PSI-Origin – Wide Area Persistent Surveillance Mission Planning and Simulation Tool Instructions for Operation

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ABSTRACT:

Wide Area Persistent Surveillance (WAPS) is an application where a Wide Field of View (*WFOV*) sensor array is made to stare at a fixed point on the ground for a prolonged period of time. A stabilized gimbal system is used to stabilize and steer the sensor's Line of Sight (*LOS*) to this fixed point.

It is through persistence that patterns of behavior and networks of activities are exposed. The data collected may be used in real time or for forensic analysis after an event. One of many potential applications for this technology relates to Vehicle Borne Improvised Explosive Devices (VBIED's).

The purpose of this paper is to describe the function of the PSI-Origin Mission Planning and Simulation Tool (MPST) for the WAPS application.

INTRODUCTION:

The WAPS application is complex with many interdependent parameters that can be varied to suite the mission objectives. The complex three-dimensional geometry is difficult to visualize. A visual simulation tool can make it much easier to recognize and understand the application and these interdependencies. A clear understanding of the WAPS problem is crucial to providing effective solutions.

The MPST was originally developed as a tool to explore the interdependencies of the WAPS application for product development purposes. It proved so useful in this role that its value as a mission planning tool became apparent. While many system parameters are fixed by a given hardware configuration, many other parameters are under the control of the mission planning team. The MPST allows them to get the most out of the given hardware by optimizing these parameters for the given mission.

More recently we have begun to see value for the MPST as a tool to help with the development of the data analysis software. It is capable of presenting the designer with a great deal of useful information about the specific area of image data that is being used to test a given function. Detailed numerical information from the field analysts on the conditions that cause functions to break down can be fed back to the designers and the mission planners to improve system functionality.

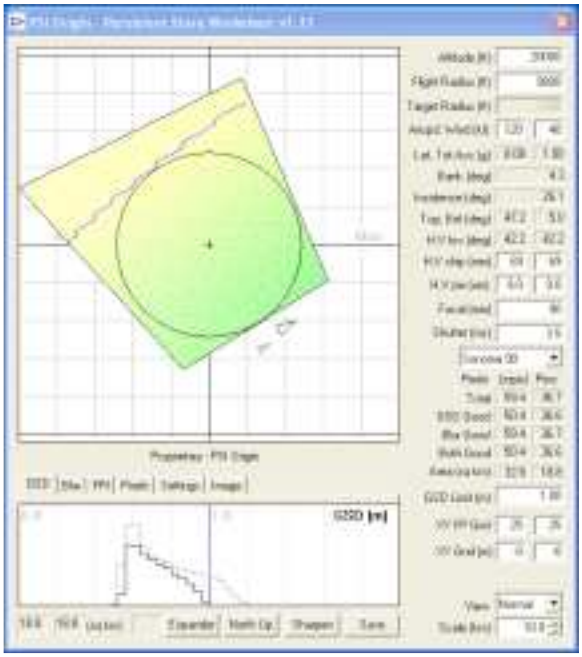

Figure 1 – PSI-Origin - Persistent Stare Worksheet

The "PSI-Origin - Persistent Stare Worksheet" is a tool that allows the user to explore and visualize the persistent surveillance problem and optimize a solution.

The program requires the USB dongle to run.

DESCRIPTION:

The large grid area shows the focal plane array projected on to the ground. The "keystone" is shown to scale on a grid background. Within the keystone is a colored grid (blue to red – small to large values) representing GSD or Blur (pixel motion). A blue line represents the threshold or limit value for GSD, Blur, or FPI. The aircraft is shown at the flight radius specified and a shadow gives an indication of height. The rotational rate is not to scale. The "+" represents the LOS. The circle represents the persistent area. Clicking inside the large grid area pauses the display.

The smaller graph area under the display shows the pixel information. By clicking on the tabs above this area you can toggle between GSD, Blur (pixel motion) FPI (focal plane incidence angle), Pixels, Settings, and Image. When you select the Blur or FPI views the lines in the large display change to the same units.

The *GSD tab* shows the GSD distribution curve. This is helpful in understanding how the GSD is distributed over the image plane and how other parameters effect this distribution. The grey curve represents the total array and the black curve represents the persistent area only. The vertical scale is dynamic and scales based on the highest point that the curve has attained. Clicking inside the graph area rescales the vertical axis. The horizontal scale is 0-2m. The vertical blue line represents the limit value.

Figure 2 – *GSD tab*

The *Blur tab* shows the image blur due to pixel motion as a distribution curve. This is helpful in understanding the effect of aircraft motion (speed and radii) and integration time (shutter speed) on pixel motion. The grey curve represents the total array and the black curve represents the persistent area only. The vertical scale is dynamic and scales based on the highest point that the curve has attained. Clicking inside the graph area rescales the vertical axis. The horizontal scale is 0-2 pixels. The vertical blue line represents the limit value.

