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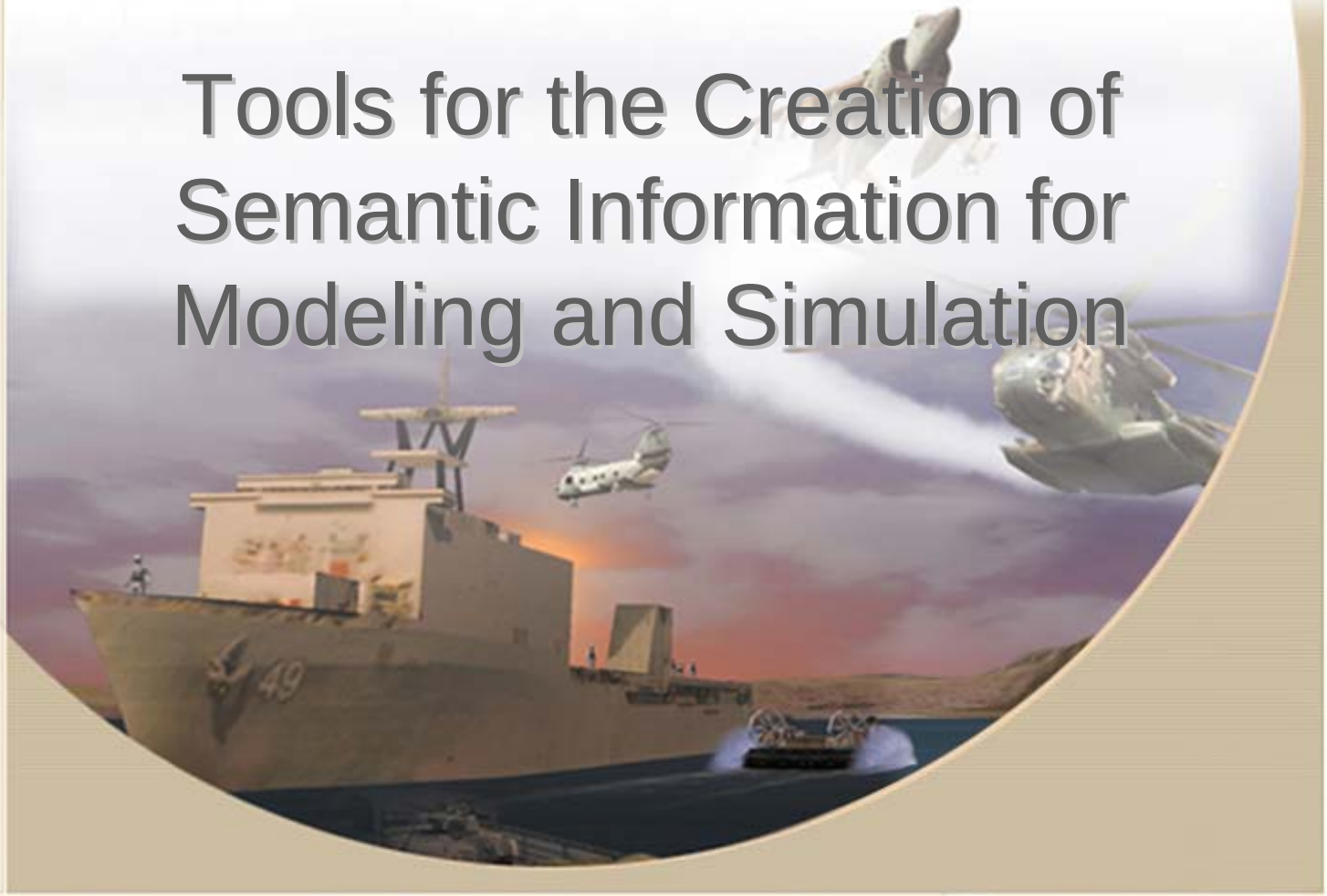
ICCRTS
JUNE 2007

Tools for the Creation of Semantic Information for Modeling and Simulation



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MÄK TECHNOLOGIES

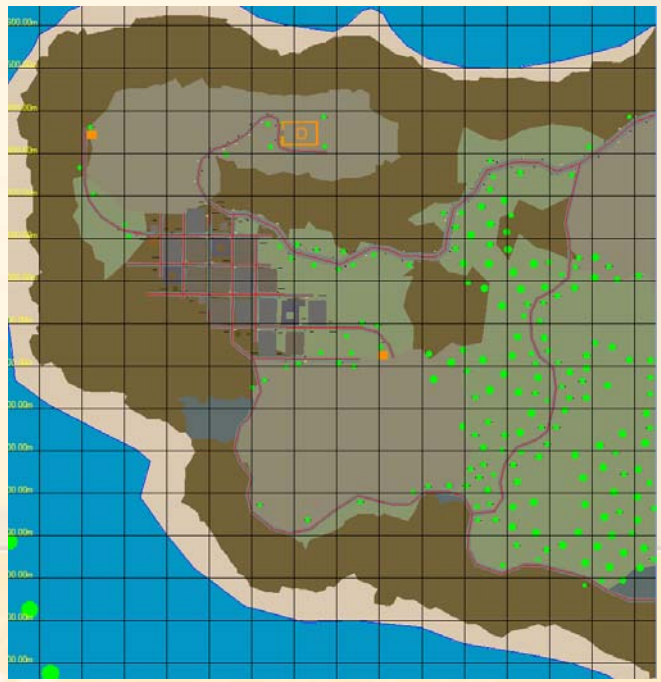
Project Overview

- Augment M&S terrain databases with semantic information for automated reasoning
  - Beyond physical characteristics, includes:
    - Relationships between terrain features
    - Non-geometric information
    - How features can be used in combat missions
- Focusing on small unit operations
  - Infantry Warrior Simulation (IWARS)
  - MÄK VR-Forces Computer Generated Forces system
- Work being done for the US Army Natick Soldier System Center

MÄK TECHNOLOGIES

CGF Terrain Databases

- 2D Visualization
  - Abstract representation (maps)
  - Realistic representation (imagery)
- Reasoning
  - Geometry and attribution of elevation and features
    - Data structures in memory
  - Uses:
    - Vehicle placement
    - Movement algorithms
      - Path planning
      - Obstacle avoidance
      - Vehicle dynamics
    - Line of sight
      - Targeting
      - Communications



MÄK TECHNOLOGIES

CGF Terrain Databases

- Terrain Skin
  - Grid or TIN of elevation values
    - May or may not be stored as polygons
  - Attributes
    - “Soil Type”
      - Water
      - Mobility Characteristics
- Features
  - Point, Lines, Areas
  - Attributes
    - Width, height, type, …
  - 3D Models
    - Typically associated with point features
    - Building models
      - Varied fidelity
      - Overturned shoe boxes to complex structures with interior details
- Spatial organization
  - Find all terrain information around a location quickly
  - Grid-based
  - Hierarchical
    - Quad trees

MÄK TECHNOLOGIES

Terrain Database Representations in M&S

- Mostly physical descriptions
- Little semantic information needed for higher level reasoning
  - Person looking at the actual terrain or map could deduce
  - How roads could be used to cross rivers at a bridge
  - Areas of mobility restriction for different vehicle types
  - How depressions or elevations can be used for cover and concealment
  - How small units can navigate within urban features
  - Prediction of enemy positions and movement

