



SIMULATION OF AN INTEGRATED LADAR IMAGING SYSTEM

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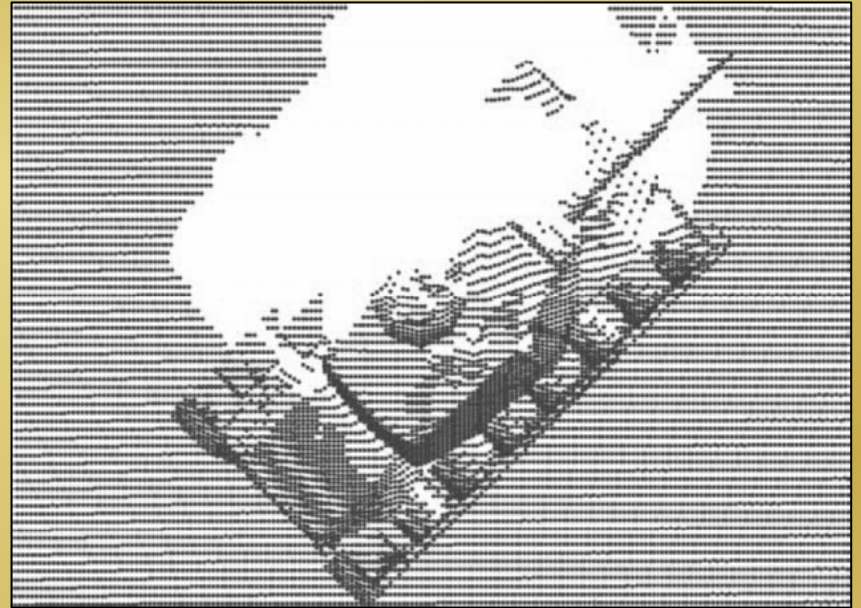
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Ladar

(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.

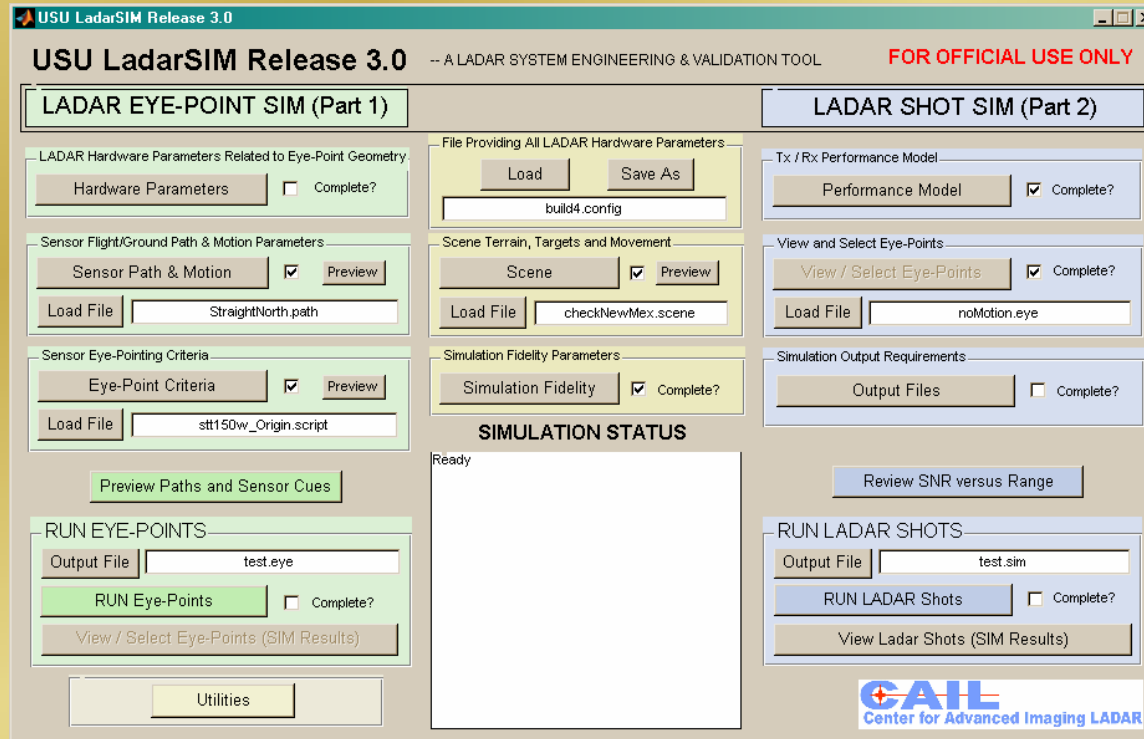


Simulation Objectives

- 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



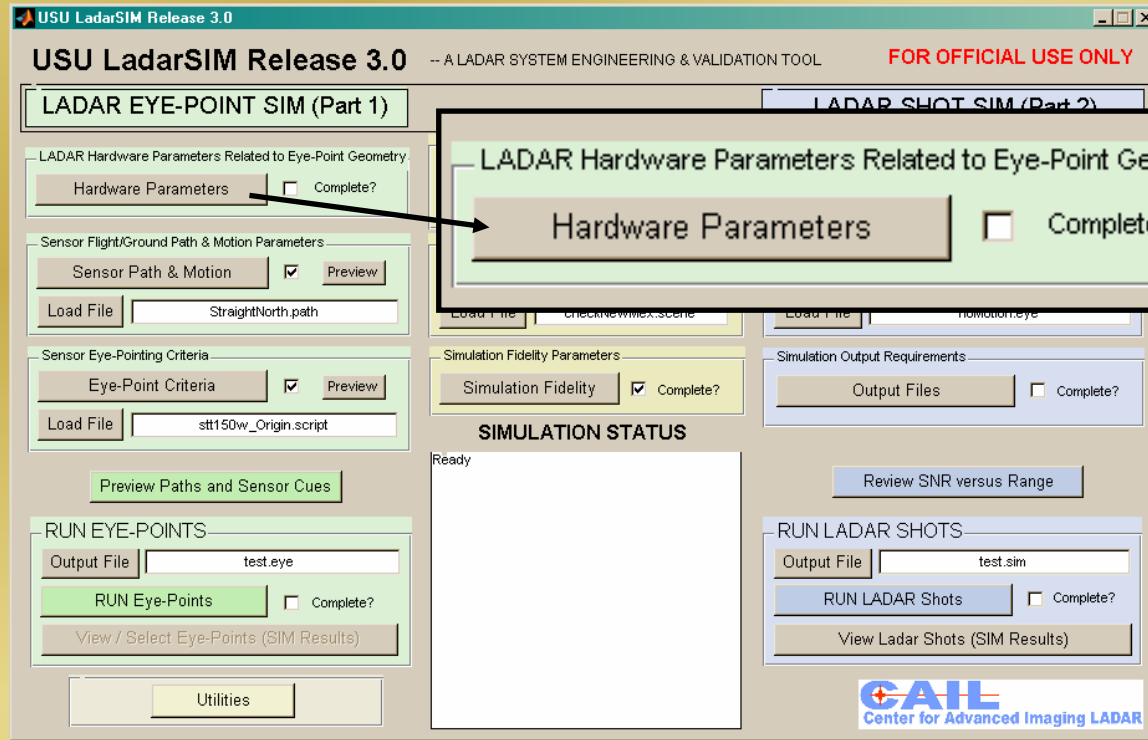
Physical
Geometric
Capabilities of
the Hardware

