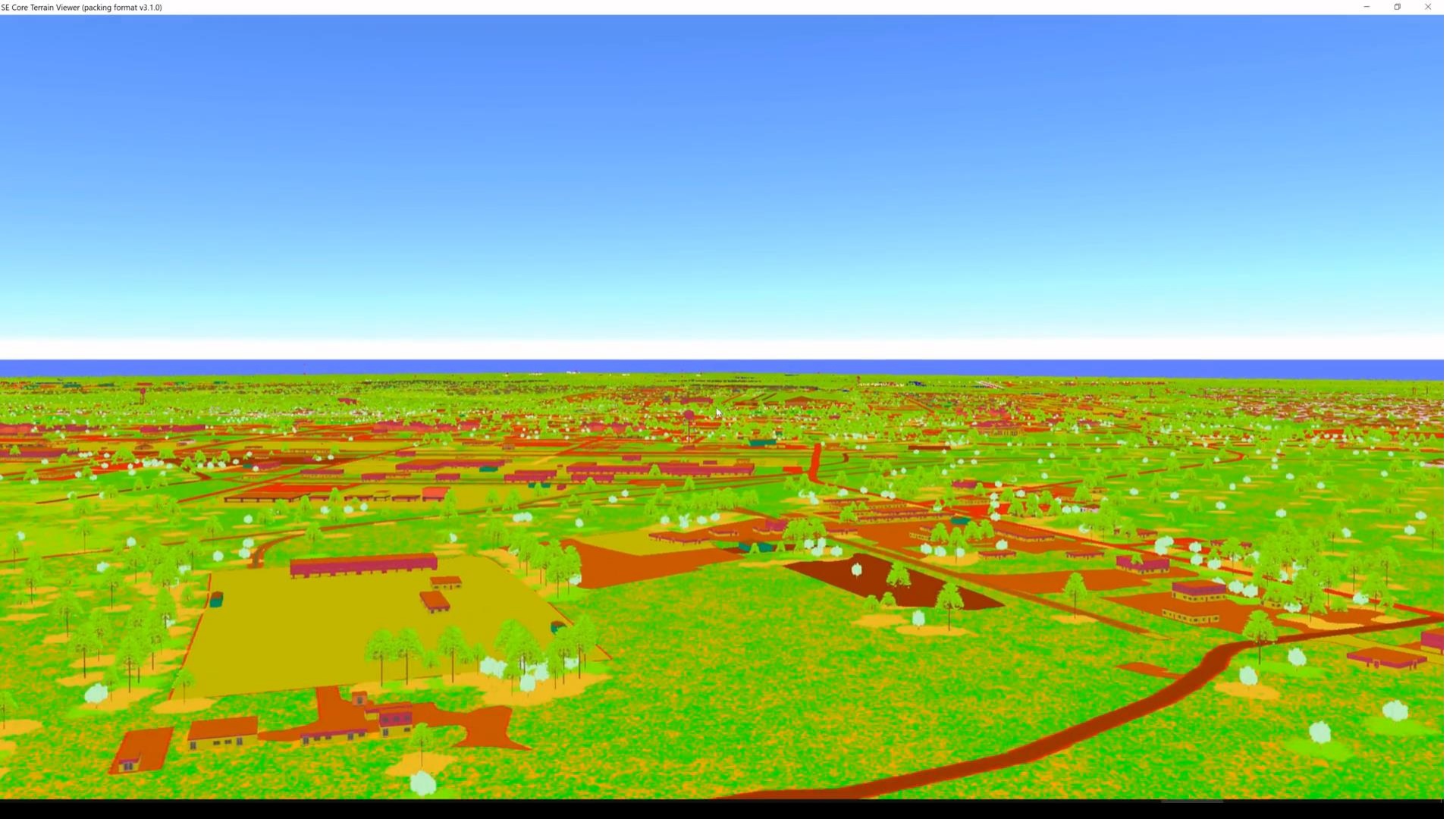
Synthetic Imagery

- Art Assets Rules
  - Shared with Procedural 3D Model
  - Specification for texture spatial resolution, wrapping and tiling schemes, texture map types, etc.
  - Consideration
    - Stored in Adobe Photoshop Document (PSD) format
    - Develop Content Specification

Support OGC Art Asset Standard



Example PSD Layers


SE Core Terrain Viewer (packing format v3.1.0)

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Standards for Materials

- Need complete and comprehensive material list for materials relevant to MS&T simulations
- Consideration
  - JRM's Material Definitions
  - Renaissance Sciences Corporation (RSC) Material Definitions
  - NAVAIR Portable Source Initiative (NPSI) Standard for Material Properties Reference Database (MPRD)
  - OGC CDB Material Definitions
  - SISO RIEDP Material Definitions

Support RIEDP to develop list for RIEDP and to update CDB

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Questions

- **Standards for Procedural Terrain Generation**

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