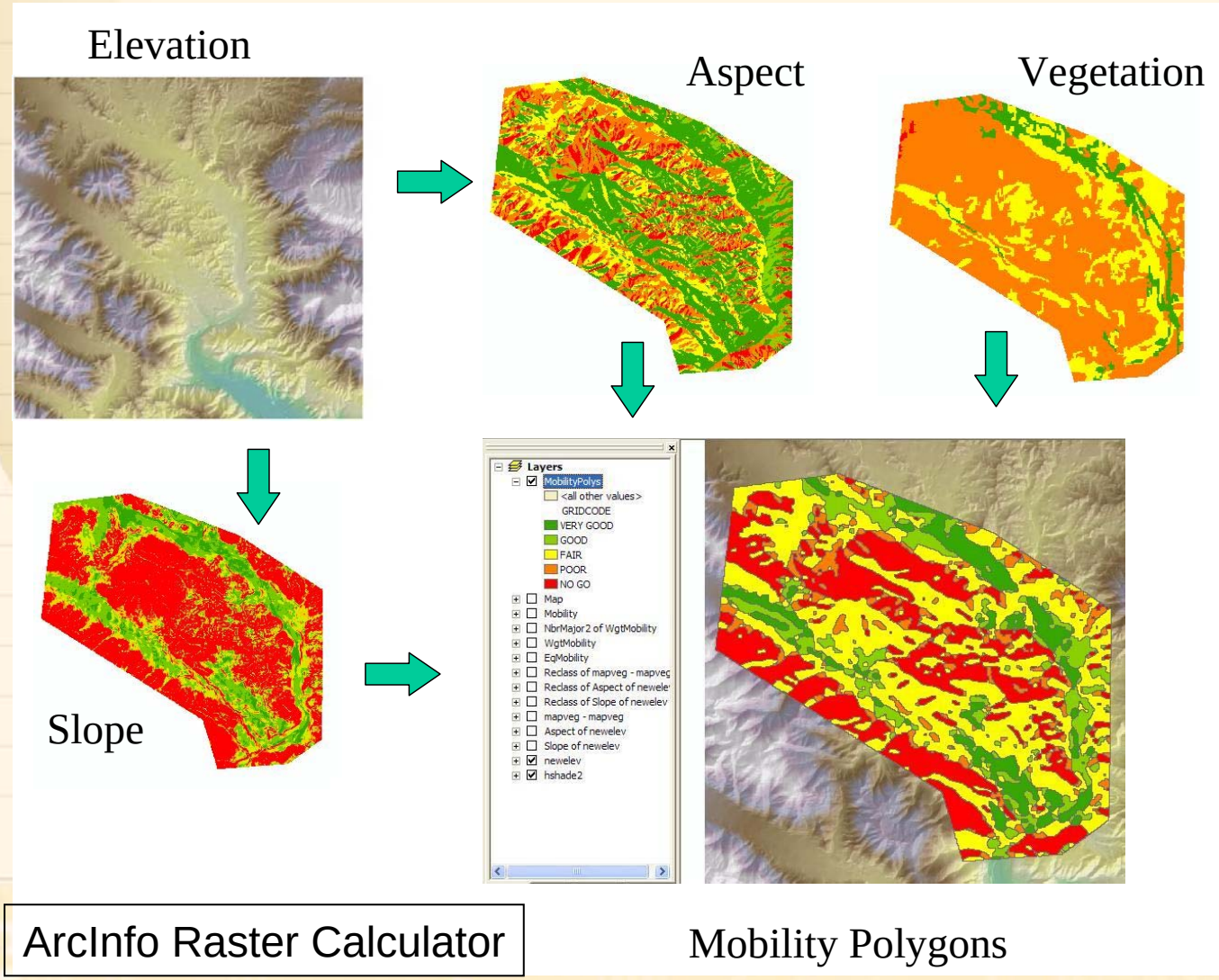
MÄK TECHNOLOGIES

Semantic Information for Cross Country Mobility

- **Military Crest**
  - Shoulder of ridge or hill
  - Highest elevation from which contour base can be seen
- **Valleys**
- **Danger Areas**
  - Large open areas w/o cover or concealment
  - Vegetation area that does not provide cover
  - Village or urban areas
- **Linear Danger Areas**
  - Roads and trails
  - Rivers and streams
- **Cover and Concealment**
  - Forested areas
  - Depressions
  - Raised earthwork
  - Rocks or boulders
- **Obstacles**
  - Lakes, rivers
  - Cliffs or steep terrain
  - Ravines, gulleys, ditches
  - Swamps, marches
- **Key Terrain**
  - High ground
  - Open areas

MÄK TECHNOLOGIES

Mobility Feature Generation

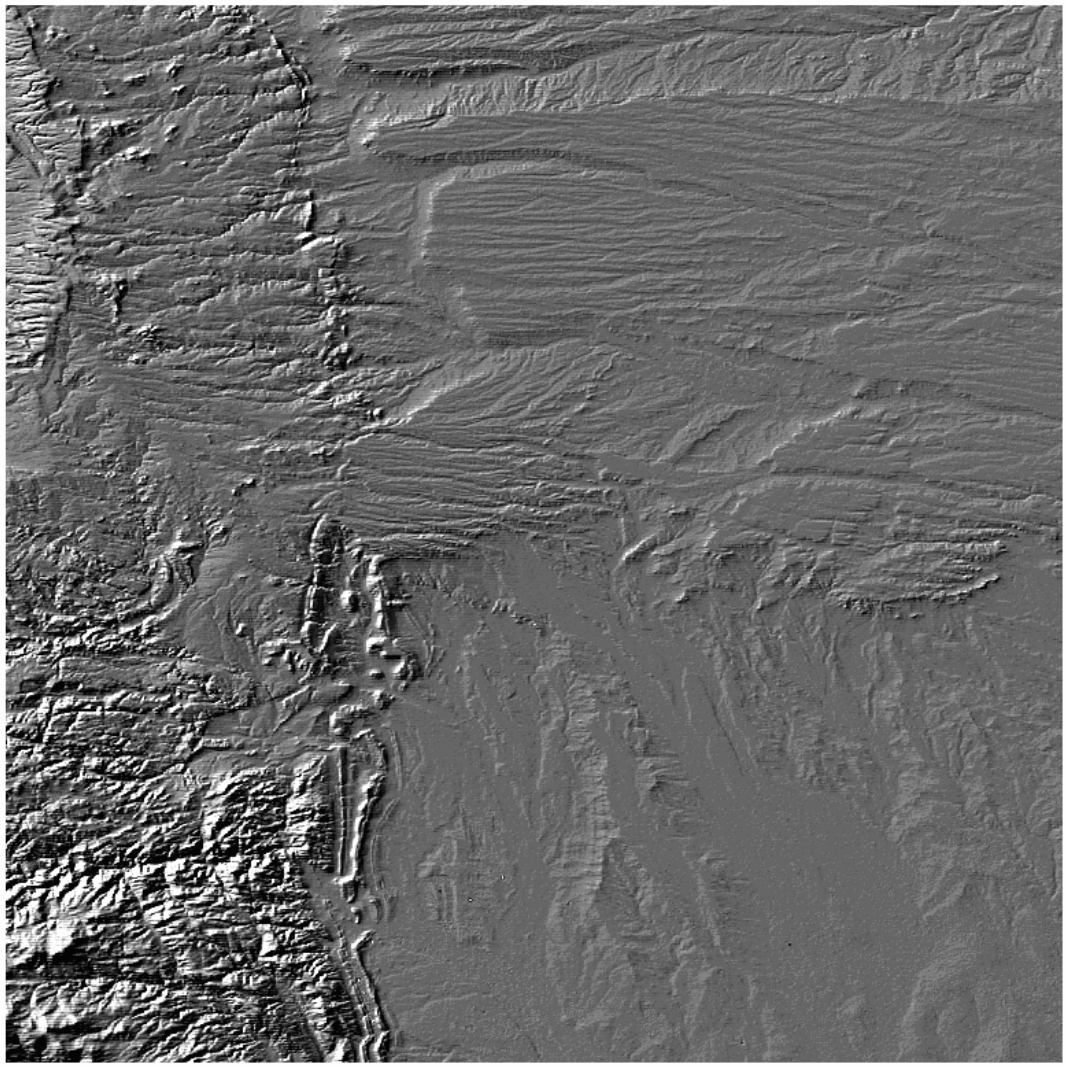


Generate Slope Polygons

- Slope tool in Spatial Analyst extension used to create slope raster
- Reclassify tool in Spatial Analyst
  - Reclassified the calculated slopes to match the slope categories in the Army Terrain Analysis FM5-33.
  - 0-3%, 3-10%, 10-20%, 20-30%, 30-45%, 45-100%
- Converted raster to polygon features in a geodatabase
  - Added Area and Shape Length (perimeter) attributes, and calculated the values for these fields
- Generalization
  - Reclassified to GO (0-10%), SLOW_GO (10-30%), and NO GO (>30%)
  - Moved very small polygons to new layers by filtering on the Area attribute
  - Simplify Polygons Tool
    - Bend Simplify & Point Removal
  - Aggregate Polygons
- Merge tool was used to combine features into a single Geodatabase
- Union tool to merge SLOW GO and Tree Areas
- Clip and Buffer tools to cut roads into SLOW GO and NO GO areas
- Converted to a Shape file and moved to the VR-Forces terrain database directory for importation into VR-Forces

