SIMULATION OF AN INTEGRATED LADAR IMAGING SYSTEM

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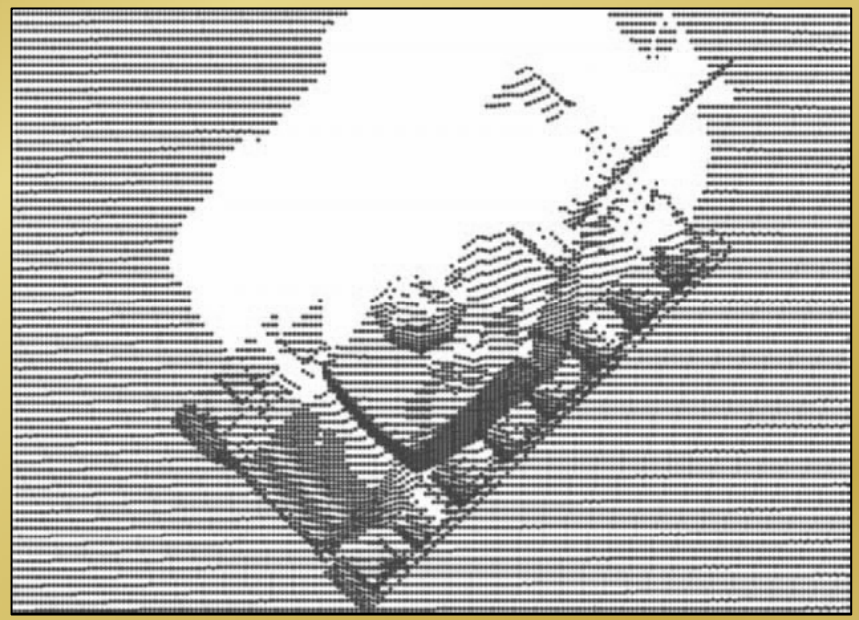
Ladar

(Laser Detection and Ranging)

- A method for determining distance to an object using a laser beam
- This distance is defined as the time it takes for a laser pulse to hit an object, reflect and then return to a sensor relative to the speed of light



Ladar vs. Radar

Ladar can produce higher resolution images

LadarSIM Background

- Matlab and Simulink based LADAR system simulator
- Developed by the Center for Advanced Imaging LADAR (CAIL) Center of Excellence at Utah State University.
- Originally funded by the Naval Air Warfare Center Weapons Division (NAVAIR) in China Lake, CA.

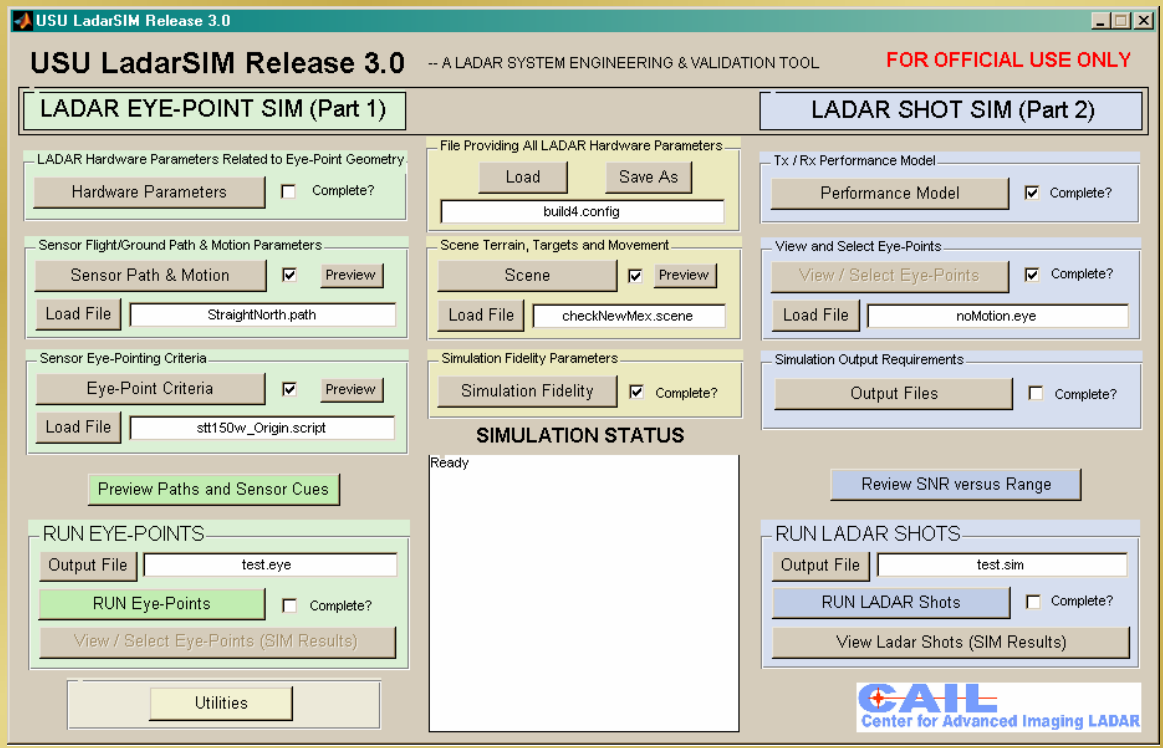
Simulation Objectives

- General System Analysis
- Error Source Modeling
- Design and Development Tool
- A Reliable Simulation that Doesn't Take All Day

LadarSIM 3.0

Two Main Areas of LADAR System Development

Physical Geometric Capabilities of the Hardware



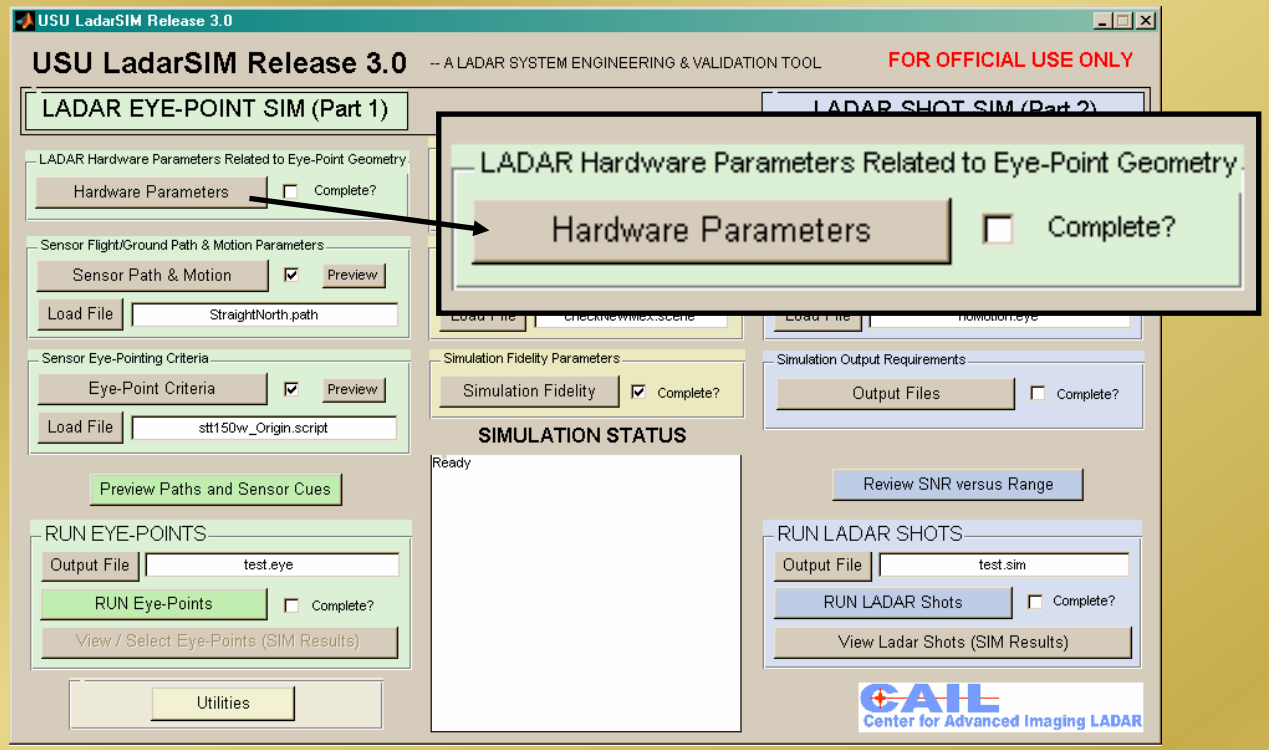
Radiometric Performance of the Electronics

LadarSIM 3.0 was designed to allow the user to focus on each of these areas independently.

LadarSIM 3.0

Two Main Areas of LADAR System Development

Physical Geometric Capabilities of the Hardware



Define the parameters of the scanner, focal plane array and navigation instruments.

