

ICG WG-B Intercessional Meeting

NASA Status Update

National Aeronautics and
Space Administration



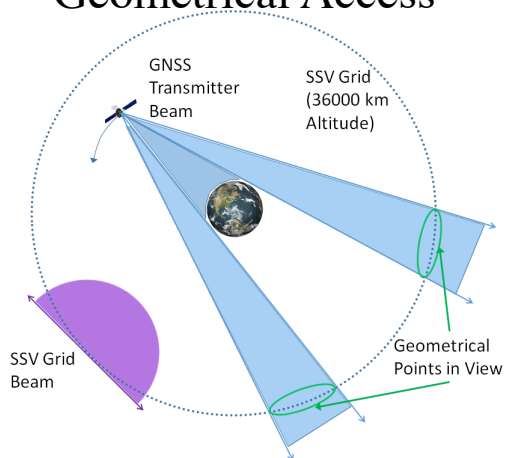
Joel J. K. Parker
June 8, 2016

www.nasa.gov

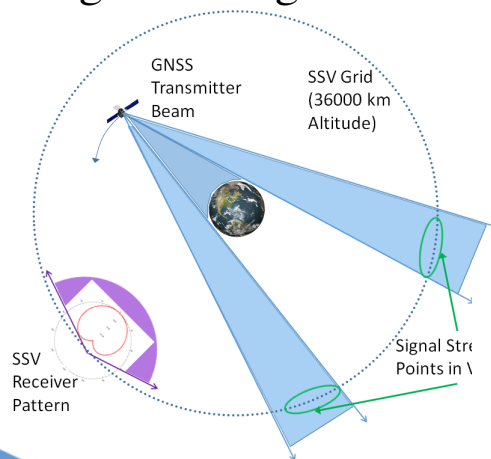


Three-Phase Analysis Approach

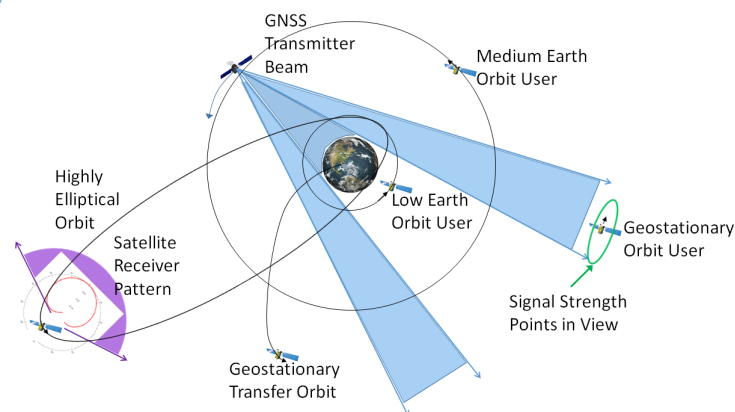
Phase 1: Geometrical Access



Phase 2: Signal Strength Access



Phase 3: Specific User Missions



Increasing Complexity

Increasing Fidelity



Three-Phase Analysis Status



Phase 1 Activities	Status
Orbit Propagation Technique	Complete
Geometrical-Based Access Calculation Technique	Complete
Figure of Merit Calculations	Complete
Documentation in ICG WG-B Booklet	In-Work
Phase 2 Activities	Status
RF Link Budget Technique	Planning
Geometrical/RF-Based Access Calculation Technique	Not Yet Started
Figure of Merit Calculations	Not Yet Started
Documentation in ICG WG-B Booklet	Not Yet Started
Phase 3 Activities	Status
Derive User-Specific Missions	Planning
RF-Based Access Calculation Technique	Not Yet Started
Figure of Merit Calculations	Not Yet Started
Documentation in ICG WG-B Booklet	Not Yet Started



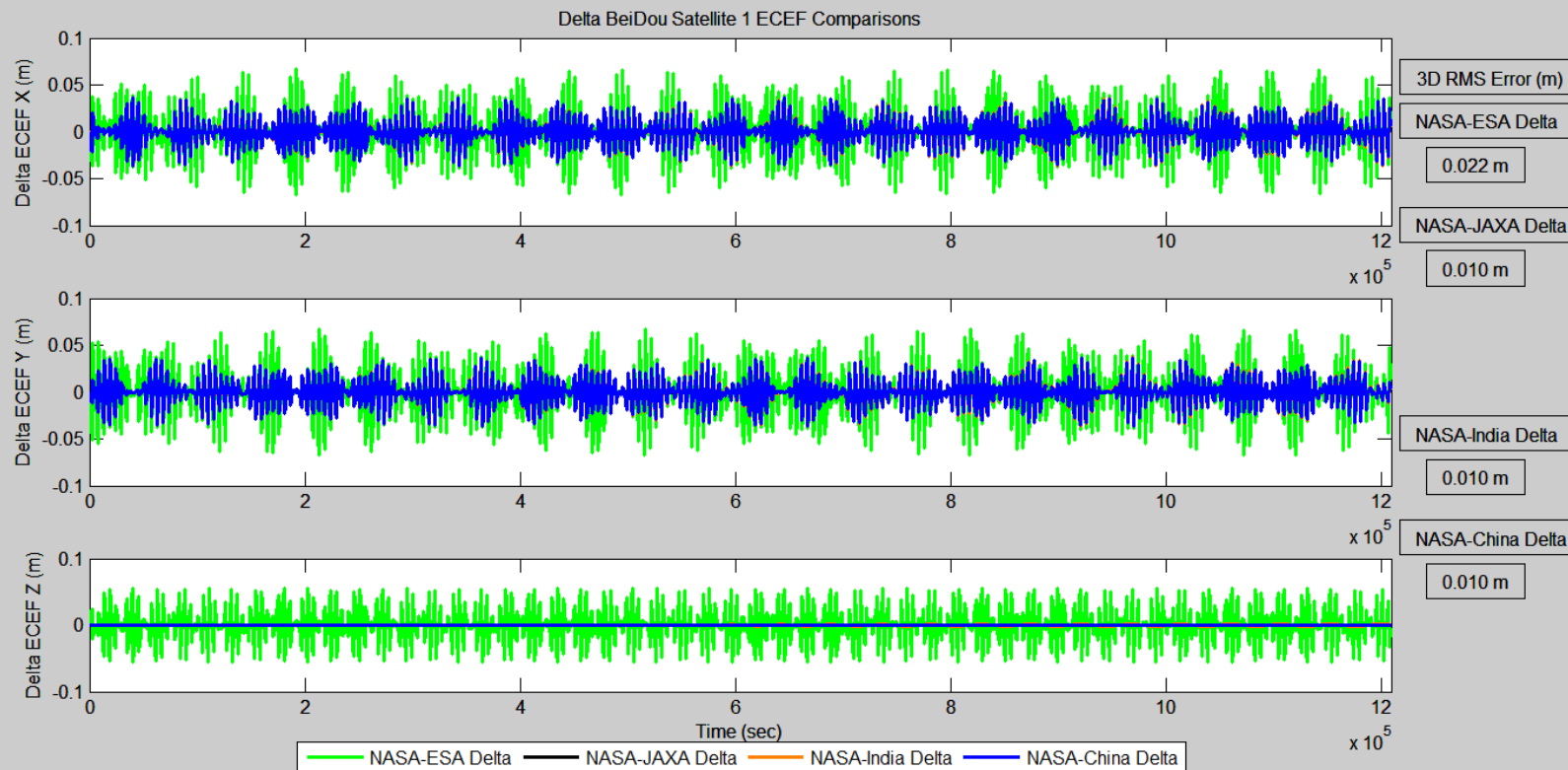
PHASE 1 FULL RESULTS PROPAGATION COMPARISONS



