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Australian Government

Department of Defence

Defence Science and
Technology Organisation

Scheduling multi-spectral collection of the Australian landmass using a 6U cubesat constellation

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Outline

- Problem we are addressing
- Scheduling tool we are using
- Scope of our analysis
- Our modelling approach
 - 6U cubesat
 - Hypothetical constellations
- Scheduling results for a single day
 - Impact of constraints related to data storage & downlink
 - Impact of cloud
- Conclusions & further work

The Problem



GA: Continuity of Earth Observation Data for Australia, Hudson 2011

Collection Planning & Analysis Workstation (CPAW)



- Schedule collections by imaging satellites
- Electro-optic & Synthetic Aperture Radar
- Operationally proven heritage
- High fidelity spacecraft modelling
- Multiple advanced scheduling algorithms
- U.S. International Traffic in Arms Regulations

Includes constraints related to:

1. Solid state recorder capacity
2. Downlink
3. Battery
4. Cloud

The screenshot displays the CPAW Workstation interface with a 'Control/Status' window and a main 'Scenes' table. The 'Control/Status' window shows details for a specific mission (DEMOSAT1_20100501000002010070100000) including CP ID, OB_ID, Ephemeris, Weather, and various status indicators. The 'Scenes' table lists individual tasks with columns for Index, Task Order, Strip, Priority, Area, Score, Status, DCF, Max CC/Strip, Angle/OR, Node/GSD, Stereo, Imaging Start Time, Duration, Start/End (LON, ENA), Access, Access Start Time, and Access End Time.

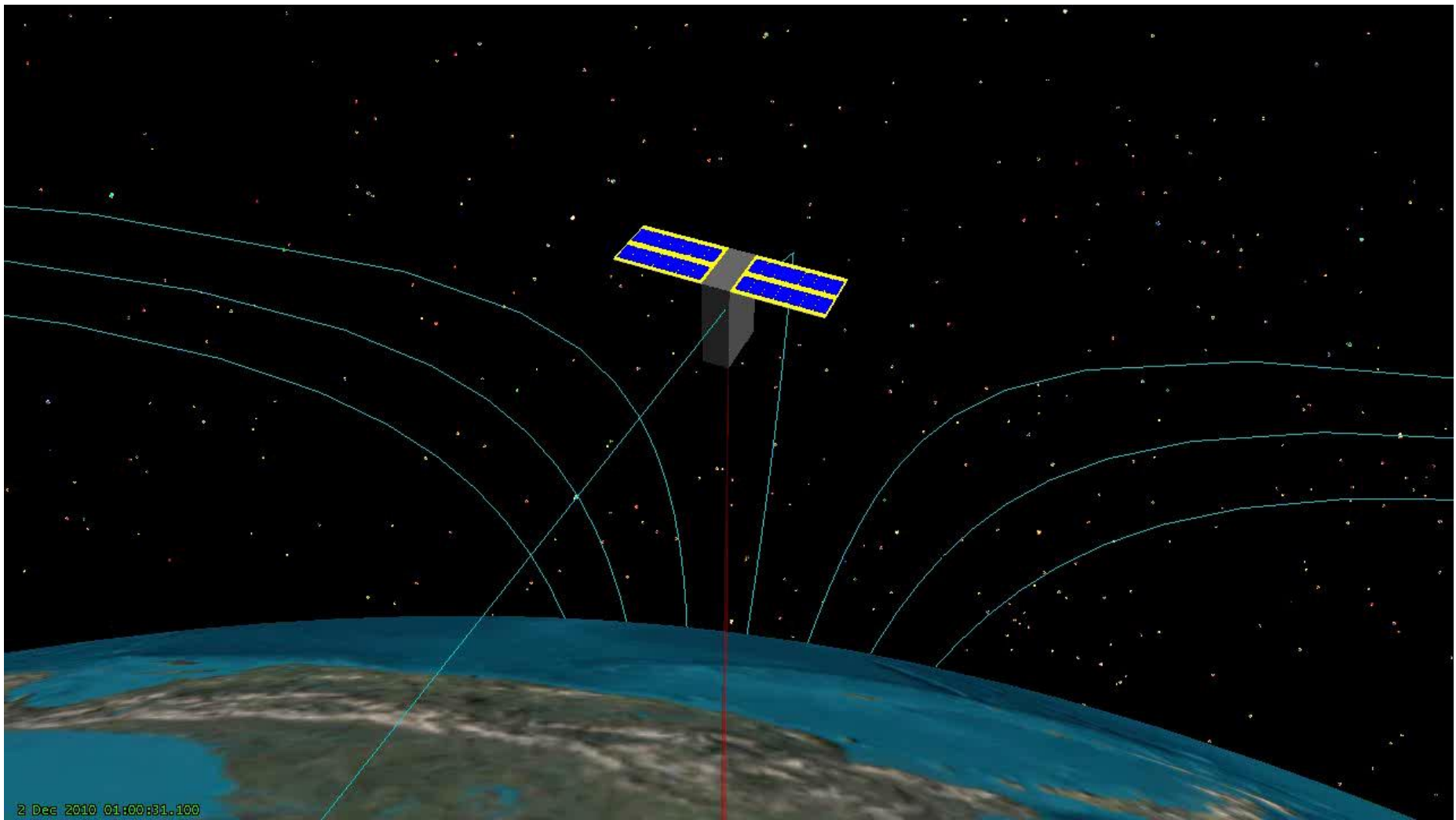
Index	Task Order	Strip	Priority	Area	Score	Status	DCF	Max CC/Strip	Angle/OR	Node/GSD	Stereo	Imaging Start Time	Duration	Start/End (LON, ENA)	Access	Access Start Time	Access End Time				
1	Image0	Image0_0	100	809	420	Available	-1	100	0.0	0.0	-	2010-05-15T03:00:00.000Z	7.6	N	12.266	11.262	2010-05-15T03:02:08.000Z	2010-05-15T03:04:05.000Z	2010-05-15T03:02:08.000Z	2010-05-15T03:04:05.000Z	
2	Image0	Image0_1	100	857	414	Available	-1	100	0.0	0.0	-	2010-05-15T03:00:00.000Z	6.8	N	13.338	12.431	2010-05-15T03:02:16.000Z	2010-05-15T03:04:04.000Z	2010-05-15T03:02:16.000Z	2010-05-15T03:04:04.000Z	
3	Image0	Image0_2	100	790	451	Available	-1	100	0.0	0.0	-	2010-05-15T03:00:00.000Z	6.2	N	14.38	13.393	2010-05-15T03:02:11.000Z	2010-05-15T03:04:04.000Z	2010-05-15T03:02:11.000Z	2010-05-15T03:04:04.000Z	
4	Image0	Image0_3	100	863	388	Available	-1	100	0.0	0.0	-	2010-05-15T03:00:00.000Z	5.4	N	15.424	14.736	2010-05-15T03:02:13.000Z	2010-05-15T03:04:03.000Z	2010-05-15T03:02:13.000Z	2010-05-15T03:04:03.000Z	
5	Image0	Image0_4	100	586	376	Available	-1	100	0.0	0.0	-	2010-05-15T03:00:00.000Z	4.8	N	16.45	15.887	2010-05-15T03:02:07.000Z	2010-05-15T03:04:02.000Z	2010-05-15T03:02:07.000Z	2010-05-15T03:04:02.000Z	
6	Image0	Image0_5	100	566	374	Available	-1	100	0.0	0.0	-	2010-05-15T03:00:00.000Z	4.8	N	17.617	16.953	2010-05-15T03:02:17.000Z	2010-05-15T03:04:02.000Z	2010-05-15T03:02:17.000Z	2010-05-15T03:04:02.000Z	
7	Image1	Image1_0	100	1331	488	Available	-1	100	0.0	0.0	-	2010-05-15T03:00:00.000Z	10.8	N	10.54	1.48	2010-05-15T03:01:10.000Z	2010-05-15T03:03:18.200Z	2010-05-15T03:01:10.200Z	2010-05-15T03:03:18.200Z	
8	Image1	Image1_1	100	1320	485	Included	-1	100	0.0	0.0	848	-	-	-	-	27.568	29.25	2010-05-15T03:01:08.000Z	2010-05-15T03:03:17.400Z	2010-05-15T03:01:08.000Z	2010-05-15T03:03:17.400Z
9	Image1	Image1_2	100	1700	510	Included	-1	100	0.0	0.0	793	-	-	-	-	19.85	17.847	2010-05-15T03:02:00.000Z	2010-05-15T03:03:14.800Z	2010-05-15T03:02:00.000Z	2010-05-15T03:03:14.800Z
10	Image1	Image1_3	100	1601	511	Included	-1	100	0.0	0.0	708	-	-	-	-	10.509	8.281	2010-05-15T03:01:06.000Z	2010-05-15T03:03:15.200Z	2010-05-15T03:01:06.000Z	2010-05-15T03:03:15.200Z
11	Image1	Image1_4	100	423	387	Available	-1	100	0.0	0.0	-	-	-	-	7.115	6.633	2010-05-15T03:01:16.000Z	2010-05-15T03:03:14.000Z	2010-05-15T03:01:16.000Z	2010-05-15T03:03:14.000Z	
12	Image2	Image2_0	100	800	438	Available	-1	100	0.0	0.0	-	-	-	-	6.36	7.288	2010-05-15T03:04:01.000Z	2010-05-15T03:05:06.000Z	2010-05-15T03:04:01.000Z	2010-05-15T03:05:06.000Z	
13	Image2	Image2_1	100	872	418	Included	-1	100	0.0	0.0	816	-	-	-	25.035	23.49	2010-05-15T03:03:36.000Z	2010-05-15T03:05:06.000Z	2010-05-15T03:03:36.000Z	2010-05-15T03:05:06.000Z	
14	Image2	Image2_2	100	863	423	Included	-1	100	0.0	0.0	78	-	-	-	19.254	17.903	2010-05-15T03:03:37.000Z	2010-05-15T03:05:06.000Z	2010-05-15T03:03:37.000Z	2010-05-15T03:05:06.000Z	
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19	Image3	Image3_2	100	1518	499	Available	-1	100	0.0	0.0	-	-	-	-	20.737	19.342	2010-05-15T03:05:00.000Z	2010-05-15T03:04:43.000Z	2010-05-15T03:05:00.000Z	2010-05-15T03:04:43.000Z	
20	Image3	Image3_3	100	1861	499	Available	-1	100	0.0	0.0	-	-	-	-	21.819	20.371	2010-05-15T03:03:48.000Z	2010-05-15T03:04:43.000Z	2010-05-15T03:03:48.000Z	2010-05-15T03:04:43.000Z	
21	Image3	Image3_4	100	1680	500	Available	-1	100	0.0	0.0	-	-	-	-	22.876	21.388	2010-05-15T03:03:48.000Z	2010-05-15T03:04:43.000Z	2010-05-15T03:03:48.000Z	2010-05-15T03:04:43.000Z	
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24	Image3	Image3_7	100	527	330	Available	-1	100	0.0	0.0	-	-	-	-	24.58	24.544	2010-05-15T03:03:51.000Z	2010-05-15T03:04:42.000Z	2010-05-15T03:03:51.000Z	2010-05-15T03:04:42.000Z	
25	Image4	Image4_0	100	2085	500	Included	-1	100	0.0	0.0	789	-	-	-	22.866	20.243	2010-05-15T03:04:54.000Z	2010-05-15T03:05:06.000Z	2010-05-15T03:04:54.000Z	2010-05-15T03:05:06.000Z	
26	Image4	Image4_1	100	2080	500	Available	-1	100	0.0	0.0	-	-	-	-	23.859	22.038	2010-05-15T03:04:59.000Z	2010-05-15T03:05:06.000Z	2010-05-15T03:04:59.000Z	2010-05-15T03:05:06.000Z	
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Scope