Figure 3 – *Blur tab*

The *FPI tab* shows the incidence angle at the focal plane as a distribution curve. This is helpful in understanding the "shading" that occurs across the image area due to efficiencies at the focal plane or "micro-lenses". The grey curve represents the total array and the black curve represents the persistent area only. The vertical scale is dynamic and scales based on the highest point that the curve has attained. The horizontal scale is 0-90 deg. The vertical blue line represents the limit value.

Figure 4 – *FPI tab*

The *Pixels tab* shows properties such as pixel shape, pixel motion, and GSD. These are the same blue and black pixels that are shown in the keystone. The blue pixel is on the focal plane and controlled by the *XY FP Grid* control. The black pixel is on ground and controlled by the *XY Gnd* control. The grey pixels show the pixel motion during one integration time (shutter speed).

Figure 5 – *Pixels tab*

The *Settings tab* allows many of the settings to be changed.
Freeze stops the rotation of the aircraft in the large display area. This is done by clicking inside the large display area.
Heading 30 advances the aircraft position around the orbit in 30-degree increments.
Heading 45 advances the aircraft position around the orbit in 45-degree increments

Expand turns on the expander mode and recalculates the optimum target radius.
Area Units toggles the area units between square miles, square kilometers, and kilometers radius. This can also be done by clicking directly on the units.
Pixel Units toggles the pixel units between Mega pixels and percent. This can also be done by clicking directly on the units.
Accel Units toggles the *Lat Acc*, *Total Acc*, and *Bank* between current, maximum, and average values. This can also be done by clicking directly on the label.
Pix Select G is used to move the blue and black pixels to the preset ground index points.
Pix Select F is used to move the blue and black pixels to the preset focal-plane index points.
Max bank uses the bank angle in *Value* to calculate the minimum *Flight Radius* based on *Airspd* and *Wind* speed. The maximum bank angle specified should allow some margin for maneuvering. The max continuous bank angle for a given aircraft will depend on loading, altitude, and airspeed. Higher bank angles will increase the effective load and reduce endurance. The aircraft operations group or aircraft manufacturer should be consulted for the maximum continuous bank angle and the required margin for maneuvering. Autopilot systems often have limited maximum bank angles.

Figure 6 – *Settings tab*

The *Image tab* shows how the current parameters should look on a sample image. The sample is re-pixilated based on the GSD at the LOS. The current sample is limited to about a 1 ft GSD. Clicking on the image toggles between a standard and a zoomed in version of the image. This is to help develop a qualitative feel for the GSD.

Figure 7 – *Image tab*

Under this graphic area are four buttons (Expander, North Up, Sharpen, and Save) and three numeric fields. "Expander" toggles between the standard steering mode (LOS on target) and the "Expander" mode (LOS steered to a circle that maximizes the persistent area). "North Up" toggles between the standard 2 axis gimbal and a 3 axis gimbal with roll steering to maintain north at the top of the frame. Note that in this mode the persistent area is not circular but closer to a square. It is also larger and has less pixel motion (blur). "Sharpen" toggles the blur reduction mode on and off. "Save" saves a text file with all of the current settings. This file can be dragged and dropped onto the tool to load its values. The three numeric fields represent the persistent area of the standard and expanded modes and the ratio between them (Expanded, Standard, Ratio). You must have the "Expander" mode on in order to calculate the expanded area. Clicking the units will toggle between area units and radii. Clicking in the ratio field sets the display into a mode that toggles back and forth between the standard and expanded mode.

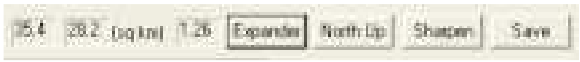

Figure 8 – Area data and mode buttons

Down the right side of the window are the PS Parameters (numeric inputs and outputs from the program). Inputs have white background and outputs have beige backgrounds.

Altitude is the altitude of the aircraft in feet.
Flight Radius is the radius that the aircraft is flying on the ground.
Target Radius is the radius that the LOS is steering to in "Expander" mode. By clicking on the "Target Radius" label the most efficient value will be calculated by iteration. This is also done automatically when related parameters are changed.
Airspd is the aircraft airspeed in knots. *Wind* is the wind speed in knots (from right to left in the large display area).
Lat is the lateral G and *Tot Acc* is the total G (normal to wings).
Bank is the bank angle of the aircraft in degrees.
Clicking on the "Bank" or "Lat" label will toggle between live, max, or average values.
Incidence is the LOS angle relative to vertical in degrees.
Top and *Bot* are the incidence angle of the top and bottom of the FOV in degrees.
H, V fov are the horizontal and vertical fields of view in degrees.
H, V chip are the horizontal and vertical dimensions of the focal plane array in millimeters.