LadarSIM 3.0

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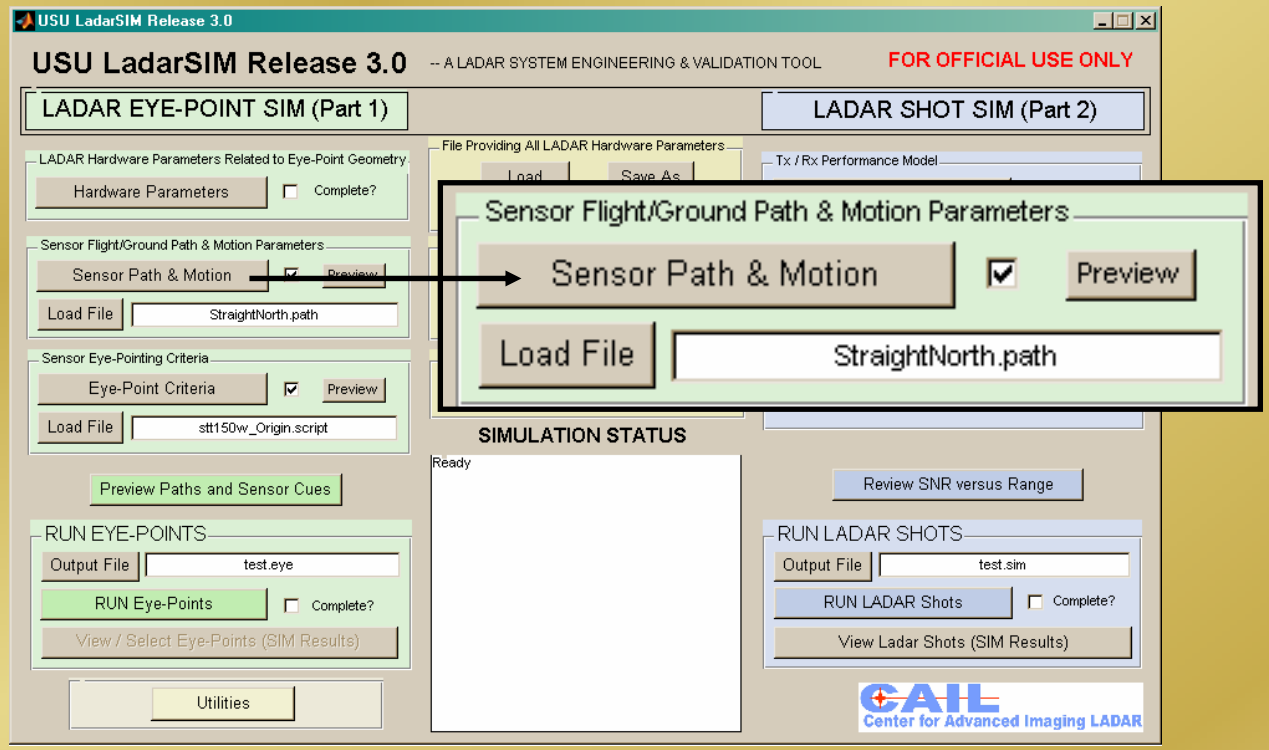

Define the sensor platform's position and orientation in six degree-of-freedom data.

LadarSIM 3.0

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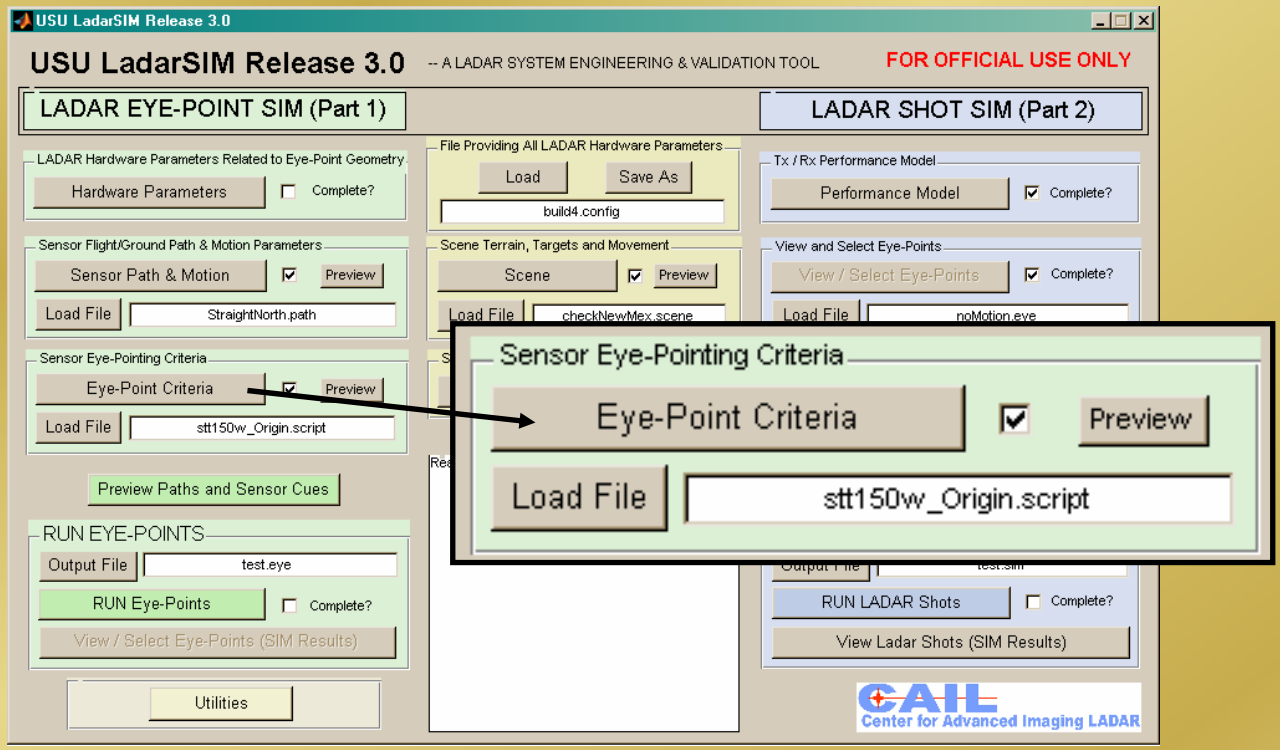
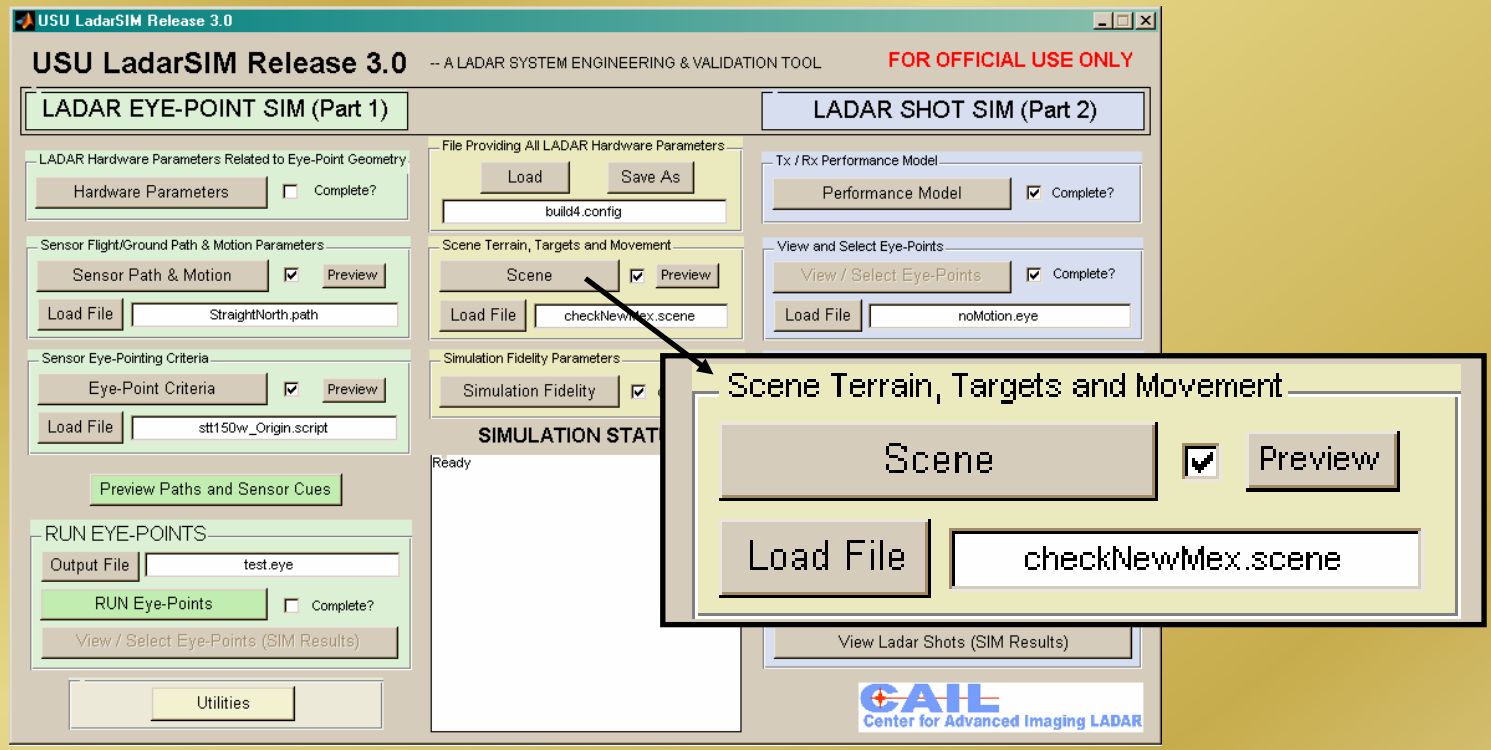


Define the point of interest about which the scan is centered.

