

# **Landsat GCP Improvement Phase 1 Triangulation Results**

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# Landsat GCP Improvement Goals

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- **The highly accurate absolute geolocation of Landsat 8 has allowed us to identify areas where the GLS-derived global control point library is deficient**
  - ◆ This is manifested as repeatable large (tens of meters) offsets for particular WRS path/row locations
- **The existing control library image chips are all Landsat 7 ETM+ (8-bit) circa 2000**
  - ◆ We want to extract up-to-date 16-bit OLI chips for the GCPs in any event
- **A GLS control improvement activity is now underway to upgrade the problem areas**
  - ◆ Regions of poor accuracy are being re-triangulated using Landsat 8 data, while holding the surrounding area fixed to ensure that scene-to-scene consistency is maintained

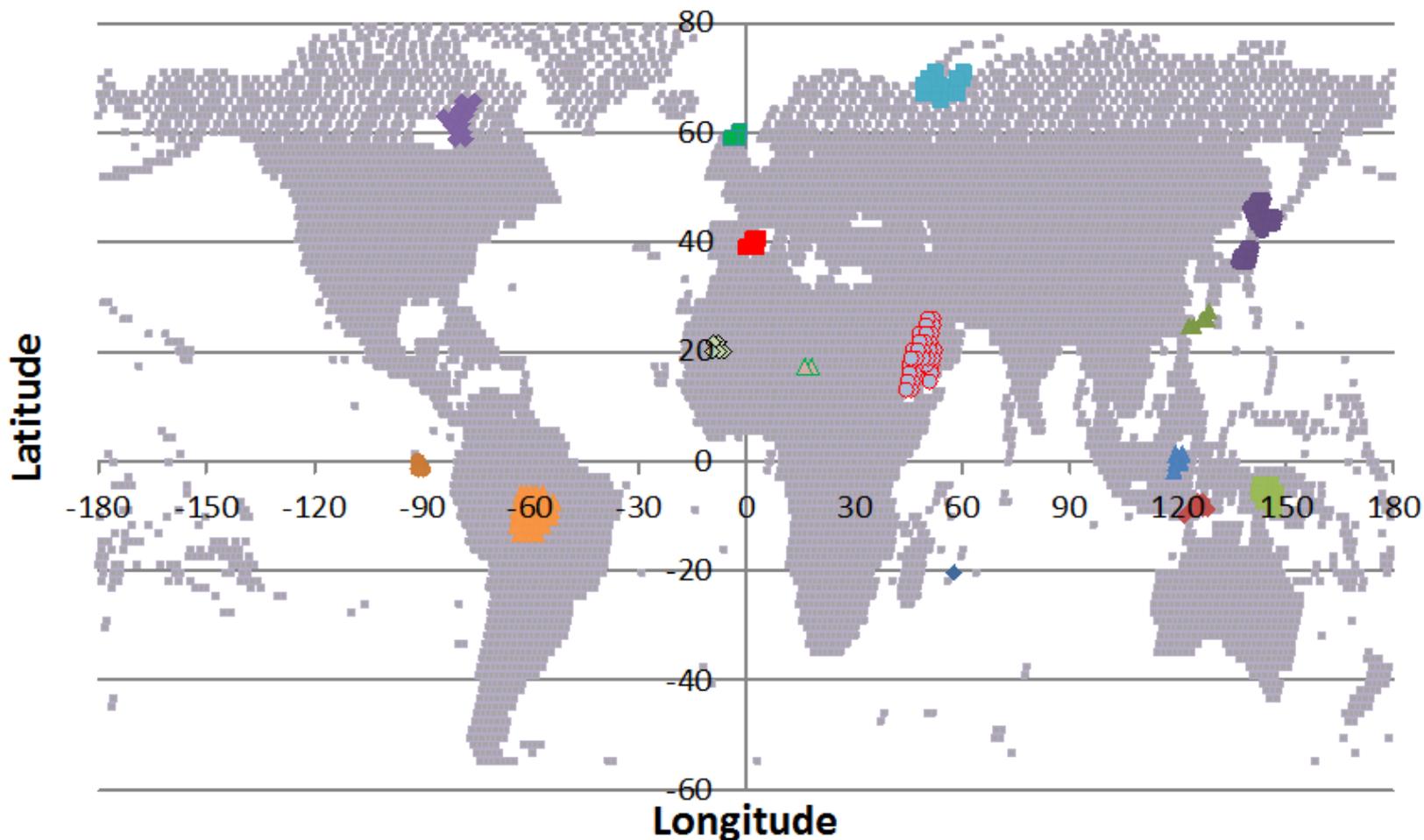
# Landsat GCP Improvement Plan

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- **Triangulation updates are proceeding in three phases:**
  - ◆ Phase 1 – Fifteen high priority areas with largest offsets
  - ◆ Phase 2 – Remaining low latitude areas
  - ◆ Phase 3 – High latitude areas
- **The updated GCP positions will be released upon the completion of each phase**
  - ◆ Phase 1 is now complete
  - ◆ The results are summarized in the remainder of this presentation
- **Once all three phases of triangulation updates are complete, new OLI image chips will be extracted for all GCPs**
  - ◆ The original ETM+ chips will also continue to be used

# Phase 1 Block Distribution

- GLS Control
- Balearic Islands
- Ryukyu Islands
- Hokkaido
- Mauritius
- Shetland Islands
- Galapagos Islands
- Sulawesi, Indonesia
- Timor, Indonesia
- Papua New Guinea
- Hudson Bay
- Russian Arctic Coast
- Mato Grosso, Brazil
- Saudi Desert
- Chad
- Mauritania



# Phase 1 Block Statistics

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- **The following table shows statistics for each triangulation block in Phase 1, including:**
  - ◆ The number of scenes containing GCPs.
  - ◆ The number of adjusted and new control points.
  - ◆ The number of adjusted and new validation points (used for post-correction accuracy testing).