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

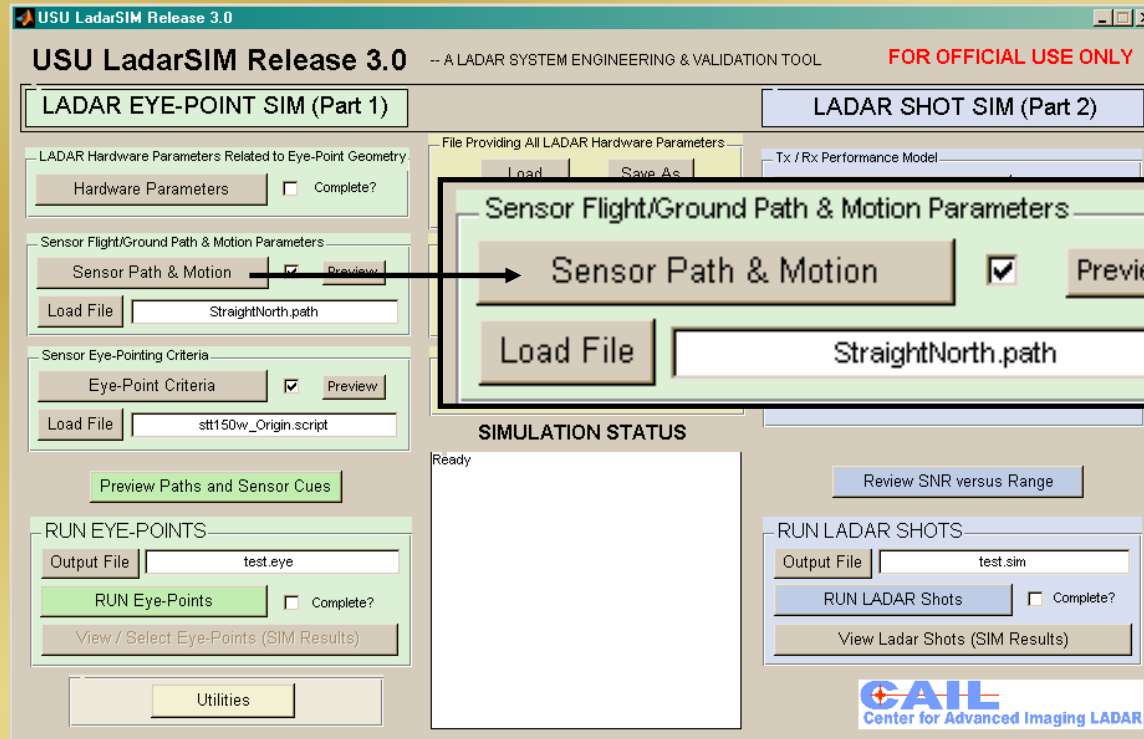


Physical
Geometric
Capabilities of
the Hardware

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

LadarSIM 3.0

Two Main Areas of LADAR System Development

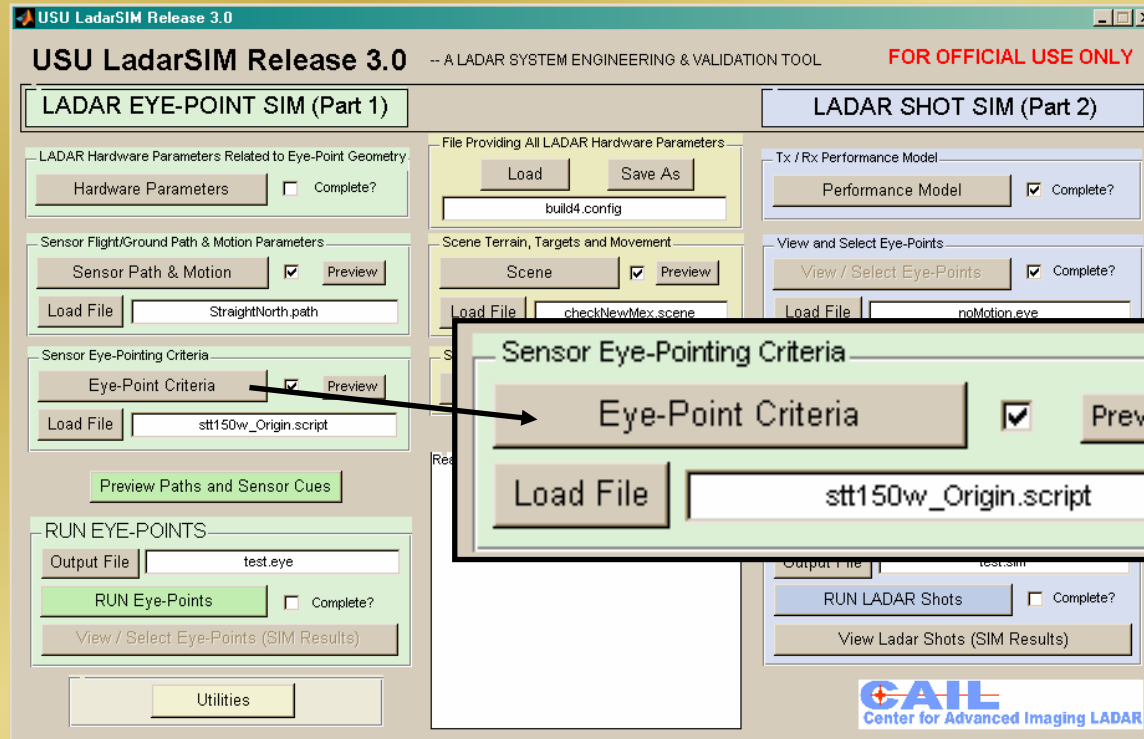


Physical
Geometric
Capabilities of
the Hardware

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

LadarSIM 3.0

Two Main Areas of LADAR System Development



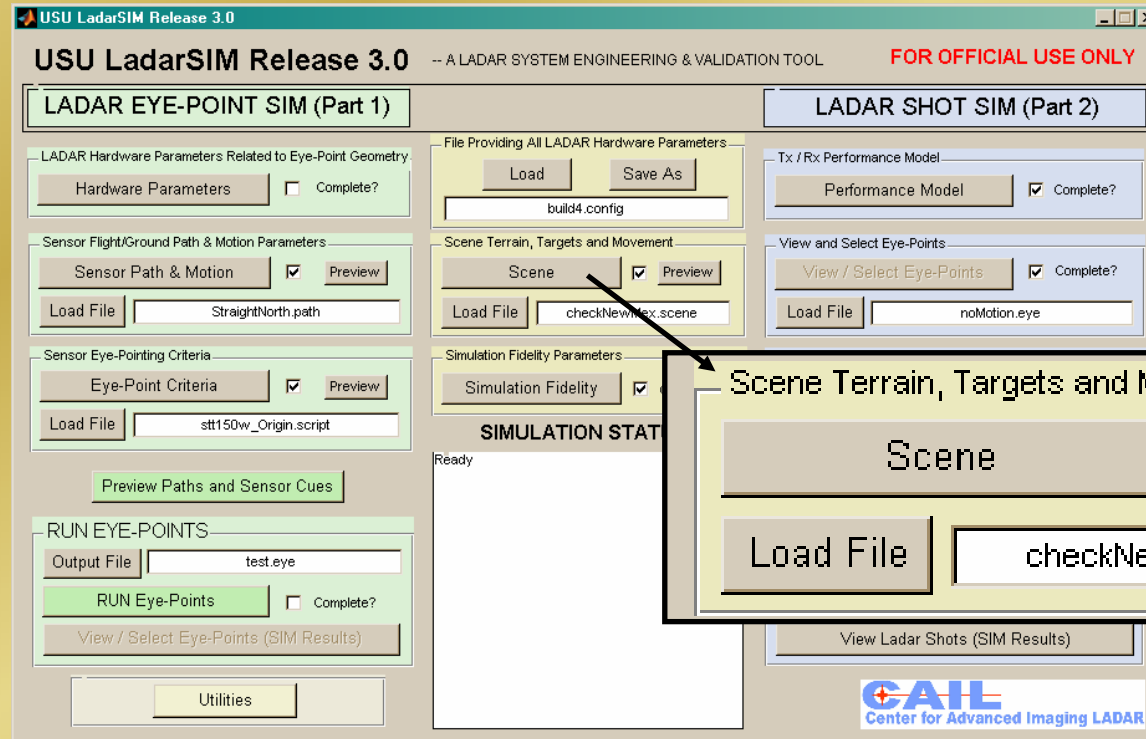
Physical
Geometric
Capabilities of
the Hardware