Orbit Propagation Alignment - BeiDou



BeiDou Satellite 1

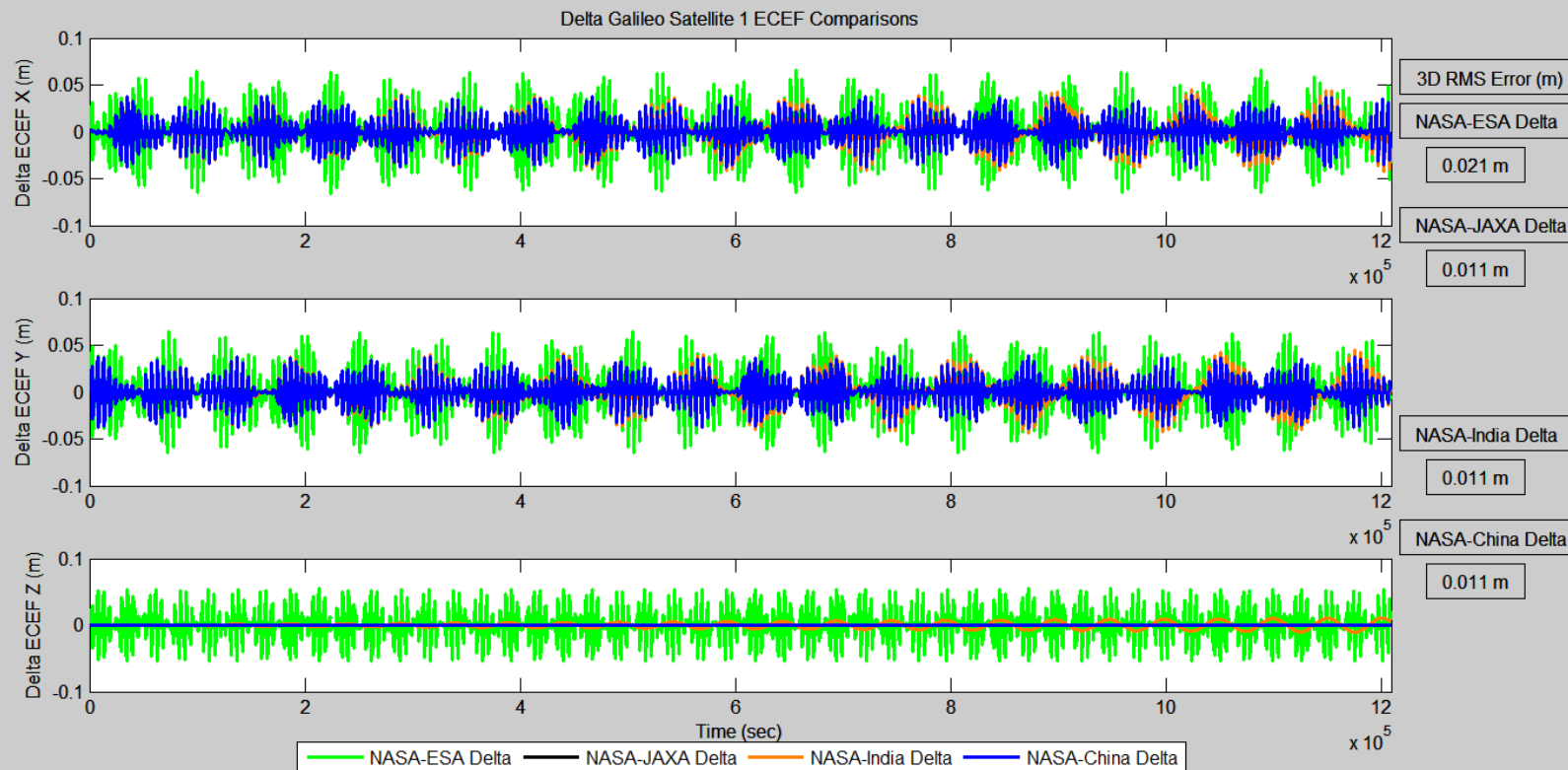




Orbit Propagation Alignment - Galileo



Galileo Satellite 1

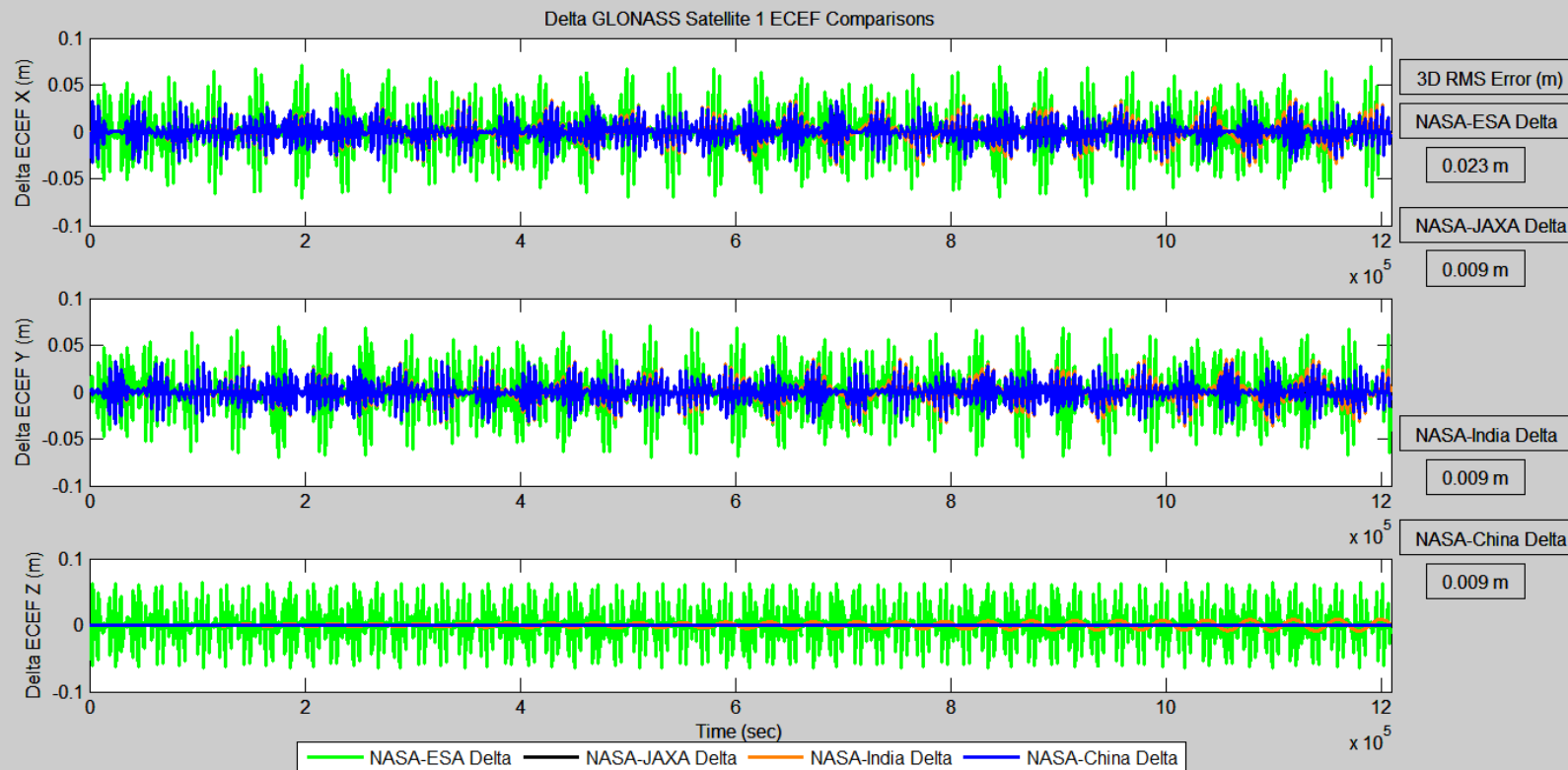




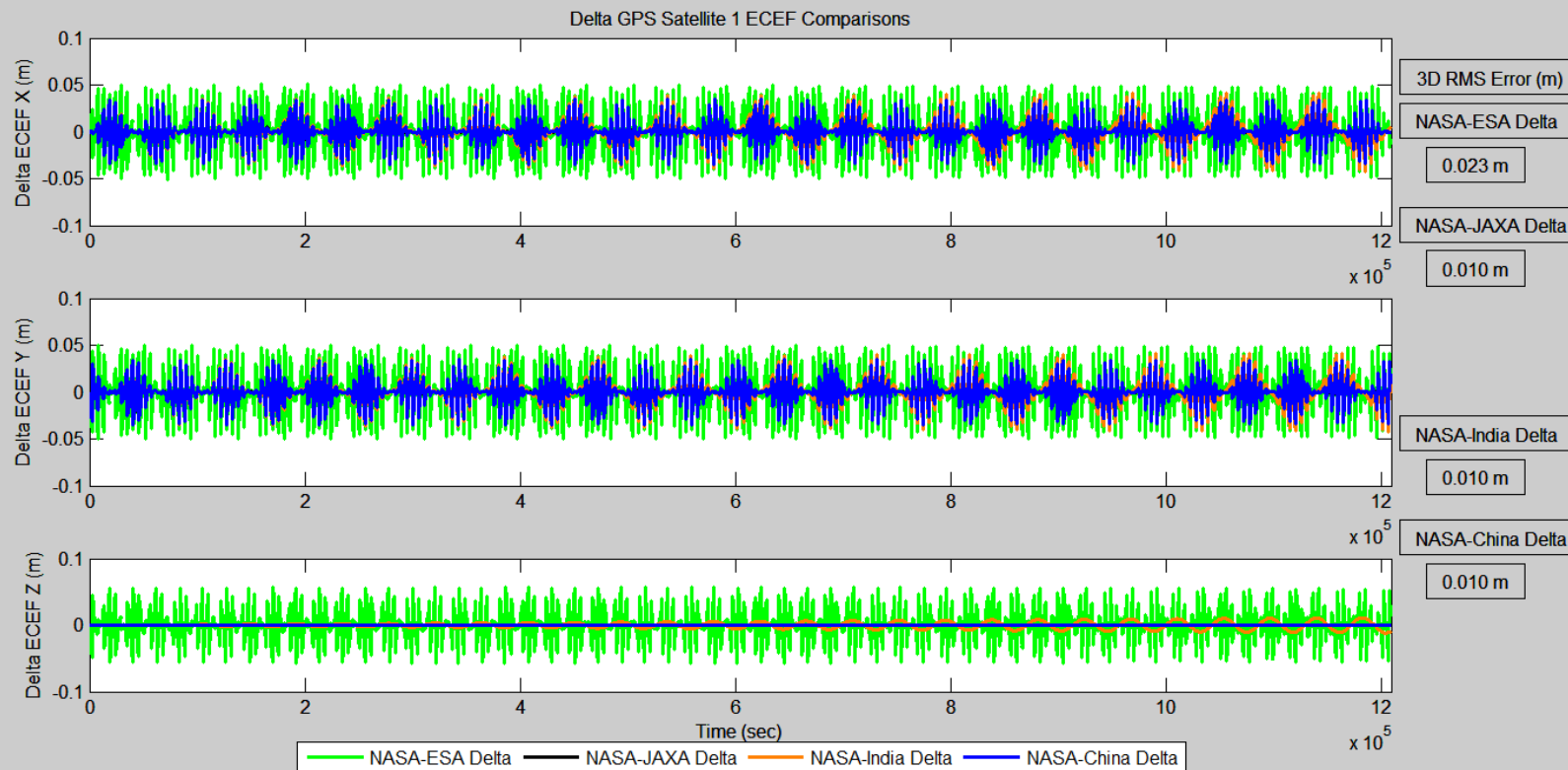
Orbit Propagation Alignment - GLONASS



GLONASS Satellite 1



GPS Satellite 1

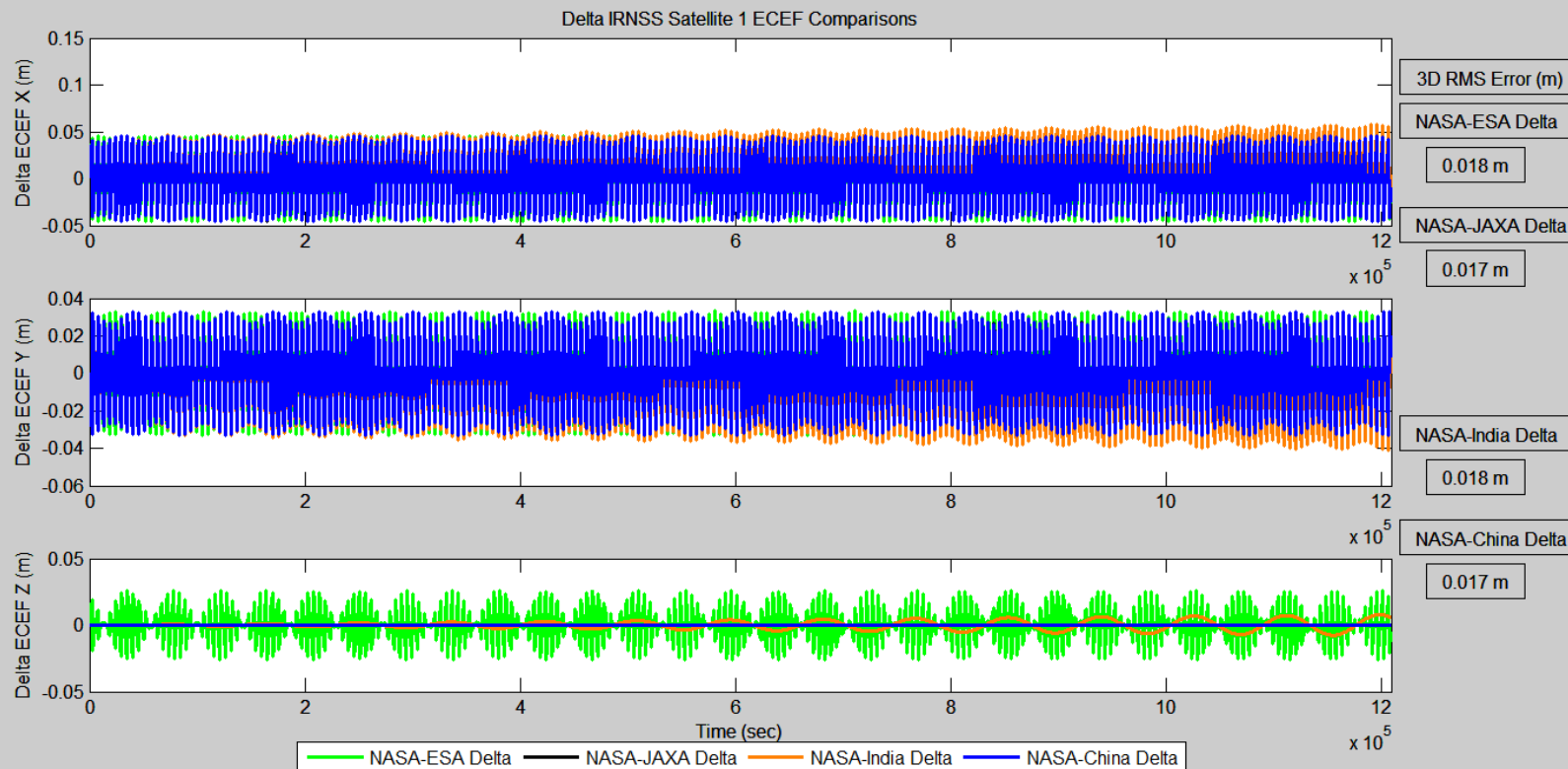




Orbit Propagation Alignment - IRNSS



IRNSS Satellite 1

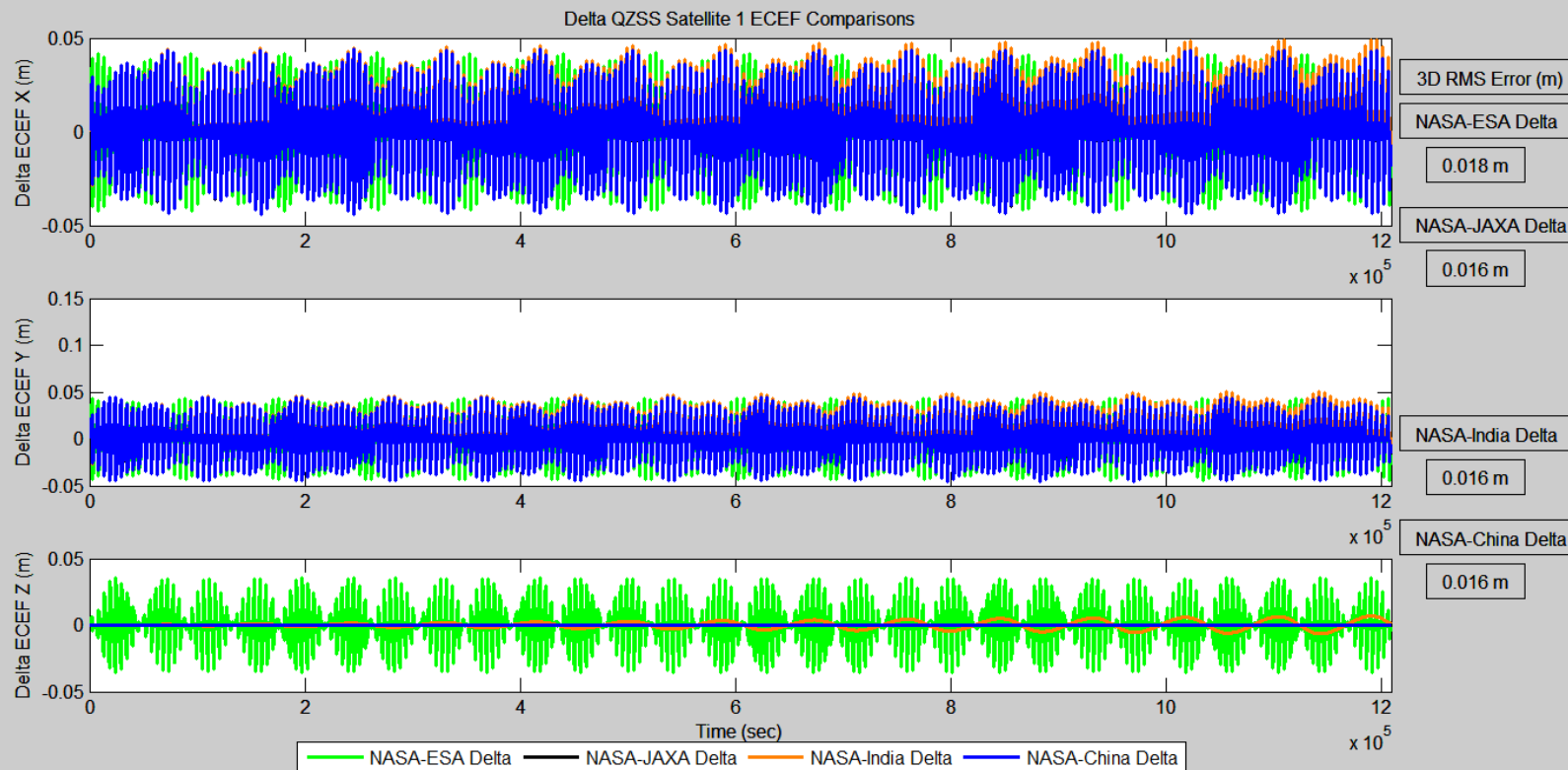




Orbit Propagation Alignment - QZSS



QZSS Satellite 1





Phase 1 Access Results



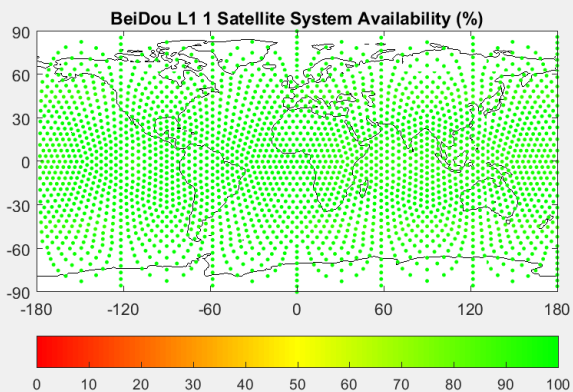
L1	BeiDou	Galileo	GLONASS	GPS	IRNSS	QZSS	All
1 Satellite System Availability (%)	97.4	78.5	59.1	90.5	-----	26.7	99.9
4 Satellite System Availability (%)	24.1	1.2	0.5	4.8	-----	0.8	94.4
1 Satellite Maximum Outage (minutes)	45	98	134	111	-----	Scenario Duration	39
4 Satellite Maximum Outage (minutes)	Scenario Duration	Scenario Duration	Scenario Duration	Scenario Duration	-----	Scenario Duration	97

L5	BeiDou	Galileo	GLONASS	GPS	IRNSS	QZSS	All