  - ◆ The total number of control and validation points that were newly generated (from the OLI imagery).
  - ◆ The number of pre-existing control points that could not be measured/adjusted and were removed (deactivated).
  - ◆ The largest latitude and the largest longitude scene-average GCP adjustment in the block.
- **The Saudi block had both temporal and accuracy problems.**
- **The Chad and Mauritania block shifts show how far the new OLI GCPs had to be adjusted to fit with the existing GCPs.**

# Phase 1 Block Summary

Triangulation Block	# Scenes	# Control	# Validation	# New	# Deactivated	Max Latitude Shift	Max Longitude Shift
Balearic Islands	5	1243	451	0	78	-87.336	-142.907
Ryukyu Islands	5	185	0	0	114	-134.876	-157.055
Hokkaido	23	4997	2451	0	793	-25.307	-115.703
Mauritius	1	37	0	0	37	-54.216	-62.543
Shetland Islands	3	592	0	0	99	6.879	-50.401
Galapagos Islands	3	247	0	0	118	72.653	-33.644
Sulawesi, Indonesia	5	638	100	0	325	80.894	17.145
Timor, Indonesia	7	982	306	0	124	55.843	68.907
Papua New Guinea	14	1489	937	0	1919	26.875	56.002
Hudson Bay	14	2973	1802	118	143	39.712	-59.395
Russian Arctic Coast	16	2686	1475	0	594	61.366	27.649
Mato Grosso, Brazil	36	6044	3696	0	5090	-61.202	39.253
Saudi Desert*	32	10656	7220	12827	5176	-60.465	-76.818
Chad*	2	541	362	903	0	-14.894	12.865
Mauritania*	5	1423	987	2410	0	-20.358	-17.982
<b>Totals</b>	171	34733	19787	16258	14610		
* Sites with temporal problems.							

# Triangulation Block Results

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- **The path/row location of each triangulation block is shown in the following slides, one slide per block**
- **For each path/row, the mean net geodetic offset (in meters) is shown before and after the triangulation adjustment**
  - ◆ The offsets for nearby scenes are also shown to provide a sense of the surrounding area
- **Not all scenes contain unique control points**
  - ◆ Some rely on GCPs extracted from adjacent scenes, particularly in high latitude and island/coastal sliver areas
  - ◆ The number of scenes in a triangulation block (highlighted in red on the following plots) thus may not match the number of scenes with adjusted GCPs (listed in the table on the previous chart).