- Not a comprehensive feasibility analysis of Tsitas & Kingston design
 - Alternative designs have been considered
- Only a subset of the key issues have been considered:
 - Mission planning
 - Orbit design
 - Ground station network
- Key issues not considered include:
 - Sensor design
 - Launch of cubesats
 - Station-keeping
 - Detailed cost estimates

6U Cubesat

Parameter	Cubesat 1	Cubesat 2
Ground Sample Distance	23.5 m	6.5 m
Swath width	94 km	26 km
Downlink rate	5.4 Mbps	
Max power generation	35 W (T-wing)	

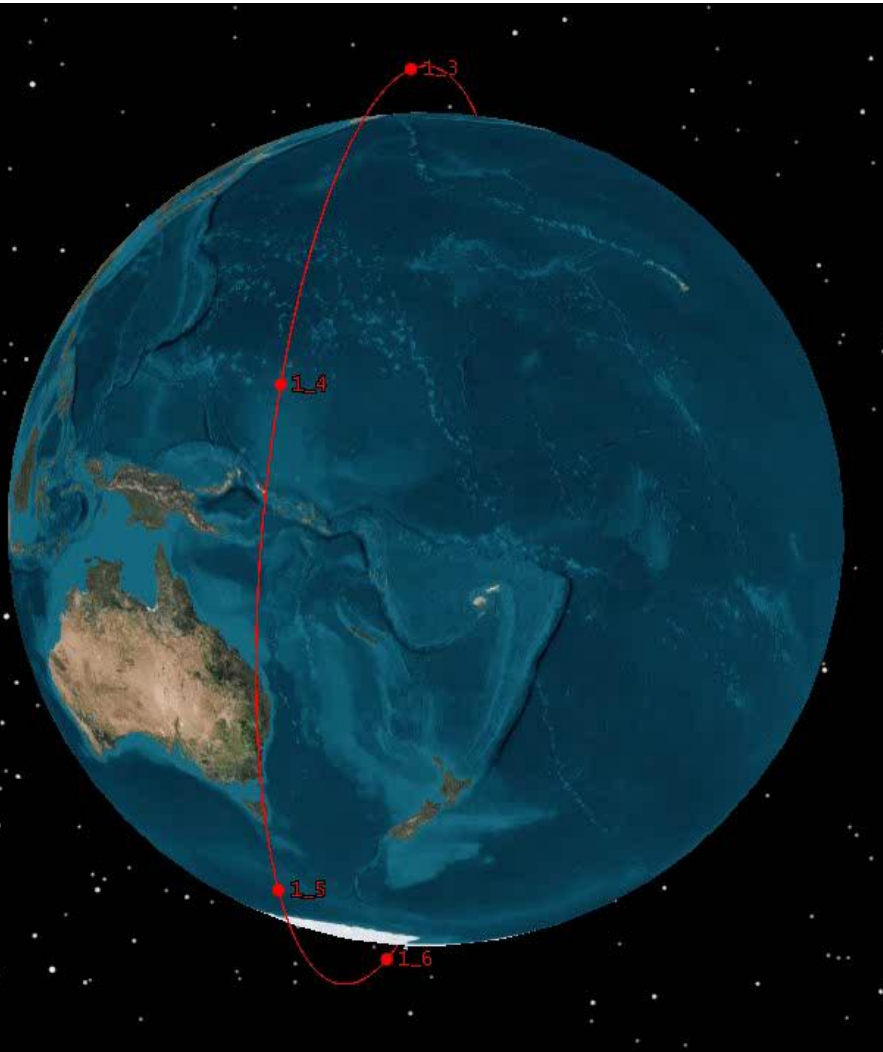


Constellation Parameters

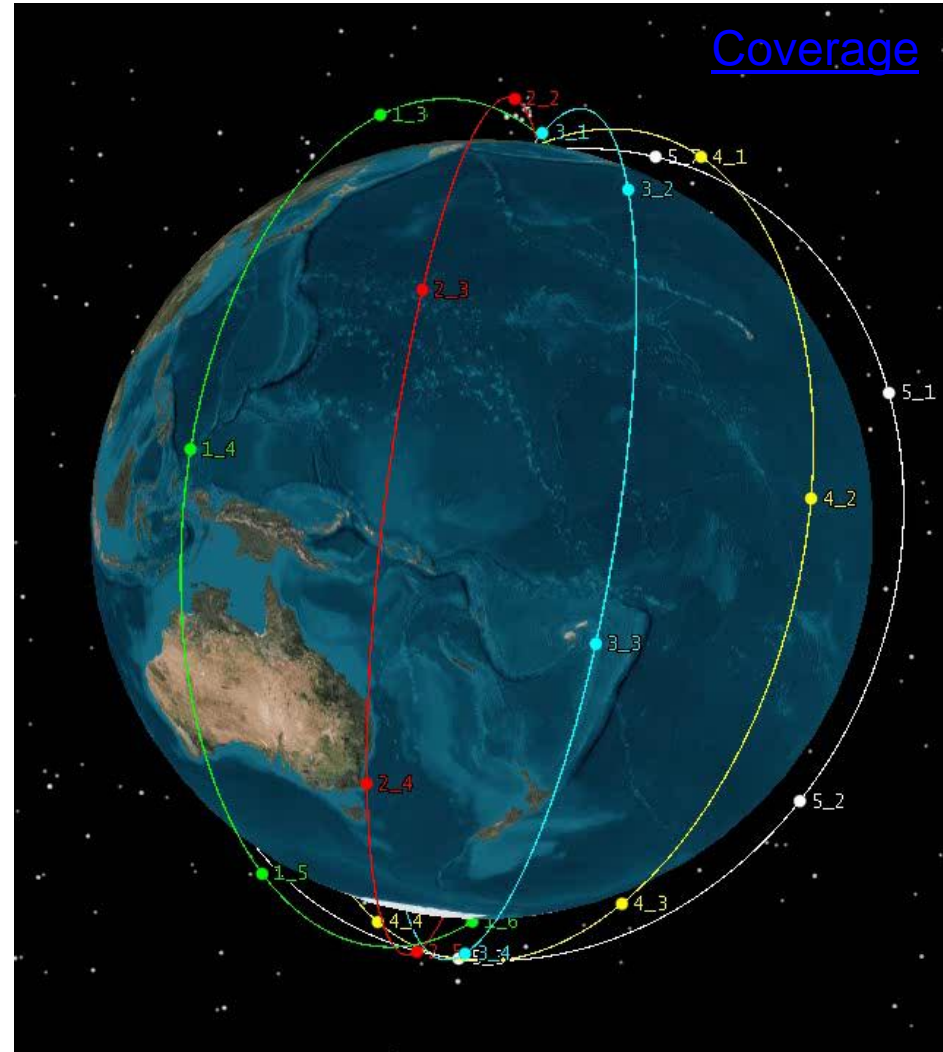
Parameter	Medium Resolution Constellation	High Resolution Constellation
Satellites per orbit plane	7	7
Orbit planes	1	5
Local time of equatorial descending pass	10:30	9:00, 10:30, 12:00 13:30, 15:00
Ground Sample Distance	23.5m	6.5m
Cost (1 sat = US \$1.3M)	US \$9.1M	US \$45M
Analogous system	ResourceSat-1	RapidEye