This may be defined in 3-d local level coordinates or in Az-El coordinates about the optical axis of the sensor.

LadarSIM 3.0

Two Main Areas of LADAR System Development

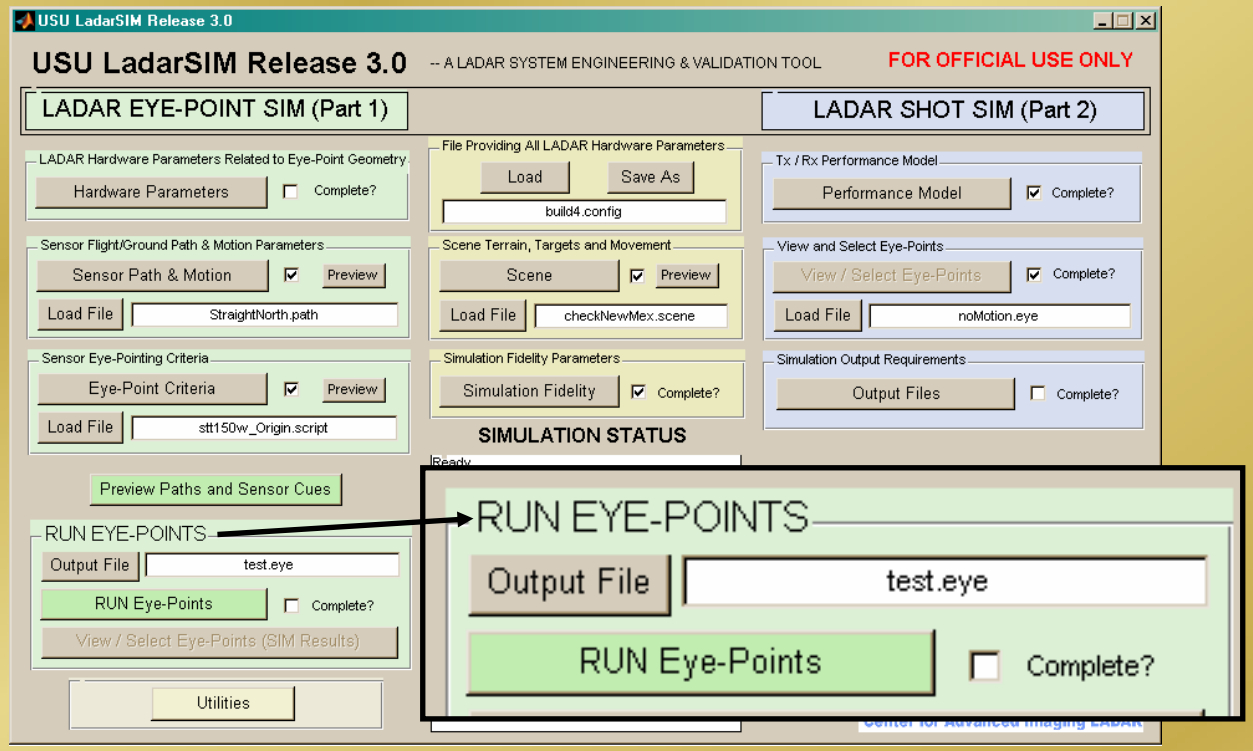


Develop custom scenes by selecting the terrain and targets and defining their positions and movement.

LadarSIM 3.0

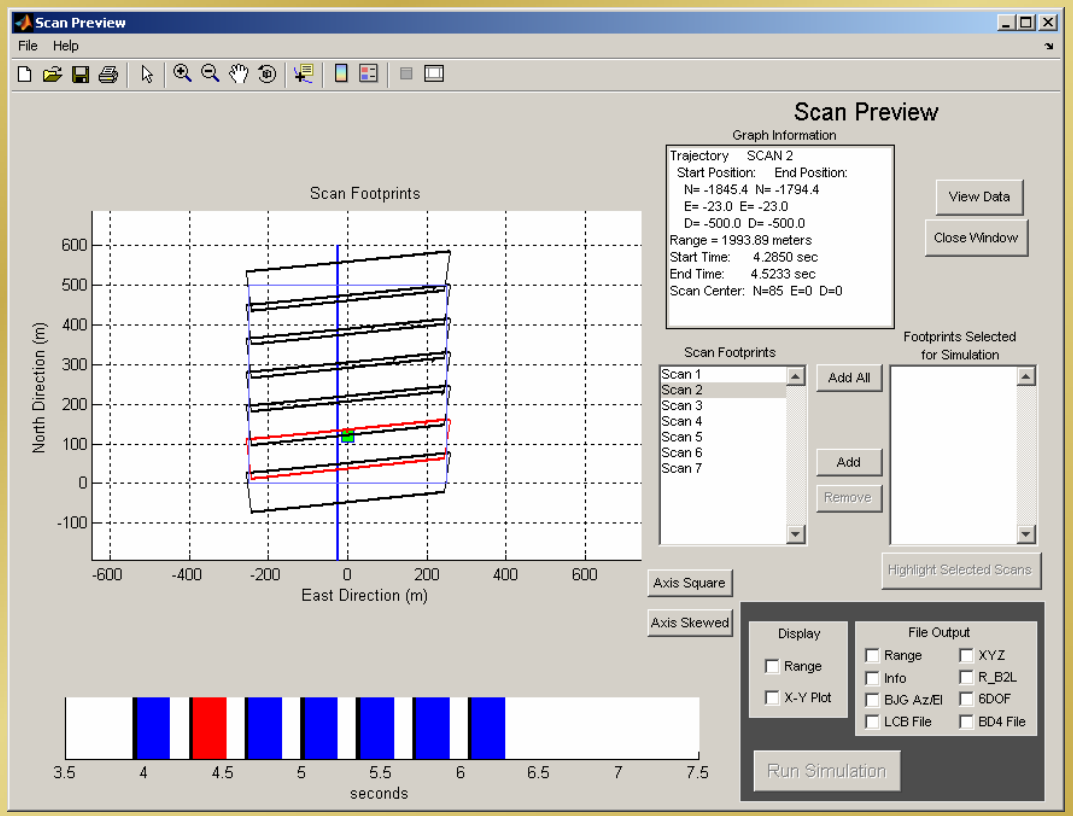
Two Main Areas of LADAR System Development

Physical Geometric Capabilities of the Hardware



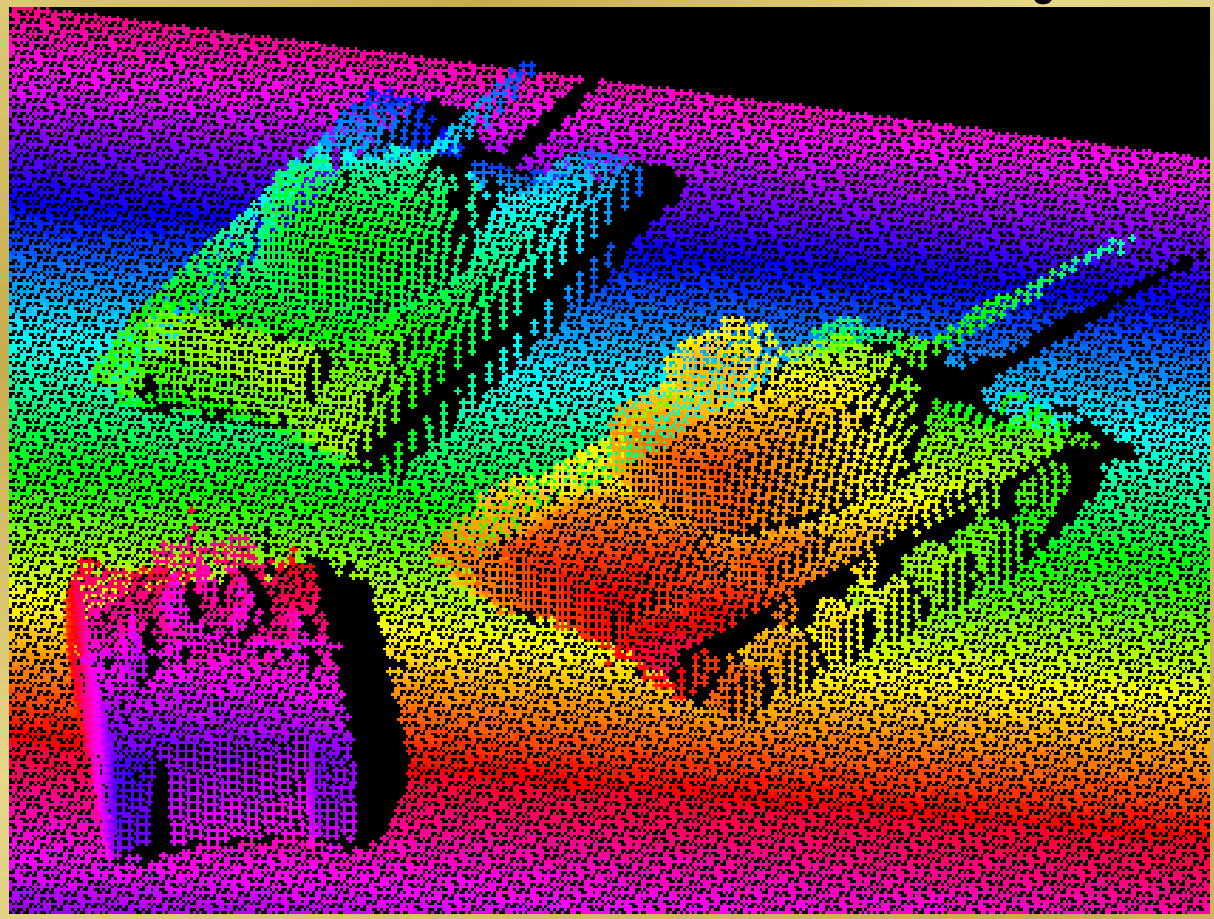
After a geometric simulation has been run the data may be viewed or used to form a radiometric simulation

