Eiler Fire Whirl

Photogrammetric Analysis

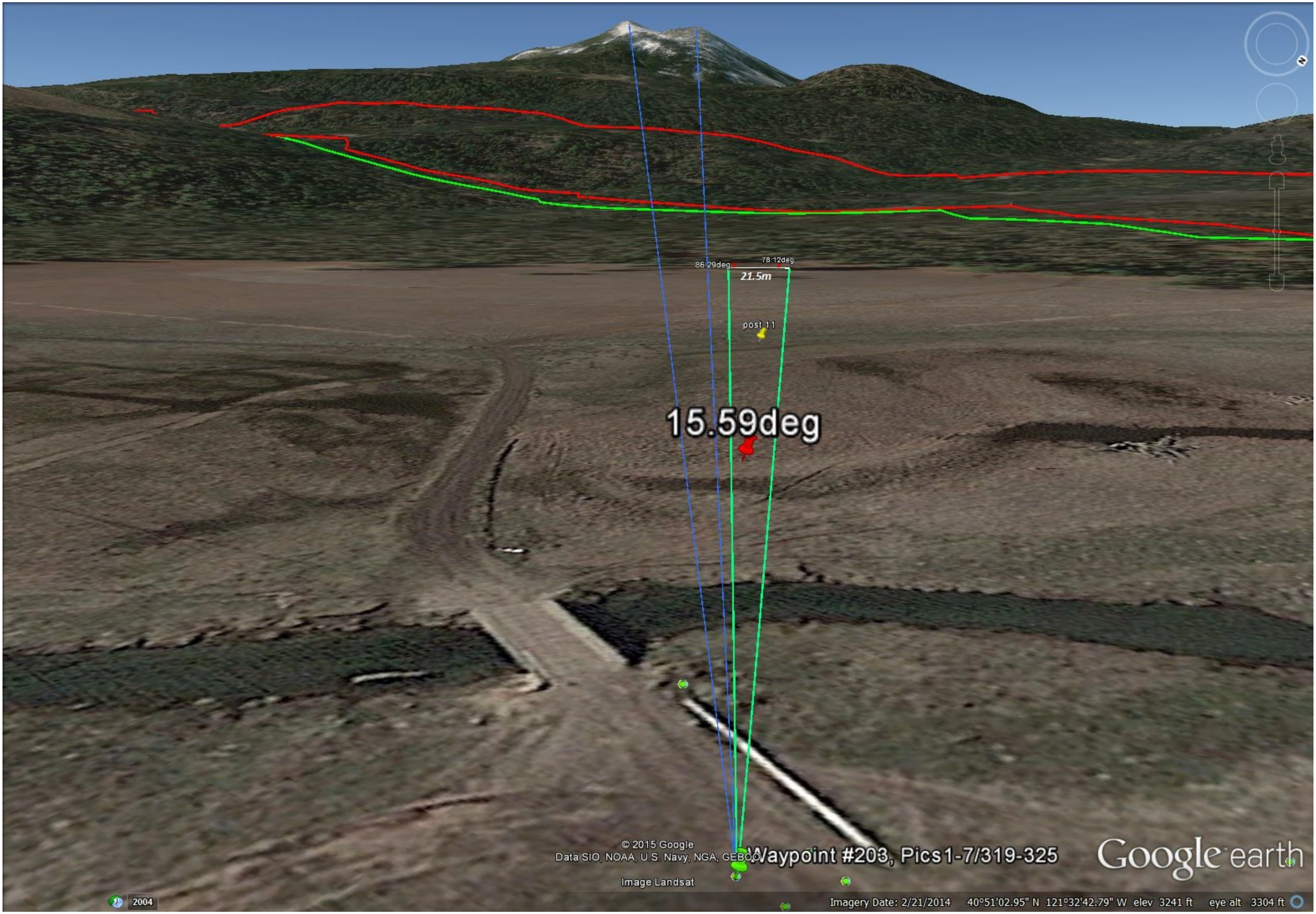
Pictures taken by Jim Brown on August 2, 2014, during the Eiler Fire near Mount Lassen, California; and by Bradley Muller following the fire in September 2014.

<u>Muller Photo 7:</u>

Focal length = 46mm, Coordinates: 40.851139, -121.544639   Waypoint #203, corresponds with JB photo #325

Google Earth View 1:

This view is a representation of the direction faced in the photos that we will use for this analysis. The aim of the analysis is to estimate the size of airborne material that was swept up in the high winds associated with the Northern fire whirl. This whirl has left the largest damage path of the 3 whirls present on the day of the Eiler fire. We can therefore assume that it would have the greatest potential to loft larger material. By estimating the size of photographed debris, we can gain an understanding of the potential threat to aircraft operating in the vicinity to such phenomena. The red line shows the estimated edge of the Northern fire whirl (thought to be the largest). The green line bounds an area roughly 50m from the Eastern edge of the whirl.