MÄK TECHNOLOGIES

1 x 1 Degree DEM – Boulder, CO



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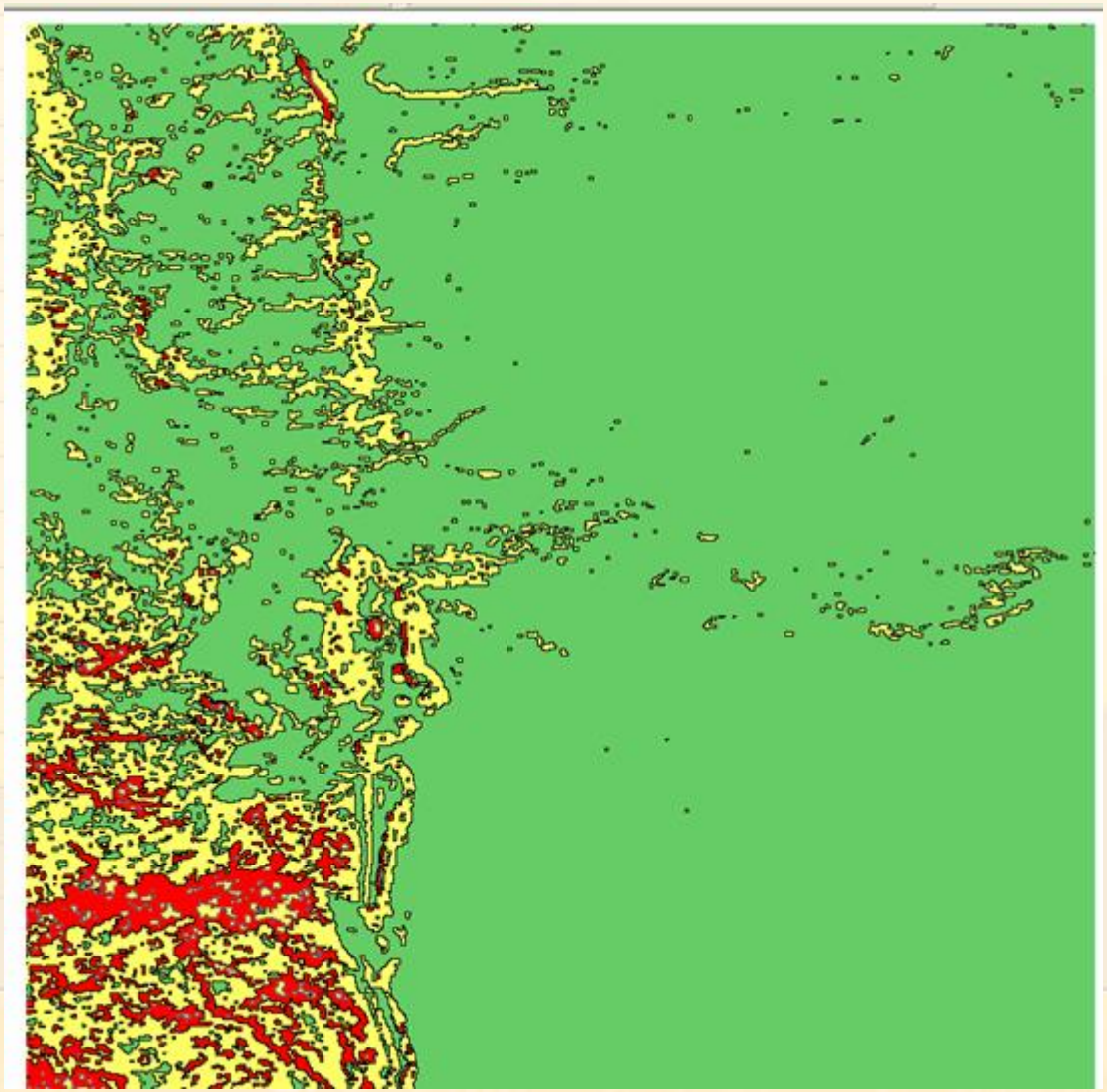
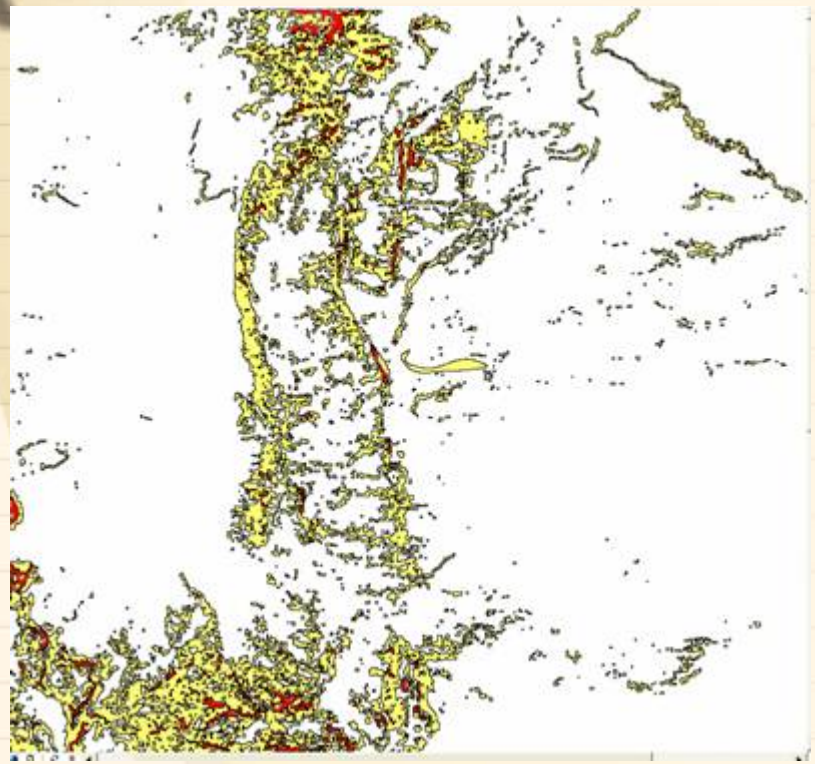
Slope Polygons