Scan Preview View



- Intermediate GUI which allows the user to view the scan footprints in relation to the targets
- The user can then specify which footprints to run a full scan on

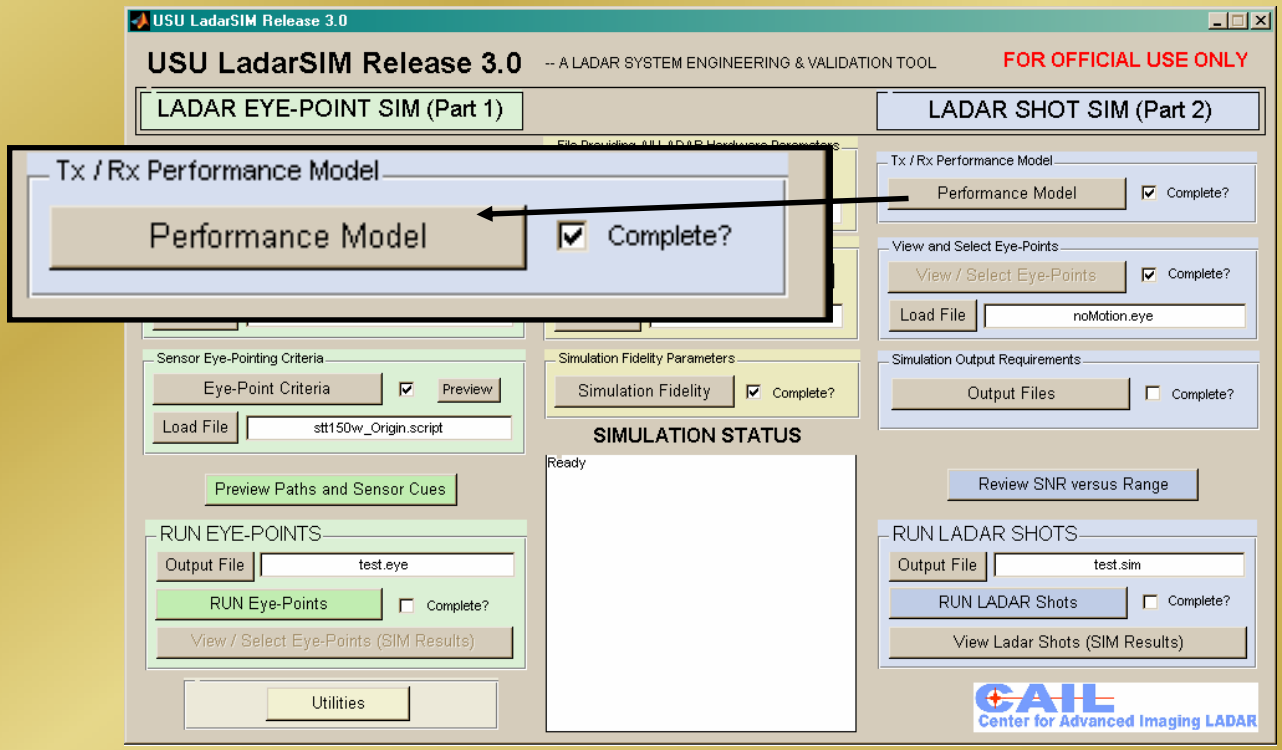
Point Cloud of Geometry Data



Geometric simulation data is free of dropouts, false alarms and range errors

LadarSIM 3.0

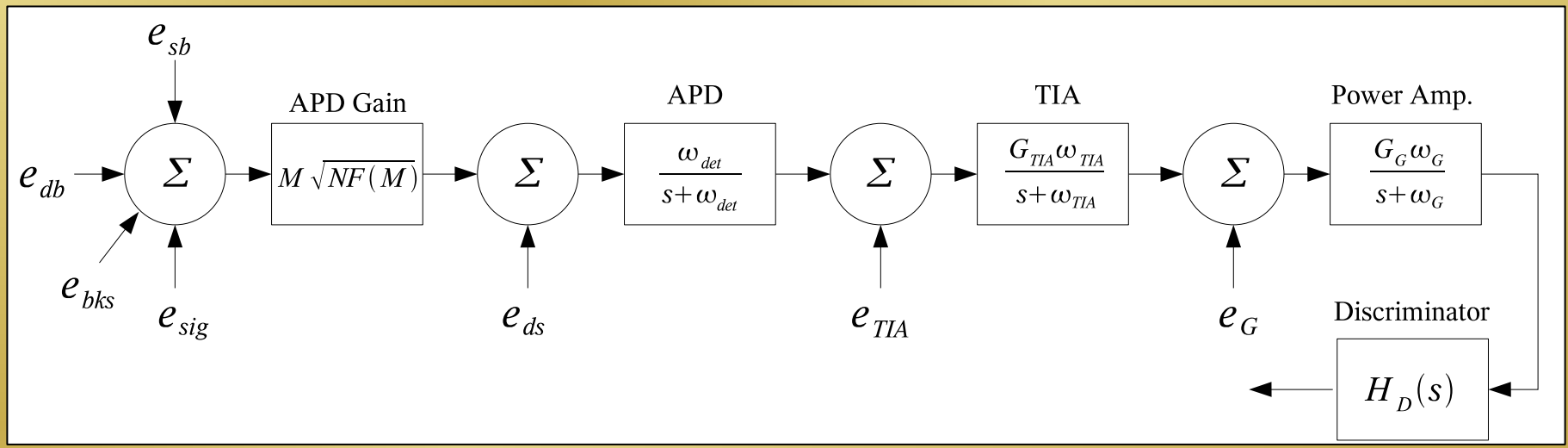
Two Main Areas of LADAR System Development