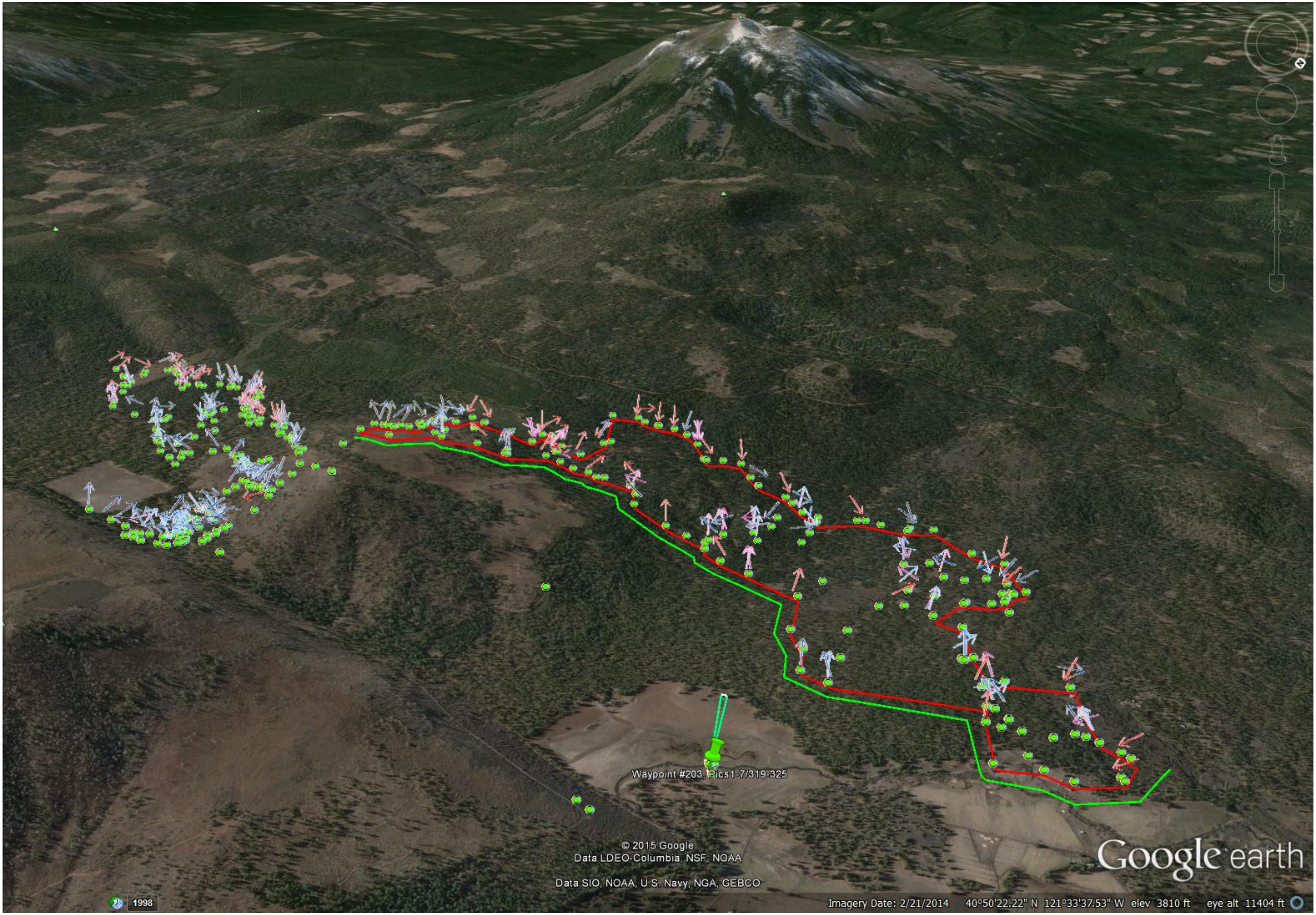


Google Earth View 2:

This view shows the angles and distances between Waypoint #203 (at which the below photos were taken) and two trees of similar height and approximately equal distance from the photographer. We will use these trees as a point of scale. The distance between the trees is 21.5 meters.

Google Earth View 3:

Shows the estimated path boundary in red and the 50m zone in green, as well as the waypoints corresponding to damage from the other fire whirls (left side of image).