Constellations

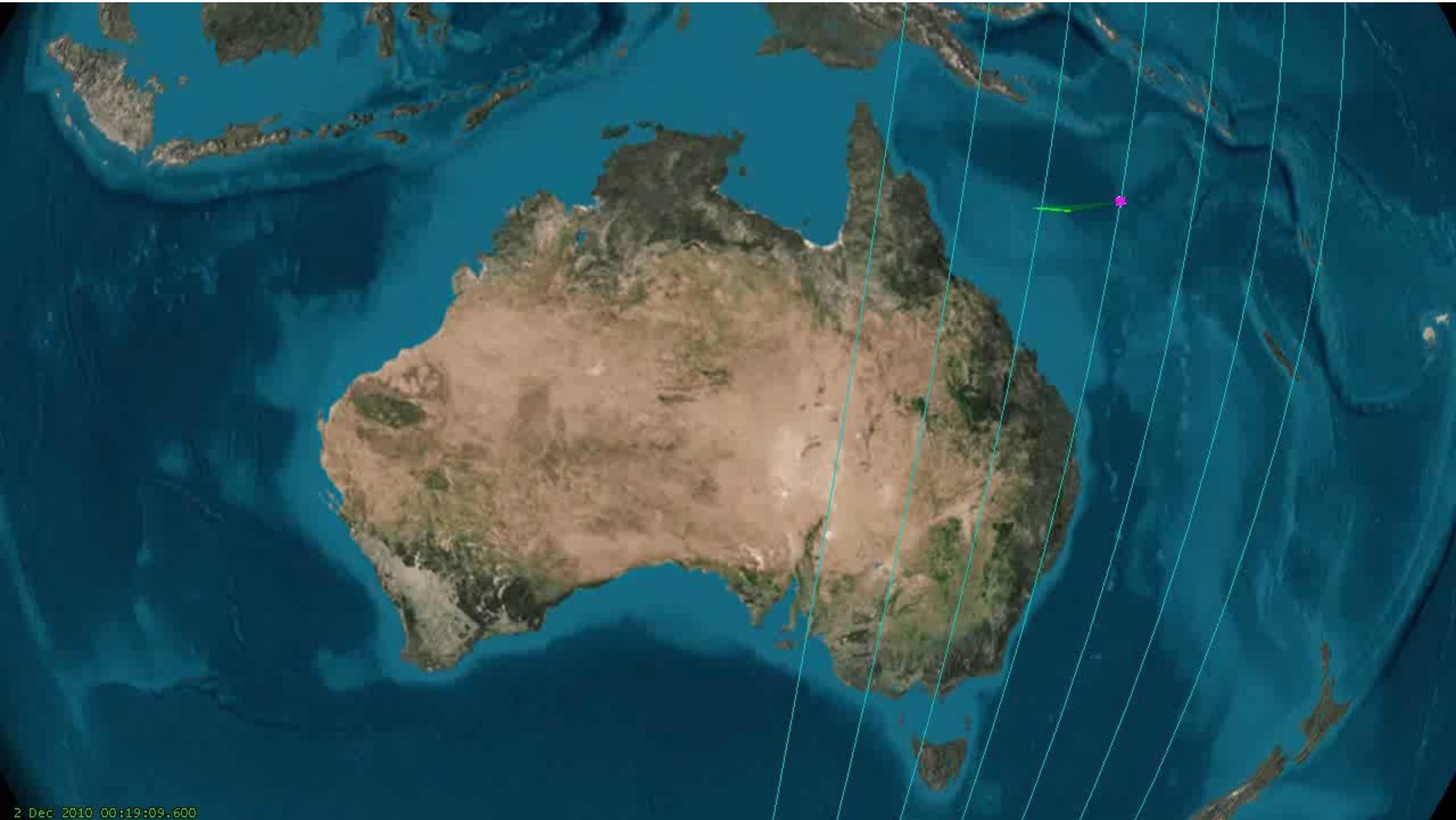
Medium Resolution



High Resolution



Example Collection Plan



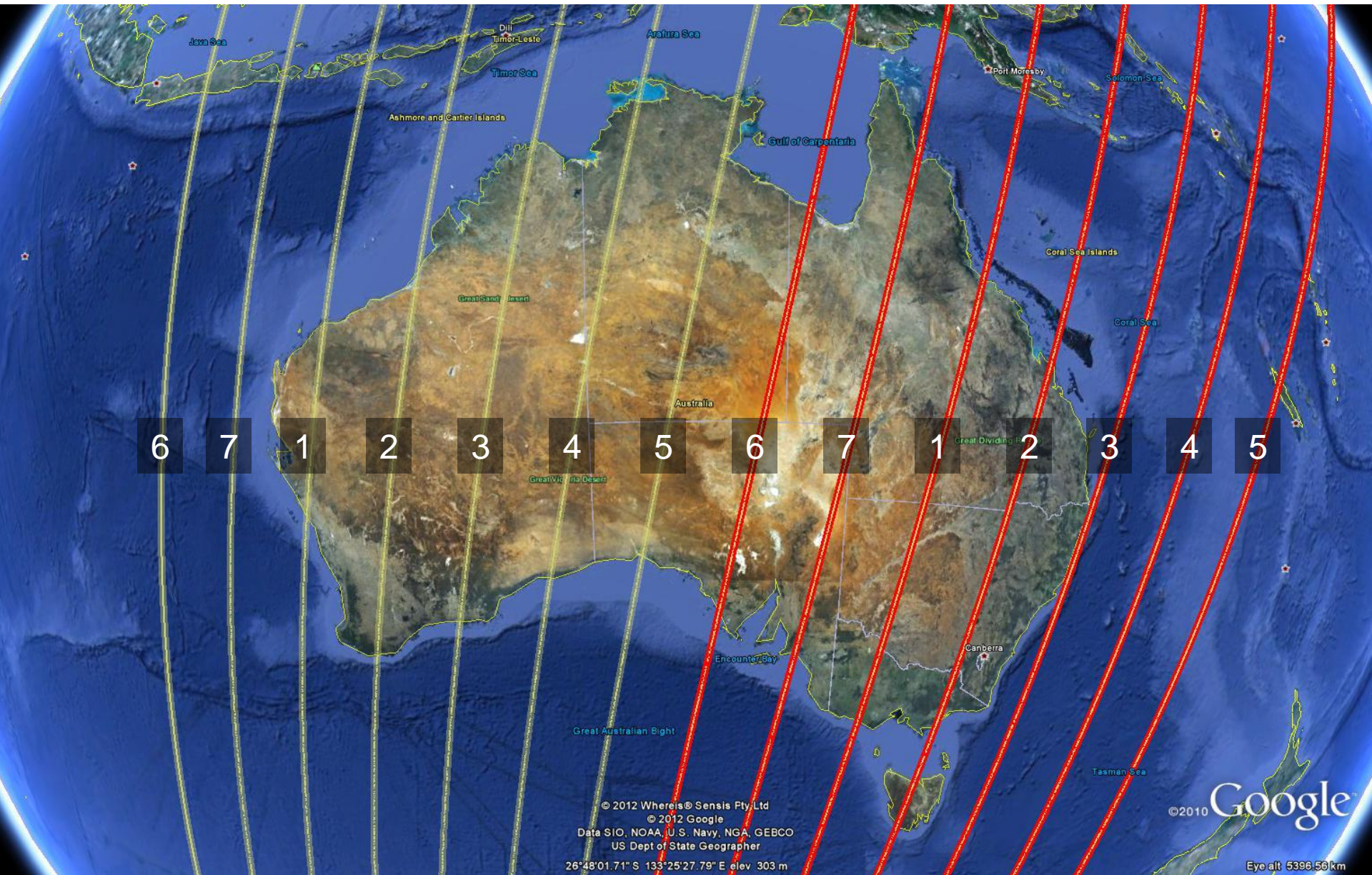
Overview of results

- Aim is to image entire landmass of Australia daily
- Scheduling results are presented for a single day
- Analysis:
 - Impact of including constraints related to data storage & downlink
 - Impact of cloud