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

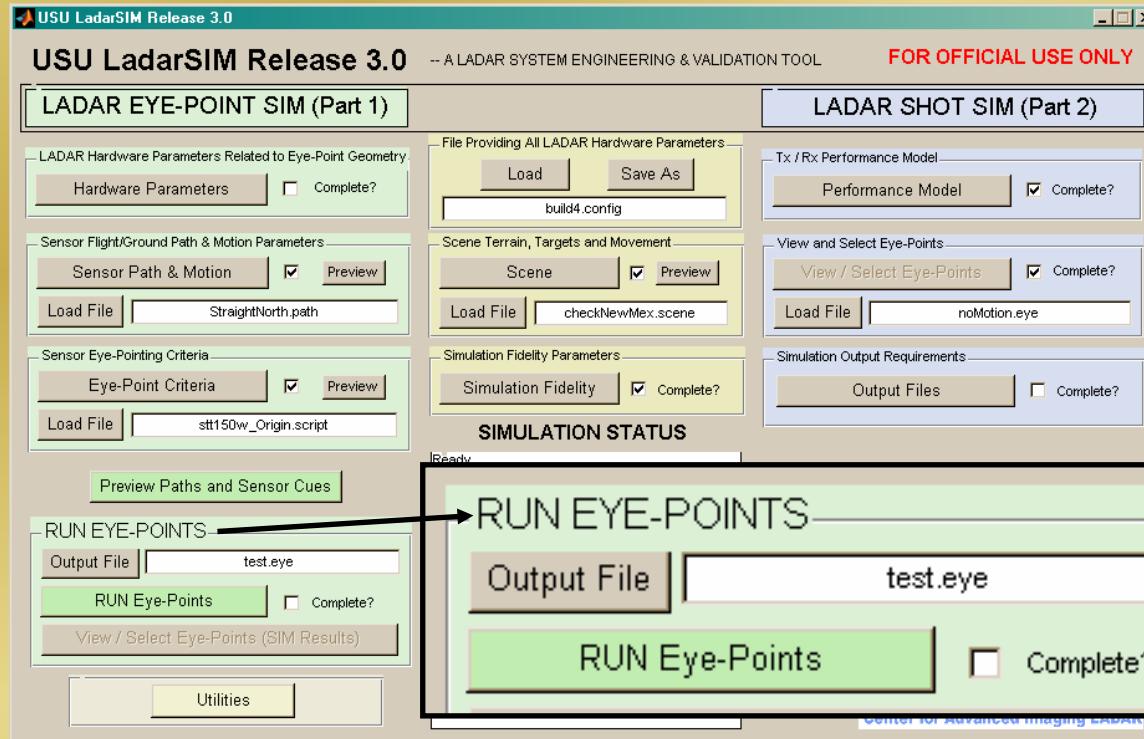
Two Main Areas of LADAR System Development



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

LadarSIM 3.0

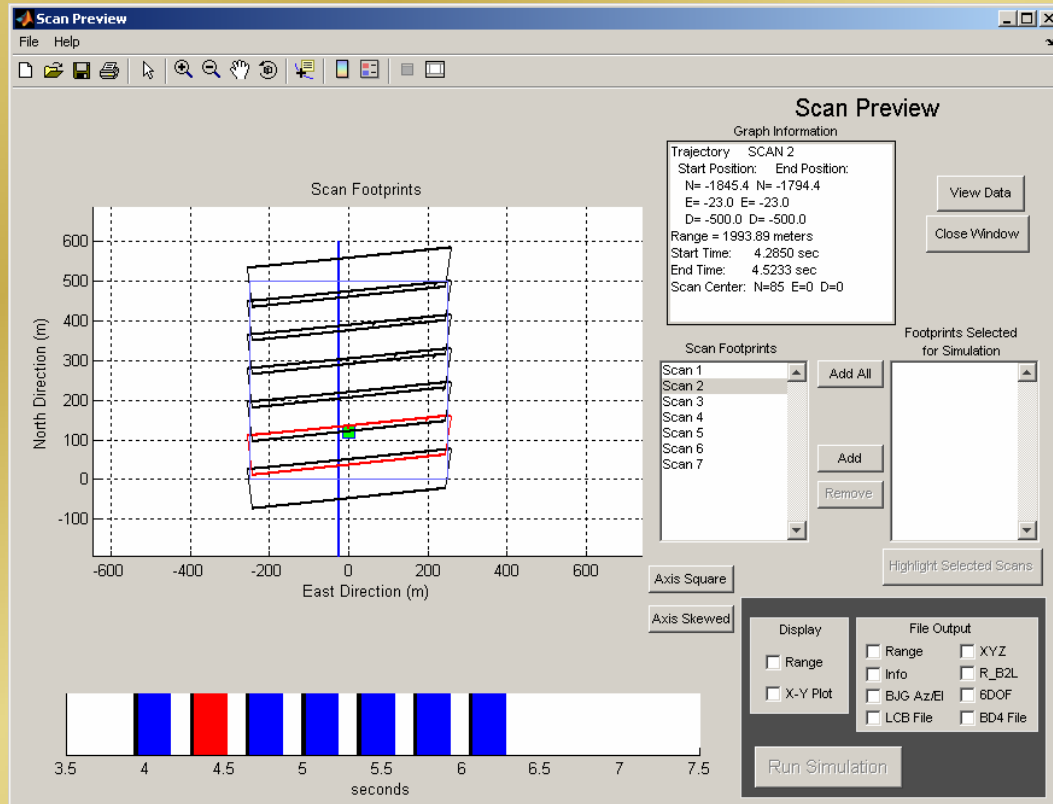
Two Main Areas of LADAR System Development



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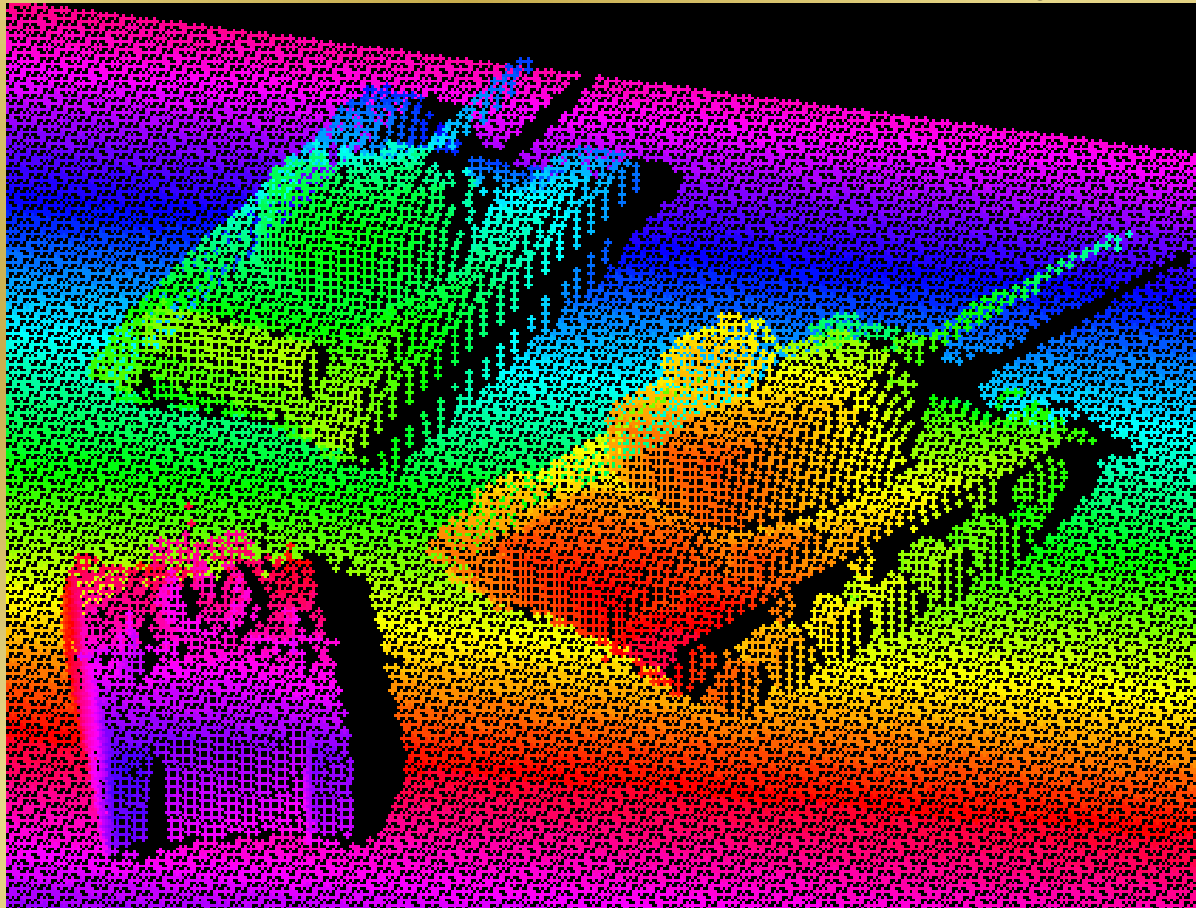
After a geometric simulation has been run the data may be viewed or used to form a radiometric simulation