JB Photo 325:

Focal length = 17mm, Waypoint #203, Corresponds with Muller photo #7

Combination of M7 and JB325:

Blending of the two pictures to show terrain behind the fire. This will allow us to determine the approximate distance to each piece of debris in photo 325. Blending done in Adobe Photoshop

<u>JB Photo 327:</u>

Focal length = 40mm, Waypoint #206, corresponds with Muller photo #9

Muller Photo 9:

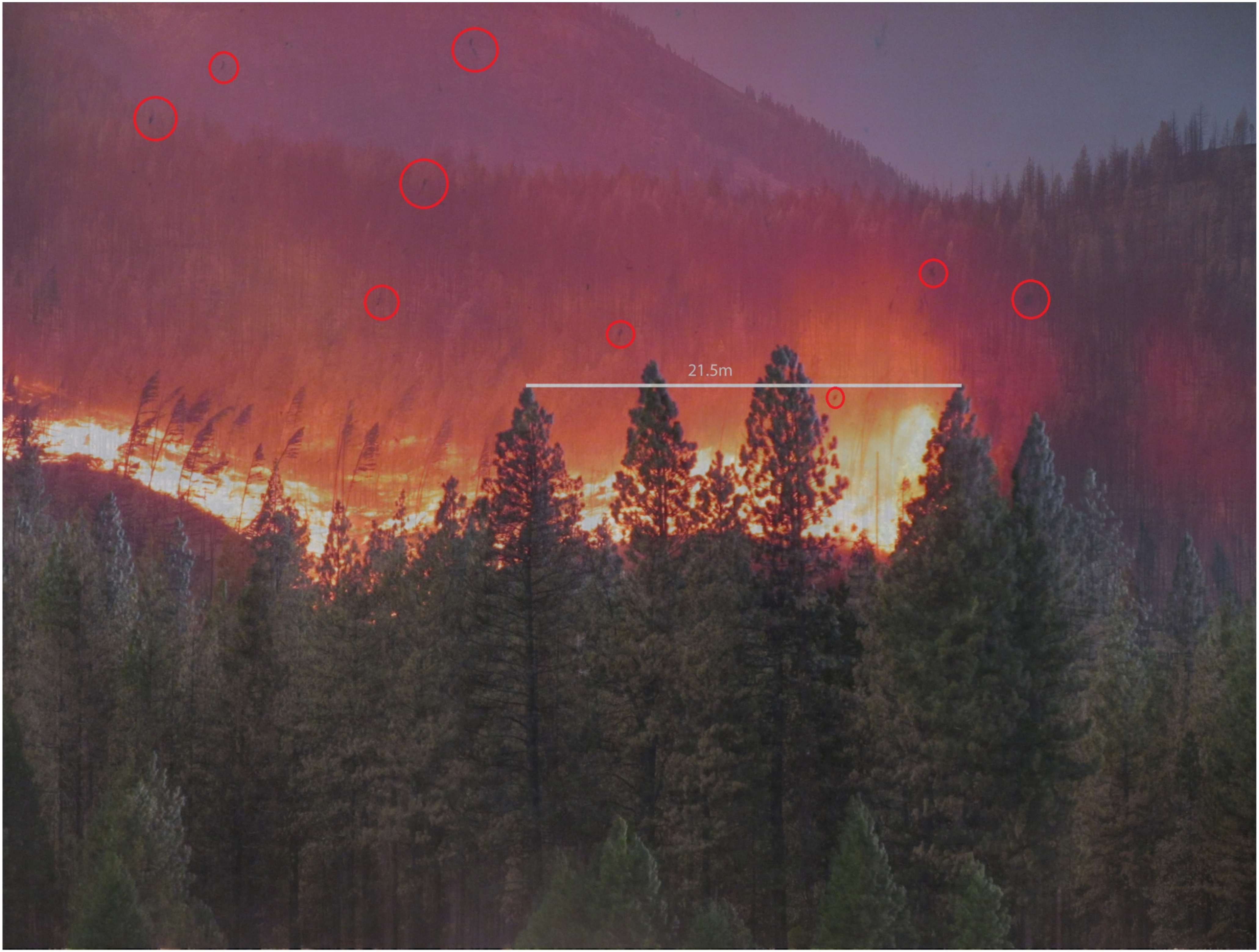
Focal length = 55mm, Waypoint #206, corresponds with JB Photo 327

Combination of M9 and JB327:

Blending of the two pictures to show terrain behind the fire. This will allow us to determine the approximate distance to each piece of debris in photo 327. Blending done in Adobe Photoshop


21.5m


21.5m


21.5m

Photogrammetric techniques:

Method 1: *Comparison to tree size/ size of debris on ground*

In these photos taken on the day of the fire there are some indications of snapped branches that are visually similar to those photographed in the whirl.