- Impact of power budget not yet considered

Area of Australia - 7,741,220 km²

1 Day - 7 satellites - 14 Passes

Medium Resolution



6 7 1 2 3 4 5 6 7 1 2 3 4 5

Area of Australia - 7,741,220 km²

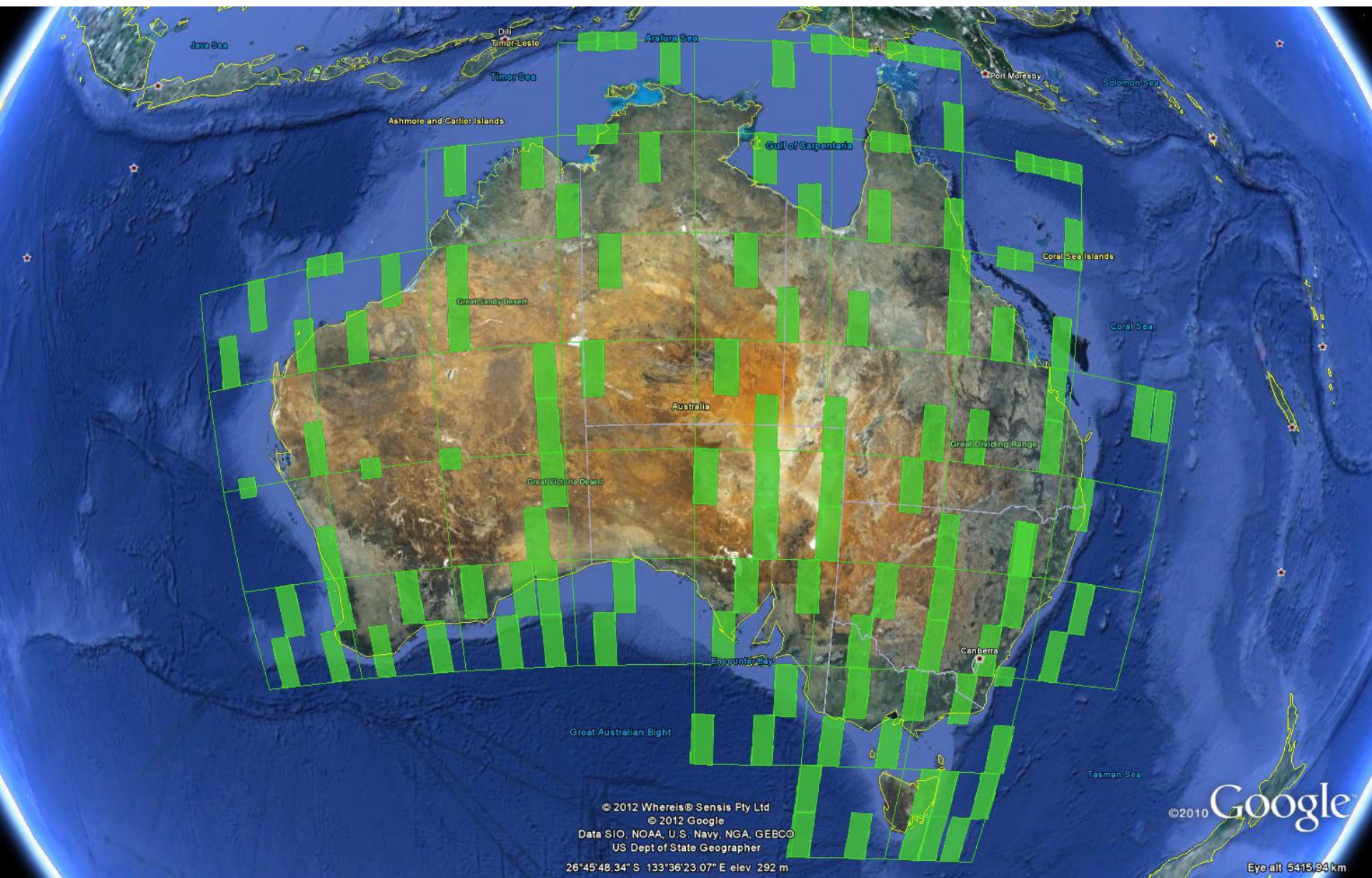
Area Collected – 2,670,592 km²

Percentage – 34%

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7 satellites, no data constraint