1 Satellite System Availability (%)	99.9	93.4	98.3	96.9	36.9	30.5	100
4 Satellite System Availability (%)	45.4	4.2	14.5	15.6	0.6	1.5	99.9
1 Satellite Maximum Outage (minutes)	7	55	35	77	Scenario Duration	Scenario Duration	0
4 Satellite Maximum Outage (minutes)	644	Scenario Duration	2252	1180	Scenario Duration	Scenario Duration	35

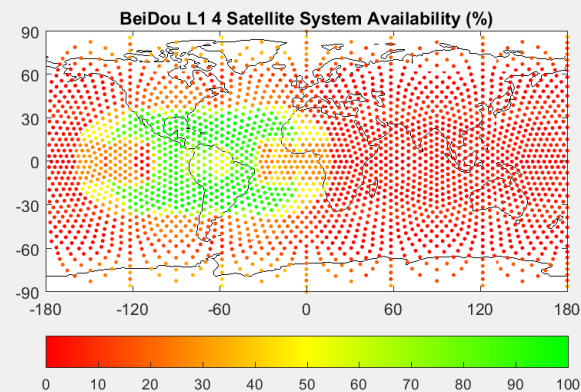


PHASE 1 FULL RESULTS

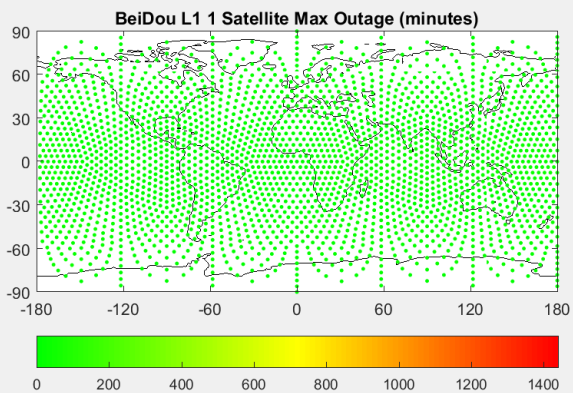
2D GRAPHICAL REPRESENTATIONS



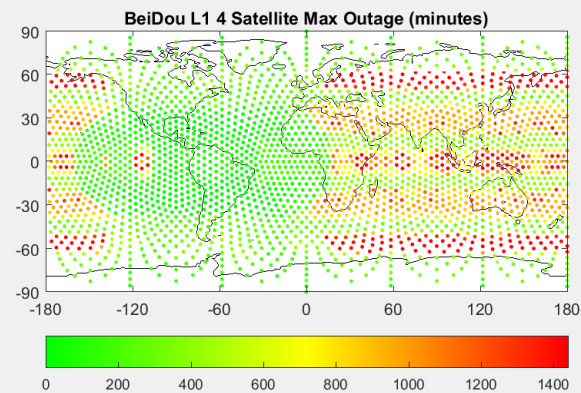
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4 Satellite System Availability

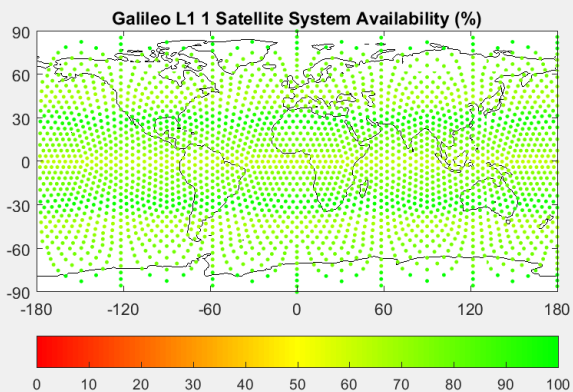


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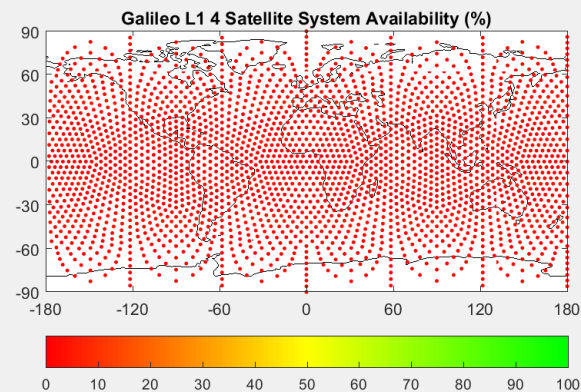


4 Satellite Maximum Outage

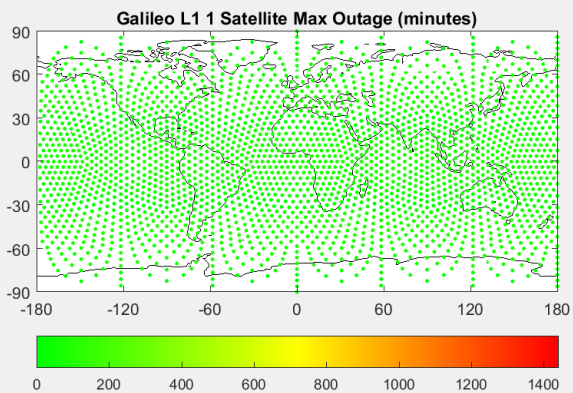
Galileo – L1



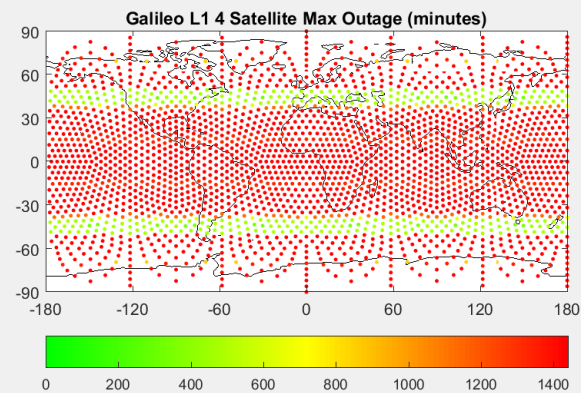
1 Satellite System Availability



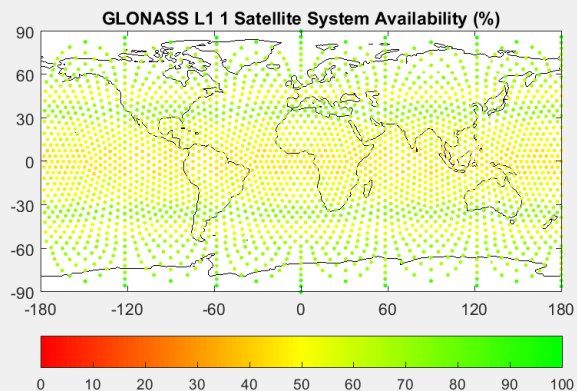
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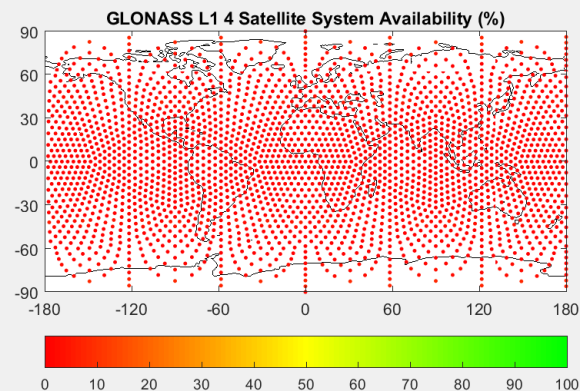
1 Satellite Maximum Outage