This piece of debris is roughly **40-50cm long** and **50cm wide.**

I think that this is likely the size of the majority of the debris in the photos. The debris in the photos looks round and only some pieces are elongated enough to resemble longer branches. The large surface area of the leaves makes these branches more susceptible to being picked up by the high winds. With the larger branches the greenery would probably separate from the branch before the branch separates from the tree.

The majority of this tree's branches have been torn off by the high winds. The size of the remaining branches gives us an indication of the approximate size of the torn off branches. I estimate the branches to be between **1m and 1.5m** in length.

At this stage it is unknown whether similar branches are those seen in the photographs, or if the debris photographed is smaller in size

I included the following photos because they are the best indicator of the resultant damage to the area in which we are performing the analysis. It is clear that the fire whirl did not reach all the way to the tree line, leaving roughly 300-500m forest.

***Method 2**: Mathematical equations using focal length and max/min distance to the debris*

Distance to object (mm) = focal length (mm) * real height/width of the object (mm) * image height/width (pixels)

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object height/width (pixels) * sensor height/width (mm)

To test the accuracy of this formula, we will do a test calculation of the height of the left hand tree

[We know the distance to the tree and have a measurement of 21.5m between trees at the same distance from the photographer. This data will allow us to double check the answer produced by the formula]

*Distance to left hand tree (from previous calculations) = 375m = **375,000mm***

*Focal length (JB327) = **40mm***

*Real object height = (**X**)*

*Image height = **3240 pixels***

Object height = Tree takes up approximate 10.75inches/18inches on photo 327 = 59.72% of vertical pixels

*0.59722 x 3240 = **1935 pixels***

*Sensor height (Canon PowerShot SX150 IS) = **4.55mm***

Using the above formula: ***375,000mm = [40mm x (X) x 3240 pixels] / [1935 pixels x 4.55mm]***

375,000mm = 129,600(X) / 8804.25

129,600(X) = 3,301,593,750

(X) = 25475.26mm

= 25.47m

Cropped photo 327 [20.625 x 26.875 inches]

21.5m (20.625 inches)

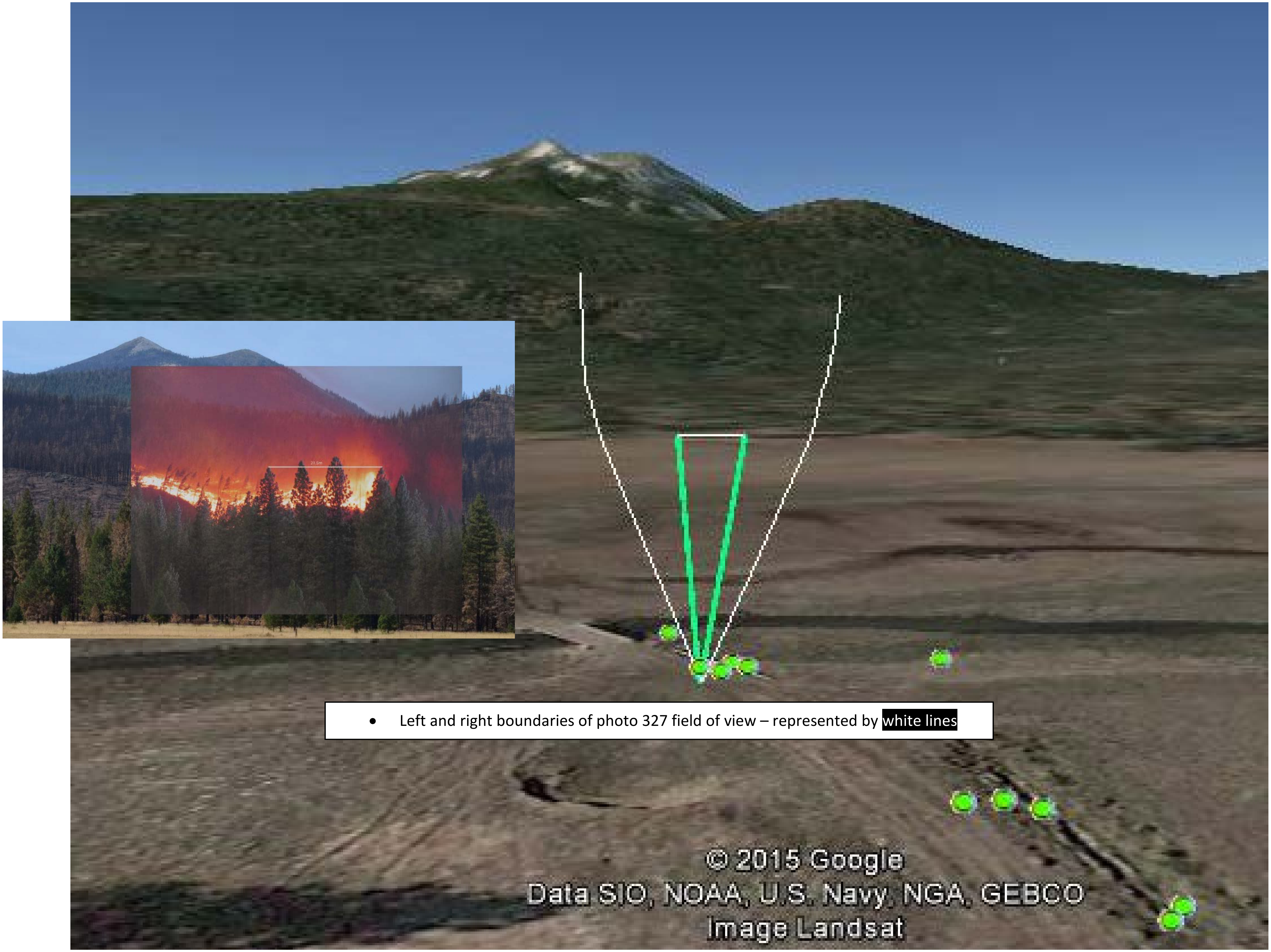
25.47m (26.875 inches)