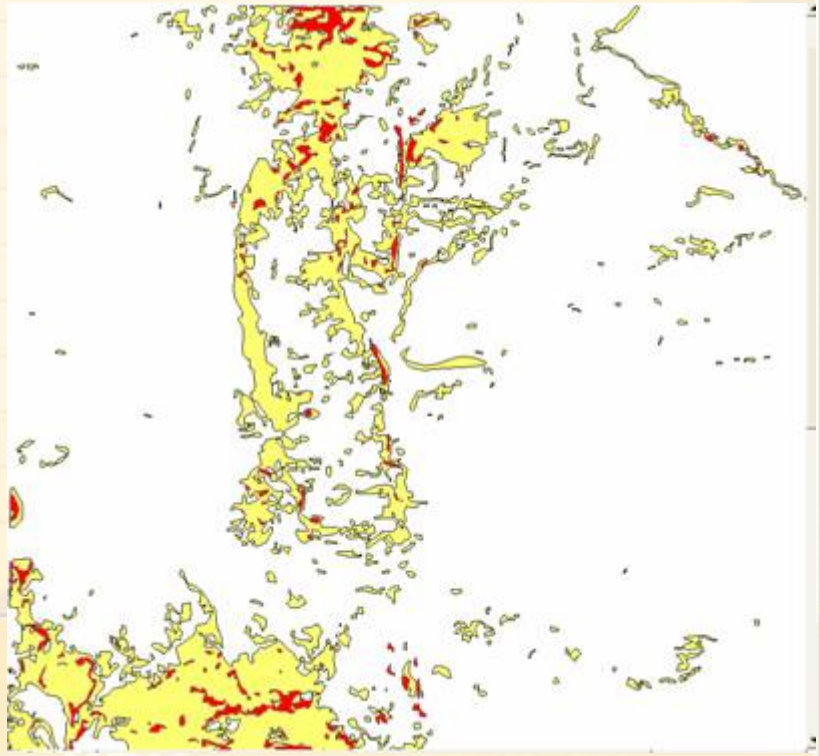


MÄK TECHNOLOGIES

Generalization

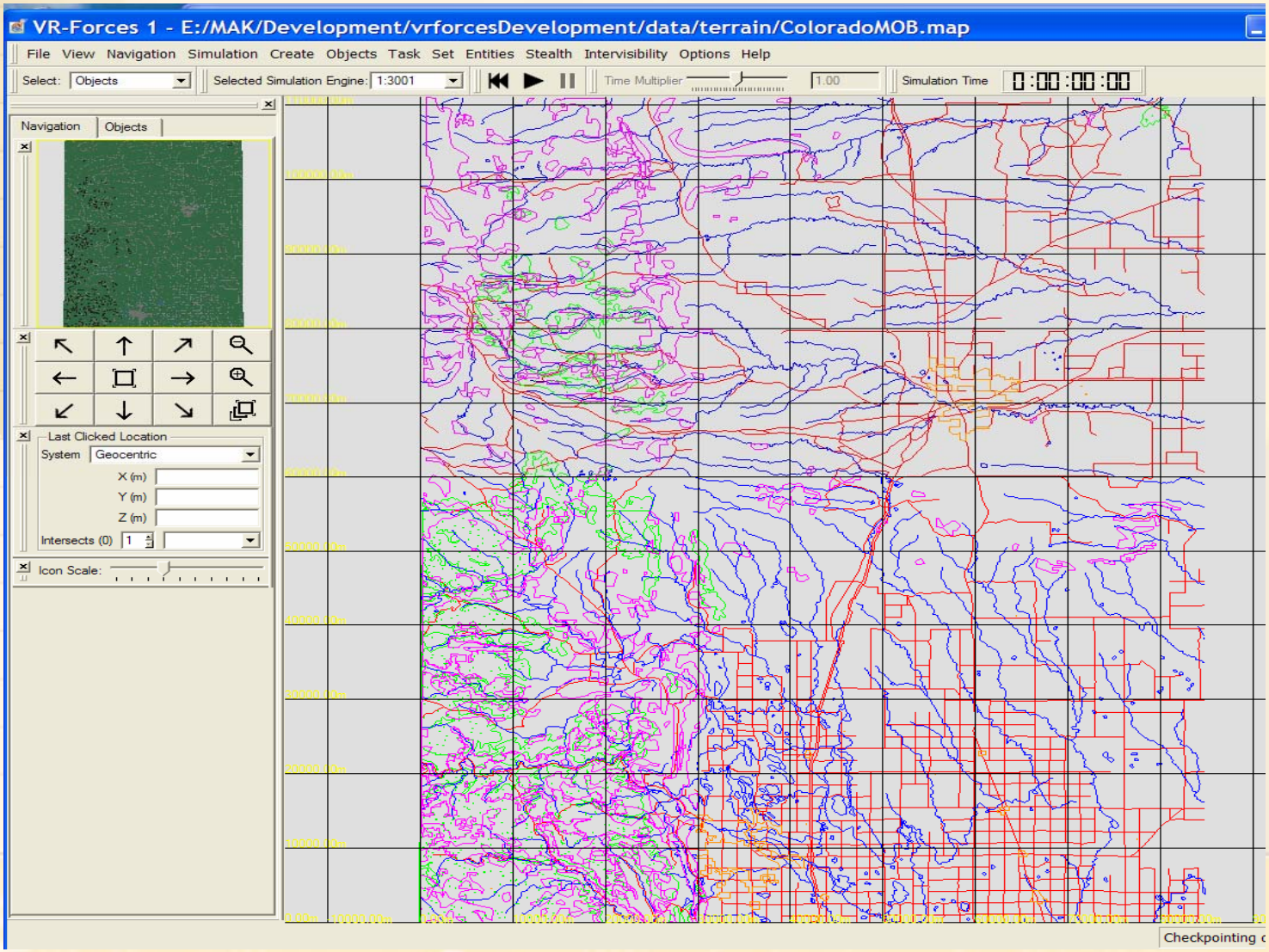


- Simplify Polygons
  - Bend Simplify
  - Point Removal
- Aggregate Polygons



MÄK TECHNOLOGIES

Mobility Polygons in VR-Forces



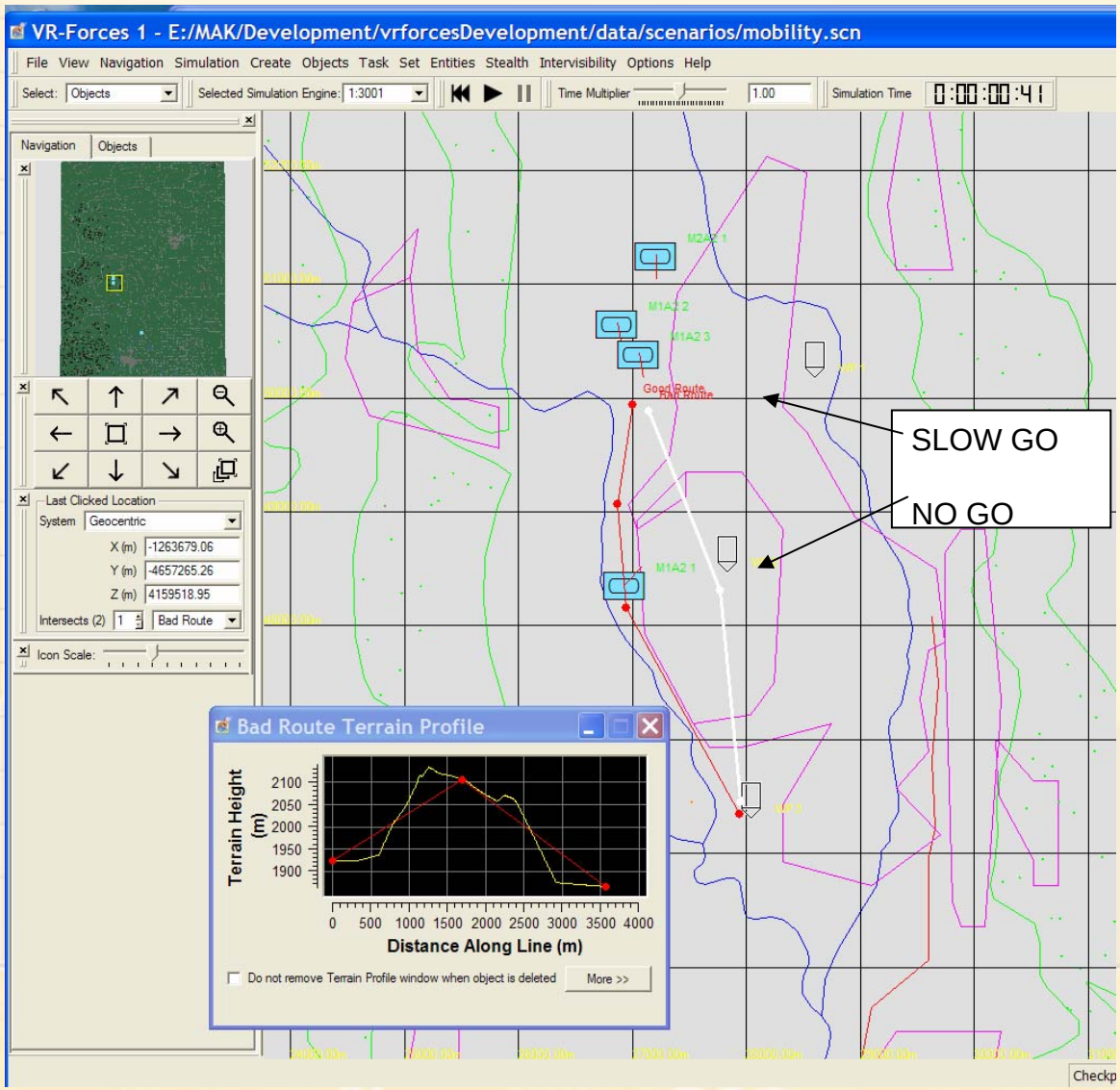
MÄK TECHNOLOGIES

VR-Forces Path Planner Modification

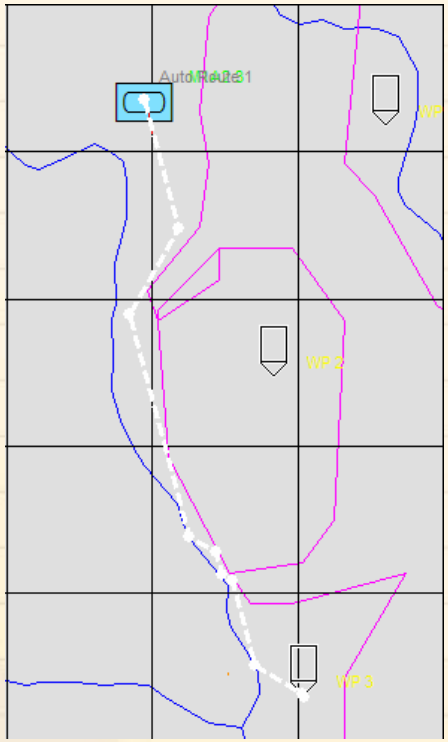
- Path planner in VR-Forces uses an A* search algorithm for finding paths across terrain in 2-D
  - Grid of evenly spaced nodes is created
  - Grid paths are considered both orthogonally and diagonally from each node
  - Features are also used in the generation of grid nodes
- New path metric written
  - Checks to see if the start or end point of the grid segment is inside a mobility area
  - If one of them is inside a NO_GO area, the cost for that segment is set to -1 (infinite), so that segment is never used
  - If one of them is inside a SLOW_GO area, the distance is doubled for that segment, allowing them to be used but at a higher cost than segments that do not cross mobility areas

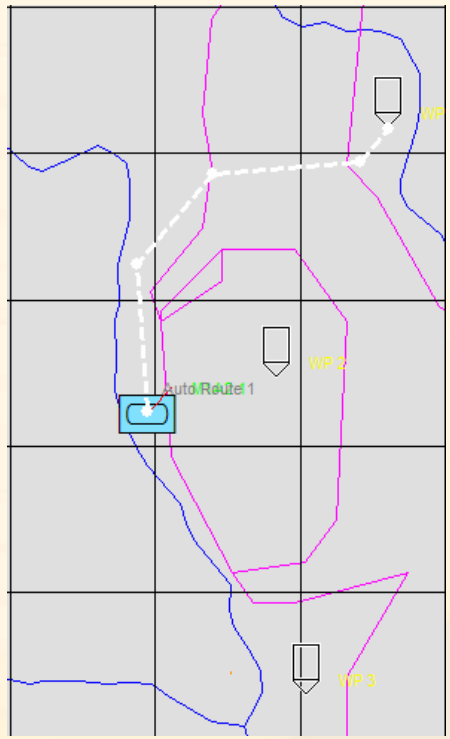
MÄK TECHNOLOGIES

Routes thru Mobility Areas



Path Planned Routes Using Mobility Areas





MÄK TECHNOLOGIES

Ridges and Valley Edges

- Developed a series of models in ArcInfo to generate ridge and valley edge area features and associated centerlines
  - Models linked embedded geoprocessing tools with parameters and default attributes
- Using ArcInfo with 3D Analyst, Spatial Analyst, and ArcScan extensions
- Start with a Digital Elevation Model (DEM)
- Create shapefiles that contain the geometry and attributes
- Document that walks user through the process