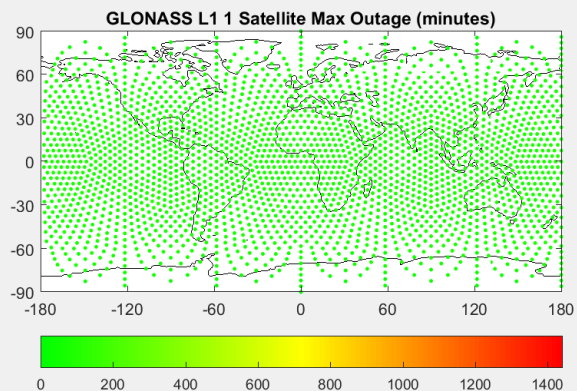
4 Satellite Maximum Outage



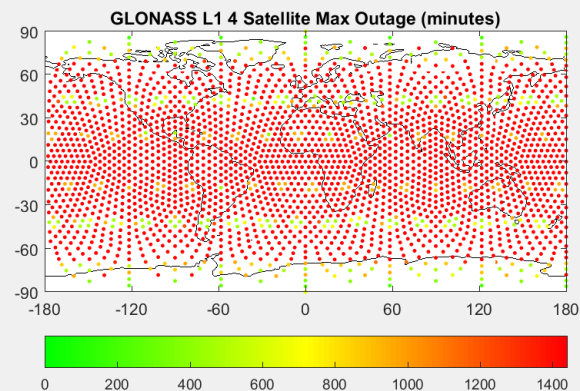
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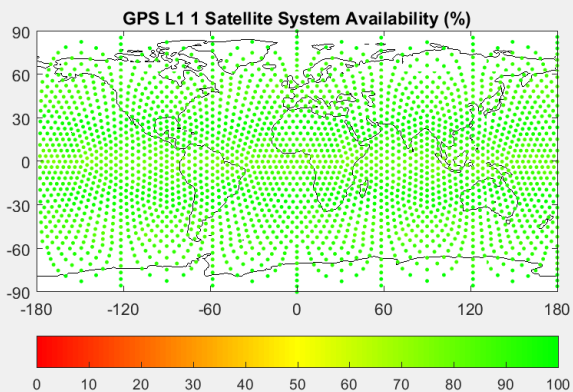
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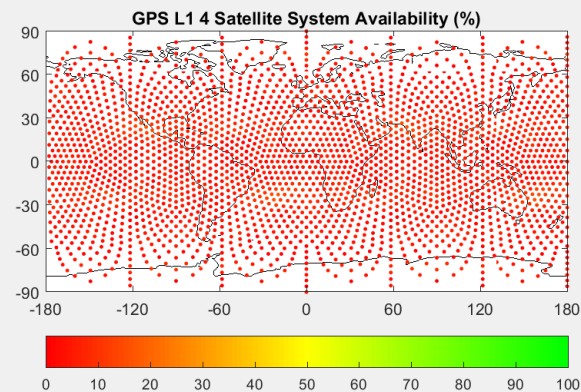
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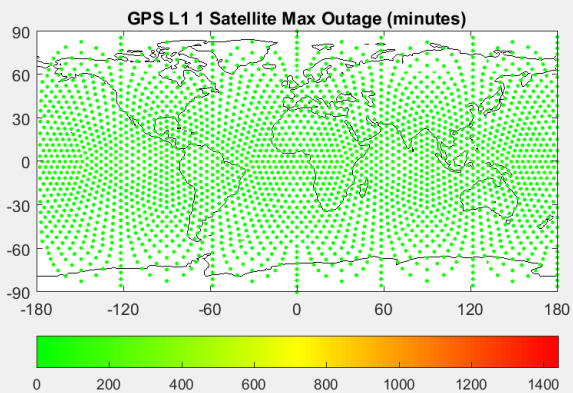
4 Satellite Maximum Outage



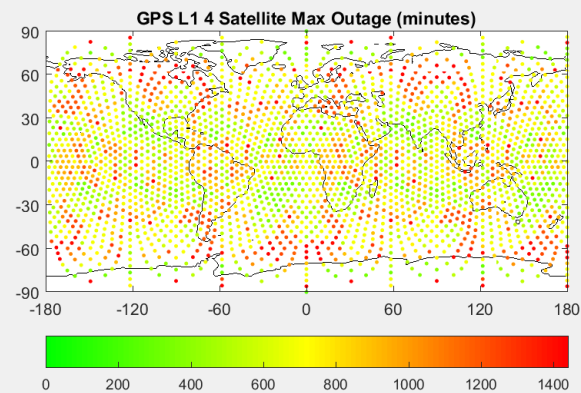
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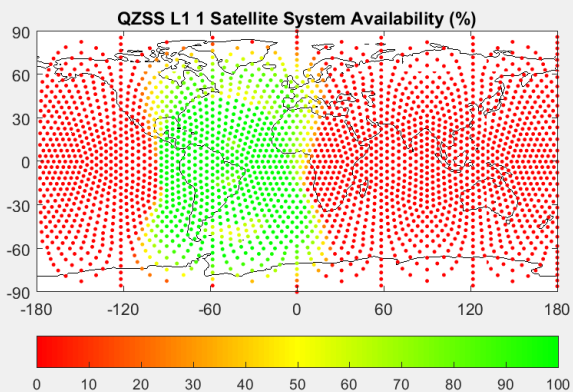
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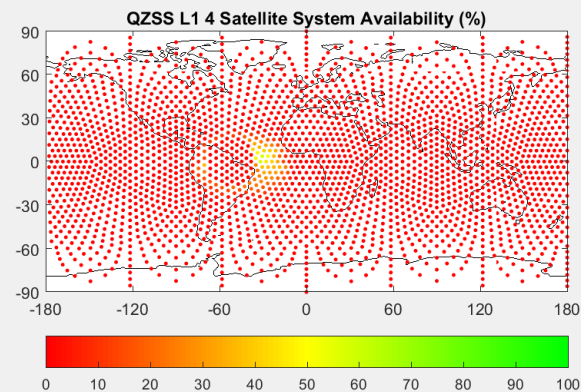
1 Satellite Maximum Outage