Radiometric Performance of the Electronics

Define the environment, optical and transceiver parameters of the system

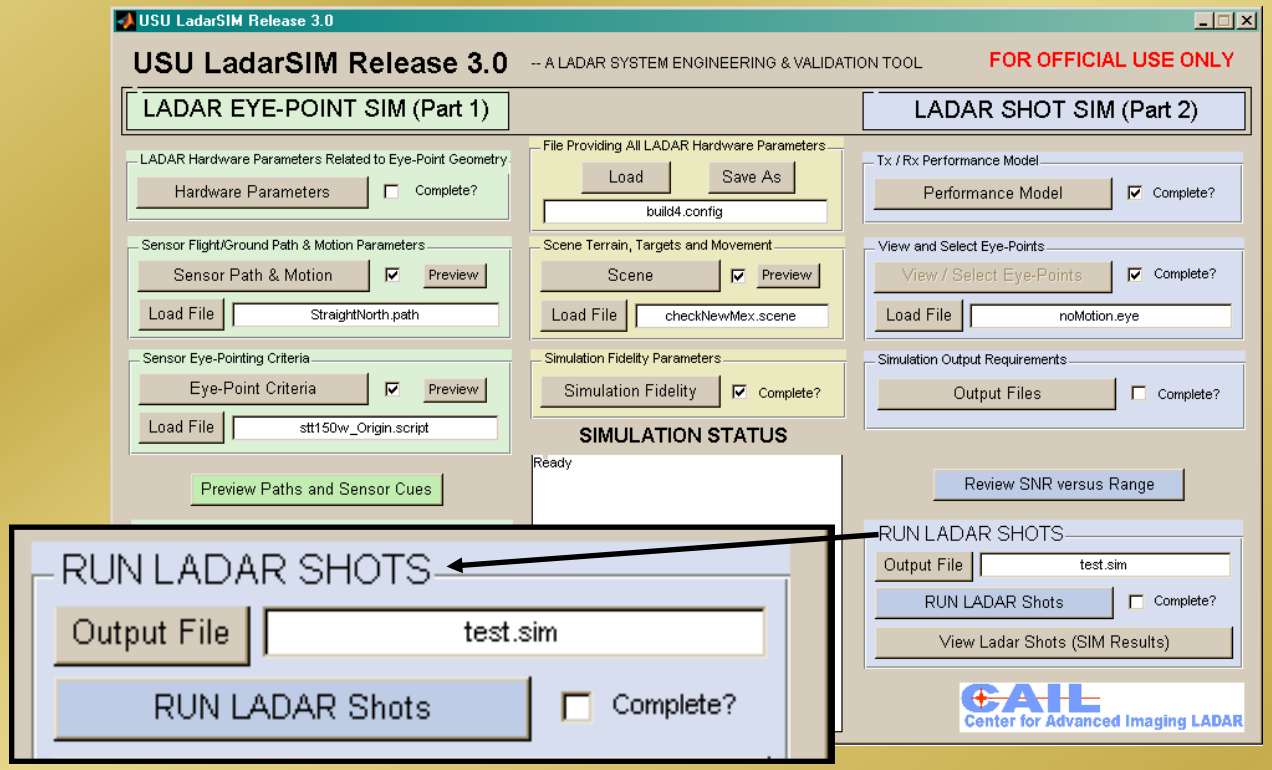
Error Model



Flow diagram of detector stages and their respective errors

LadarSIM 3.0

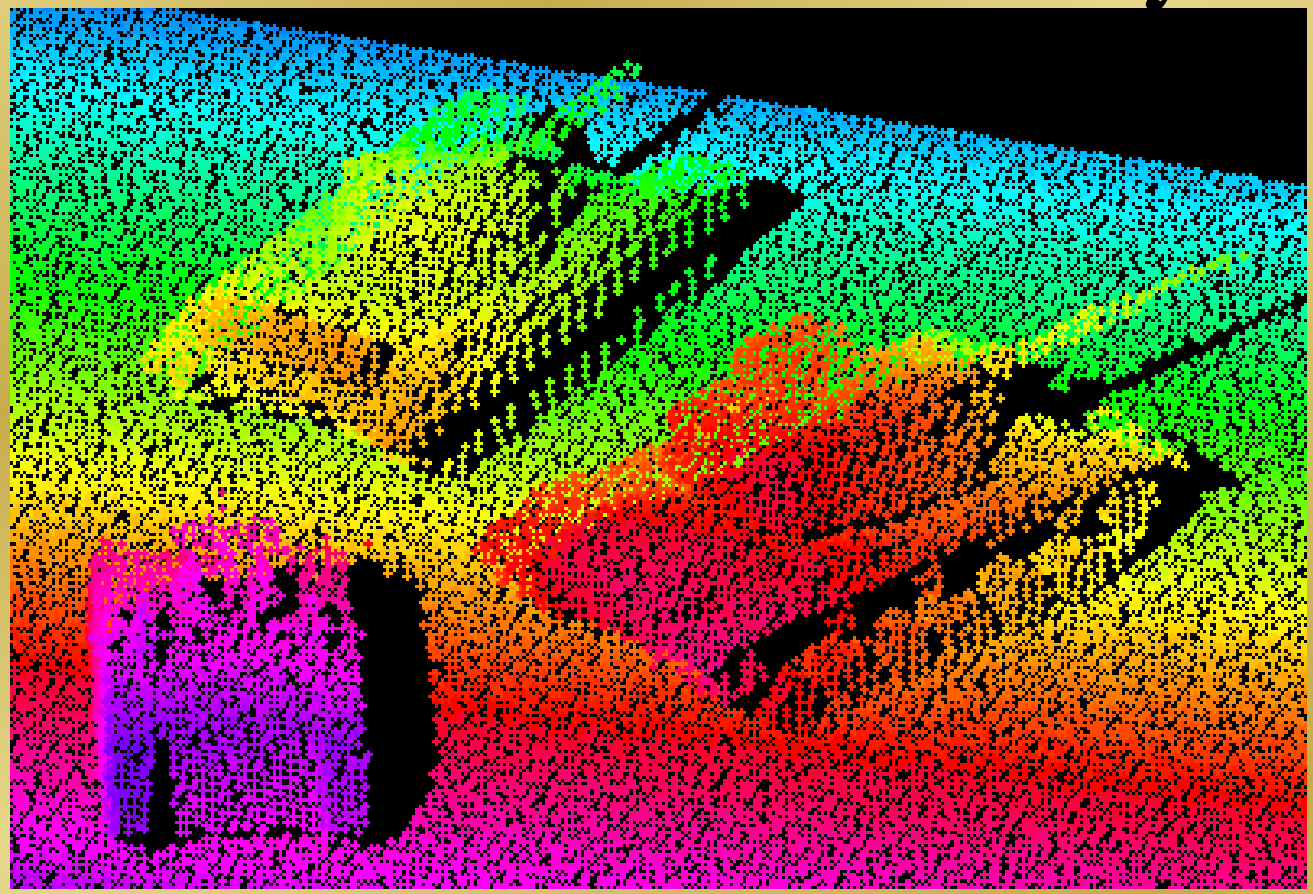
Two Main Areas of LADAR System Development



Radiometric Performance of the Electronics

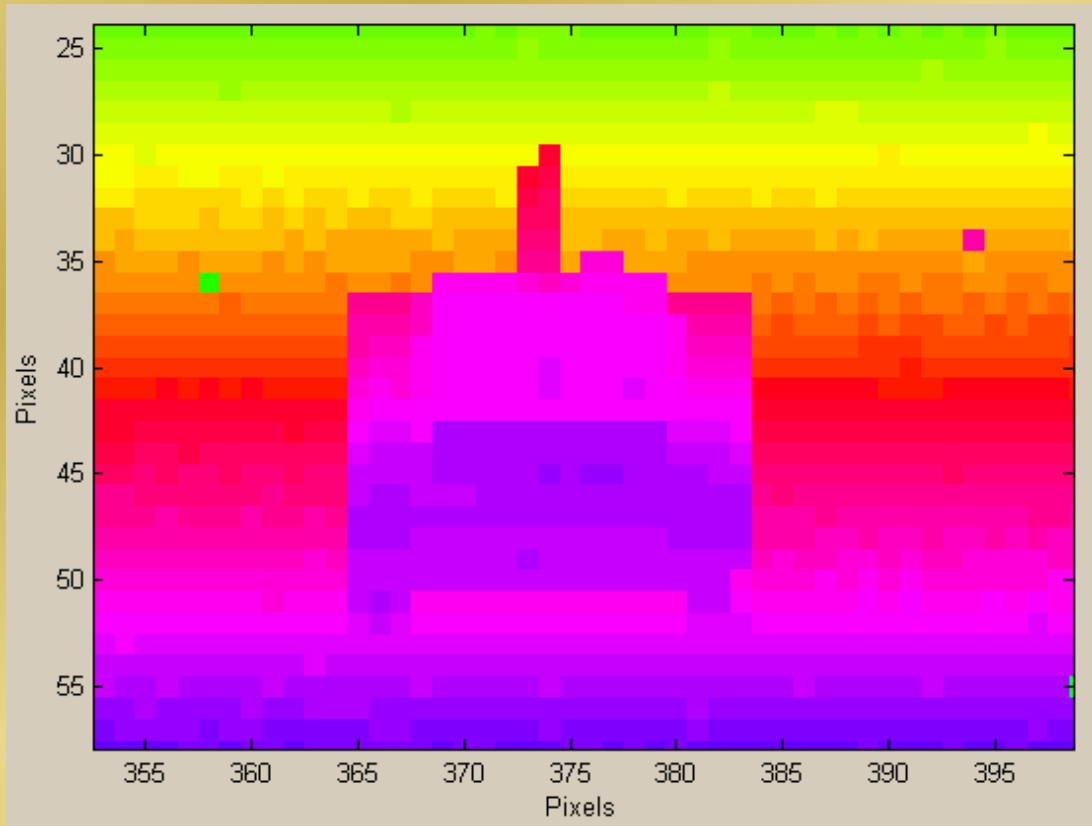
The data received from a radiometric simulation parallels that of an actual system including dropouts, false alarms and range errors

Point Cloud of Radiometry Data



- Three-dimensional display environment developed through xyz data processing
- Can rotate, zoom and pan around the data set as desired to explore and analyze the results

Range Image View



- 2-d image allowing the user to view the data colored according to range value
- Each point may be queried to display the xyz and range data for that point.