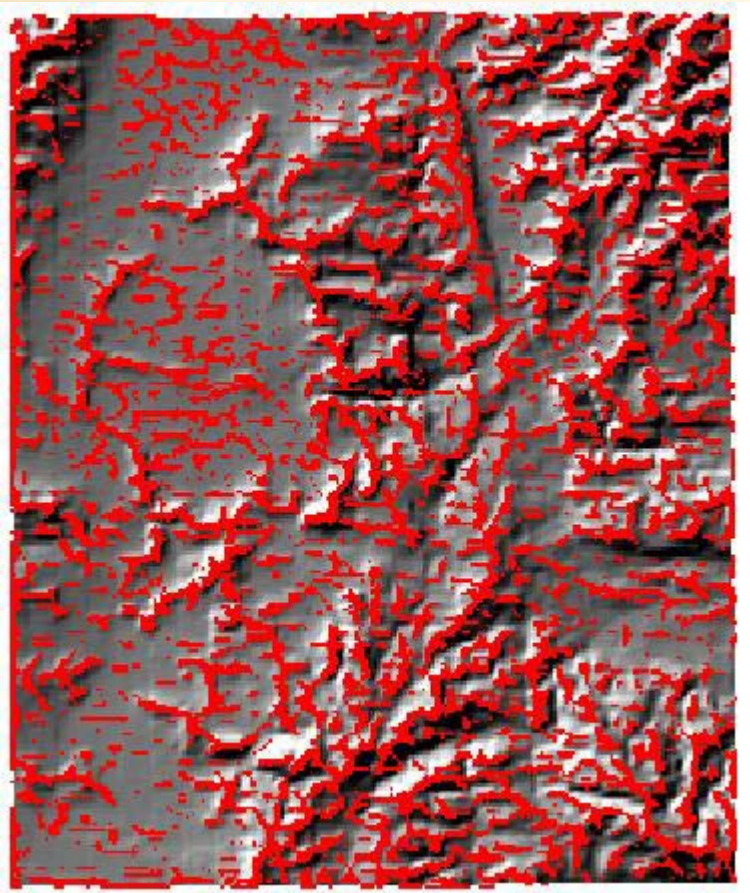
MÄK TECHNOLOGIES

Ridge Feature Generation

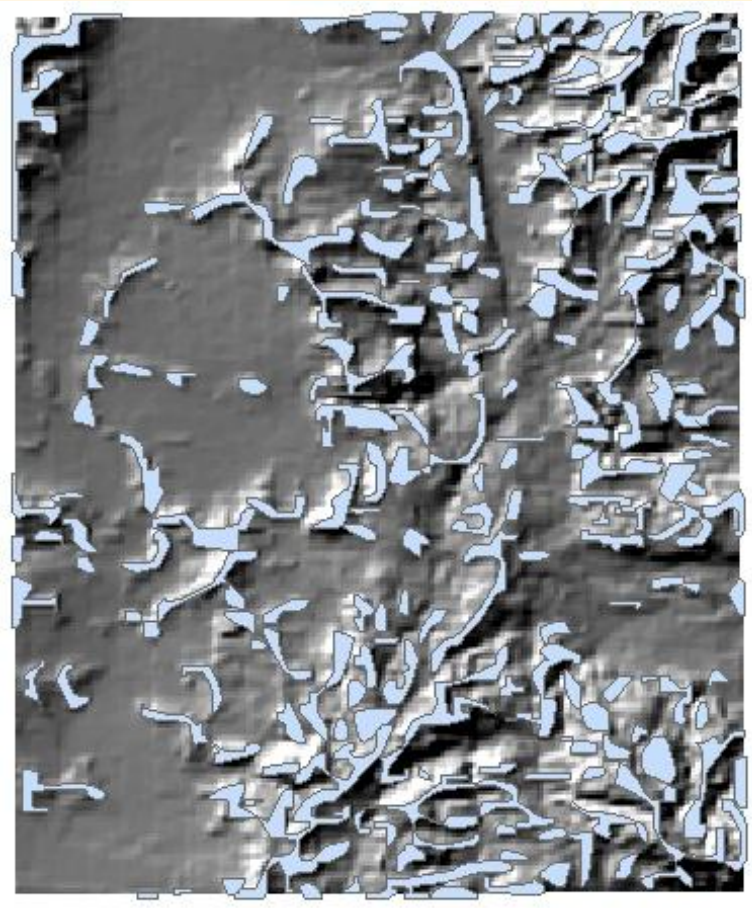
- Use hydrology tools to find areas of zero flow accumulation in DEM
  - Flow Direction tool
    - Creates a raster of flow direction from each cell to its steepest downslope neighbor
    - Calculates percent drop in elevation in the flow direction as a separate raster
  - Flow Accumulation tool
    - Uses the flow direction and percent drop rasters
    - Creates a raster of accumulated flow to each cell.
  - Majority filter
    - Expands the zero accumulation raster areas
- Select only those cells that correspond to high slopes
- Convert raster areas to polygonal areas
- Clean up and generalization
- Convert polygonal areas back to rasters and use ArcScan vectorization functions to find centerlines
- Associate centerlines with corresponding area feature
- Export shapefiles of ridge area polygons and centerlines

MÄK TECHNOLOGIES

Ridge Features



Zero Accumulation Pixels



Ridge Polygons

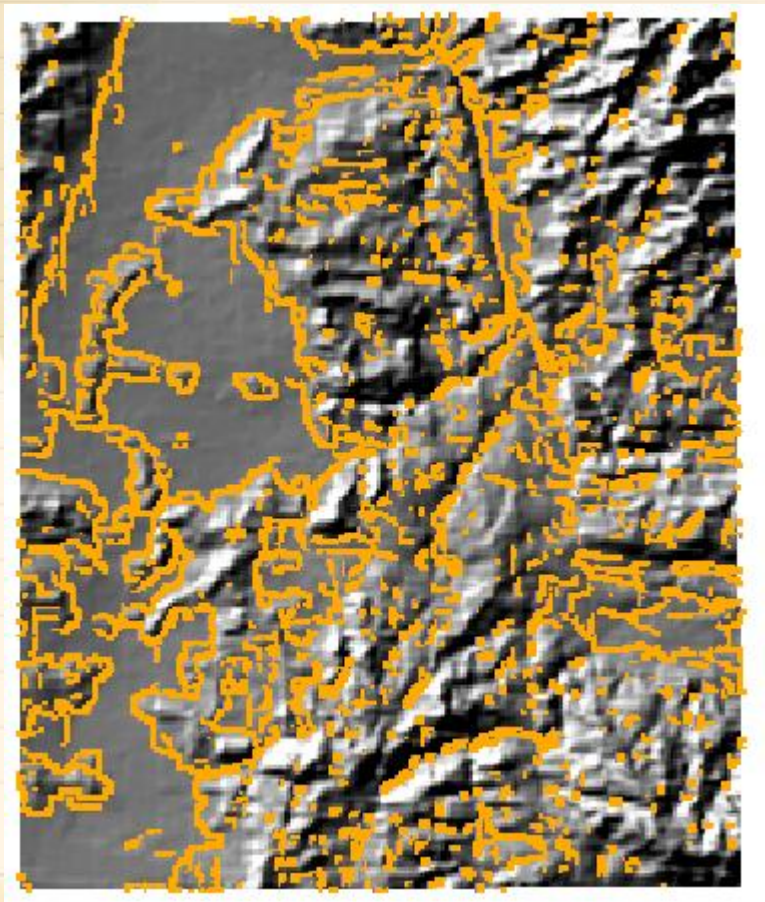
MÄK TECHNOLOGIES

Valley Edge Feature Generation

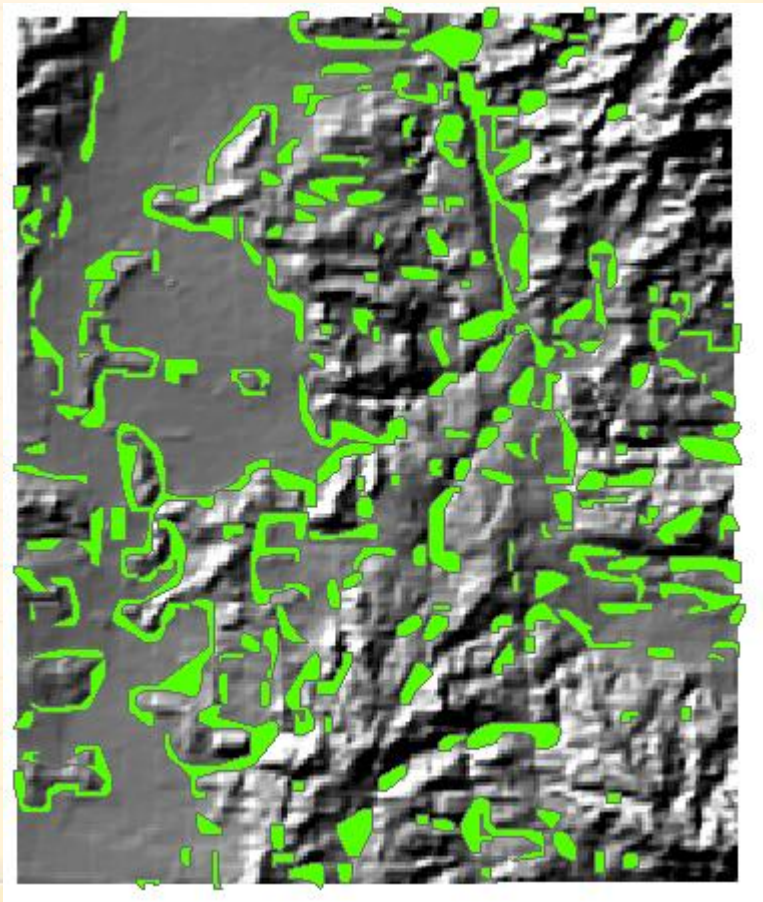
- Use DEM to generate toe-in-slope areas
  - Separate the slope raster into a raster of high slopes (greater than 6%) and a raster of low slopes (less than or equal to 6%).
  - Use these rasters to select the original elevation data from the DEM for each of these slope categories
  - Run a 3x3 Mean filter over each of these elevation rasters to expand them slightly
  - A Map Algebra expression finds the areas where they overlap
  - Resulting raster has data only where high slope areas meet low slope areas, corresponding to valley edges
- Convert raster areas to polygonal areas
- Clean up and generalization
- Convert polygonal areas back to rasters and use ArcScan vectorization functions to find centerlines
- Associate centerlines with corresponding area feature
- Export shapefiles of valley area polygons and centerlines