H, V pix are the horizontal and vertical dimensions of a pixel on the focal plane in micro-meters.
Focal is the focal length of the lens in millimeters.
Shutter is the shutter speed of the camera in milliseconds.
The payload selection box allows some standard Payloads to be selected from a list. This fills in the payload parameters for you.

The next section displays information about the efficiency of the system. By clicking the units beside "Pixels" you can toggle between mega-pixels and percent of total for the units. The first column is for the total focal plane array and the second column is for the persistent area only.

Total is the number of pixels.
GSD Good is the number of pixels below the *GSD Limit* value.
Blur Good is the number of pixels below the *Blur Limit* value.
Both Good is the number of pixels below both the *GSD* and *Blur Limit* values.

Area is the total area projected onto the ground and the persistent area on the ground. Clicking on the units will toggle between area units and radii.

GSD Limit is the maximum acceptable GSD size in meters (this is measured vertically on the focal plane).
Blur Limit is the maximum acceptable pixel motion between frames measured in pixels. This limit will be displayed when the *Blur tab* is selected.
FPI Limit is the maximum acceptable focal plane incidence angle. This limit will be displayed when the *FPI tab* is selected.

XY FP Grid is the Focal Plane (FP) location of the blue pixel in the *Pixels tab* and is controlled by entering its X and Y grid indices in this pair of fields. The FP array is represented by a rectangle divided into a 50 by 50 grid. The upper left element is 0,0 and the lower right element is 49,49. Preset locations (corners and midpoints) can be entered using the *Pix Select F* button in the *Settings tab* or by clicking on the *XY FP Grid* label.

XY Gnd are the ground coordinates of the black pixel in the *Pixels tab* and are controlled by entering its X and Y coordinates in meters. The center of the map view is 0,0. Preset coordinates can be entered using the *Pix Select G* button in the *Settings tab* or by clicking on the *XY Gnd* label.

View is the display mode selection box and allows you to set the display in Normal, Donut, or Both modes. Donut mode allows you to see how the persistent area is arrived at. Normal mode is easier to view.

Scale sets the scale of the display area. It is the total size of the display in km.

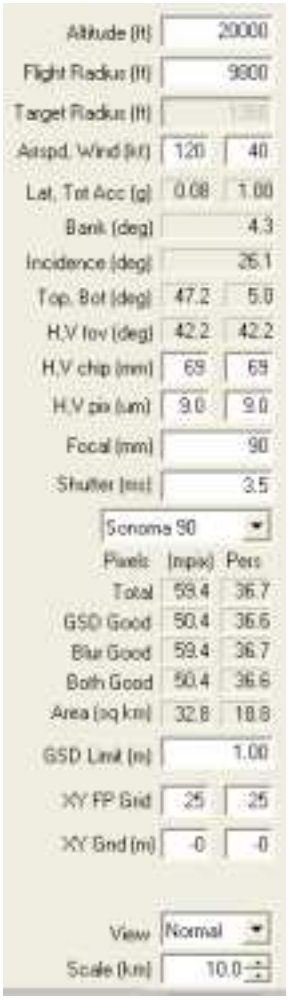

Figure 9 – PS Parameters

The ray tracing assumes a simple pinhole camera.

TEST POINTS:

The following are pre-configured text files (saved from the MPST) that can be dragged and dropped onto the MPST to apply their settings.

LLNL-Sonoma90.txt ; CH-Sonoma60.txt ; CH-Sonoma60Exp.txt ; CH-Sonoma60Bank.txt

LLNL Sonoma 90
Initial LLNL test plan: 20 Kft, 9800 ft, 0 ft, 120 kts, 40 kts, Sonoma 90, GSD limit 1m

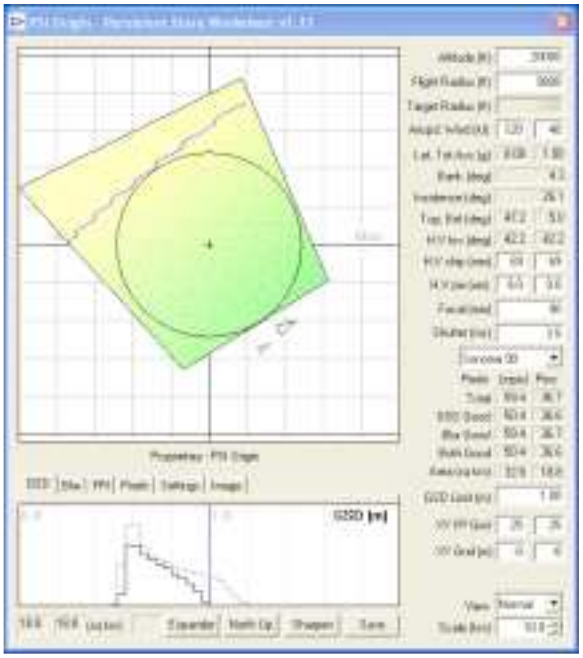

Figure 10 – LLNL Sonoma 90

CH Sonoma 60
CH: 17Kft, 9800 ft, 0 ft, 140 kts, 40 kts, Sonoma 60, GSD limit 1m (Note that GSD is bad).