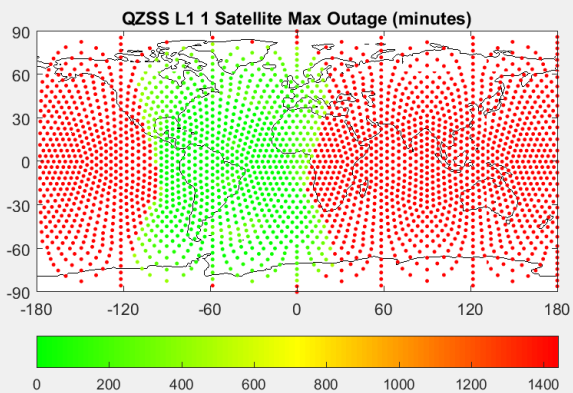
4 Satellite Maximum Outage



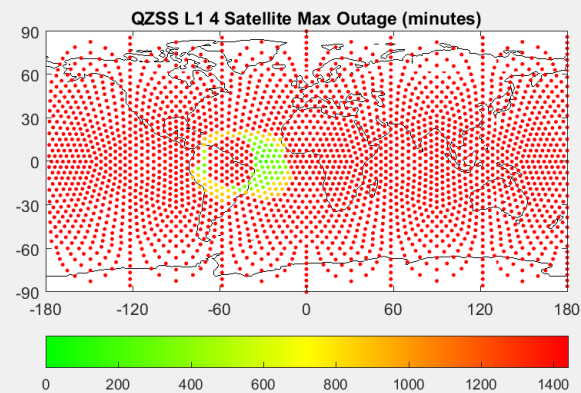
1 Satellite System Availability



4 Satellite System Availability



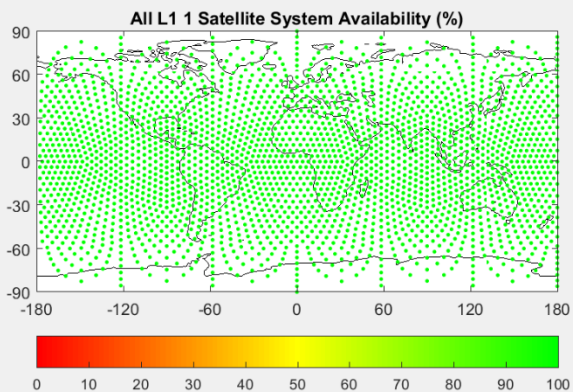
1 Satellite Maximum Outage



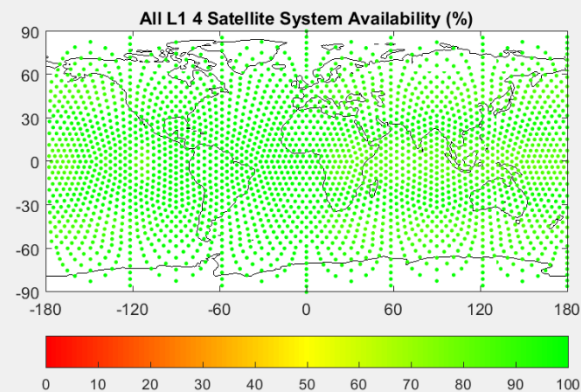
4 Satellite Maximum Outage



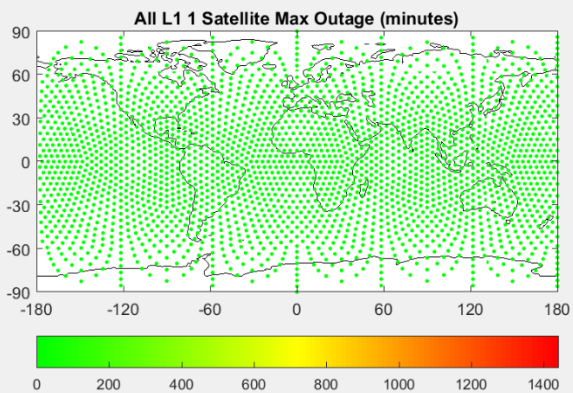
All - L1



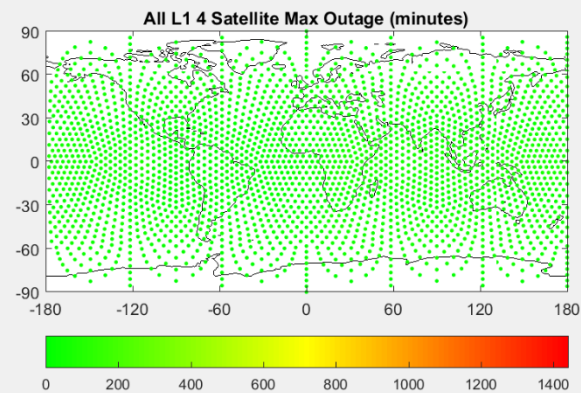
1 Satellite System Availability



4 Satellite System Availability



1 Satellite Maximum Outage



4 Satellite Maximum Outage



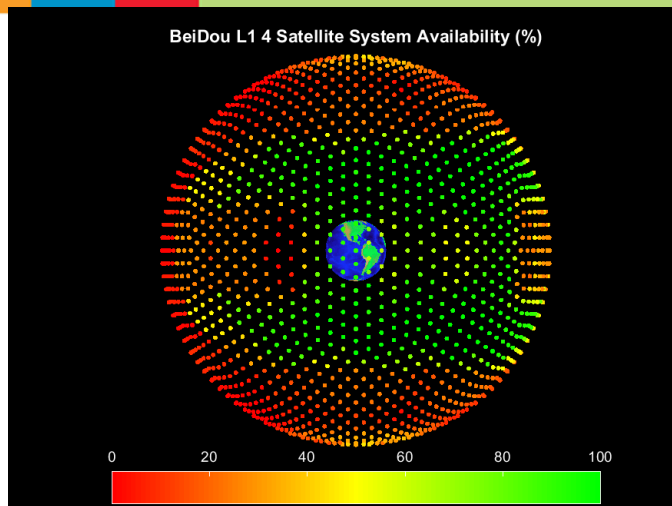
PHASE 1 FULL RESULTS

3D GRAPHICAL REPRESENTATIONS

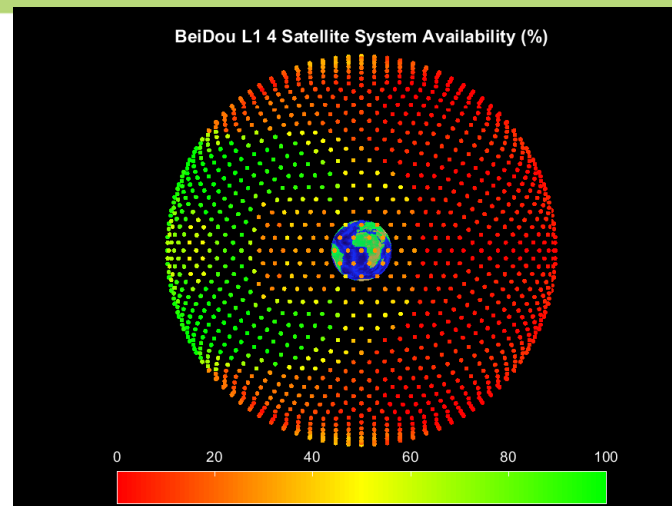


BeiDou – L1

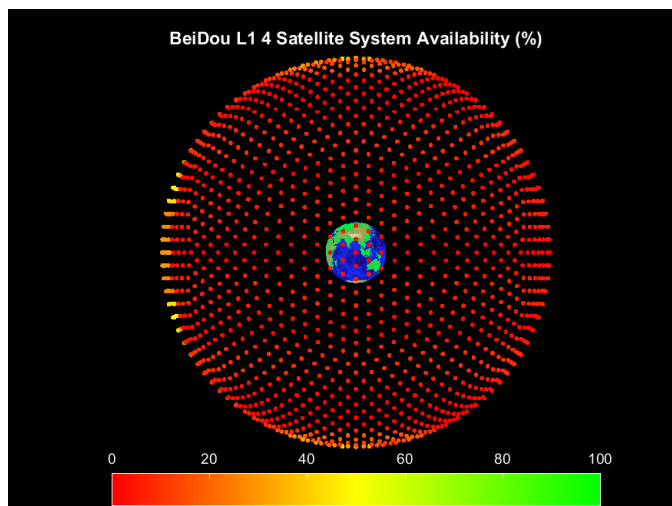
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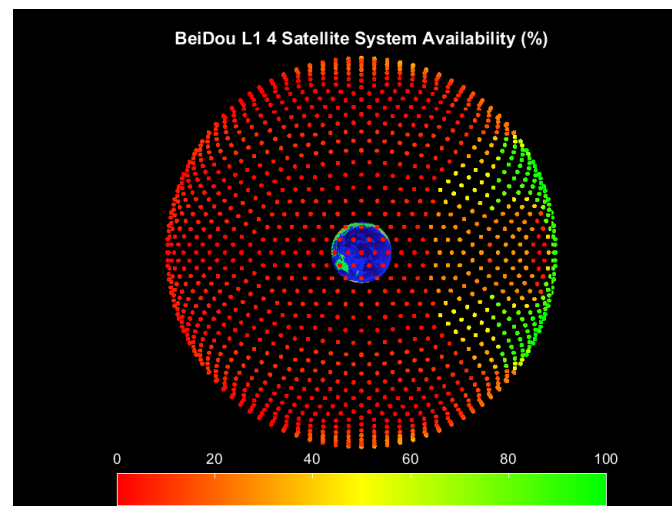
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

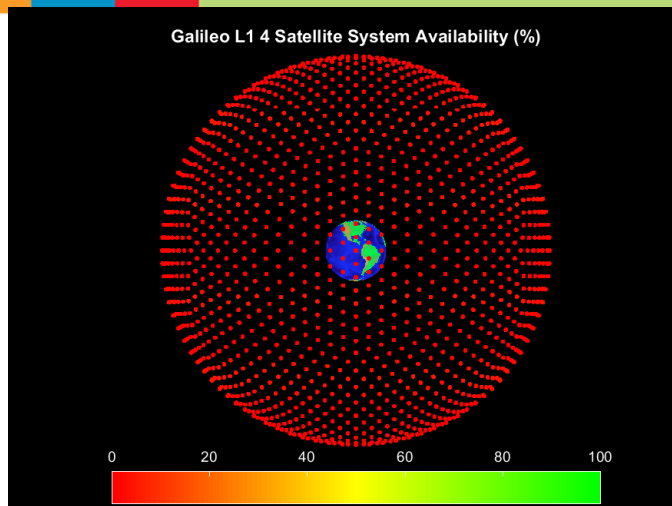


Viewed from 180E Longitude

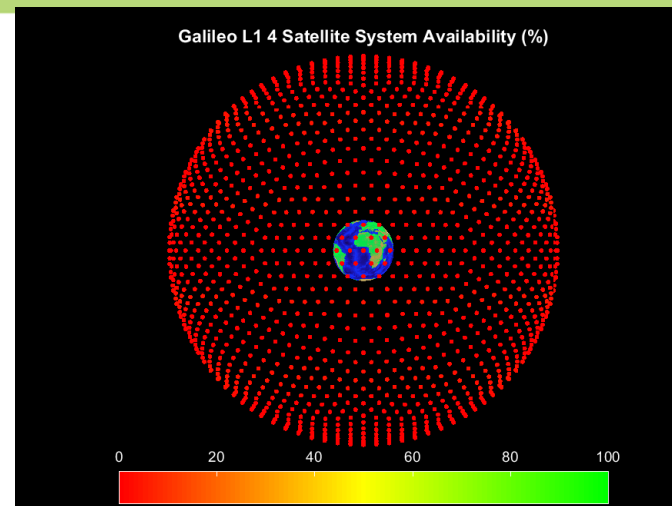


Galileo – L1

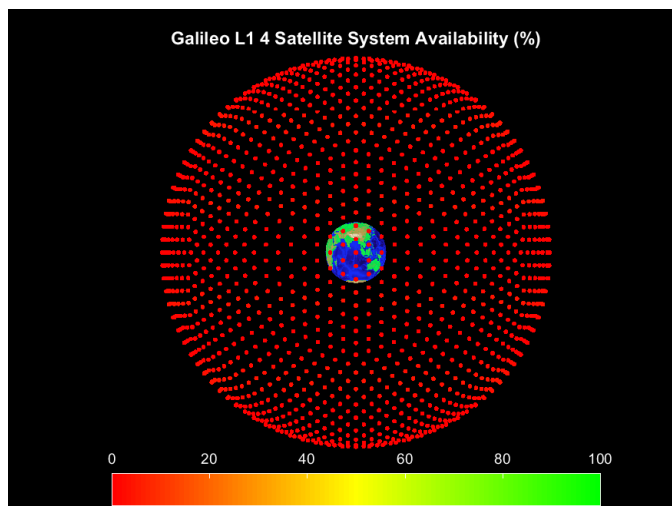
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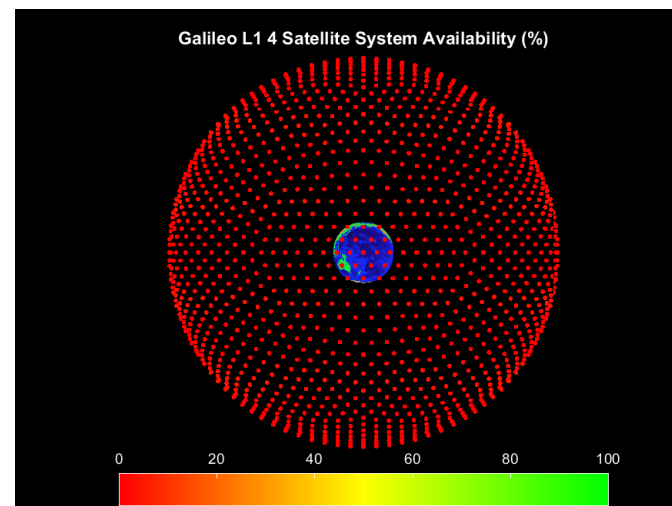
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Viewed from 0E Longitude



Viewed from 90E Longitude

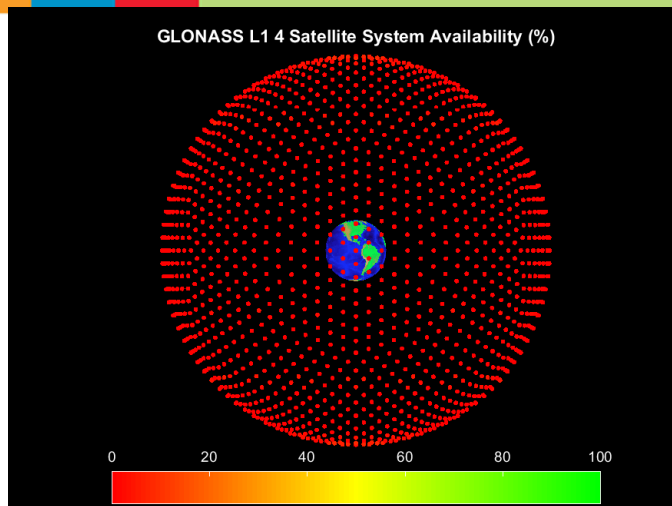


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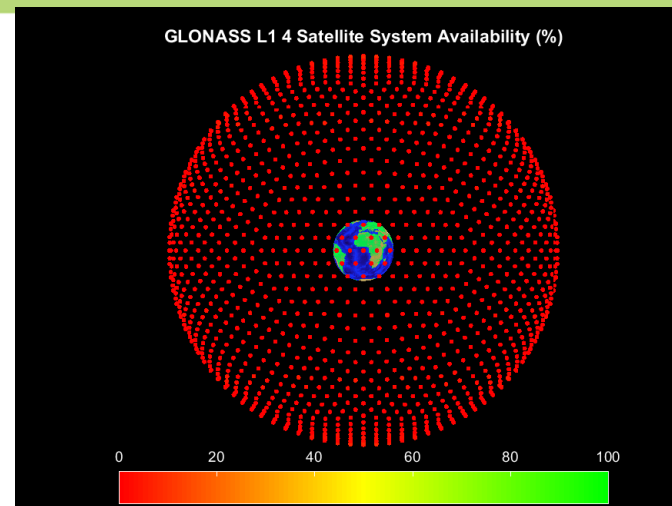


GLONASS – L1

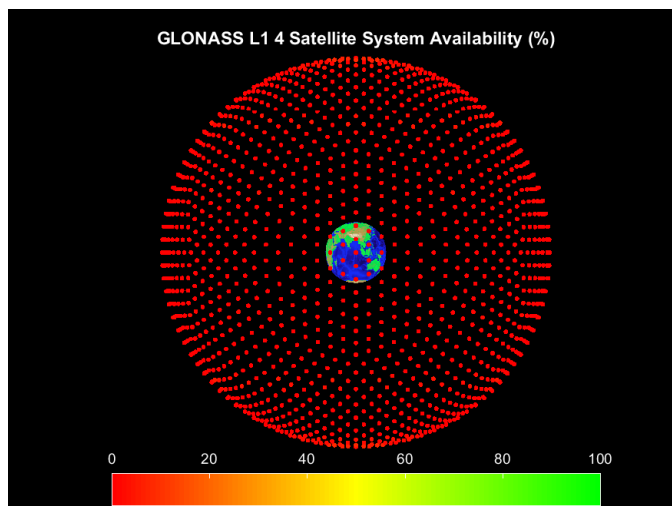
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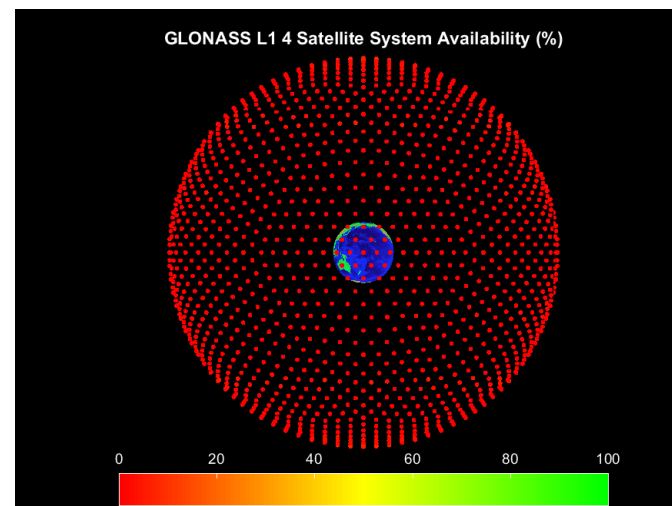
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