# Balearic Islands Block

## Net Geodetic Offset in Meters

Triangulation Scenes  
Pre-Adjustment

Pre-Fit		WRS Path		
		198	197	196
WRS Row	31	10	<b>8</b>	
	32	13	166	174
	33	57	156	167
	34	29	18	25
	35	<b>17</b>	10	<b>18</b>

Validation Scenes  
Post-Adjustment

Test Scenes		WRS Path		
		198	197	196
WRS Row	31	10	<b>8</b>	
	32	13	12	21
	33	29	20	20
	34	29	18	25
	35	<b>17</b>	10	<b>18</b>

**Red** indicates scenes that were adjusted in the triangulation.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# Ryukyu Islands Block

## Net Geodetic Offset in Meters

### Triangulation Scenes Pre-Adjustment

Pre-Fit		WRS Path				
		116	115	114	113	112
WRS ROW	40				8	16
	41				<b>80</b>	15
	42			*	*	
	43	41	57			
	44		43			

### Validation Scenes Post-Adjustment

Test Scenes		WRS Path				
		116	115	114	113	112
WRS ROW	40				8	16
	41				4	15
	42			10	5	
	43	8	5			
	44		8			

Red indicates scenes that were adjusted in the triangulation.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

Red asterisk (\*) indicates scenes that had never successfully processed to L1T.

# Hokkaido/Sakhalin Island Block Net Geodetic Offset in Meters

## Triangulation Scenes Pre-Adjustment

Pre-Fit	WRS Path							
	110	109	108	107	106	105	104	103
25	10	7	19	21				
26	<b>8</b>	6	16	18				
27	12	29	<b>69</b>	<b>68</b>				
28	29	*	<b>88</b>	<b>78</b>			20	<b>14</b>
29			<b>42</b>	<b>74</b>	<b>53</b>	<b>24</b>	<b>33</b>	22
30			<b>15</b>	<b>27</b>	<b>53</b>	<b>34</b>	<b>42</b>	
31			14	17	<b>34</b>			
32			<b>11</b>	<b>4</b>	27			
33		32	<b>31</b>	<b>21</b>	8			
34	23	<b>38</b>	<b>46</b>	<b>46</b>	45			
35	8	<b>20</b>	<b>29</b>	<b>32</b>	40			
36	3	<b>5</b>	14	24				
37	2	6						

## Validation Scenes Post-Adjustment

WRS Path								
110	109	108	107	106	105	104	103	
10	7	19	21					
<b>8</b>	6	16	18					
12	29	<b>12</b>	<b>11</b>					
29	<b>6</b>	<b>9</b>	<b>11</b>			20	<b>14</b>	
		<b>8</b>	<b>12</b>	<b>6</b>	<b>20</b>	<b>18</b>	22	
		<b>15</b>	<b>5</b>	<b>22</b>	<b>17</b>	<b>15</b>		
		14	17	<b>9</b>				
		<b>11</b>	<b>4</b>	27				
	32	<b>10</b>	<b>6</b>	8				
23	<b>10</b>	<b>11</b>	<b>14</b>	45				
8	<b>6</b>	<b>12</b>	<b>17</b>	40				
3	<b>5</b>	14	24					
2	6							

Red indicates scenes that were adjusted in the triangulation.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

Red asterisk (\*) indicates scenes that had never successfully processed to L1T.

# Mauritius Block

## Net Geodetic Offset in Meters

Triangulation Scenes  
Pre-Adjustment

Pre-Fit		WRS Path		
		153	152	151
WRS ROW	73			
	74	45	79	
	75	43		

Validation Scenes  
Post-Adjustment

Test Scenes		WRS Path		
		153	152	151
WRS ROW	73			
	74	45	8	
	75	43		

Note: 152/074 and 153/074 contain separate isolated islands with no overlap.

**Red** indicates scenes that were adjusted in the triangulation.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# Shetland Islands Block

## Net Geodetic Offset in Meters

### Triangulation Scenes Pre-Adjustment

### Validation Scenes Post-Adjustment

Pre-Fit		WRS Path				
		207	206	205	204	203
WRS ROW	16					
	17		59	60		
	18	27	56	62	76	
	19	3	7	16		
	20	12	<b>15</b>	13	32	

Test Scenes		WRS Path				
		207	206	205	204	203
WRS ROW	16					
	17		14	19		
	18	27	6	5	27	
	19	3	2	6		
	20	12	<b>15</b>	13	32	

**Red** indicates scenes that were adjusted in the triangulation.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# Galapagos Islands Block Net Geodetic Offset in Meters

## Triangulation Scenes Pre-Adjustment

Pre-Fit		WRS Path				
		20	19	18	17	16
WRS Row	59					
	60		79	71	68	
	61			67	98	
	62					