MÄK TECHNOLOGIES

Valley Edge Features



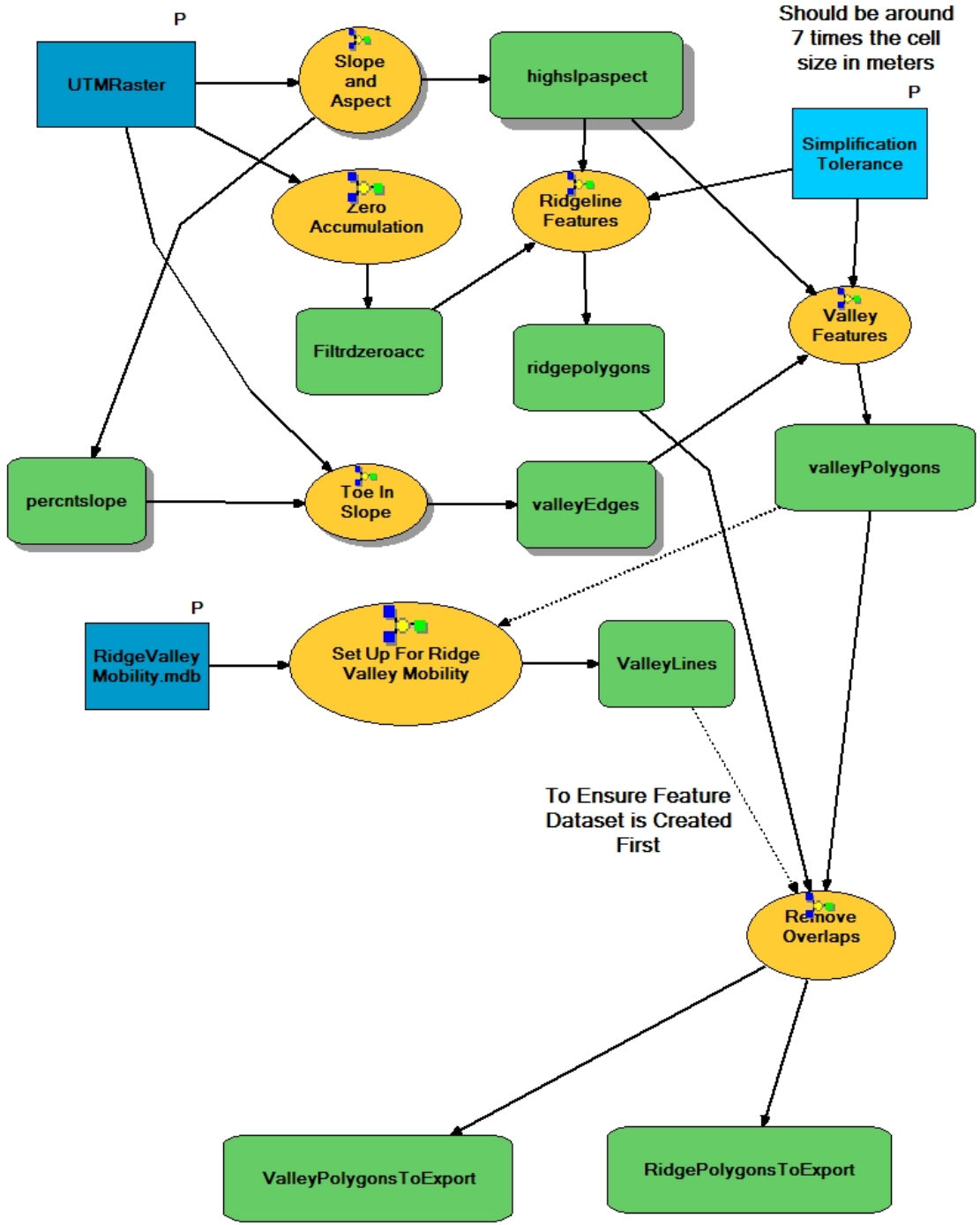
Toe-In-Slope Pixels



Valley Polygons

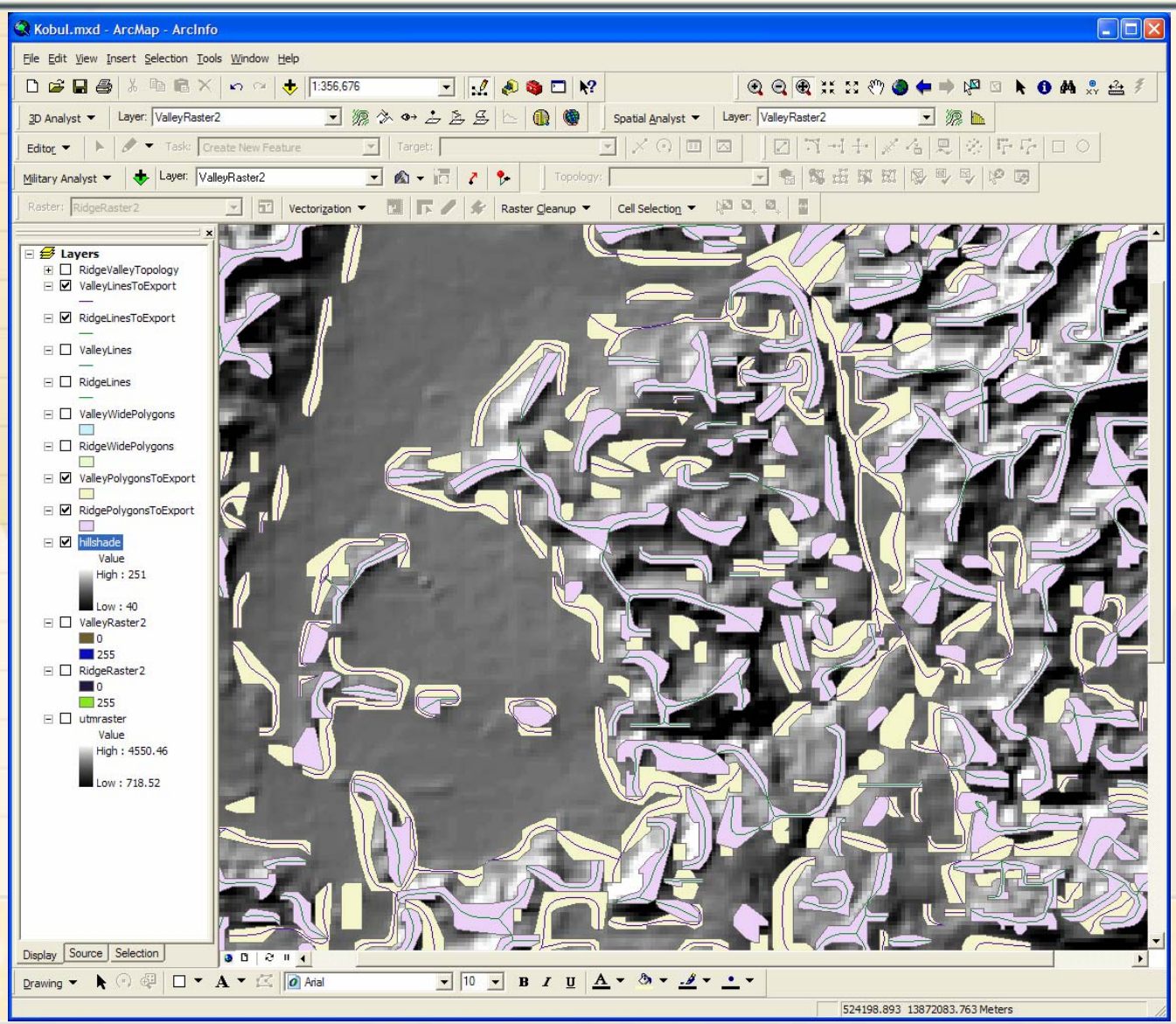
MÄK TECHNOLOGIES

Ridge and Valley Tool



MÄK TECHNOLOGIES

Ridge and Valley Features

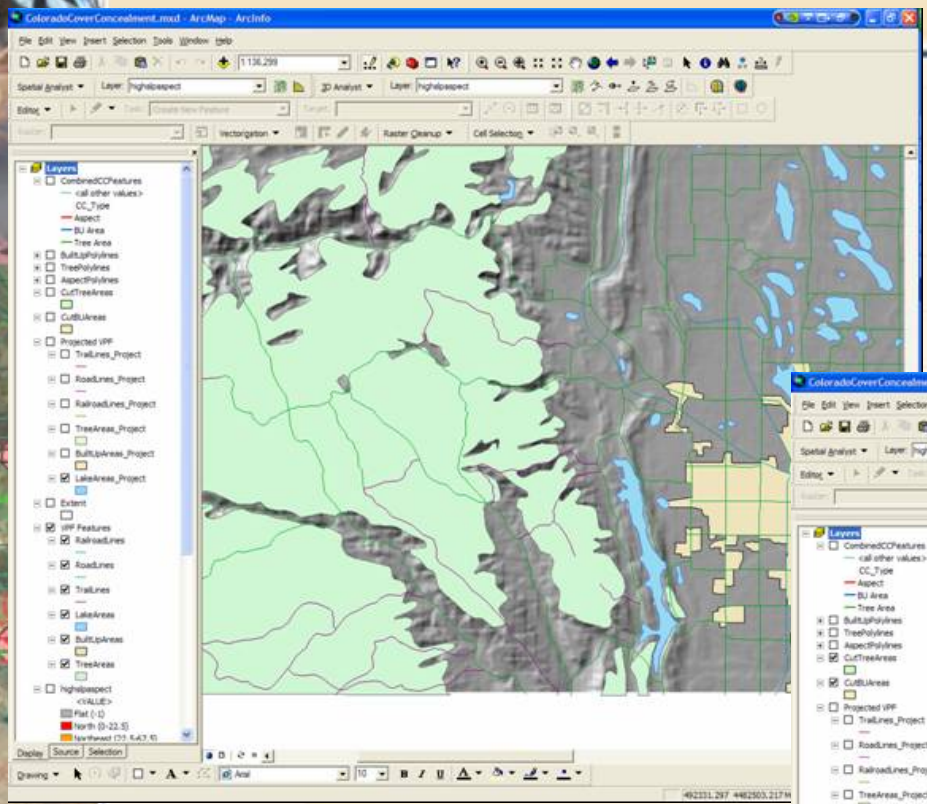


Cover and Concealment

- Linear features that provide covered and concealed routes
- Based on aspect, tree areas, and built up areas in 8 cardinal directions
- Converted area polygons to binary rasters
  - First cut roads, railroads, and trails into tree and built up areas
- Used a Focal Statistics tool with Wedge neighborhood and MAXIMUM statistics type to shift pixels
- Used Subtraction tool to eliminate original pixels, leaving only shifted pixels