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

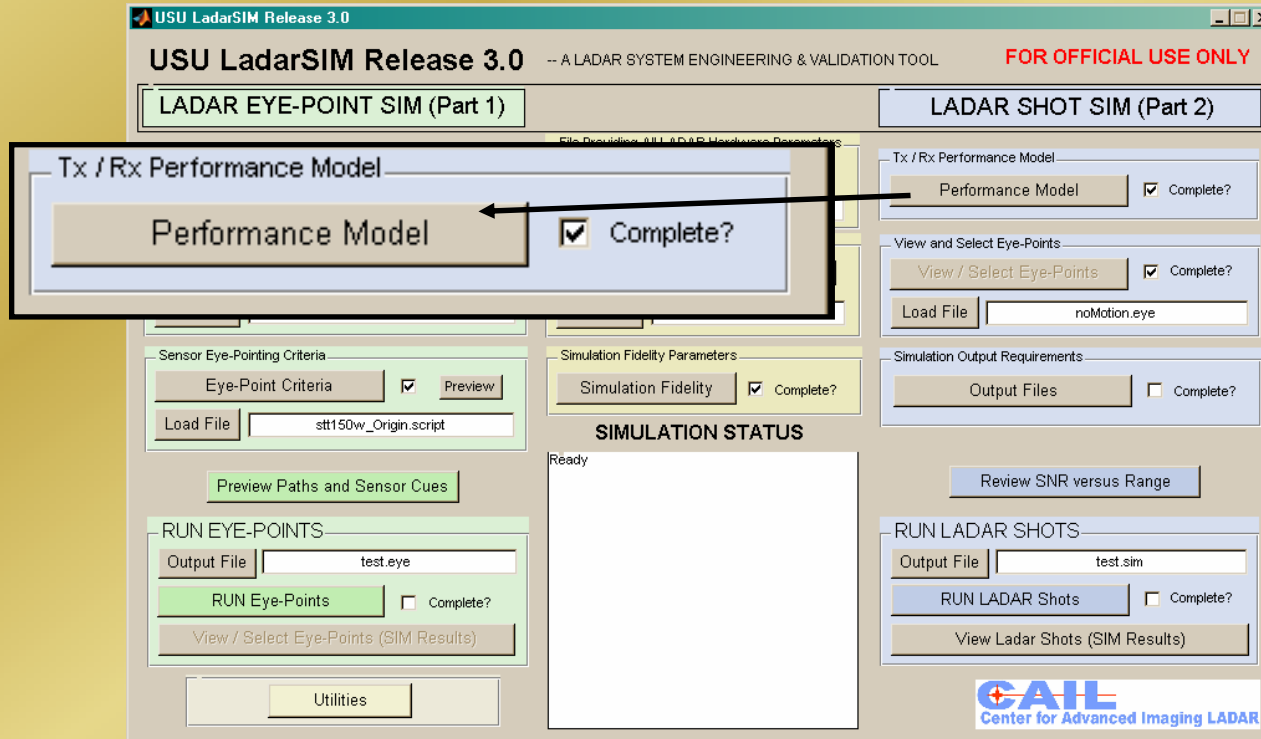
Point Cloud of Geometry Data



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

LadarSIM 3.0

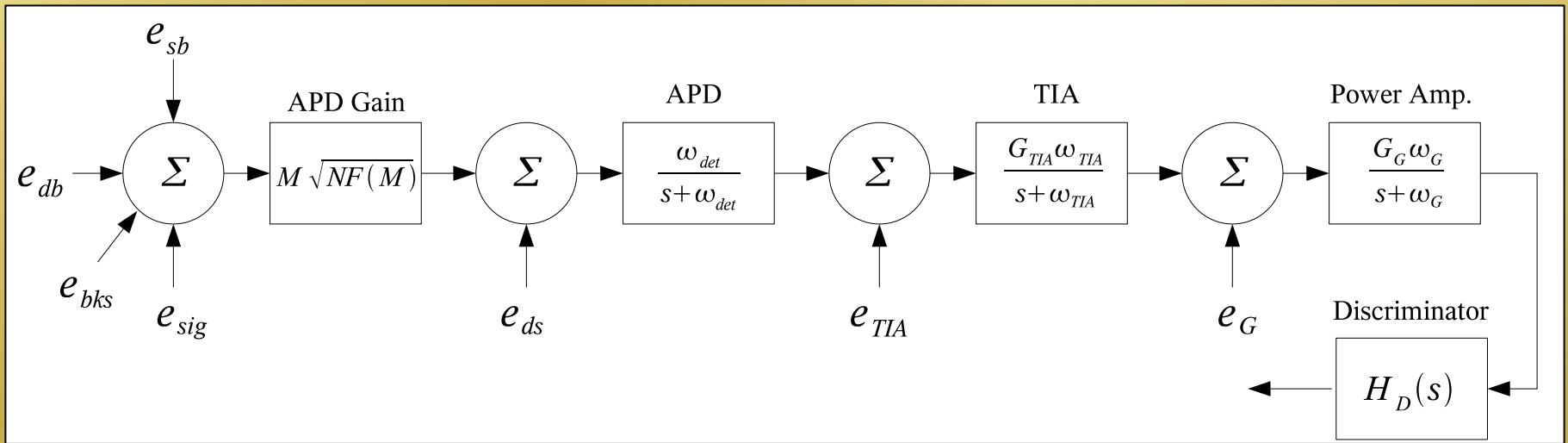
Two Main Areas of LADAR System Development