20.625/21.5m = 0.959

*26.875/**25.47m =** 1.055*

0.959 ~ 1.055 *[there will be some disparity due to inaccurate image cropping and rounding of numbers during the calculation]*

Thus, the formula used is suitable for further calculations of debris size.


• Left and right boundaries of photo 327 field of view – represented by white lines
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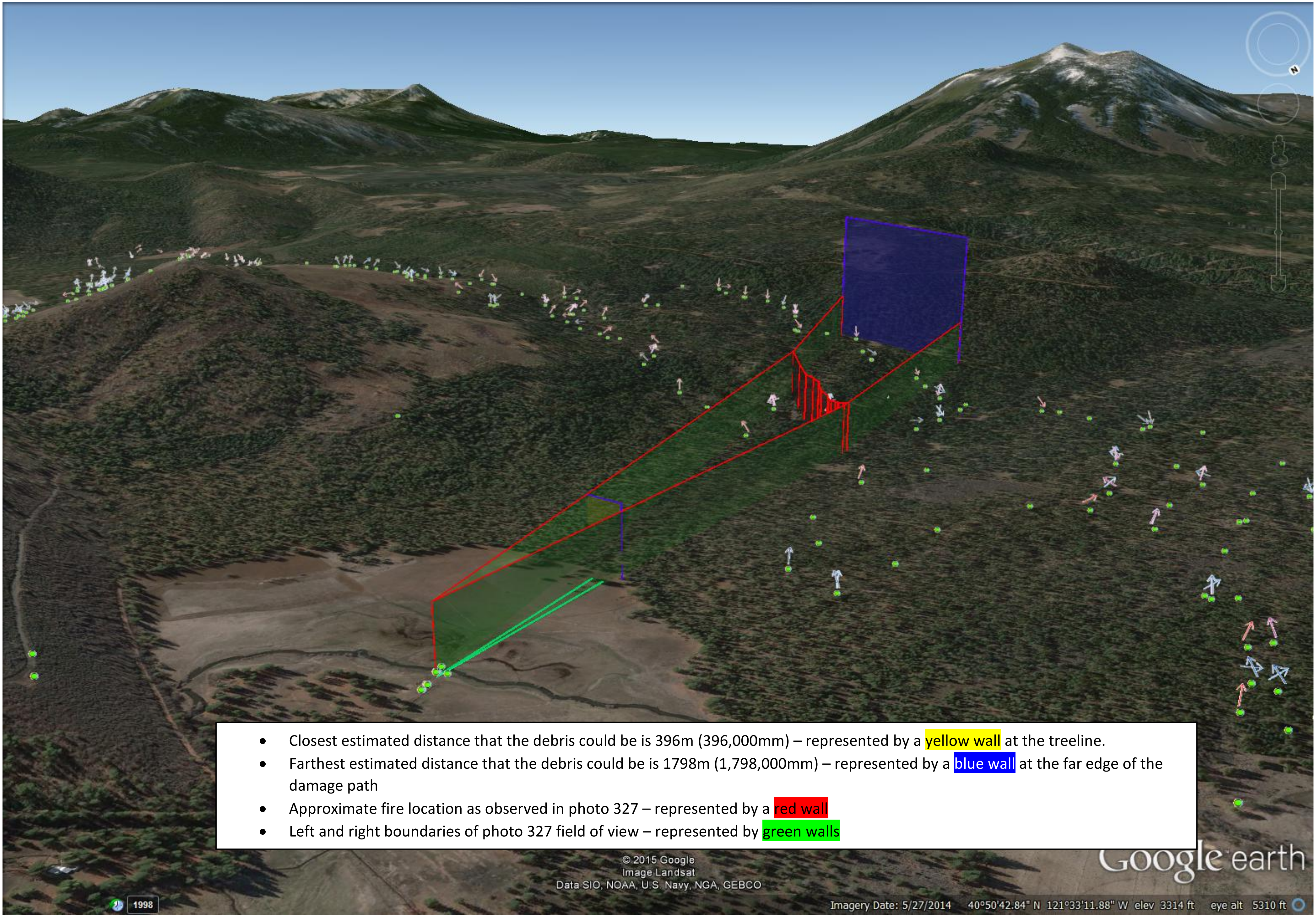
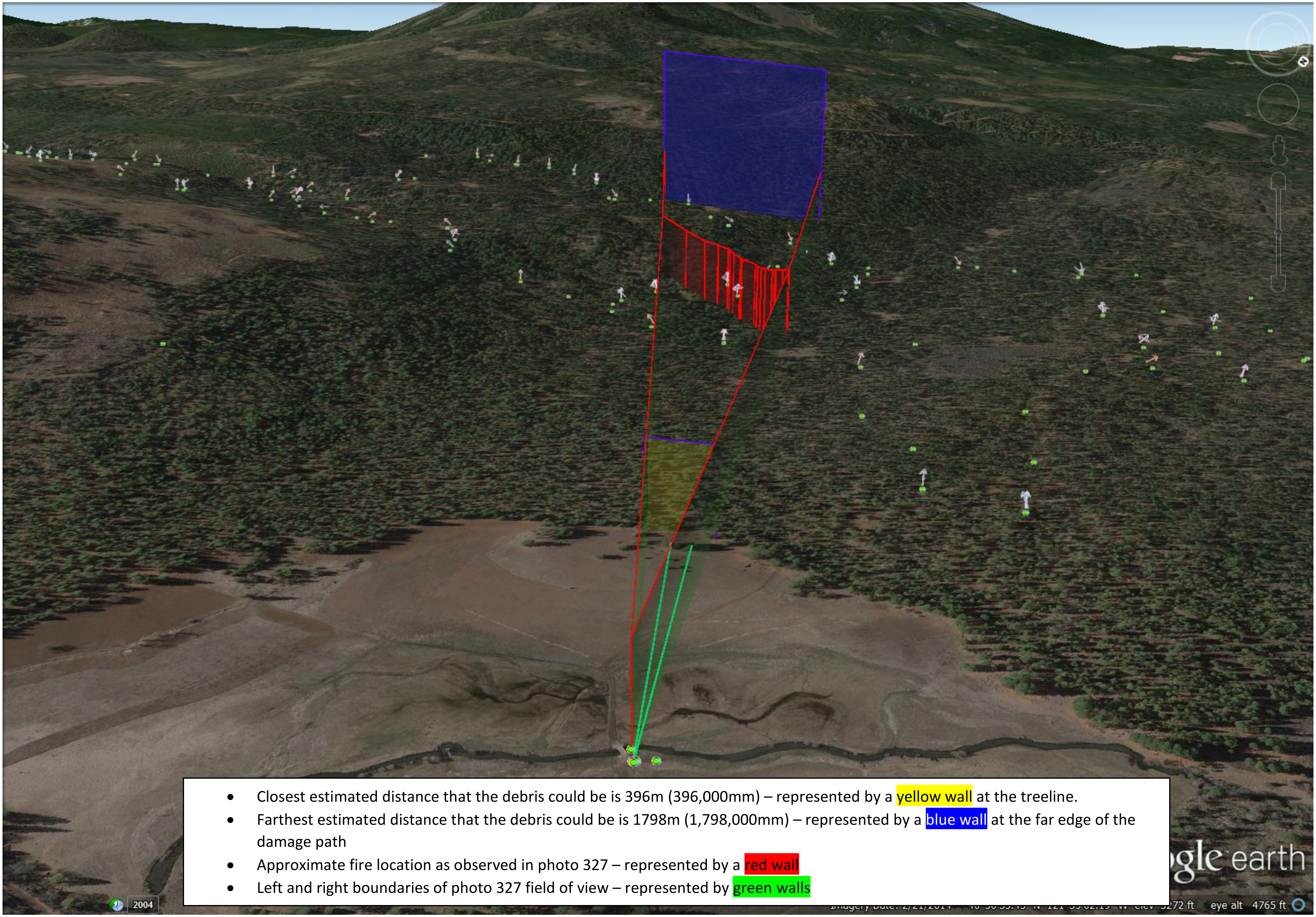
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat



- Closest estimated distance that the debris could be is 396m (396,000mm) – represented by a yellow wall at the treeline.
- Farthest estimated distance that the debris could be is 1798m (1,798,000mm) – represented by a blue wall at the far edge of the damage path
- Approximate fire location as observed in photo 327 – represented by a red wall
- Left and right boundaries of photo 327 field of view – represented by green walls



- Closest estimated distance that the debris could be is 396m (396,000mm) – represented by a yellow wall at the treeline.
- Farthest estimated distance that the debris could be is 1798m (1,798,000mm) – represented by a blue wall at the far edge of the damage path
- Approximate fire location as observed in photo 327 – represented by a red wall
- Left and right boundaries of photo 327 field of view – represented by green walls

Distance to object (mm)	**=**	***focal length (mm) * real height of the object (mm) * image height (pixels)***
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		Object height (pixels) * sensor height (mm)

- Closest estimated distance that the debris could be is 396m (396,000mm)
- Farthest estimated distance that the debris could be is 1798m (1,798,000mm)
- Distance to location of main blaze is approximately 900m (900,000mm)

Photo 327 dimensions = 4320 x 3240 pixels, 24 inches x 18 inches

Largest piece of debris *in picture = 0.667 inches wide x 1.306 inches tall*

[(0.667/24) x 4320] = 120.06 pixels wide

[(1.306/18) x 3240] = 235.08 pixels high

Assume object lies at farthest possible distance from photographer (1798m) and a straight on view (object not angled toward or away from photographer)

Distance to object = ***1,798,000mm*** *Focal length =* ***40mm*** *Real height of the object =* ***(X)*** *Real width of the object =* ***(Y)***
Object height = ***235.08 pixels*** *Object width =* ***120.06 pixels*** *Sensor height =* ***4.55mm*** *Sensor width =* ***6.17mm***

Therefore: *1,798,000mm = (40mm x (X) x 3240 pixels) / (235.08 pixels x 4.55mm)*

1,798,000 = 129600(X) / 1069.614

129,600(X) = 1,923,165,972

(X) = 14839mm

(X) = 14.84m (real height of the object)

And: *1,798,000mm = (40mm x (Y) x 4320 pixels) / (120.06 pixels x 6.17mm)*

1,798,000 = 172,800(Y) / 740.770

172,800(Y) = 1331904460

(Y) = 7707mm

(Y) = 7.71m (real width of the object)

So, if the largest observed piece of debris was the furthest possible distance away, we obtain a maximum possible debris size of 14.84m x 7.71m

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Now assume object lies at closest possible distance from photographer (396m) and a straight on view (object not angled toward or away from photographer)

Distance to object = ***396,000mm*** *Focal length =* ***40mm*** *Real height of the object =* ***(X)*** *Real width of the object =* ***(Y)***
Object height = ***235.08 pixels*** *Object width =* ***120.06 pixels*** *Sensor height =* ***4.55mm*** *Sensor width* ***= 6.17mm***

Therefore: *396,000mm = (40mm x (X) x 3240 pixels) / (235.08 pixels x 4.55mm)*

396,000 = 129600(X) / 1069.614

129,600(X) = 423,567,144

(X) = 3268.27mm

(X) = 3.26m (real height of the object)

And: *396,000mm = (40mm x (Y) x 4320 pixels) / (120.06 pixels x 6.17mm)*

396,000 = 172,800(Y) / 740.4

172,800(Y) = 293,198,400

(Y) = 1696.75mm

(Y) = 1.70m (real width of the object)

So, if the largest observed piece of debris was the closest possible distance away, we obtain a debris size of 3.26m x 1.70m

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Now assume largest observed debris lies over the center of the main fire and a straight on view (object not angled toward or away from photographer)

*Distance to object = **900,000mm*** *Focal length = **40mm*** *Real height of the object = **(X)*** *Real width of the object = **(Y)***
*Object height = **235.08 pixels*** *Object width = **120.06 pixels*** *Sensor height = **4.55mm*** *Sensor width **= 6.17mm***