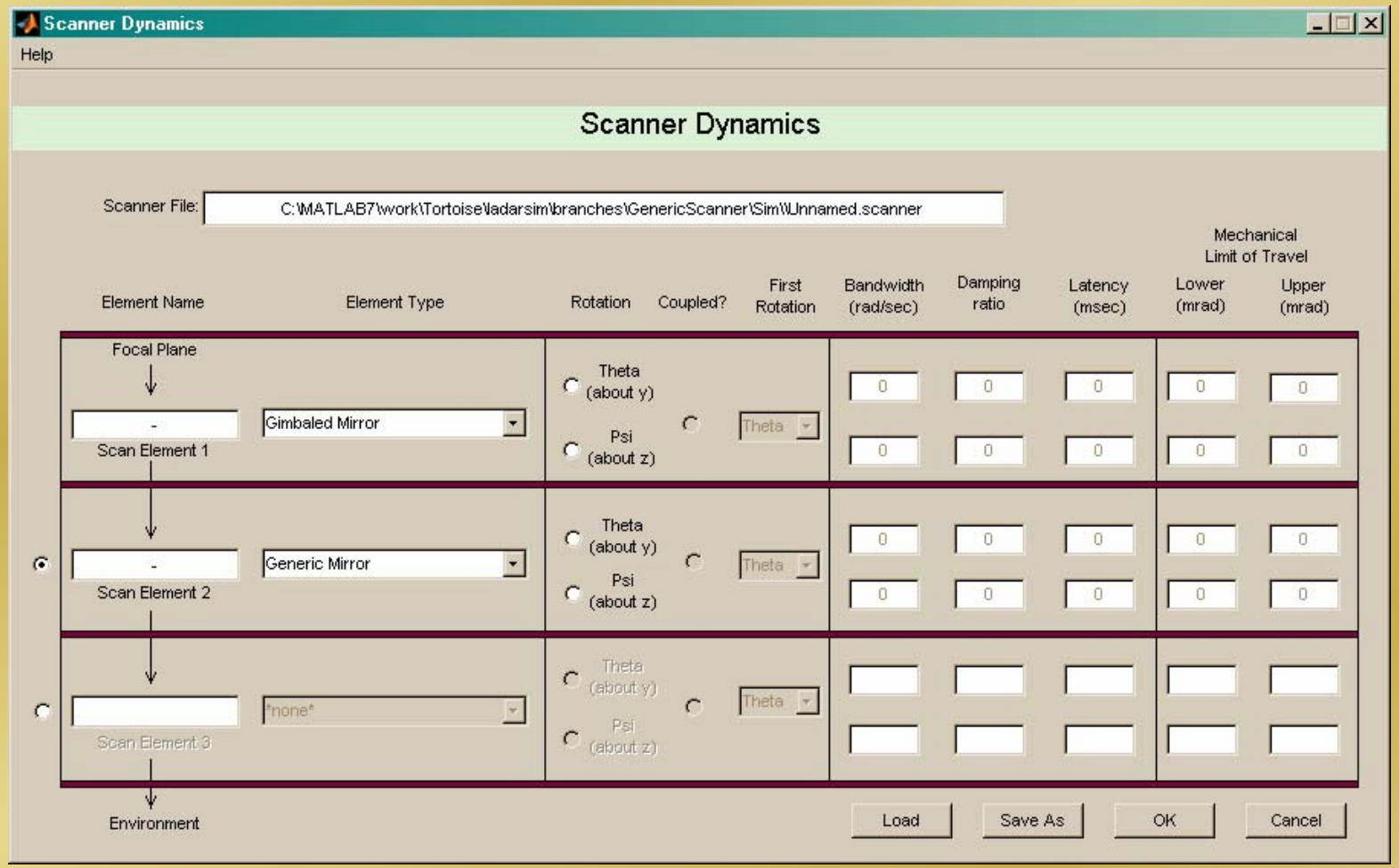
Recent Improvements

- Generic Scanning
- Movement of Targets and Sensor Platform
- Waveform Modeling

Generic Scanning

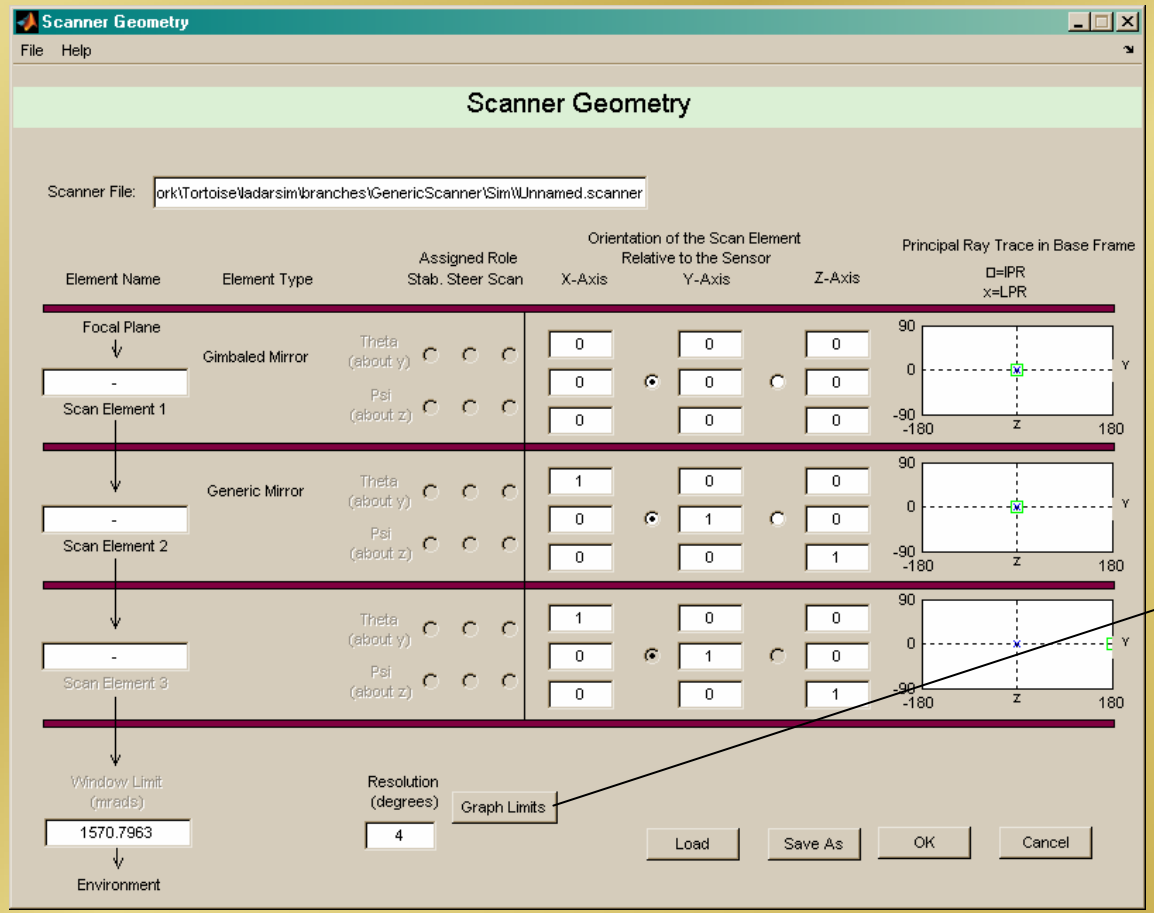
- Up to three scan elements may be defined, each having a steering, stabilization and/or pattern-scanning role
- Scan element commands are fed through a dynamic scanner model to achieve realistic results

Scanning Dynamics



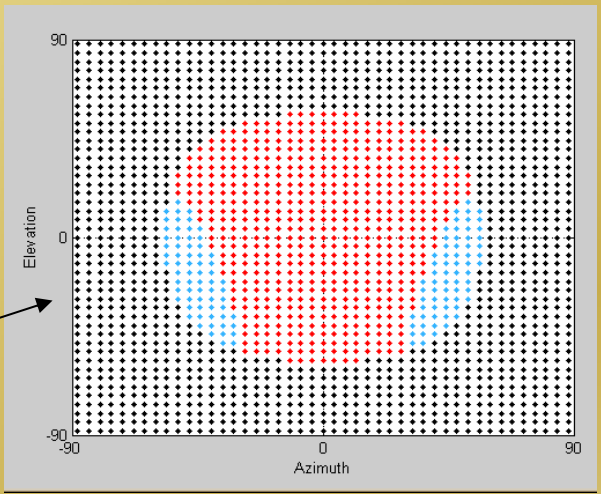
In the scanner dynamics GUI the scan elements along with their dynamic parameters may be specified

Scanning Geometry



This GUI defines the relative orientation of the optical elements as well as the roles they will play in scanning, steering and stabilization

In the geometry GUI the Az-El limits to the input configuration may be viewed, yielding immediate feedback to the user

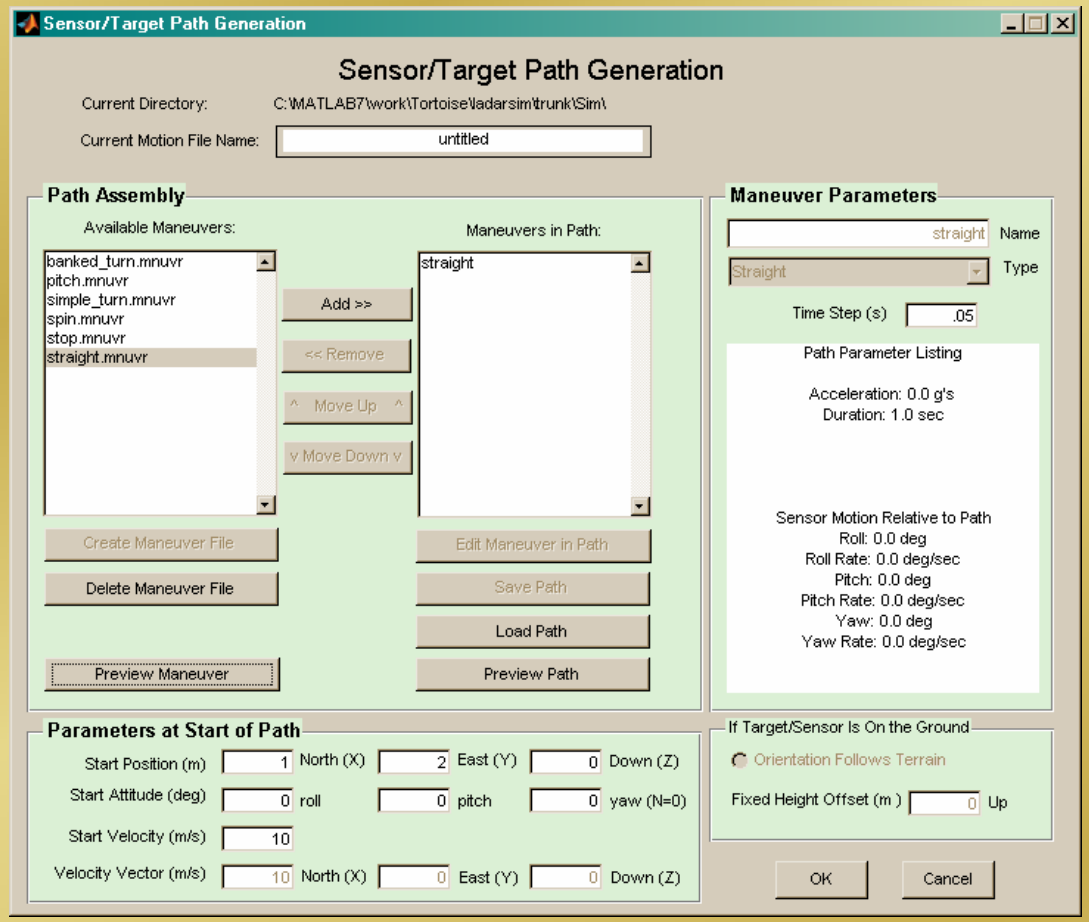


- Red indicates obtainable rotations
- Blue indicates mechanical limits reached
- Black indicates the aperture window limits