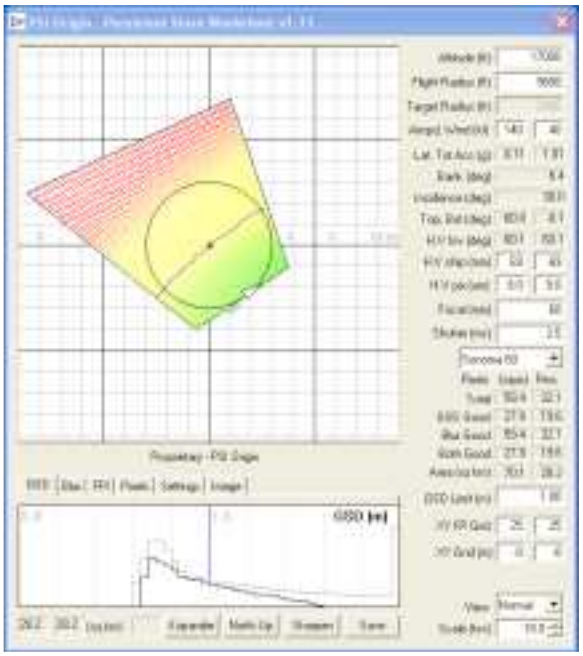

Figure 11 – CH Sonoma 60

CH Sonoma 60 with Expander
CH: 17Kft, 9800 ft, 0 ft, 140 kts, 40 kts, Sonoma 60, GSD limit 1m (Note that GSD is bad).

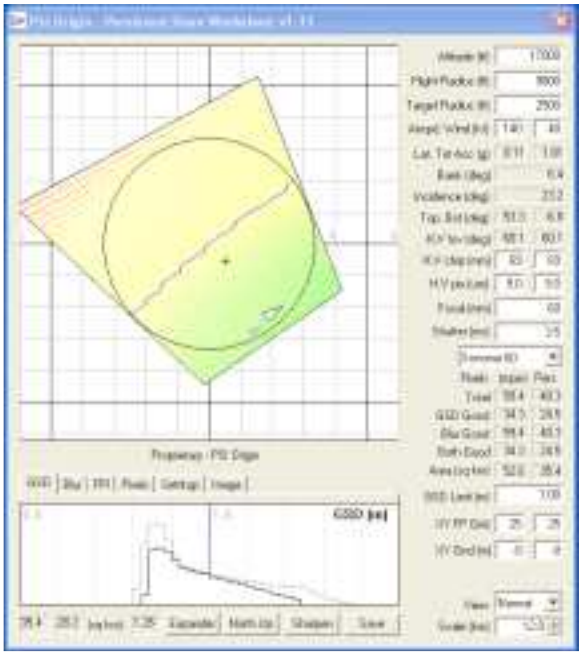

Figure 12 – CH Sonoma 60 with Expander Mode

CH Sonoma 60 at 1.2 G
Suggested CH: 17Kft, 4331 ft, 1000 ft, <140 kts, 40 kts, Sonoma 60, GSD limit 1m (GSD is good). Bank limited to 33.5 degrees to get 1.20 G loading.

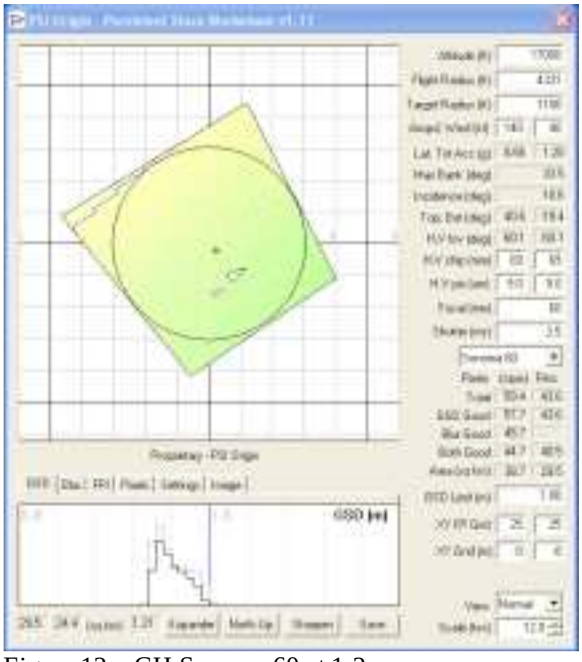

Figure 12 – CH Sonoma 60 at 1.2