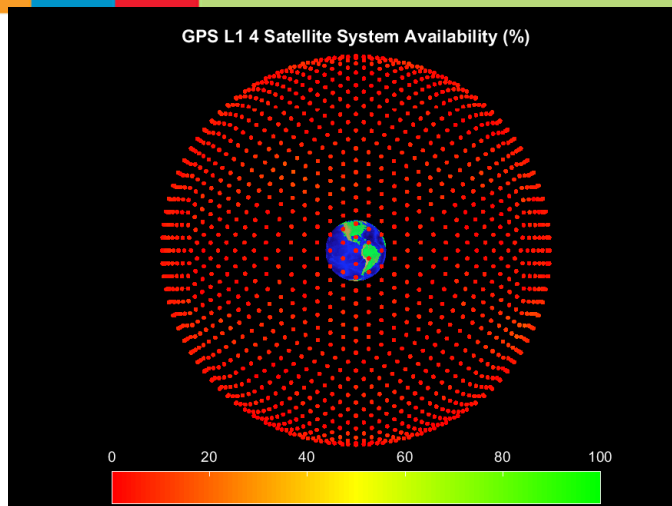


Viewed from 180E Longitude

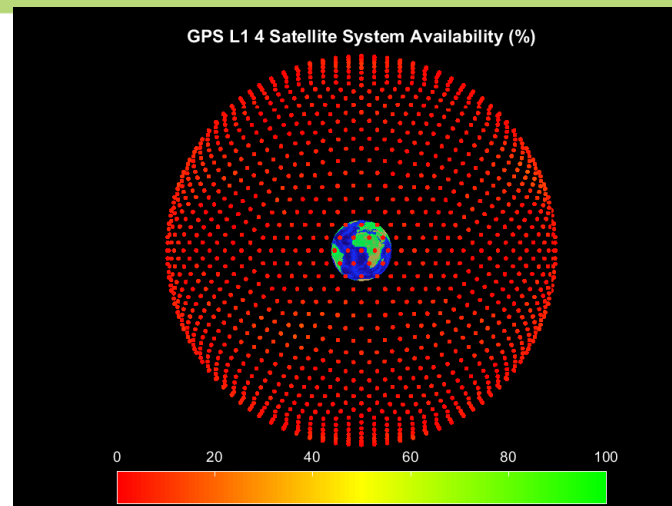


GPS – L1

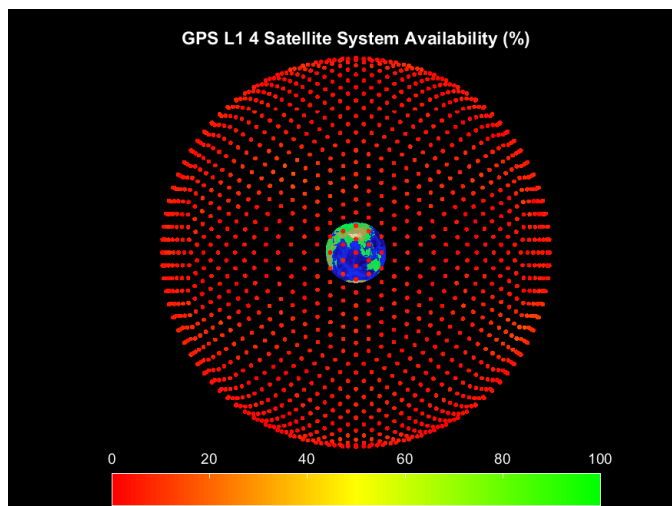
4 Satellite Grid Availability



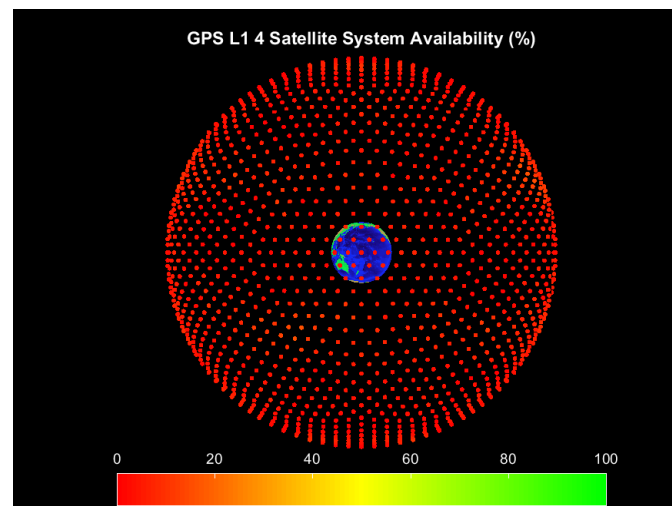
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Viewed from 0E Longitude



Viewed from 90E Longitude

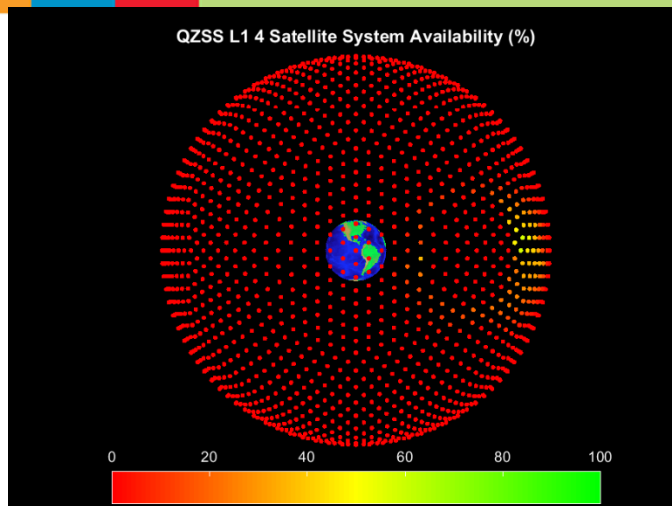


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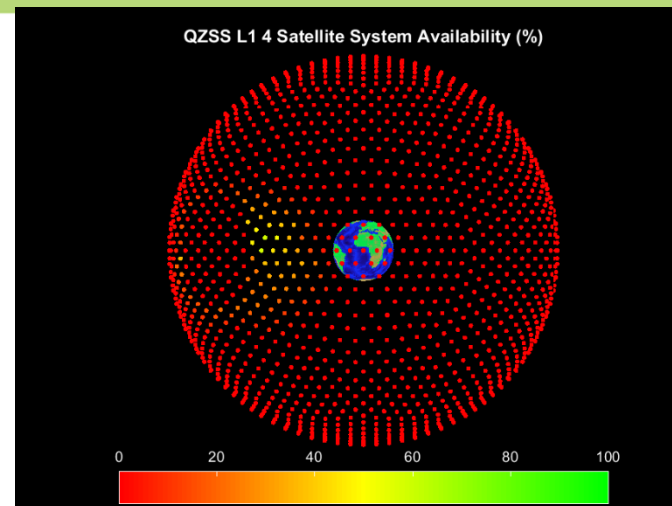


QZSS – L1

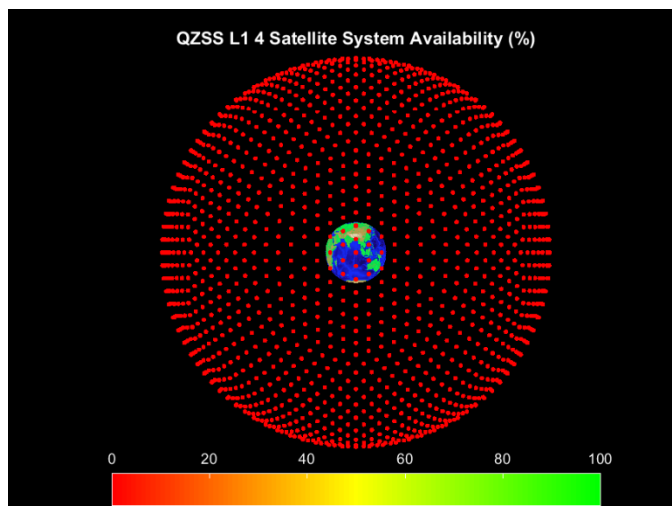
4 Satellite Grid Availability



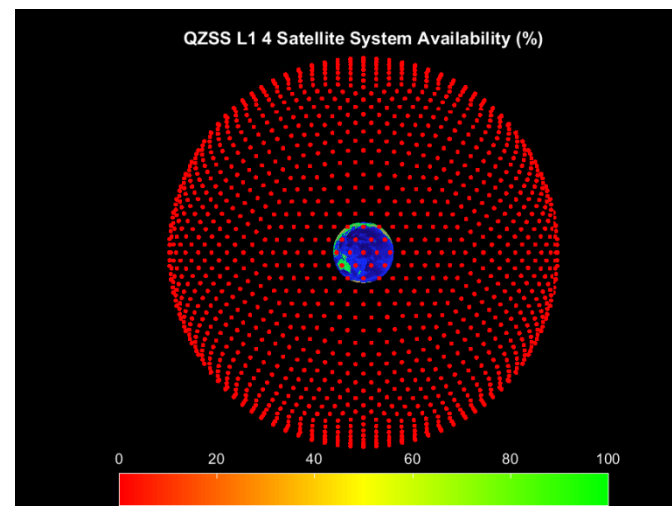
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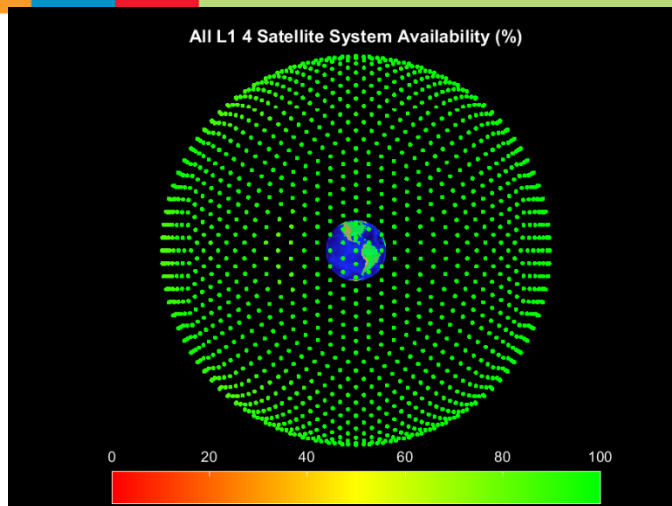