Radiometric
Performance
of the
Electronics

Define the environment, optical and transceiver parameters of the system

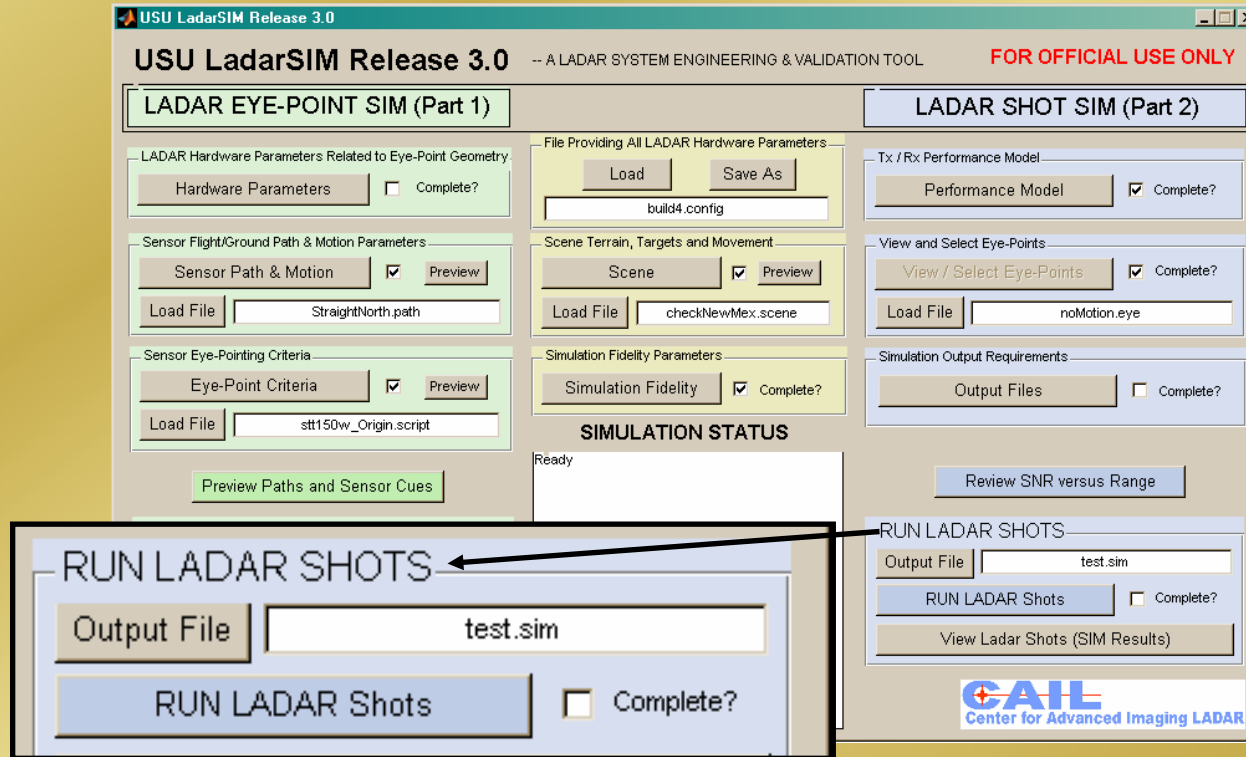
Error Model



Flow diagram of detector stages and their respective errors

LadarSIM 3.0

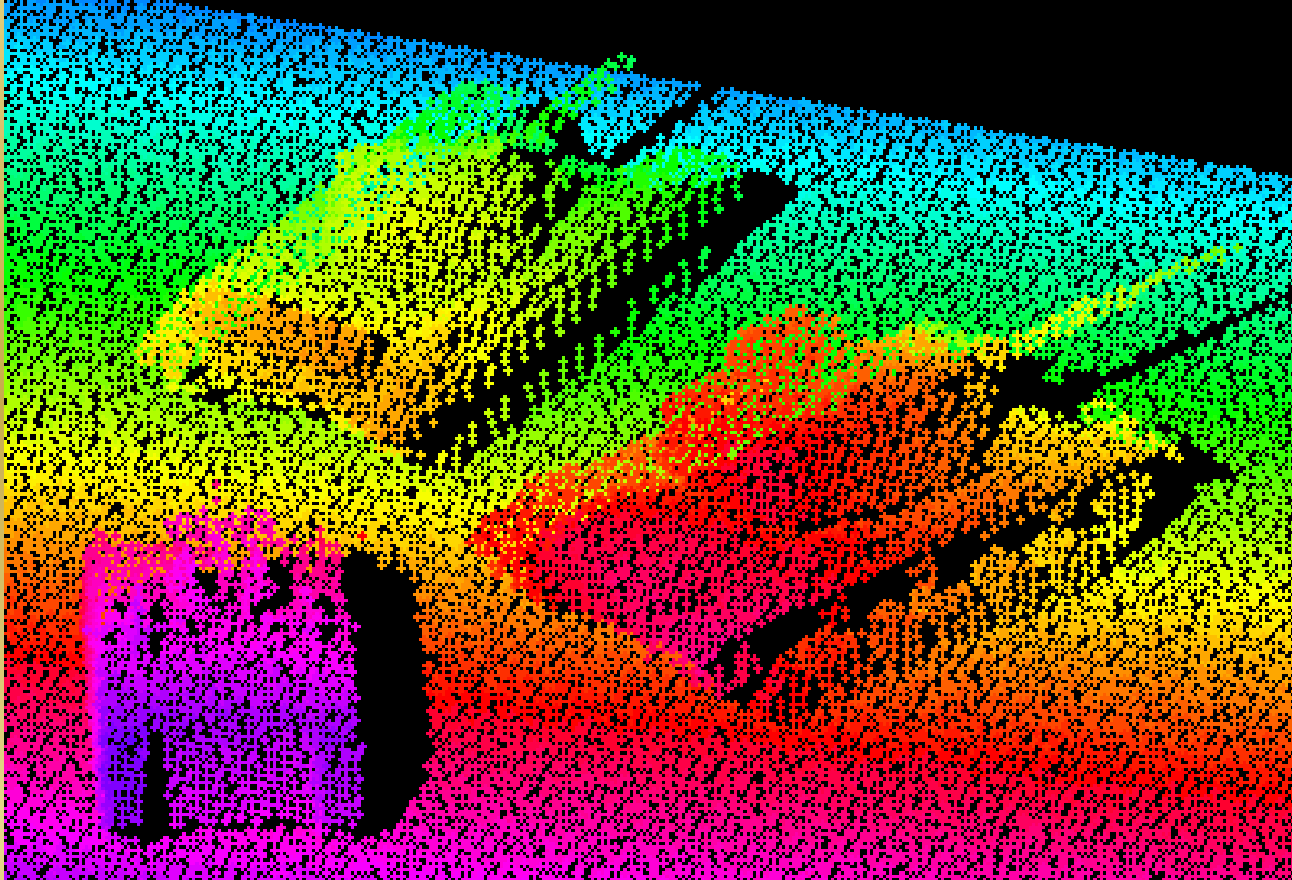
Two Main Areas of LADAR System Development



Radiometric
Performance
of the
Electronics

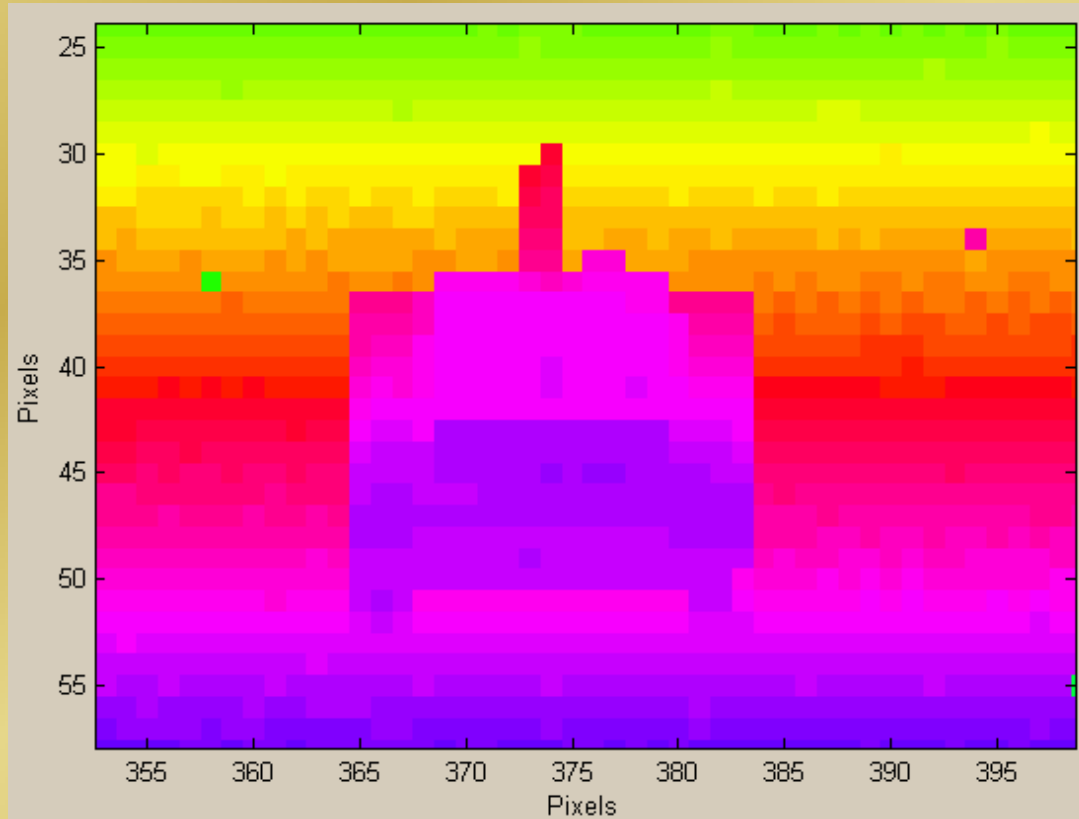
The data received from a radiometric simulation parallels that of an actual system including dropouts, false alarms and range errors