- Converted pixels to linear features, with attribution for direction concealment is from
  - Clip with lake areas to remove segments in water

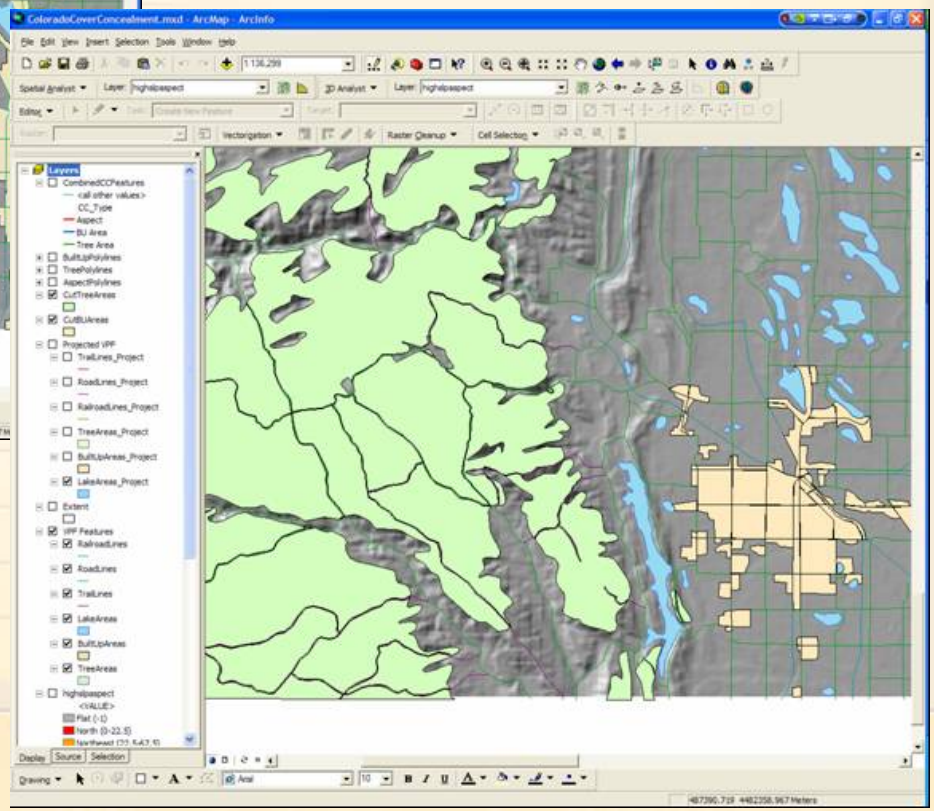
MÄK TECHNOLOGIES

Area Features for C&C



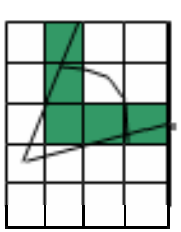
Tree and Built Up Areas Before Cut by Linear Features

Tree and Built Up Areas after Cut by Linear Features and Buffered

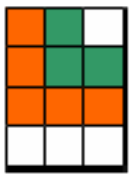


MÄK TECHNOLOGIES

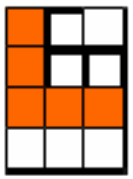
Focal Statistics Tool



Original Pixels



SW Shifted Pixels



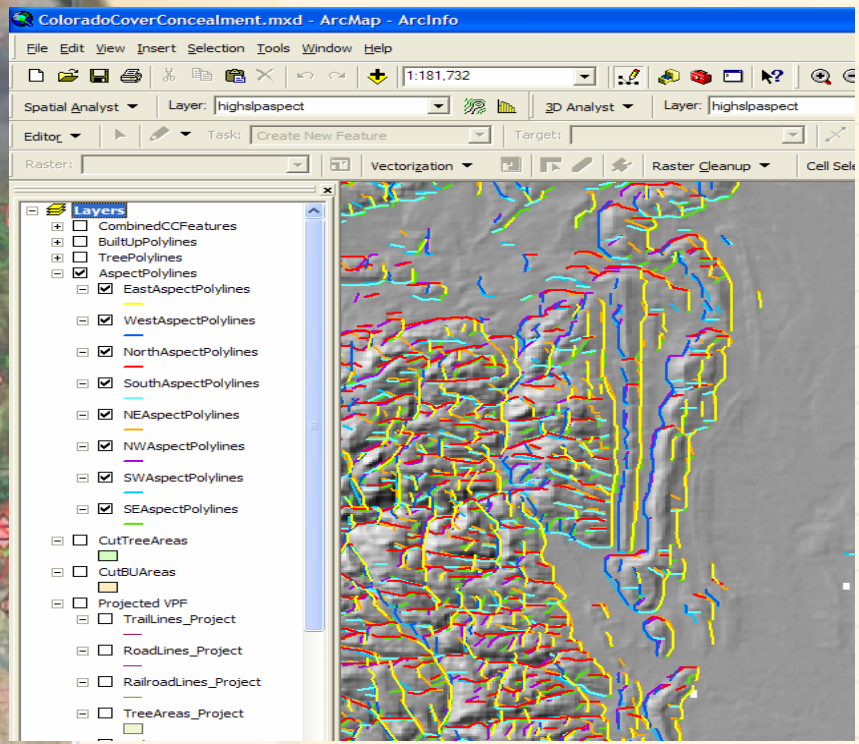
Subtracted Pixels

Focal Statistics Values

Direction	Start Angle	End Angle	Radius
North	255	285	1
NorthEast	210	240	2
East	165	195	1
SouthEast	120	150	2
South	75	105	1
SouthWest	30	60	2
West	345	15	1
NorthWest	300	330	2