## Validation Scenes Post-Adjustment

Test Scenes		WRS Path				
		20	19	18	17	16
WRS Row	59					
	60		7	7	14	
	61			21	11	
	62					

**Red** indicates scenes that were adjusted in the triangulation.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# Sulawesi, Indonesia Block

## Net Geodetic Offset in Meters

Triangulation Scenes  
Pre-Adjustment

Pre-Fit		WRS Path					
		117	116	115	114	113	112
WRS Row	58	18	15				
	59	36	10	80	91	8	1
	60	19	7	15	69	14	5
	61	4	20	21	10	27	11
	62	20	34	11	5	22	12

Validation Scenes  
Post-Adjustment

Test Scenes		WRS Path					
		117	116	115	114	113	112
WRS Row	58	18	15				
	59	36	10	4	12	8	1
	60	19	7	20	7	14	5
	61	4	20	19	10	27	11
	62	20	34	11	5	22	12

**Red** indicates scenes that were adjusted in the triangulation.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# Timor, Indonesia Block

## Net Geodetic Offset in Meters

### Triangulation Scenes Pre-Adjustment

Pre-Fit		WRS Path						
		113	112	111	110	109	108	
WRS Row	64	22	15					
	65	30	21	26	82	71		
	66	12	15	16	40	71	39	7
	67	8	68	13	13			
	68			28				

### Validation Scenes Post-Adjustment

Test Scenes		WRS Path						
		113	112	111	110	109	108	
WRS Row	64	22	15					
	65	30	21	11	21	2		
	66	12	15	7	8	7	13	7
	67	8	14	13	13			
	68			28				

**Red** indicates scenes that were adjusted in the triangulation.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# Papua New Guinea Block Net Geodetic Offset in Meters

## Triangulation Scenes Pre-Adjustment

Pre-Fit		WRS Path						
		100	99	98	97	96	95	
WRS Row	61		37		24			
	62	22	7	39	25	40	34	26
	63	19	25	71	78			22
	64	23	27	62	56	30	32	29
	65	10	9	34	40	38	20	39
	66	12	22	21		41	18	14
	67		23	24		32	38	14

## Validation Scenes Post-Adjustment

Test Scenes		WRS Path						
		100	99	98	97	96	95	
WRS Row	61		37		24			
	62	22	7	19	25	40	34	26
	63	19	13	26	14			22
	64	23	19	26	11	10	32	29
	65	10	9	17	20	28	20	39
	66	12	22	21		25	18	14
	67		23	24		32	38	14

**Red** indicates scenes that were adjusted in the triangulation.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# Chad Block

## Net Geodetic Offset in Meters

Triangulation Scenes  
Pre-Adjustment

Validation Scenes  
Post-Adjustment

Pre-Fit		WRS Path			
		185	184	183	182
WRS ROW	47	16	16	21	19
	48	10	<b>162</b>	<b>21</b>	15
	49	15	15	<b>17</b>	18
	50	6	8	3	10

Test Scenes		WRS Path			
		185	184	183	182
WRS ROW	47	16	16	21	19
	48	10	<b>26</b>	<b>16</b>	15
	49	15	15	<b>17</b>	18
	50	6	8	3	10

**Red** indicates scenes for which new GCPs were extracted and then adjusted in the triangulation.

No pre-existing control points were adjusted.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# Hudson Bay Block

## Net Geodetic Offset in Meters

### Triangulation Scenes Pre-Adjustment

Pre-Fit		WRS Path							
		27	26	25	24	23	22	21	20
WRS Row	13	16	21	20	26	13	17	22	17
	14	5		<b>36</b>	<b>32</b>	<b>29</b>	19	17	20
	15	<b>20</b>	14	<b>33</b>	<b>31</b>	<b>31</b>	18	14	20
	16	<b>39</b>	<b>29</b>	<b>51</b>	<b>52</b>	<b>33</b>	<b>31</b>	5	21
	17			<b>68</b>	<b>83</b>	<b>50</b>	<b>39</b>	9	6
	18				*	<b>24</b>	<b>28</b>	13	12
	19					*	<b>37</b>	<b>11</b>	<b>10</b>
	20	6					<b>15</b>	<b>15</b>	<b>11</b>
	21	3	3	6	10	9	14	13	12