Movement of Targets and Sensor Platform

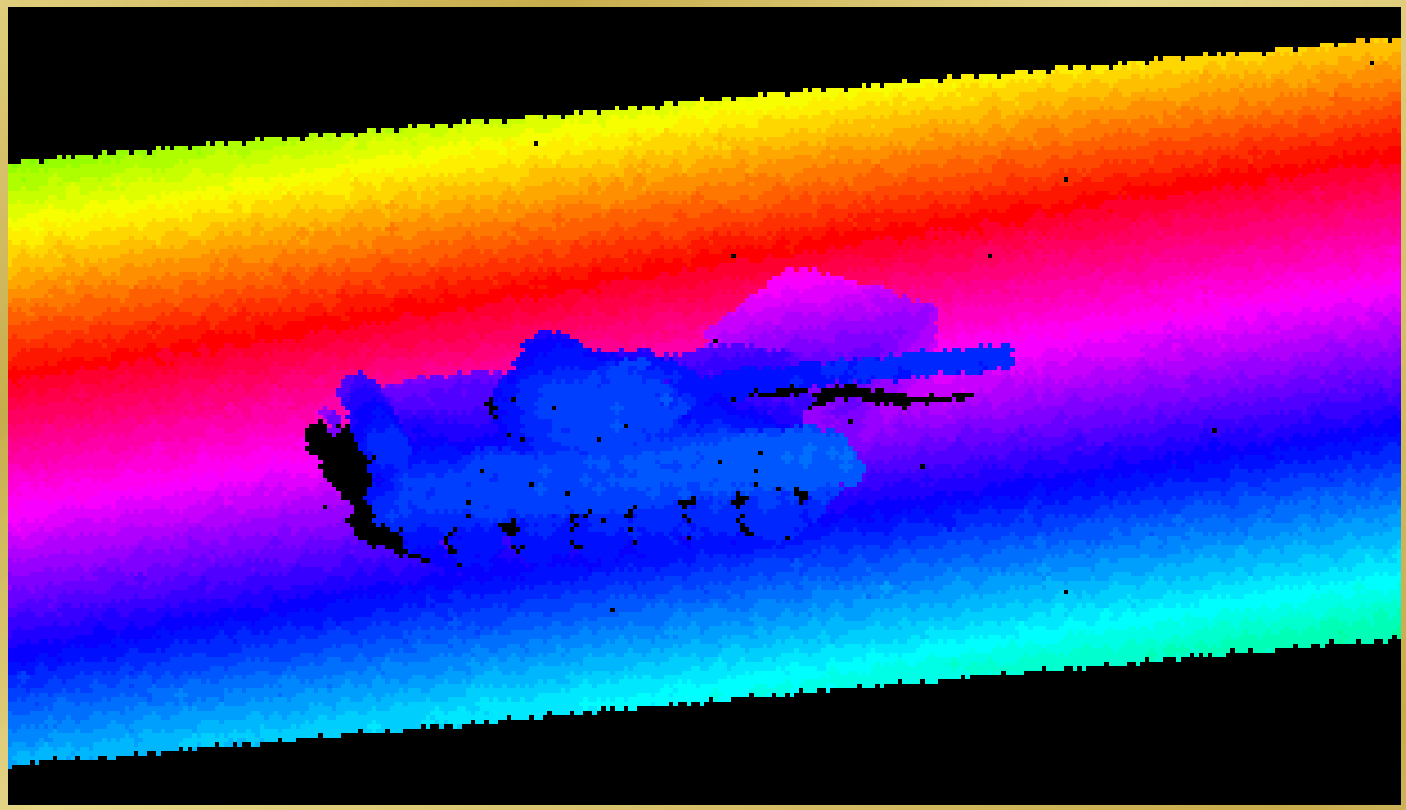
- Motion may be added to the targets and sensor platform to better simulate the physical world
- The moving objects may be terrain following or independent of the terrain such as flying objects
- Turbulence may be also be added to all moving objects
- High-frequency, low-amplitude jitter may be added to the sensor platform

Target and Sensor Movement



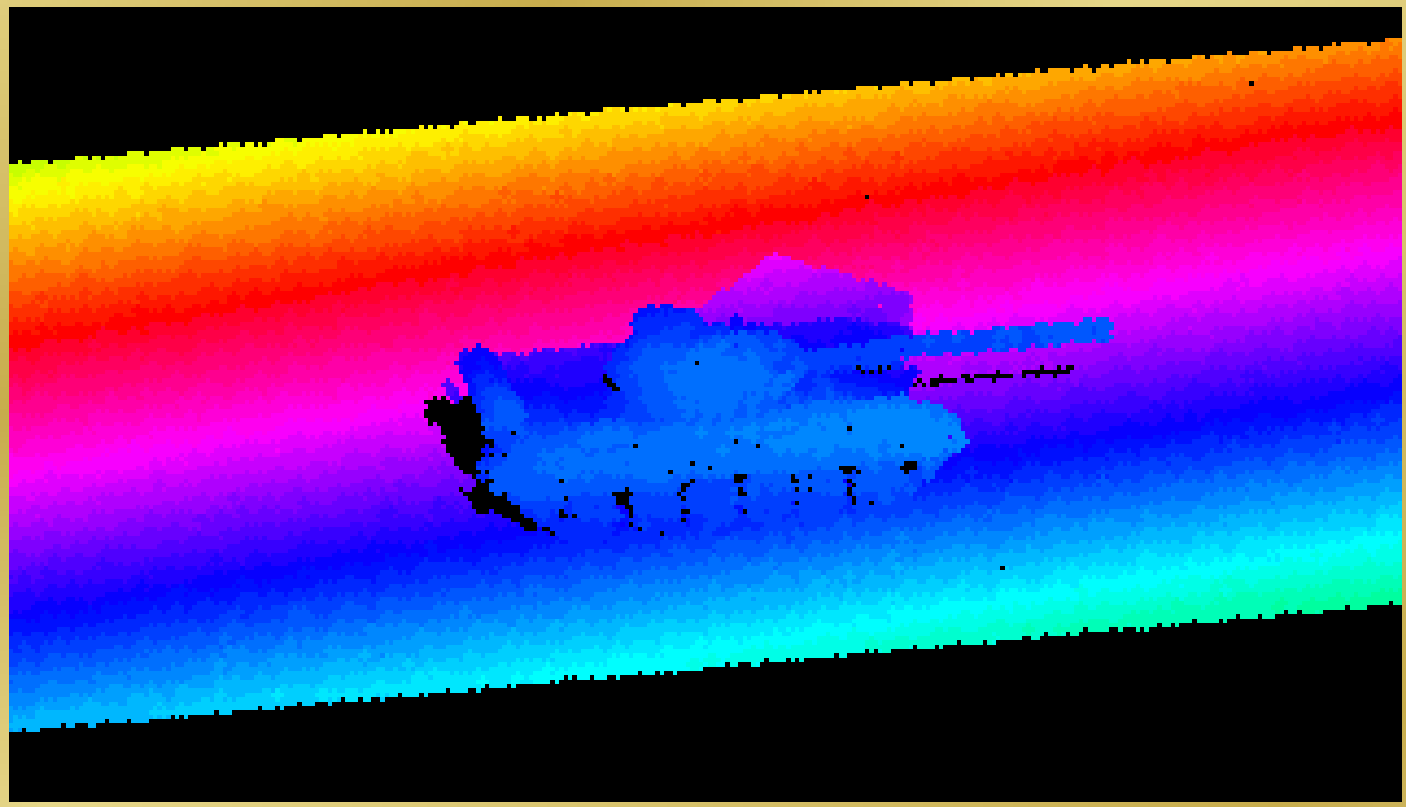
Six degree-of-freedom motion is defined by path segment selection and definition on the part of the user so that objects may turn, pitch, spin, and move forward with constant acceleration.