Medium Resolution



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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer

26°45'48.34" S 133°36'23.07" E elev 292 m

©2010 Google

Eye alt 5415.94 km

Area of Australia - 7,741,220 km²

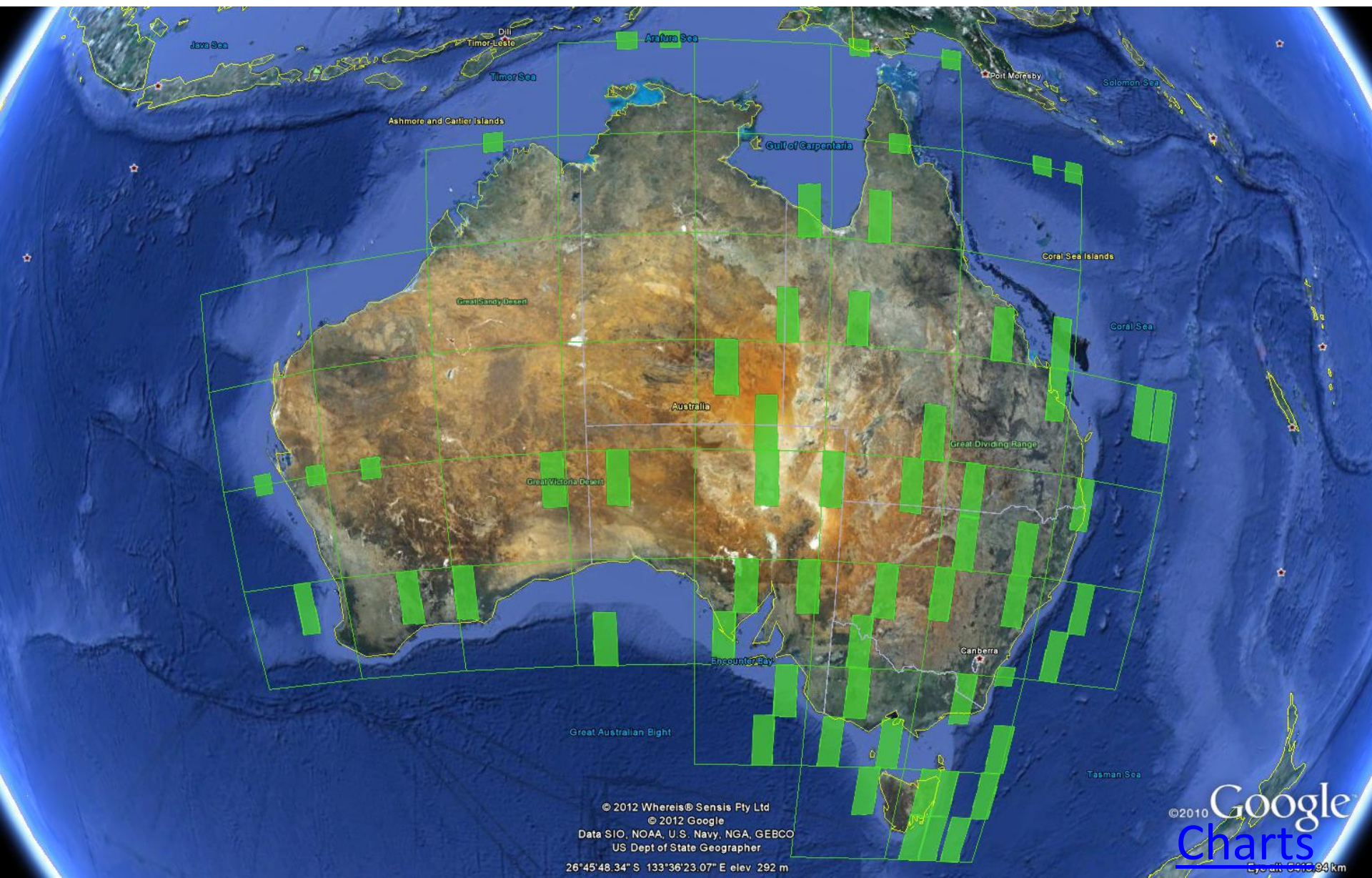
Area Collected – 1,417,530 km²

Percentage – 18%

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7 satellites, data constraint

Medium Resolution



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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer
26°45'48.34" S 133°36'23.07" E elev 292 m