### Validation Scenes Post-Adjustment

Post-Fit		WRS Path							
		27	26	25	24	23	22	21	20
WRS Row	13	16	21	20	26	13	17	22	17
	14	5		<b>18</b>	<b>19</b>	<b>10</b>	19	17	20
	15	<b>20</b>	14	<b>15</b>	<b>22</b>	<b>14</b>	18	14	20
	16	<b>36</b>	<b>21</b>	<b>14</b>	<b>13</b>	<b>12</b>	<b>21</b>	5	21
	17			<b>15</b>	<b>14</b>	<b>15</b>	<b>24</b>	9	6
	18				<b>18</b>	<b>12</b>	<b>15</b>	13	12
	19					<b>16</b>	<b>28</b>	<b>4</b>	<b>10</b>
	20	6					<b>15</b>	<b>15</b>	<b>11</b>
	21	3	3	6	10	9	14	13	12

Post-fit triangulation scene results are shown for 024/018 due to a lack of usable scenes.

**Red** indicates scenes that were adjusted in the triangulation.

**Bold red** indicates path/row locations that contain GCPs.

New control points were added in 023/018 and 023/019.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# Saudi Desert Block

## Net Geodetic Offset in Meters

### Triangulation Scenes Pre-Adjustment

Pre-Fit		WRS Path						
		166	165	164	163	162	161	160
WRS Row	41	28	21	24	26	20	<b>15</b>	10
	42	14	12	21	<b>49</b>	<b>60</b>	7	6
	43	2	12	14	<b>45</b>	<b>40</b>	18	13
	44	12	22	<b>29</b>	<b>75</b>	<b>46</b>	11	14
	45	10	18	<b>42</b>	<b>100</b>	<b>70</b>	11	14
	46	16	<b>26</b>	<b>96</b>	<b>91</b>	<b>78</b>	<b>25</b>	15
	47	15	<b>33</b>	<b>59</b>	<b>58</b>	<b>50</b>	<b>37</b>	18
	48	23	<b>47</b>	<b>23</b>	8	<b>26</b>	<b>30</b>	20
	49	24	<b>48</b>	<b>29</b>	12	8	<b>23</b>	15
	50	13	<b>34</b>	<b>18</b>	<b>12</b>	5	<b>29</b>	
	51	9	<b>38</b>	<b>33</b>	21			33
	52	<b>21</b>	26	27	38	41	26	39

### Validation Scenes Post-Adjustment

Test Scenes		WRS Path						
		166	165	164	163	162	161	160
WRS Row	41	28	21	24	26	20	<b>15</b>	10
	42	14	12	21	<b>23</b>	<b>17</b>	7	6
	43	2	12	14	<b>7</b>	<b>17</b>	18	13
	44	12	22	<b>5</b>	<b>18</b>	<b>16</b>	11	14
	45	10	18	<b>7</b>	<b>2</b>	<b>12</b>	11	14
	46	16	<b>5</b>	<b>14</b>	<b>4</b>	<b>18</b>	<b>17</b>	15
	47	15	<b>16</b>	<b>9</b>	<b>16</b>	<b>16</b>	<b>20</b>	18
	48	23	<b>18</b>	<b>12</b>	8	<b>24</b>	<b>20</b>	20
	49	24	<b>31</b>	<b>12</b>	12	8	<b>17</b>	15
	50	13	<b>14</b>	<b>14</b>	<b>12</b>	5	<b>26</b>	
	51	9	<b>21</b>	<b>26</b>	21			33
	52	<b>21</b>	26	27	38	41	26	39

**Red** indicates scenes that were adjusted in the triangulation.

**Red bold** text over a dark stipple pattern indicates scenes for which new control points were extracted and then adjusted in the triangulation.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# Russia Arctic Coast Block

## Net Geodetic Offset in Meters

Triangulation Scenes  
Pre-Adjustment

Pre-Fit		WRS Path										
		179	178	177	176	175	174	173	172	171	170	169
WRS ROW	10		40	38	7	0	55	40	74			16
	11	32	11	27	47	82	68		54	17	6	15
	12	10	7	22	36	56	65	68	47	25	22	19
	13	7	13	14	13	26	35	45	43	39	30	16
	14	8	4	3	8	13	15	22	27	17	13	5
	15	6	5	5	10	14	20	18	19	16	8	2

Validation Scenes  
Post-Adjustment

Test Scenes		WRS Path										
		179	178	177	176	175	174	173	172	171	170	169
WRS ROW	10		17	14	7	0	12	40	32			16
	11	32	9	8	6	20	11		24	12	6	15
	12	10	7	4	4	8	7	16	18	14	22	19
	13	7	13	14	3	13	10	8	16	15	12	16
	14	8	4	3	8	13	15	22	16	15	13	5
	15	6	5	5	10	14	20	18	19	16	8	2

Red indicates scenes that were adjusted in the triangulation.