Target Movement in Point Cloud



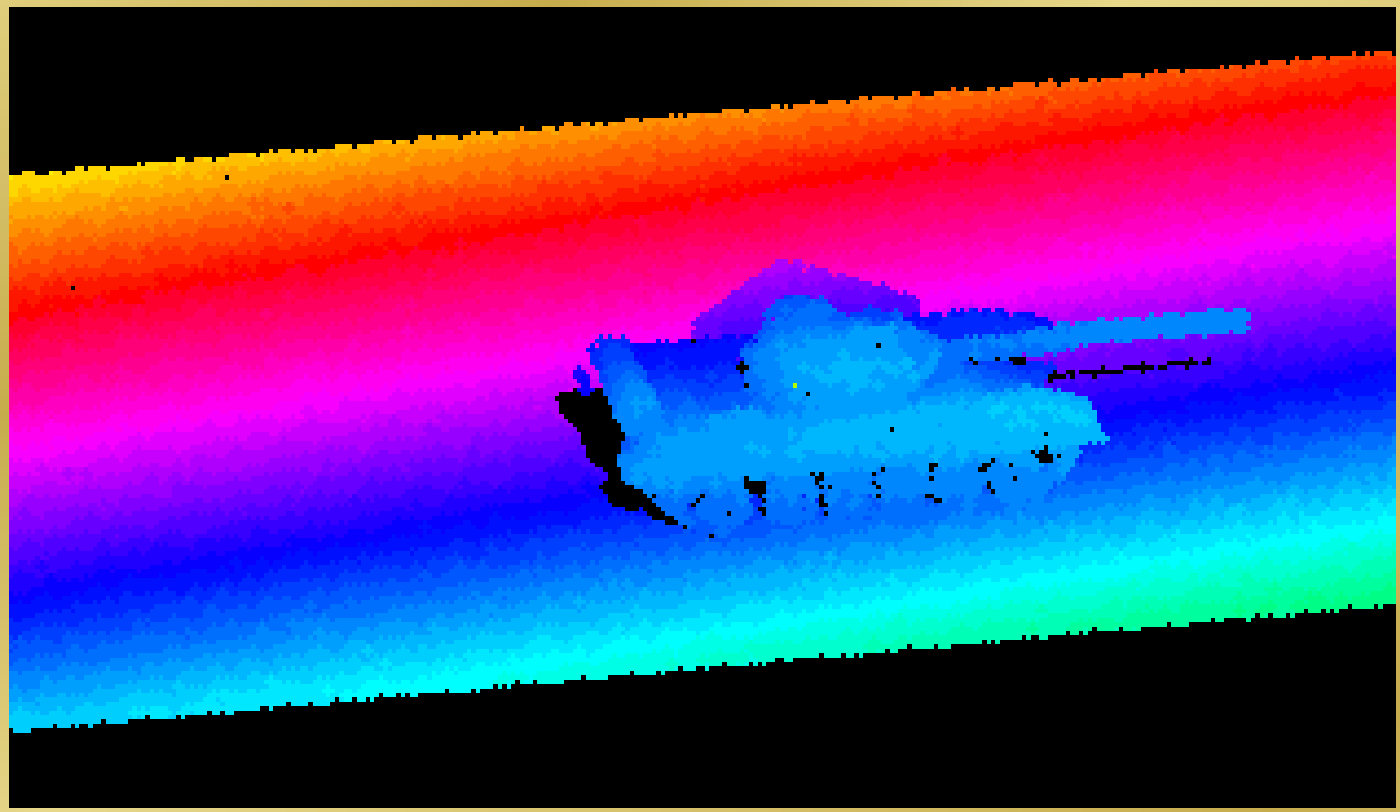
Point Cloud Images Showing Target Motion

Target Movement in Point Cloud



Point Cloud Images Showing Target Motion

Target Movement in Point Cloud



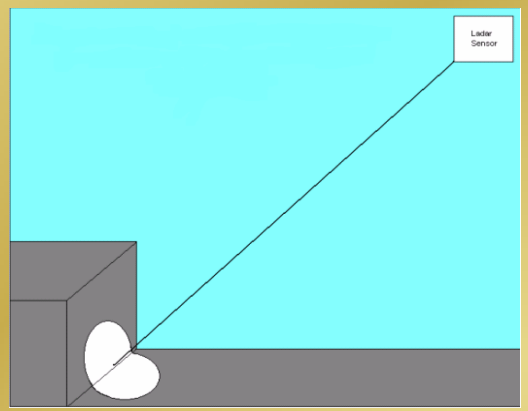
Point Cloud Images Showing Target Motion

Waveform Modeling

- Generate return signal waveforms
- Utilize various detection methods
- Create multiple returns
- Analyze radiometric phenomena such as dropouts, false alarms, and range error

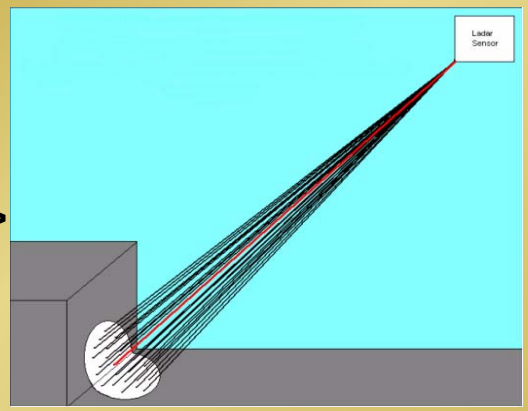
Modeling Return Signals

To conserve computation time, waveform processing is only used in areas of interest.



Diverged beam on edge

=>



Sub-sampled beam footprint

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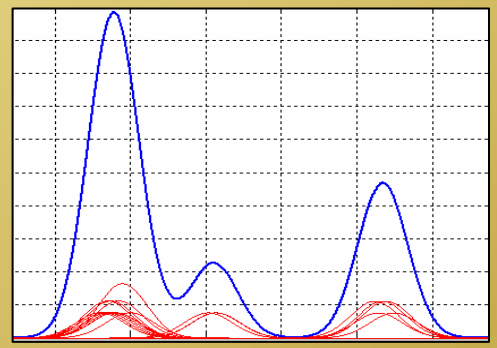
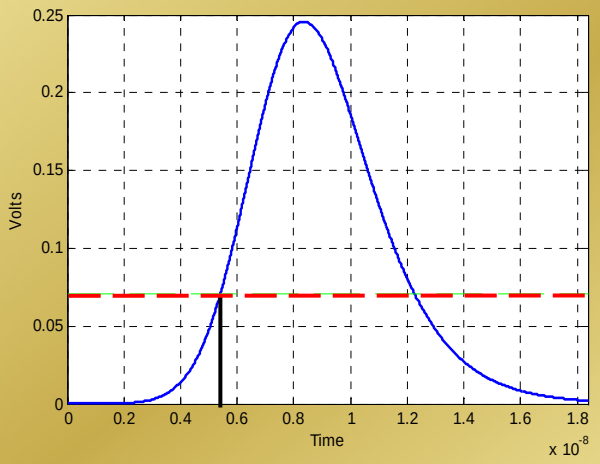


Example Return Signal at the Detector

By sub-sampling inside the area of a diverged ladar beam footprint, an approximate return signal can be constructed by summing all of the scaled return pulses.

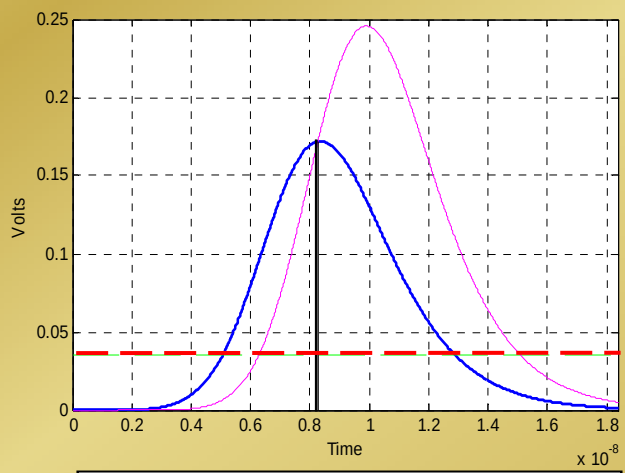
Detection Methods

Leading Edge



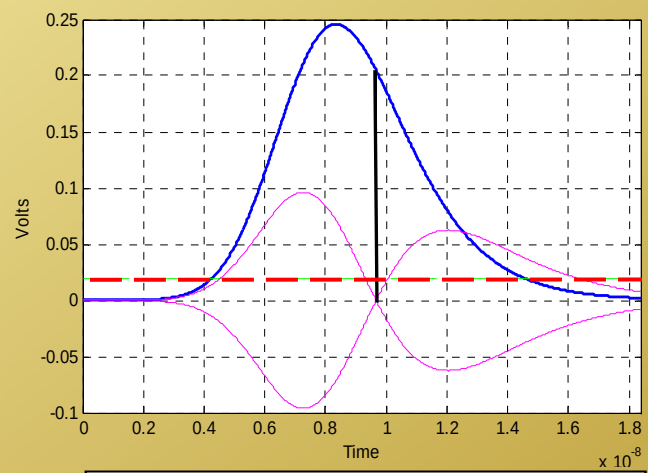
A detection is declared at the point in which the signal exceeds a set voltage threshold.

Constant Fraction



A detection is declared at the point in which a delayed version of the pulse intersects with a fractional version of itself.

Crossover (Derivative)



A detection is declared at the point in which the derivative of the pulse and its negative crossover.

Conclusion

- LadarSIM is a reliable and effective tool in predicting the behavior of most common LADAR systems
- Improvements to the simulation have been done using efficient methods in order to preserve the strength of LadarSIM – SPEED!