©2010 Google
Charts
Eye alt: 660.94 km

Area of Australia - 7,741,220 km²

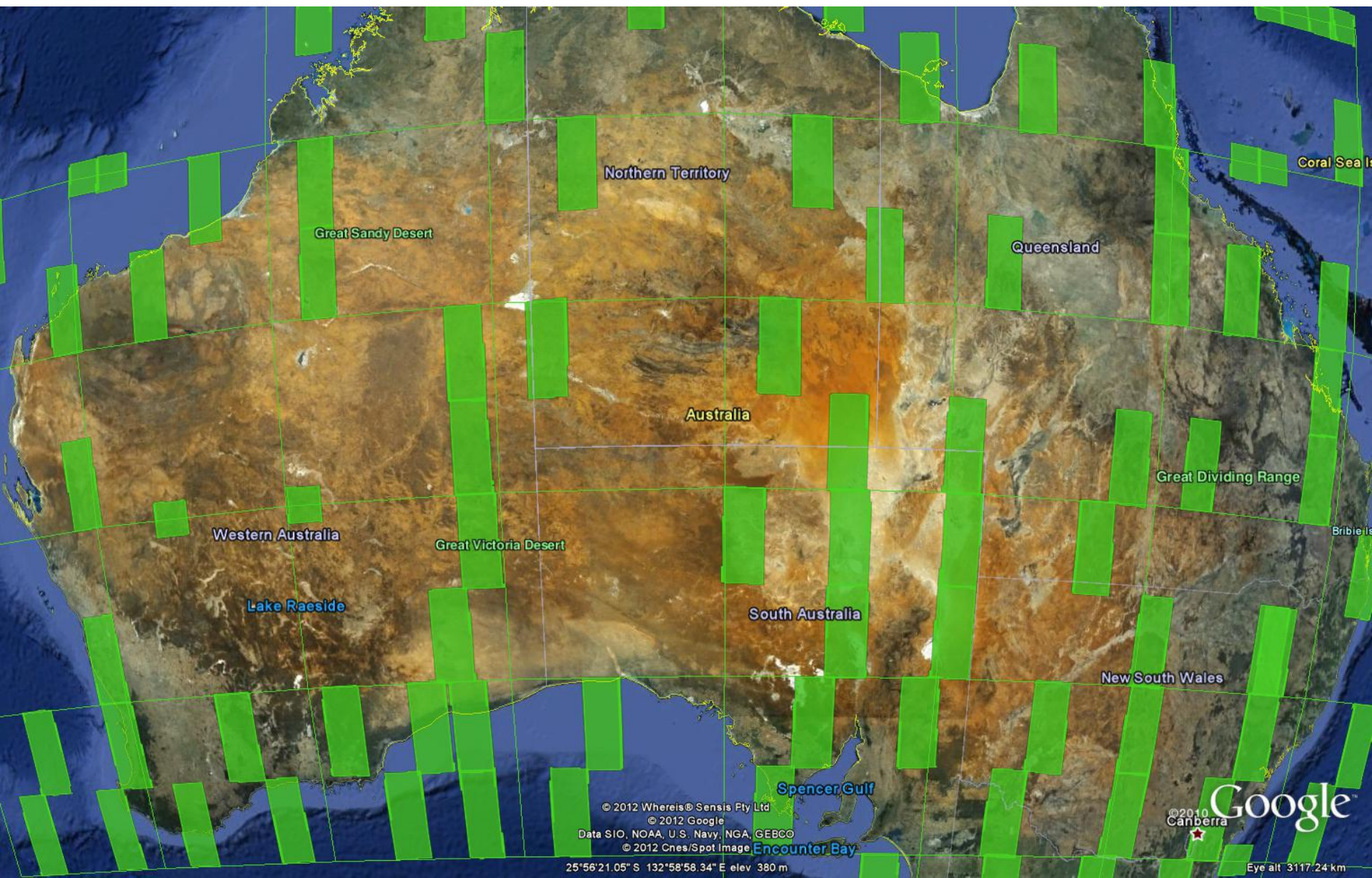
Area Collected – 2,670,592 km²

Percentage – 34%

7 satellites, no data constraint

Medium Resolution

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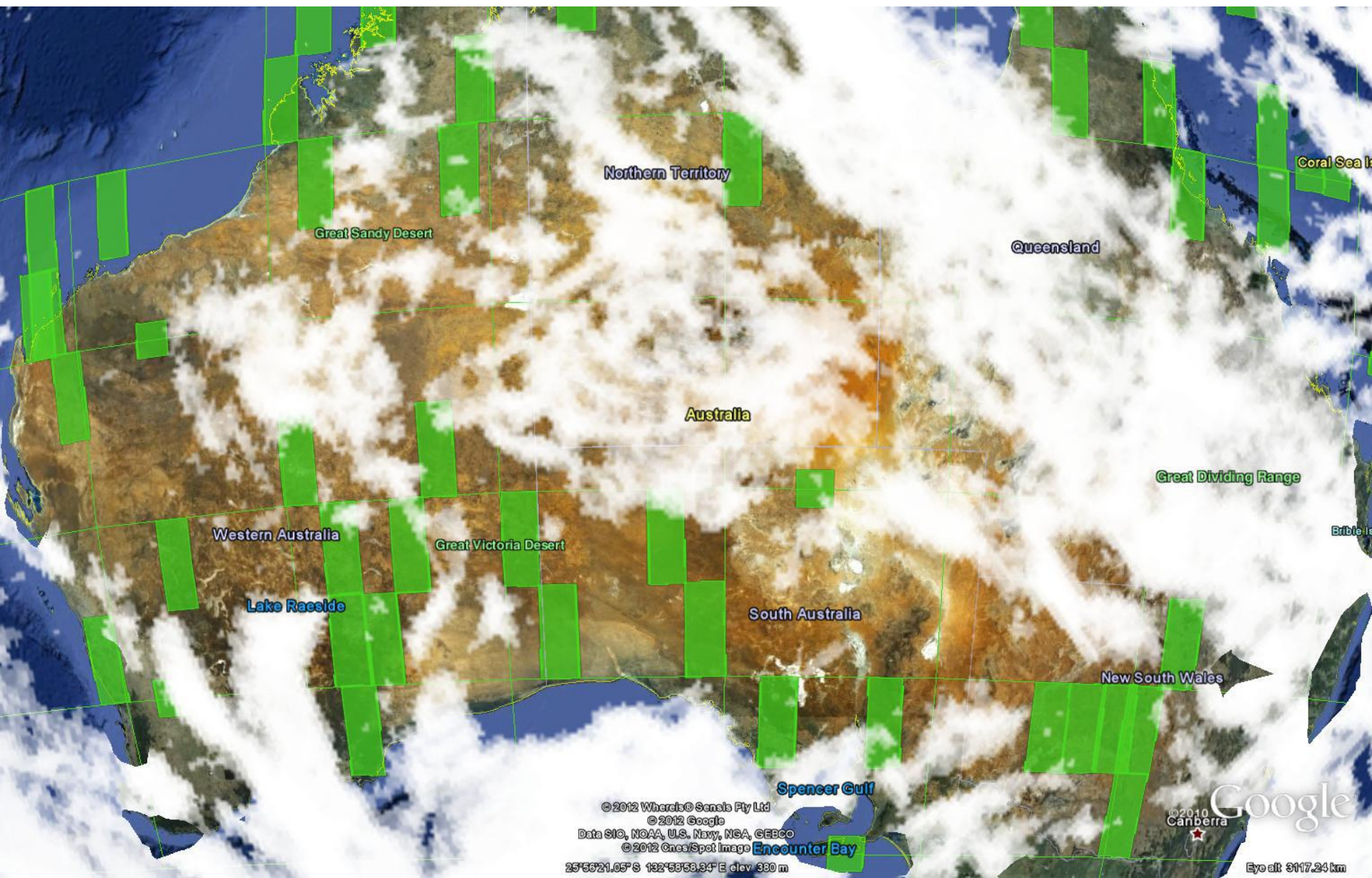
Area of Australia - 7,741,220 km²

Area Collected – 1,323,645 km²

Percentage – 17%

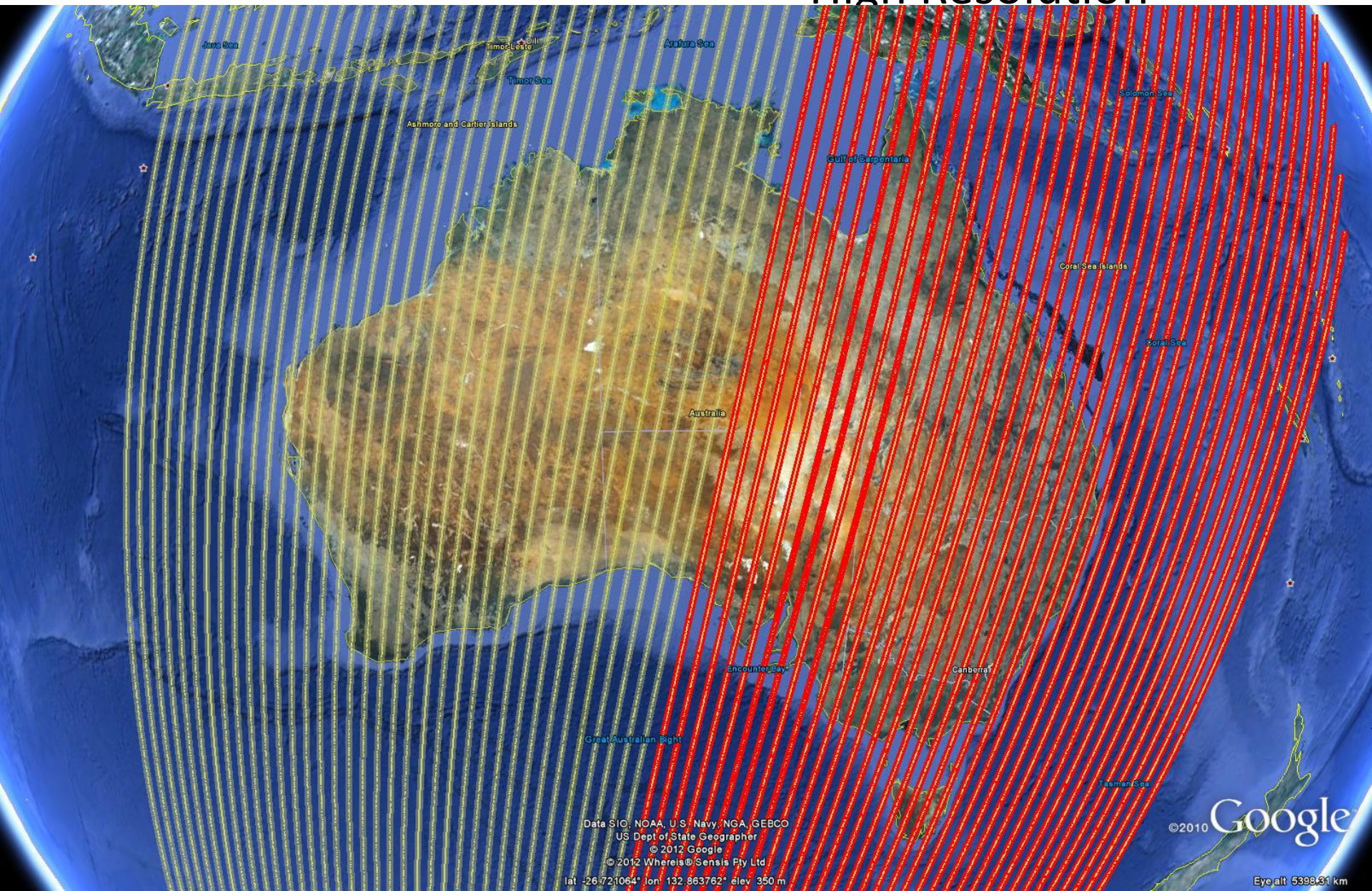
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7 satellites, cloud constraint