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

Scanner Dynamics

Help

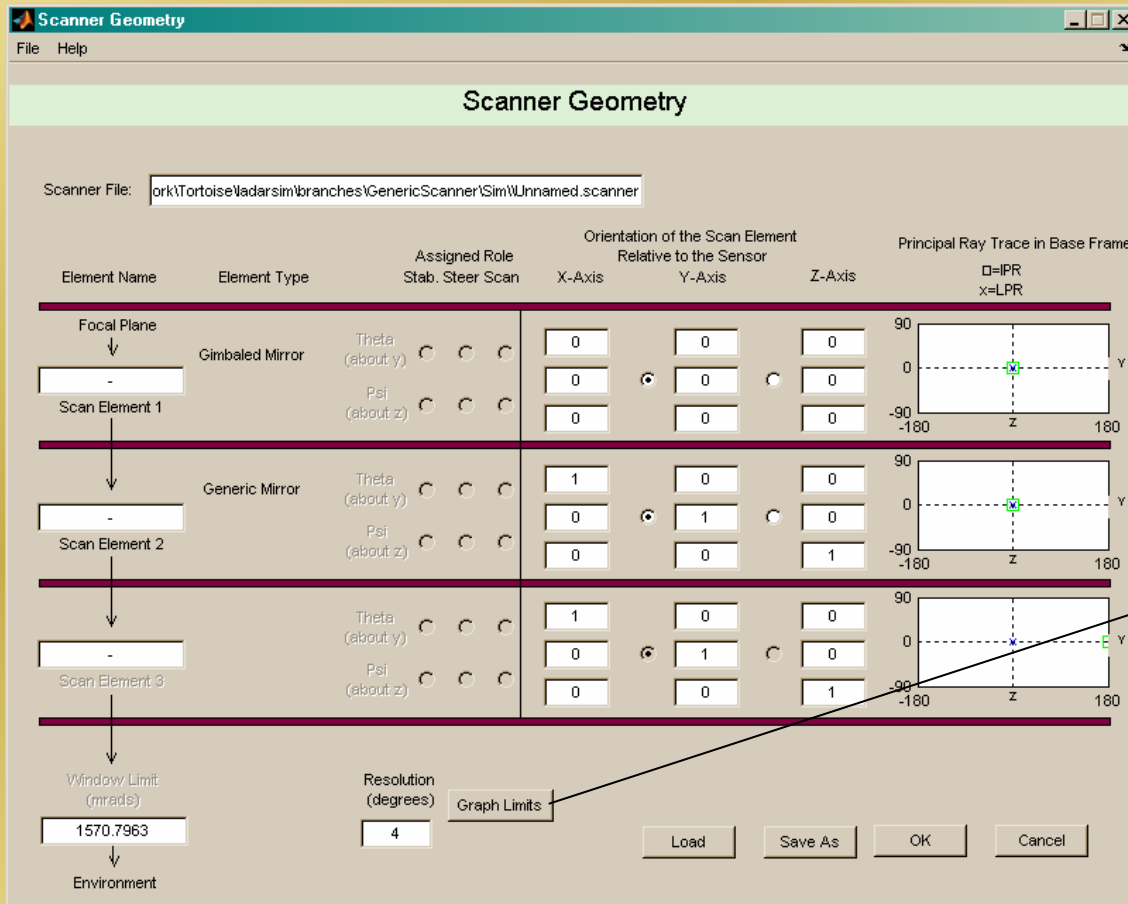
Scanner File: C:\MATLAB7\work\Tortoise\ladarsim\branches\GenericScanner\Sim\U\named.scanner

Element Name	Element Type	Rotation	Coupled?	First Rotation	Bandwidth (rad/sec)	Damping ratio	Latency (msec)	Mechanical Limit of Travel	
								Lower (mrad)	Upper (mrad)
Focal Plane ↓ Scan Element 1	Gimbaled Mirror	<input type="radio"/> Theta (about y) <input type="radio"/> Psi (about z)	<input type="checkbox"/>	Theta	0	0	0	0	0
↓ Scan Element 2	Generic Mirror	<input type="radio"/> Theta (about y) <input type="radio"/> Psi (about z)	<input type="checkbox"/>	Theta	0	0	0	0	0
↓ Scan Element 3	"none"	<input type="radio"/> Theta (about y) <input type="radio"/> Psi (about z)	<input type="checkbox"/>	Theta					
↓ Environment									

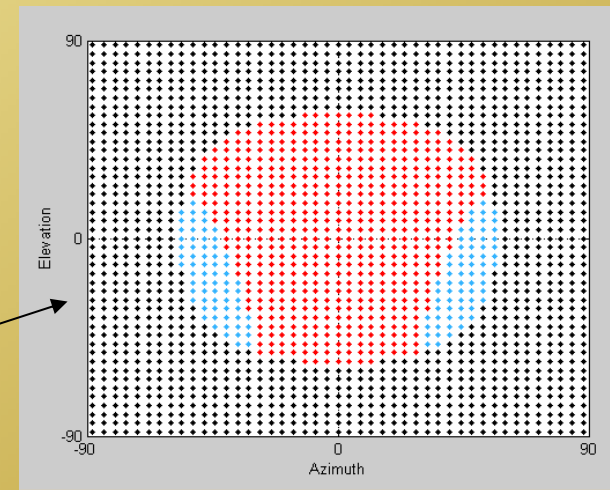
Load Save As OK Cancel

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

Scanning Geometry



In the geometry GUI the Az-EI 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

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

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

The screenshot shows the 'Sensor/Target Path Generation' software interface. The window title is 'Sensor/Target Path Generation'. The current directory is 'C:\MATLAB7\work\Tortoise\ladarsim\trunk\Sim\'. The current motion file name is 'untitled'.

Path Assembly

Available Maneuvers:

- banked_turn.mnuvr
- pitch.mnuvr
- simple_turn.mnuvr
- spin.mnuvr
- stop.mnuvr
- straight.mnuvr

Maneuvers in Path:

- straight

Buttons: Add >>, << Remove, ^ Move Up ^, v Move Down v, Create Maneuver File, Delete Maneuver File, Edit Maneuver in Path, Save Path, Load Path, Preview Path, Preview Maneuver.

Maneuver Parameters

Name: straight
Type: Straight
Time Step (s): .05

Path Parameter Listing

Acceleration: 0.0 g/s
Duration: 1.0 sec

Sensor Motion Relative to Path

Roll: 0.0 deg
Roll Rate: 0.0 deg/sec
Pitch: 0.0 deg
Pitch Rate: 0.0 deg/sec
Yaw: 0.0 deg
Yaw Rate: 0.0 deg/sec

Parameters at Start of Path

Start Position (m): 1 North (X), 2 East (Y), 0 Down (Z)
Start Attitude (deg): 0 roll, 0 pitch, 0 yaw (N=0)
Start Velocity (m/s): 10
Velocity Vector (m/s): 10 North (X), 0 East (Y), 0 Down (Z)