Red bold indicates path/row locations that contain control points.

Bold outline indicates NGA anchor sites.

Yellow background indicates scenes included in the triangulation.

# Brazil Mato Grosso Block

## Net Geodetic Offset in Meters

Triangulation Scenes  
Pre-Adjustment

Pre-Fit		WRS Path							
		233	232	231	230	229	228	227	226
WRS Row	63	6	17	26	27	12	28	22	<b>24</b>
	64	<b>16</b>	28	39	42	28	28	22	11
	65	20	36	49	52	45	52	45	26
	66	14	32	57	58	58	72	51	30
	67	11	33	53	59	60	73	58	35
	68	11	21	41	45	44	57	37	<b>20</b>
	69	9	15	25	31	27	35	22	9
	70	5	7	17	21	25	27	10	15

Validation Scenes  
Post-Adjustment

Test Scenes		WRS Path							
		233	232	231	230	229	228	227	226
WRS Row	63	6	17	26	27	12	28	22	<b>24</b>
	64	<b>16</b>	15	9	14	4	11	22	11
	65	20	1	9	18	3	9	14	15
	66	14	11	3	2	16	5	10	13
	67	11	7	1	6	4	15	14	16
	68	11	6	3	14	19	5	14	<b>20</b>
	69	9	15	4	14	8	7	22	9
	70	5	7	17	21	25	27	10	15

**Red** indicates scenes that were adjusted in the triangulation.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# Mauritania Block

## Net Geodetic Offset in Meters

Triangulation Scenes  
Pre-Adjustment

Validation Scenes  
Post-Adjustment

Pre-Fit		WRS Path				
		202	201	200	199	198
WRS ROW	44	2	17	14	14	7
	45	5	55	54	25	16
	46	29	100	71	30	18
	47	18	16	30	17	11

Test Scenes		WRS Path				
		202	201	200	199	198
WRS ROW	44	2	17	14	14	7
	45	5	5	3	25	16
	46	29	5	8	15	18
	47	18	16	30	17	11

**Red** indicates scenes for which new GCPs were extracted and then adjusted in the triangulation.

No pre-existing control points were adjusted.

**Bold outline** indicates NGA anchor sites.

**Yellow background** indicates scenes included in the triangulation.

# WorldView Verification Summary

- **Used WorldView data to test at least one scene in each block where control points were readjusted**
  - ◆ Chad and Mauritania had new points extracted and were not tested
- **Consistent with results from L8 validation scenes**

Triangulation Block	Path	Row	# Points	X Mean (m)	Y Mean (m)	X StdDev (m)	Y StdDev (m)
Balearic Islands	196	32	10	-4.50	1.13	7.03	4.35
Balearic Islands	196	33	10	-6.75	-0.38	4.94	4.13
Ryukyu Islands	113	42	26	7.93	0.29	5.84	4.49
Hokkaido	105	30	10	9.75	21.00	6.66	4.74
Hokkaido	107	29	10	-4.50	7.88	5.53	7.17
Hokkaido	108	28	15	-7.25	1.00	7.43	6.41
Mauritius	152	74	20	2.92	-6.18	6.51	3.28
Shetland Islands	205	18	20	-6.38	4.50	7.31	6.51
Galapagos Islands	18	60	20	7.50	2.25	4.39	3.31
Sulawesi, Indonesia	114	59	20	2.81	-9.56	5.82	6.61
Timor, Indonesia	109	66	20	-7.13	-7.13	4.70	9.73
Papua New Guinea	98	63	20	23.44	-12.00	7.49	5.25
Hudson Bay	23	18	20	1.50	-8.06	5.89	6.35
Russian Arctic Coast	174	12	20	7.50	-4.50	4.71	7.26
Mato Grosso, Brazil	228	67	20	-0.94	1.13	3.41	4.57
Mato Grosso, Brazil	229	67	20	6.75	6.75	5.52	9.15
Saudi Desert	163	46	10	3.75	-10.13	9.52	15.52
<b>Totals</b>	17	scenes	291	2.14	-0.71	6.21	7.03