Medium Resolution



Area of Australia - 7,741,220 km²

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1 Day - 35 satellites – 70 Passes
High Resolution



Area of Australia - 7,741,220 km²

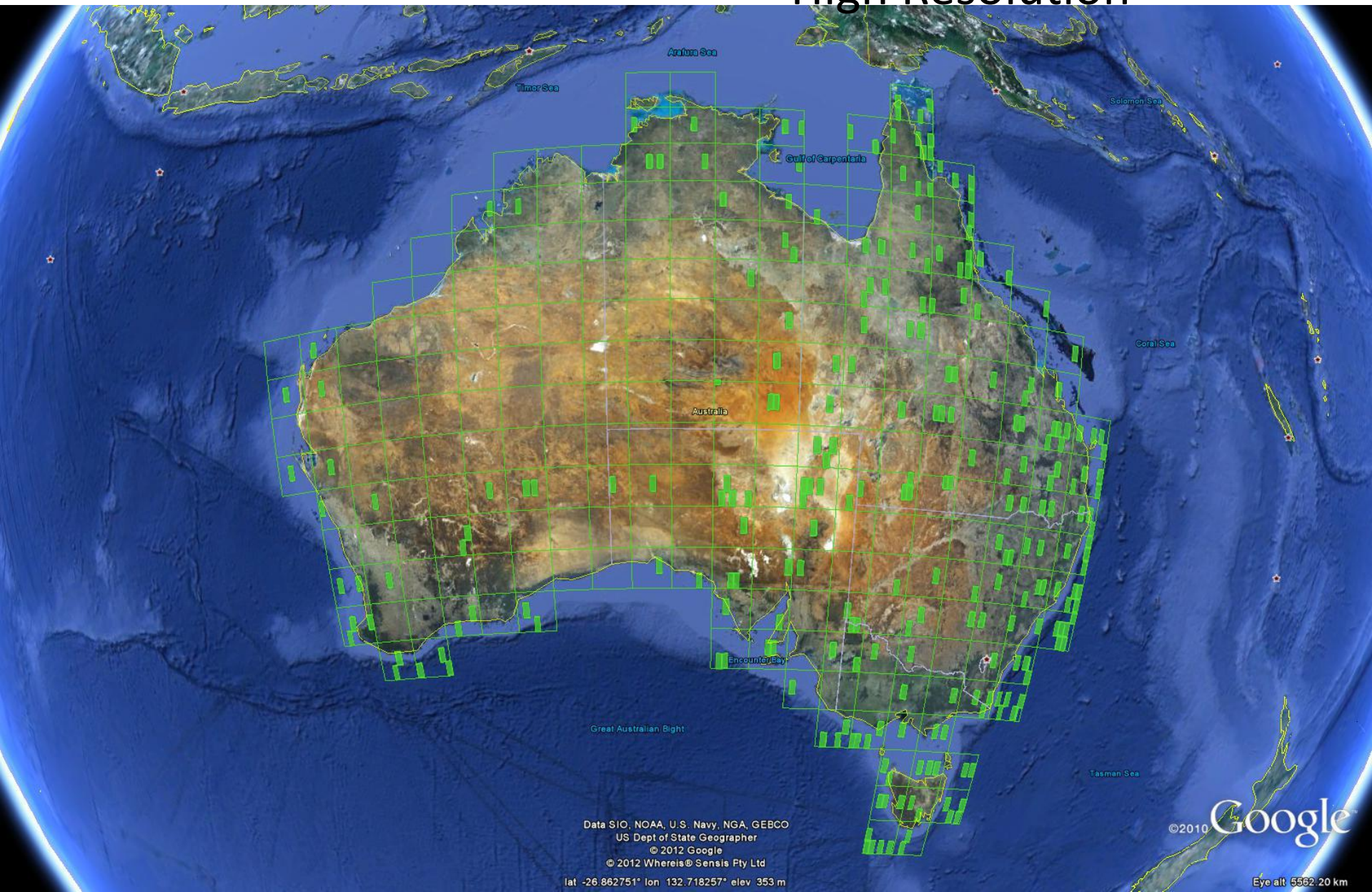
Area Collected – 533,806 km²

Percentage – 7%

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35 satellites, data constraint

High Resolution



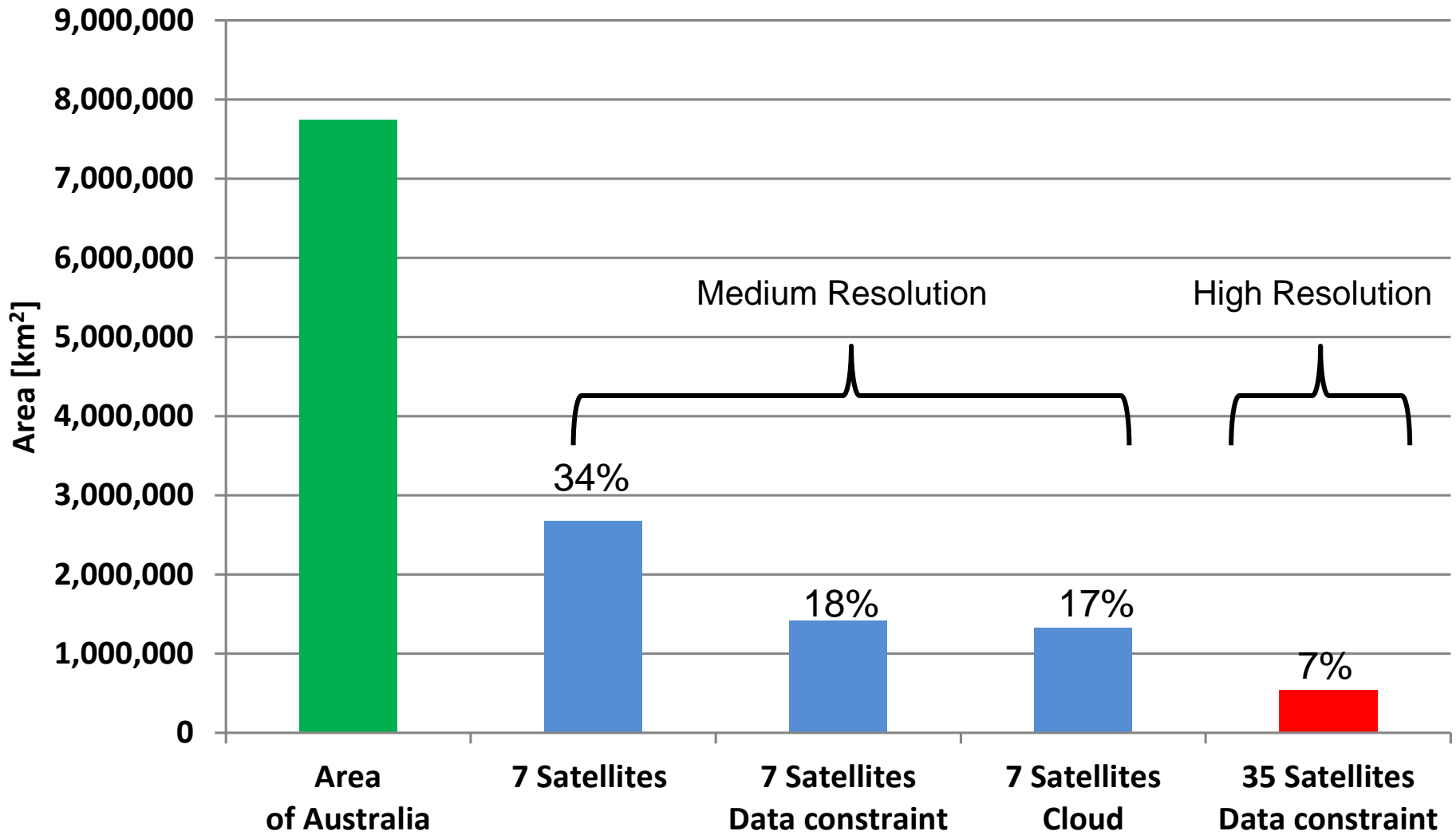
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer
© 2012 Google
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lat -26.862751° lon 132.718257° elev 353 m