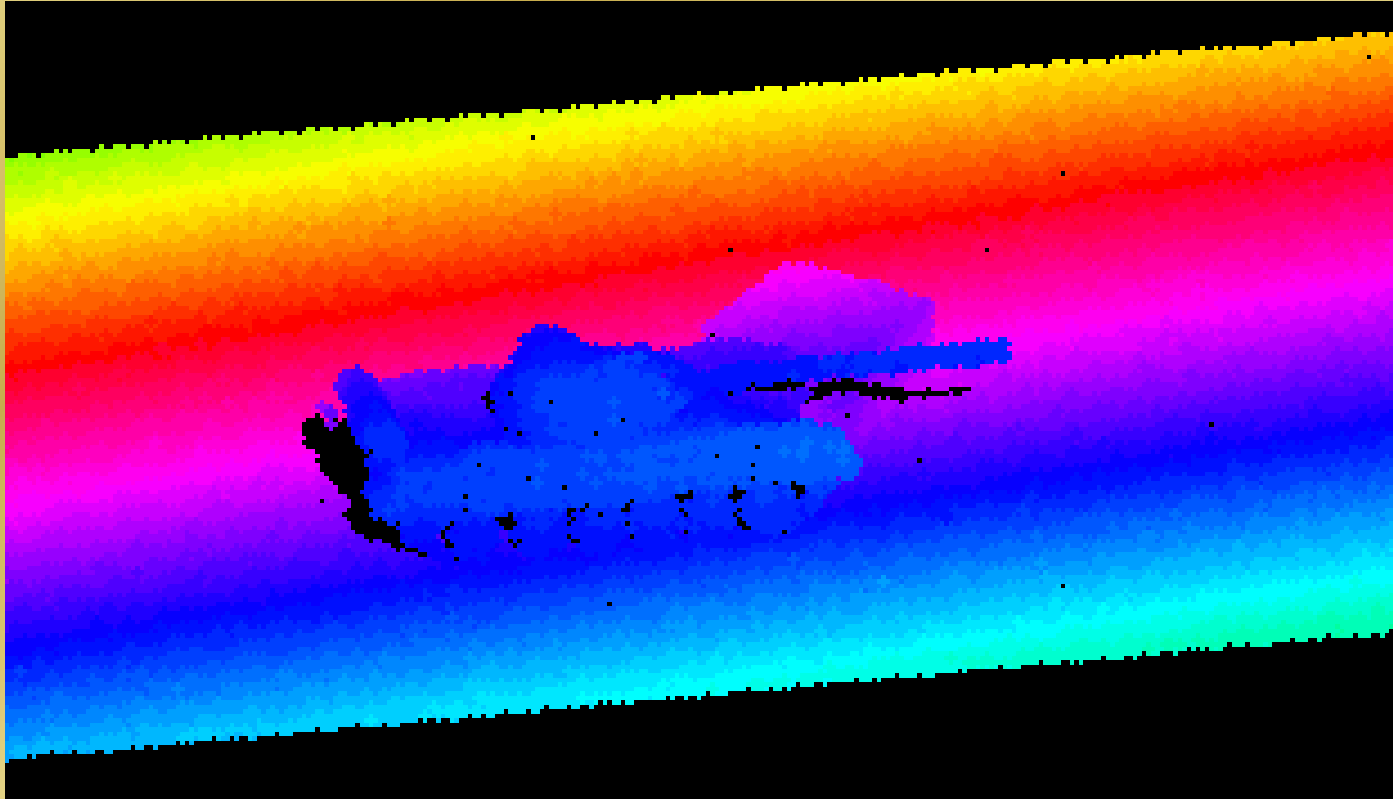
If Target/Sensor Is On the Ground

Orientation Follows Terrain
Fixed Height Offset (m): 0 Up

Buttons: OK, Cancel

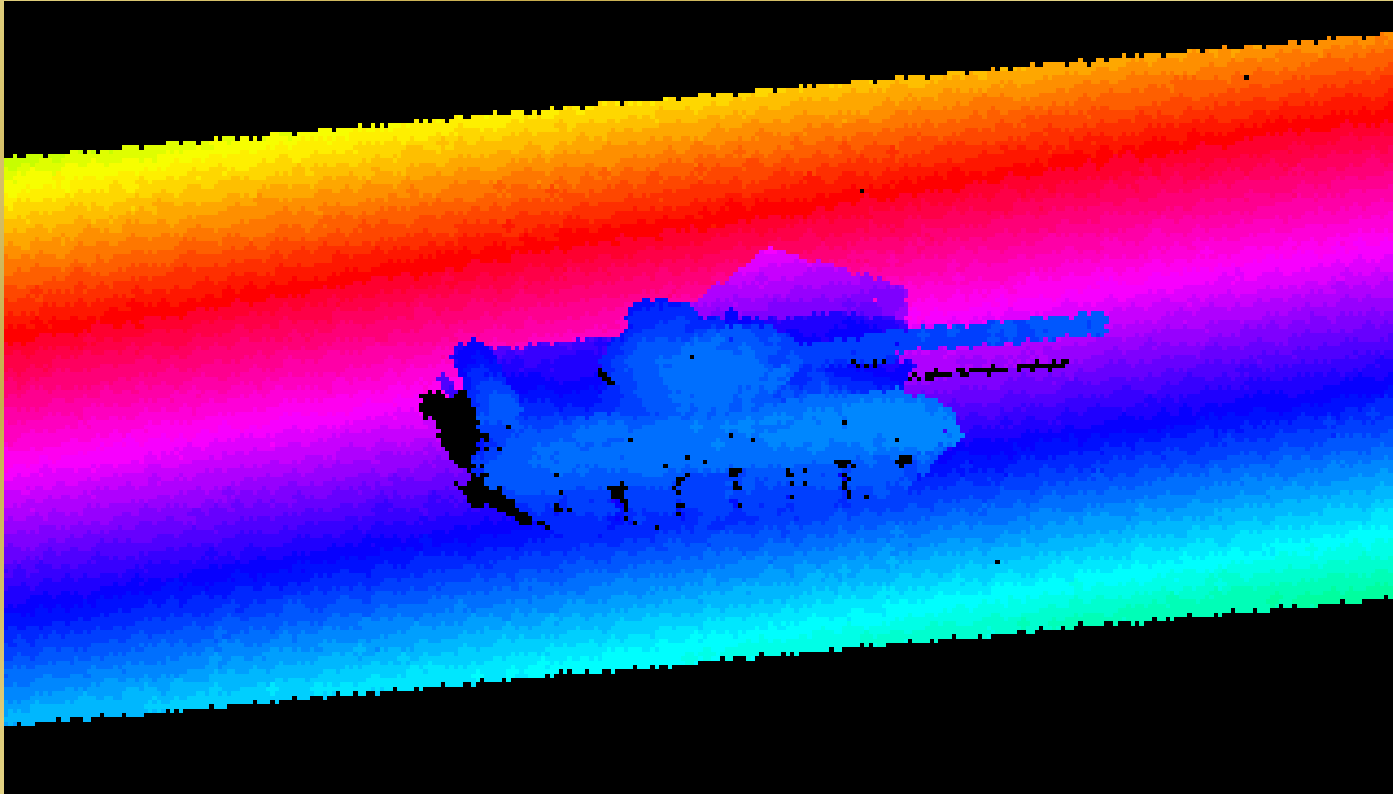
Six degree-of-freedom motion is defined by path segment selection and definition on the part of the user so that objects may turn, pitch, spin, and move forward with constant acceleration.