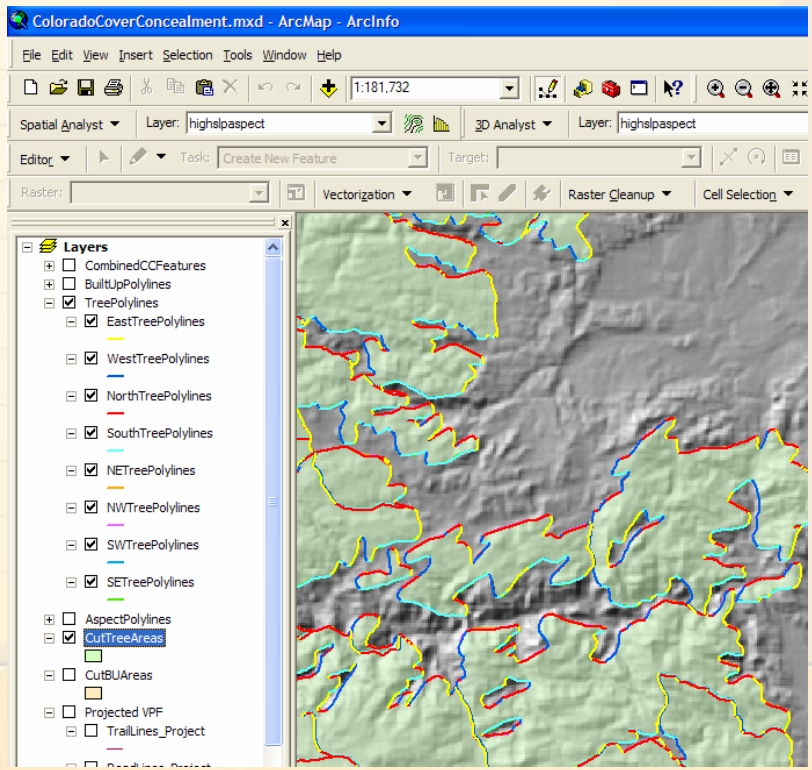
MÄK TECHNOLOGIES

Cover and Concealment



Concealment from Aspect

Concealment from Tree Areas



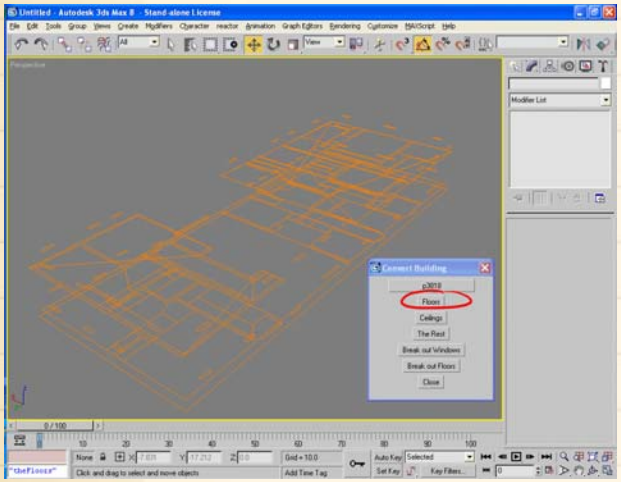
MÄK TECHNOLOGIES

Building Interiors

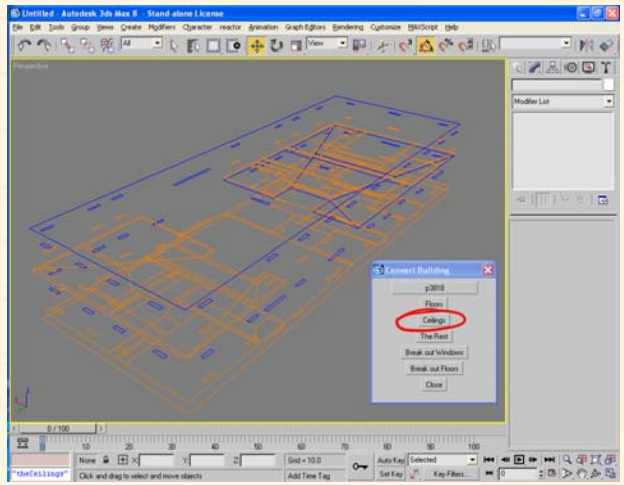
- IWARS uses enclosures, apertures, climbing devices and topology
- Generating scripts in 3ds Max and TerraTools to generate interior semantic information
- Find each floor and ceiling, and stairs that connect them
- For each floor, scripts locate walls, doors, and windows, and then break up the rooms into enclosures and apertures.
- Data exported as XML for IWARS

MÄK TECHNOLOGIES

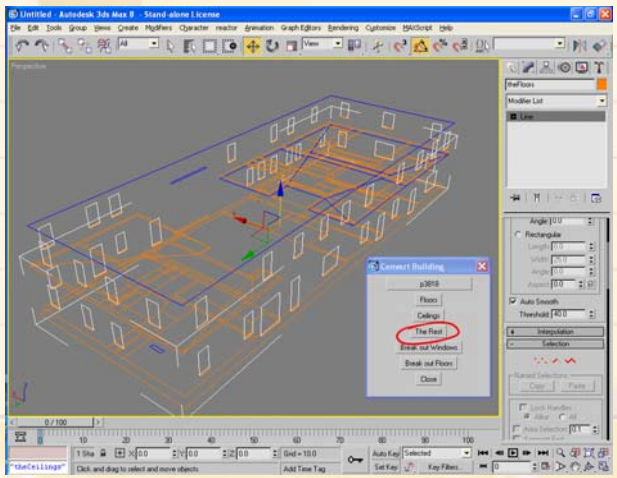
Building Interior Scripts



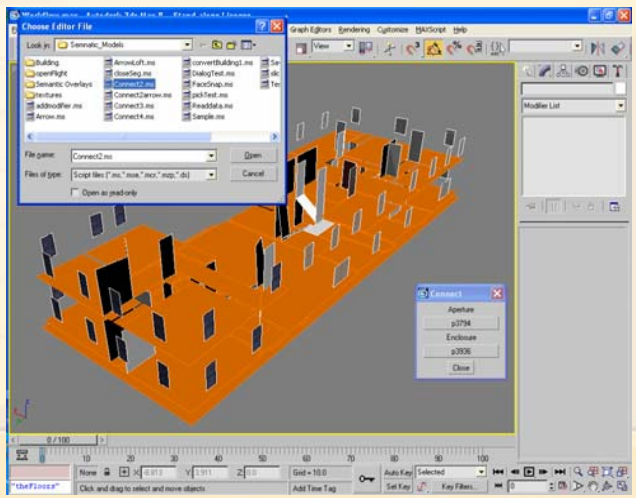
Create Floor Schematic Shape



Create Ceiling Schematic Shape



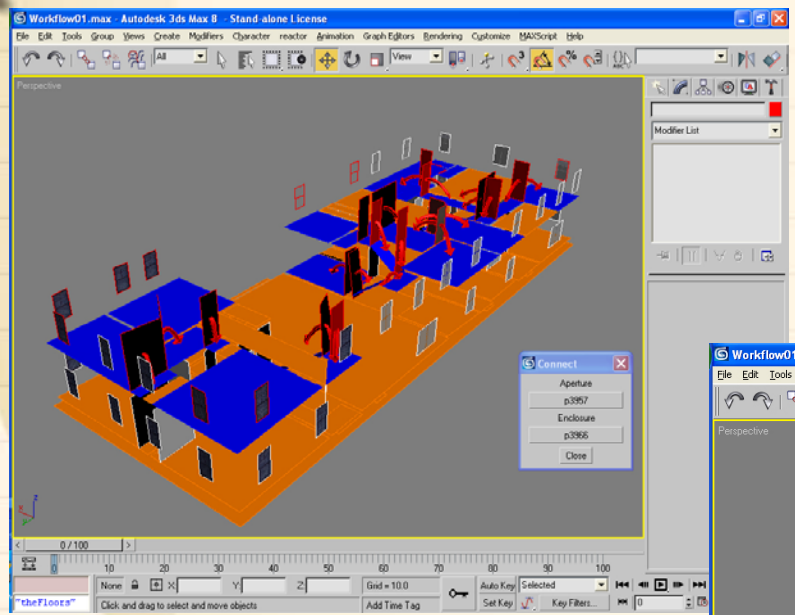
Create Window Schematic Shape



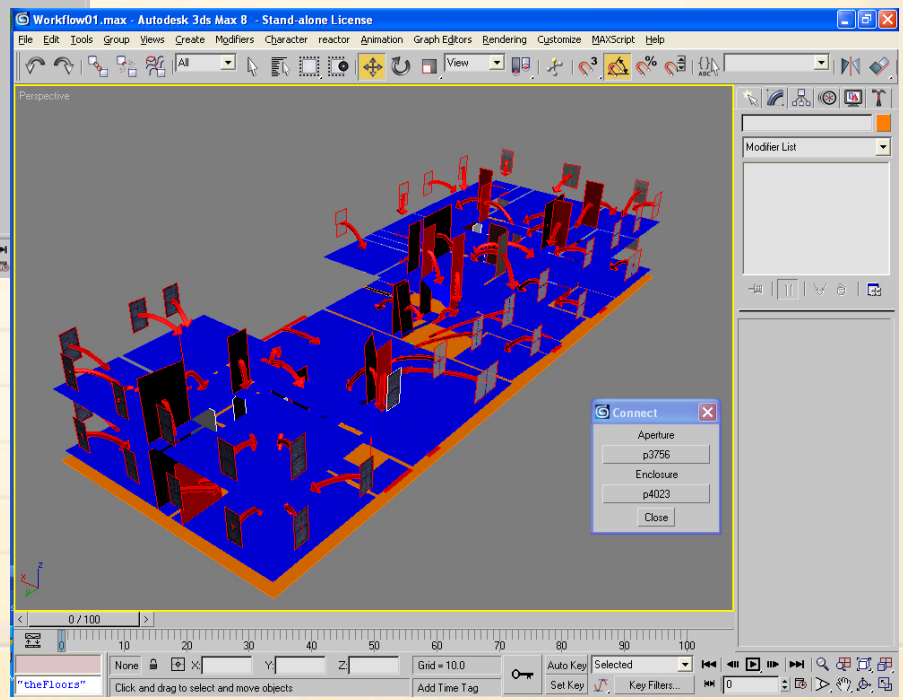
Semantic Connection Script

MÄK TECHNOLOGIES

Building Interior Scripts



Connections between Doors and Enclosures



Complete Topology

MÄK TECHNOLOGIES

Conclusion

- ArcGIS and 3ds Max provide powerful set of features for generating semantic information for M&S
- New feature types enabling higher level behaviors models to be developed
- Expect to use even more ArcGIS tools and capabilities in the future for M&S terrain database representations