© 2010 Google

Eye alt 6562.20 km

Results Summary

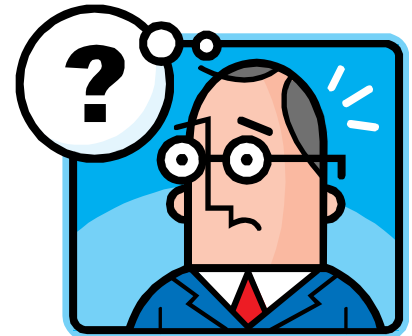


Conclusions & Further Work

- CPAW is a valuable tool for assessing mission effectiveness
- Constraints associated with data flow are a bottleneck in the analysed 6U cubesat systems
- It is essential to include cloud forecasts in the assessment
- Future work includes:
 - Gain better understanding of constraints related to:
 - Power
 - Star tracker pointing
 - Explore alternative options for the ground station network

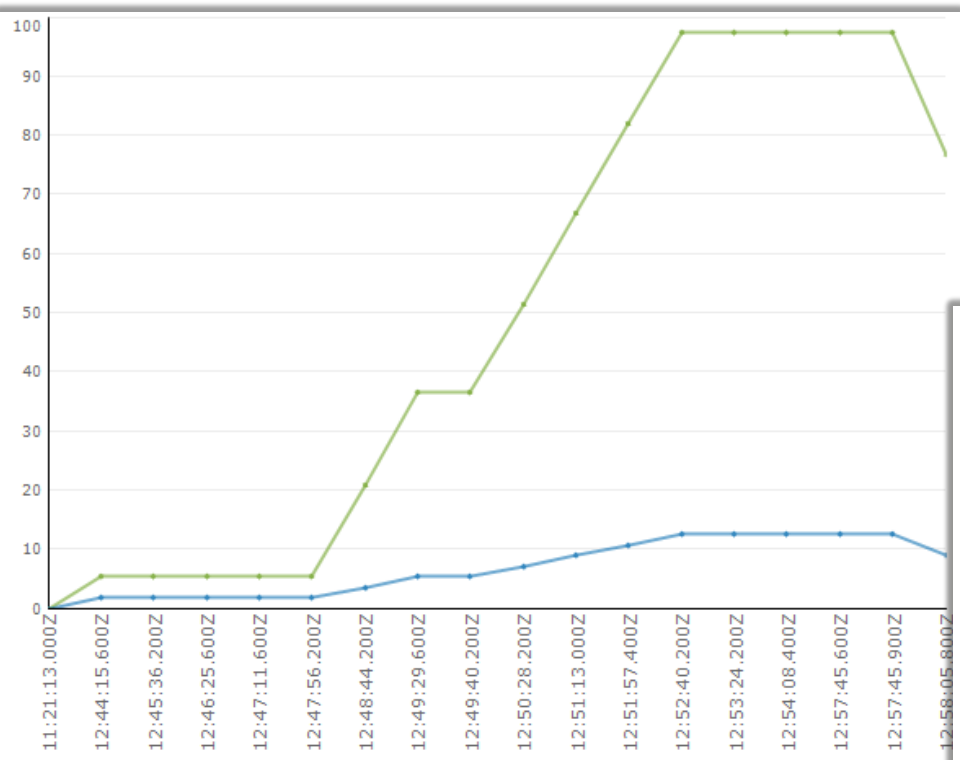


Questions??

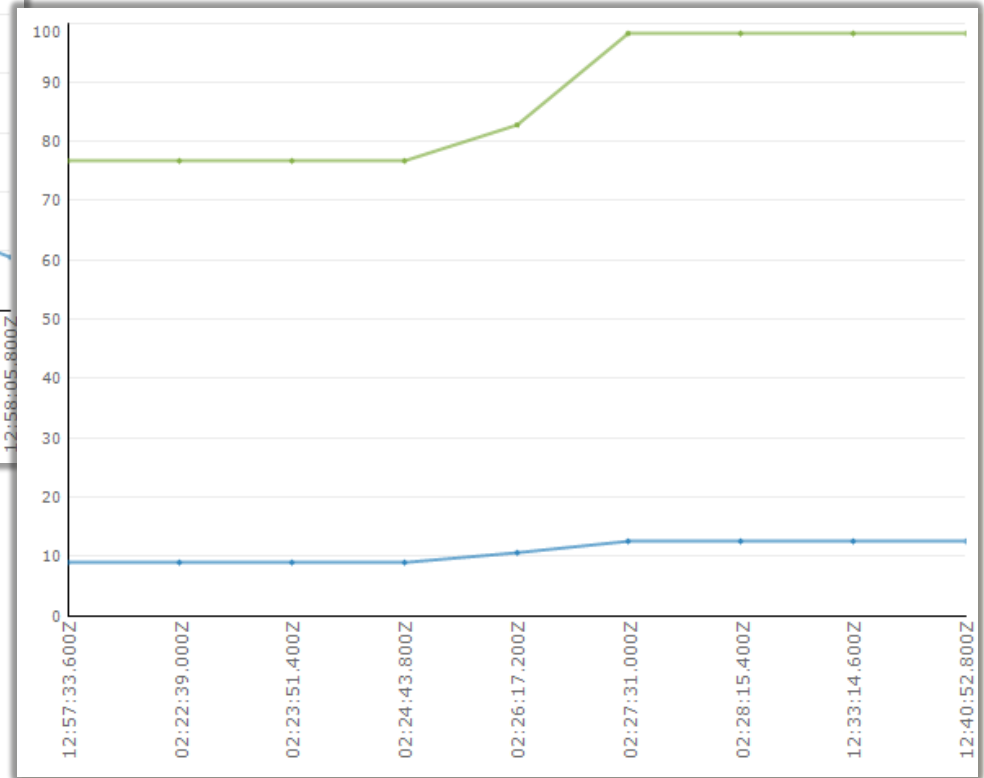


SSR state

1st pass



2nd pass



Coverage by Constellations

Medium Resolution



High Resolution



[Return](#)