Target Movement in Point Cloud



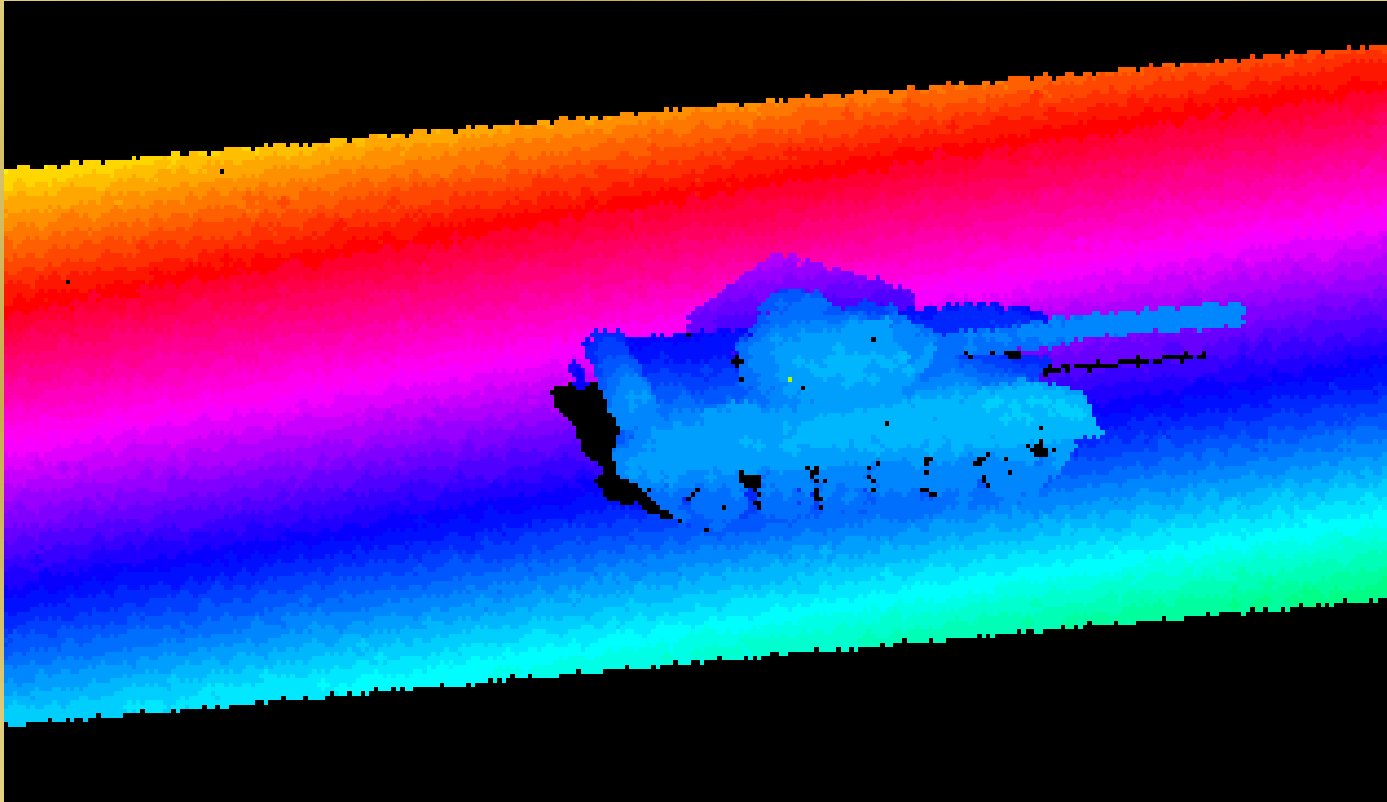
Point Cloud Images Showing Target Motion

Target Movement in Point Cloud



Point Cloud Images Showing Target Motion

Target Movement in Point Cloud



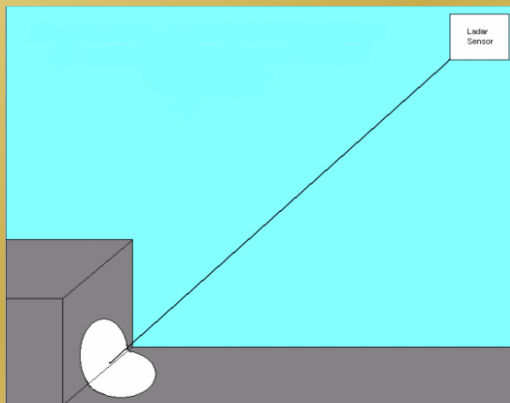
Point Cloud Images Showing Target Motion

Waveform Modeling

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

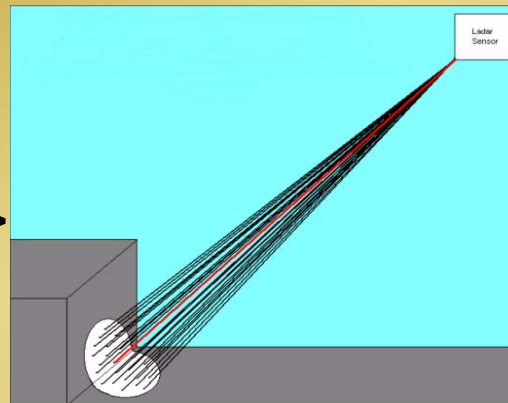
Modeling Return Signals

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



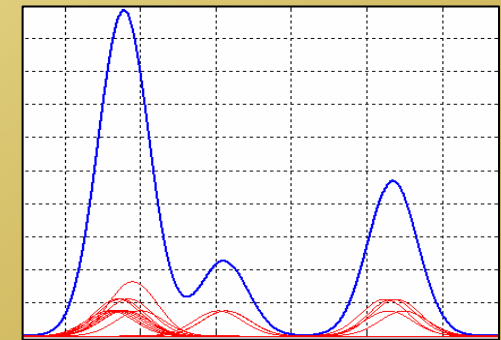
Diverged beam on edge

=>



Sub-sampled beam footprint

=

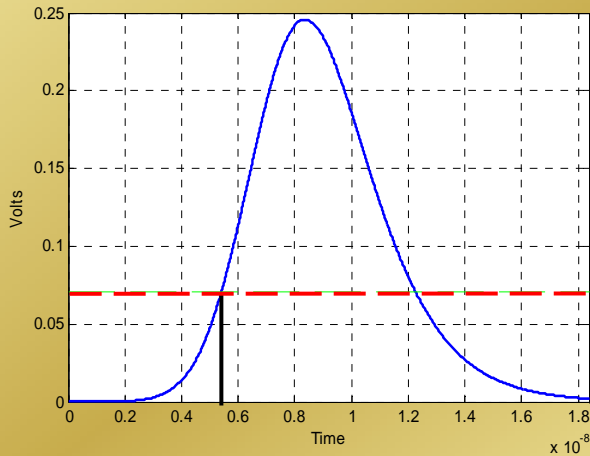


Example Return Signal at the Detector

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

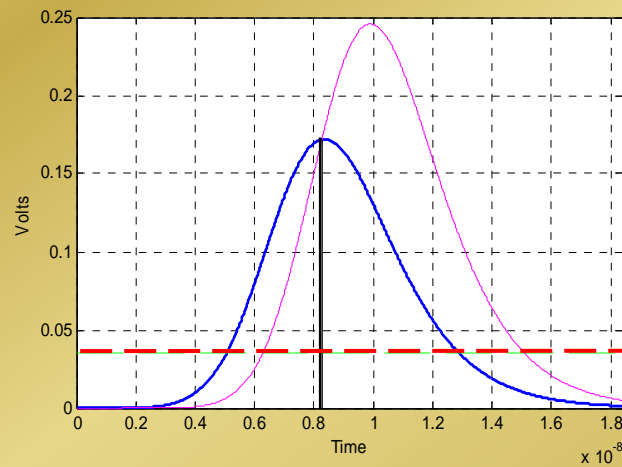
Detection Methods

Leading Edge



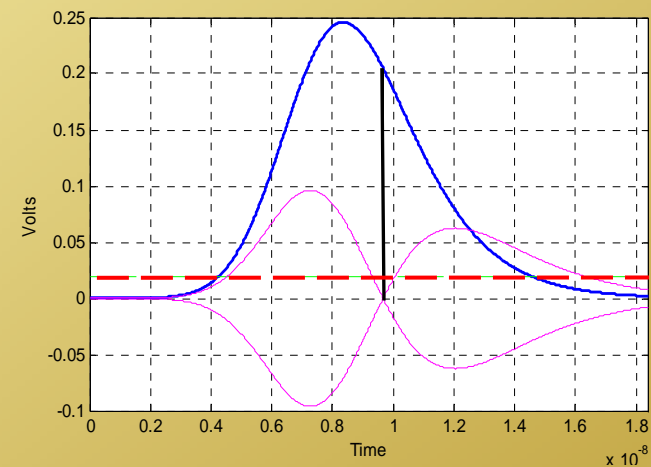
A detection is declared at the point in which the signal exceeds a set voltage threshold.

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!