Therefore: *900,000mm = (40mm x (X) x 3240 pixels) / (235.08 pixels x 4.55mm)*

900,000 = 129600(X) / 1069.614

129,600(X) = 962,652,600

(X) = 7427.875mm

(X) = 7.43m (real height of the object)

And: $900{,}000mm = (40mm \times (Y) \times 4320\ pixels) / (120.06\ pixels \times 6.17mm)$

$900{,}000 = 172{,}800(Y) / 740.4$

$172{,}800(Y) = 666{,}360{,}000$

$(Y) = 3856.25mm$

(Y) = 3.89m (real width of the object)

If the largest observed piece of debris is over the center of the main fire, we obtain a debris size of 7.43m x 3.89m

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$$\text{Distance to object (mm)} = \frac{\text{focal length (mm)} * \text{real height of the object (mm)} * \text{image height (pixels)}}{\text{Object height (pixels)} * \text{sensor height (mm)}}$$

Smallest piece of debris *in picture = 0.222 inches wide x 0.194 inches tall*

[(0.222/24) x 4320] = 39.96 pixels wide

[(0.194/18) x 3240] = 34.92 pixels high

Assume object lies at farthest possible distance from photographer (1798m) and a straight on view (object not angled toward or away from photographer)

Distance to object = ***1,798,000mm*** *Focal length =* ***40mm*** *Real height of the object =* ***(X)*** *Real width of the object =* ***(Y)***
Object height = ***34.92 pixels*** *Object width =* ***39.96 pixels*** *Sensor height =* ***4.55mm*** *Sensor width* ***= 6.17mm***

Therefore: *1,798,000mm = (40mm x (X) x 3240 pixels) / (34.92 pixels x 4.55mm)*

1,798,000 = 129600(X) / 158.886

129,600(X) = 285,677,028

(X) = 2204.30mm

(X) = 2.20m (real height of the object)

And: *1,798,000mm = (40mm x (Y) x 4320 pixels) / (39.96 pixels x 6.17mm)*

1,798,000 = 172,800(Y) / 246.55

172,800(Y) = 443302653.6

(Y) = 2565.41mm

(Y) = 2.57m (real width of the object)

So, if the smallest observed piece of debris was the farthest possible distance away, we obtain a debris size of 2.20m x 2.57m

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Now assume object lies at closest possible distance from photographer (1798m) and a straight on view (object not angled toward or away from photographer)

Distance to object = ***396,000mm*** *Focal length =* ***40mm*** *Real height of the object =* ***(X)*** *Real width of the object =* ***(Y)***
Object height = ***34.92 pixels*** *Object width =* ***39.96 pixels*** *Sensor height =* ***4.55mm*** *Sensor width* ***= 6.17mm***

Therefore: *396,000mm = (40mm x (X) x 3240 pixels) / (34.92 pixels x 4.55mm)*

396,000 = 129600(X) / 158.886

129,600(X) = 62,918,856

(X) = 485.49mm

<u>(X) = 0.485m (real height of the object</u>

<u>And:</u> *396,000mm = (40mm x (Y) x 4320 pixels) / (39.96 pixels x 6.17mm)*

396,000 = 172,800(Y) / 246.5532

172,800(Y) = 97635067.2

(Y) = 565.02

<u>(Y) = 0.565m (real width of the object)</u>

So, if the <u>smallest</u> observed piece of debris was the <u>closest possible distance</u> away, we obtain a <u>minimum possible debris size</u> of 0.485m x 0.565m

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Now assume smallest observed debris lies <u>over the center of the main fire</u> and a <u>straight on view</u> (object not angled toward or away from photographer)

*Distance to object = **900,000mm*** *Focal length = **40mm*** *Real height of the object = **(X)*** *Real width of the object = **(Y)***
*Object height = **34.92 pixels*** *Object width = **39.96 pixels*** *Sensor height = **4.55mm*** *Sensor width **= 6.17mm***

Therefore: *900,000mm = (40mm x (X) x 3240 pixels) / (34.92 pixels x 4.55mm)*

900,000 = 129600(X) / 158.886

129,600(X) = 142,997,400

(X) = 1103.38mm

(X) = 1.10m (real height of the object)

And: *900,000mm = (40mm x (Y) x 4320 pixels) / (39.96 pixels x 6.17mm)*

900,000 = 172,800(Y) / 246.5532

172,800(Y) = 221,897,880

(Y) = 1284.13

(Y) = 1.28m (real width of the object)

So, If the smallest observed piece of debris is over the center of the main fire, we obtain a debris size of 1.10m x 1.28m

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