Viewed from 180E Longitude

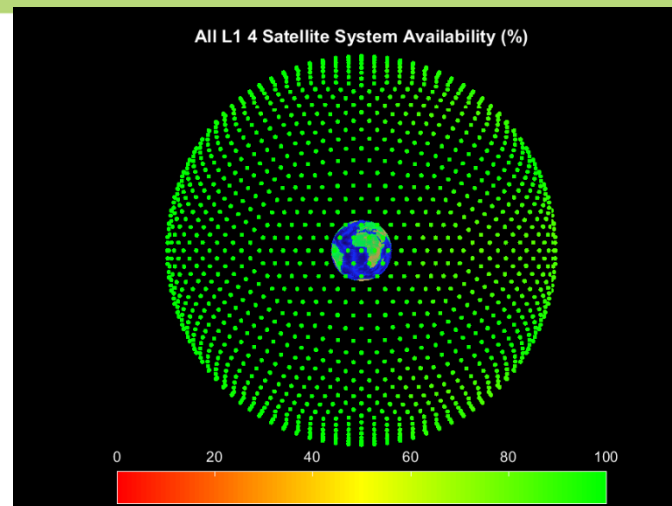


All – L1

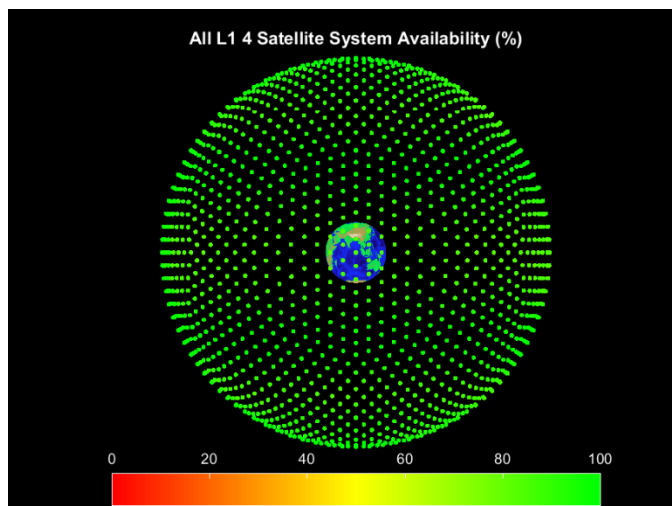
4 Satellite Grid Availability



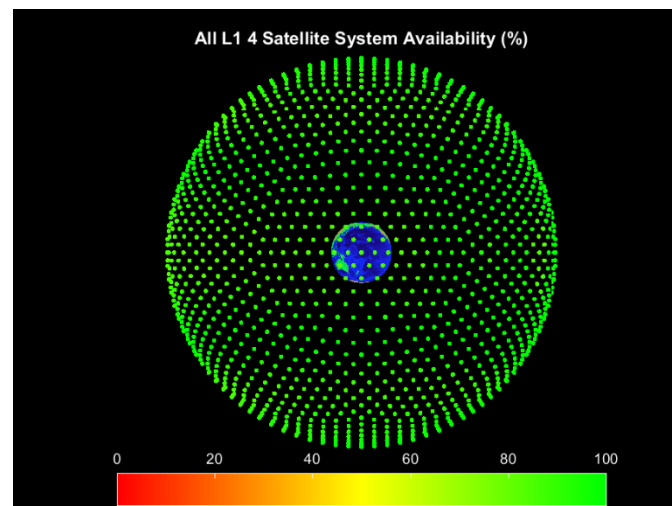
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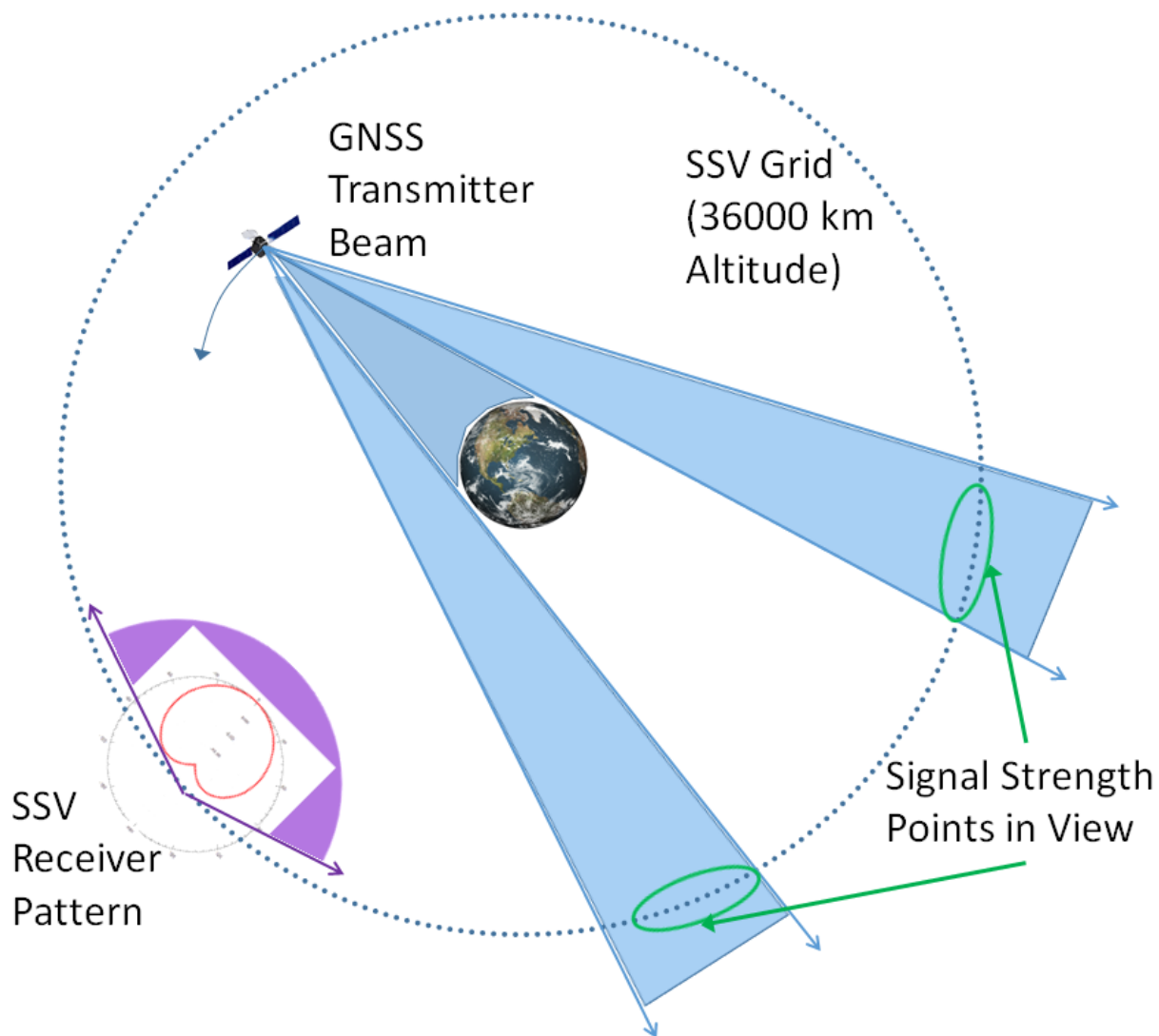


Viewed from 180E Longitude



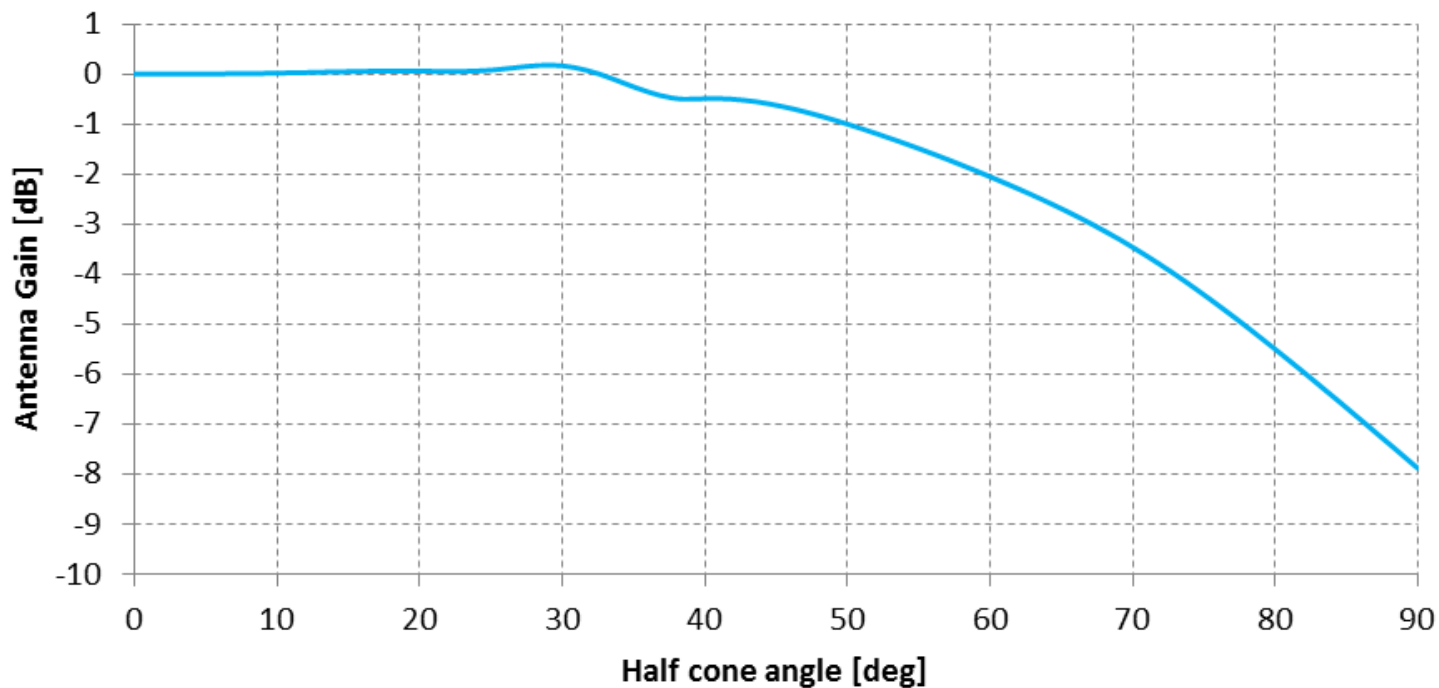
PHASE 2 RECOMMENDATIONS

Phase 2: Signal Strength Access

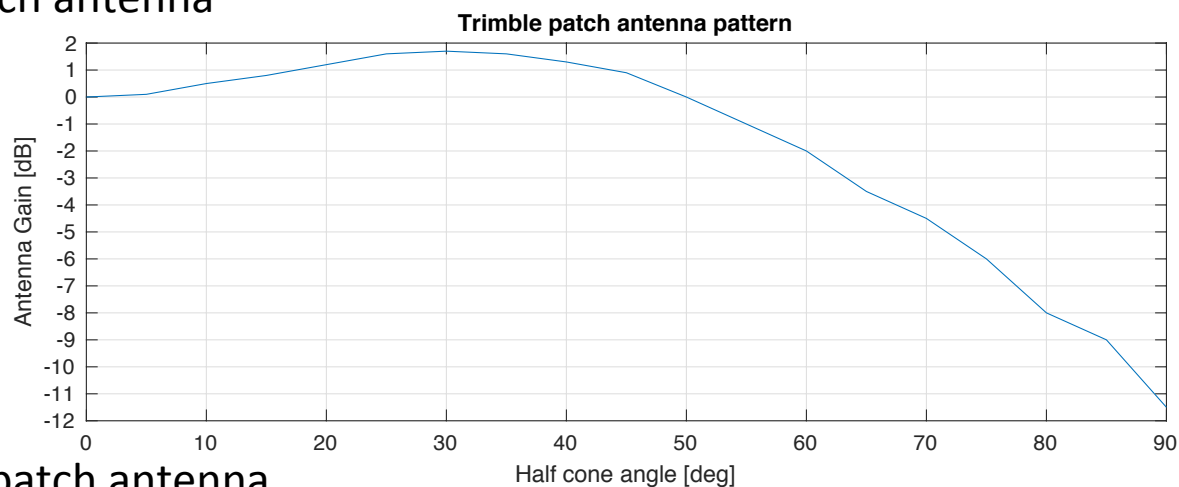


EU-proposed patch antenna pattern:

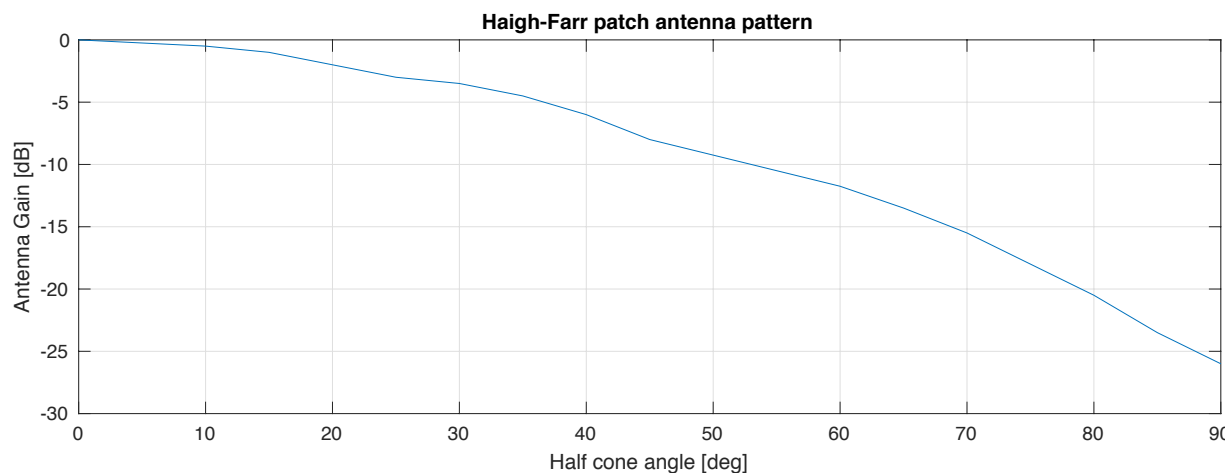
Typical receiver Patch Antenna pattern



- Typical NASA reference patterns:
 - Trimble patch antenna



- Haigh-Farr patch antenna





Receiver Antenna: Recommendations



- Goal of Phase 2 is to perform coverage-grid analysis with link budget included for added realism
- On use of receiver antenna pattern:
 - Realistic receiver antenna patterns vary by mission type and application
 - When patch antennas are used, roll-off varies widely
 - For coverage-based analysis, key result to users is the capability level available at grid location and altitude – *before* receiver hardware is applied
 - **Recommendation:** Change Phase 2 link budget to NOT include receiver antenna pattern, and instead apply representative mission-specific patterns as part of Phase 3.
 - **Recommendation:** If receiver antenna pattern is chosen, use 0dB omni antenna instead of realistic patch antenna.



Link Budget Recommendations



- If receiver gain is removed for Phase 2, link budget is reduced to:

$$P_r = EIRP + L_s$$

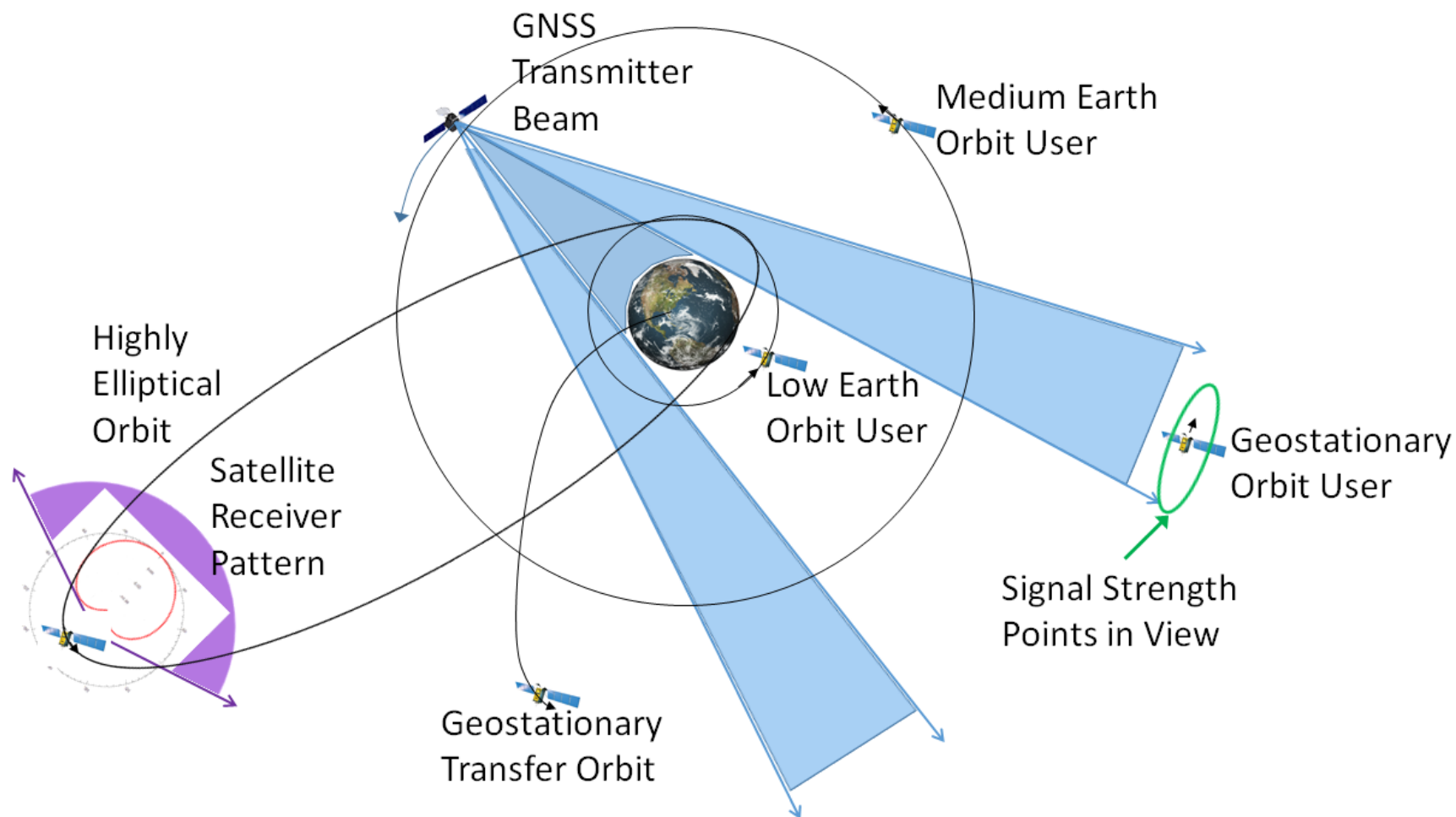
$$\frac{C}{N_0} = EIRP + L_s - 10 \log_{10} T_{sys} - 10 \log_{10} k$$

- T_{sys} (nadir-pointing): 290K (standard Earth value)
- T_{sys} (zenith-pointing): 150K (from Bryan)
- We agree with other EU-proposed values
- **Recommendation:** Proceed with Phase 2 while addressing any remaining Phase 1 items in parallel



PHASE 3 RECOMMENDATIONS

Phase 3: Specific User Missions





Proposed Mission Types and KPIs



ID	Mission Class	Specific Example	Mission Drivers	KPIs
1	Scientific (HEO beyond GEO altitude)	PROBA-3	- Orbit accuracy - Quality of GNSS data - Availability of GNSS data at specific mission phases	- Number of visible GNSS SV over time/altitude - Percent 1+ GNSS visibility - Percent 4+ GNSS visibility - Quality of relative geometry (DOP)
2	Earth weather (GEO)	GOES-R	- Rapid maneuver recovery - Stability of GNSS solution - Nearly-continuous service	- Number of visible GNSS SV over time - Percent 1+ GNSS visibility - Max outage time of 1 SV
3	Launch vehicle upper stage (GTO)	KSC GTO launch	Availability of GNSS data by altitude	- Number of visible GNSS SV over time/altitude - Percent 4+ GNSS visibility - Max outage time of 4 SV
4	High-latitude communications (Molniya)	Molniya	Availability of GNSS data by altitude & high-latitude	- Max outage time of 1 SV - Number of visible GNSS SV over time/altitude
5	Cis-lunar	EM-1 (Orion)	Single-SV visibility at extreme altitude	- Number of visible GNSS SV over time/altitude - Percent 1+ SV visibility - Max outage time of 1 SV - DOP



Proposed Mission Parameters



	GOES-R	GTO	Molniya	EM-1
Perigee alt (km)	35786	200	1023	391
Apogee alt (km)	35786	36786	39169	378021
Semi-major axis (km)	35786	24371	26610	195584
Eccentricity	0	0.73	0.95	0.965
Inclination (deg)	0	28.5	63.4	28.5
Right ascension of the ascending node (deg)	0	(to be selected)	(to be selected)	(to be selected)
Argument of perigee (deg)	0	-180	-90	-90
Orbit Period	24 h	10.5 h	12 h	10 d

- All parameters are estimated as typical values



Phase 3 Recommendations



- Goal of Phase 3 is to provide examples of GNSS capability for different orbit regimes
 - Must capture KPIs of importance to chosen mission types
- **Recommendation:** Limit to 5 example missions
- **Recommendation:** Choose single set of KPIs to encompass all missions
 - Proposed set of KPIs:
 - Number of visible GNSS SVs over simulation time period
 - Number of visible GNSS SVs by altitude (except for GEO)
 - Percent of time with 1+ visible, 4+ visible
 - Maximum continuous outage time for 1+ SV, 4+ SV
 - DOP by time
 - DOP by altitude (except for GEO)
- **Recommendation:** Ephemeris, receiver antenna pattern, attitude profile should be agreed upon before analysis begins



WORK PLAN RECOMMENDATIONS



Work Plan Recommendations



- There is a need for a high-level SSV capabilities booklet for decision-makers (mission analysts, program managers, receiver developers, business-people)
 - Provide quick glance at “what is possible” in SSV using multi-GNSS
- There is also a need for a much more comprehensive dataset for mission engineers:
 - SSV template data
 - Assumptions & analysis methods
 - Constellation reference configurations and pointing
 - Raw result data & reference code (if possible)
- We propose an expanded work plan for ICG11 & ICG12:
 - **ICG11:** Finish analysis through Phase 3; publish SSV booklet
 - Host special topics session at ICG11, attended by commercial SSV stakeholders, as discussed at Providers’ Forum
 - **ICG12:** Write joint analysis paper for IAC 2017; publish analysis data
 - IAC 2017 deadlines line up with ICG12 midterm & full meetings
 - Location: Adelaide, Australia, Sep 2017
 - Analysis paper authorship can be shared between all participants

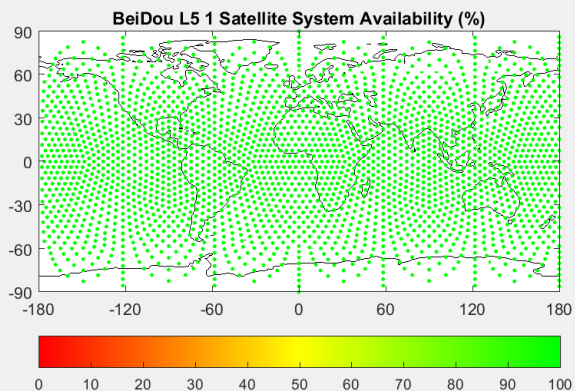


BACKUP

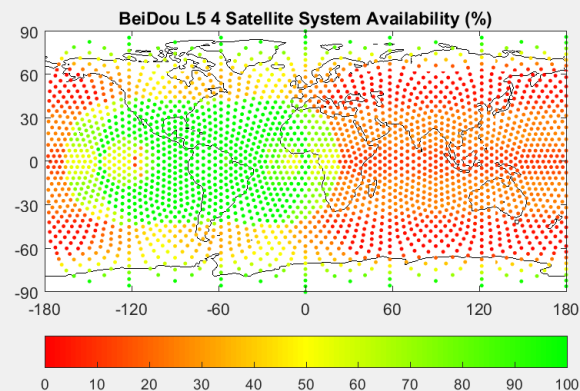


PHASE 1 FULL RESULTS

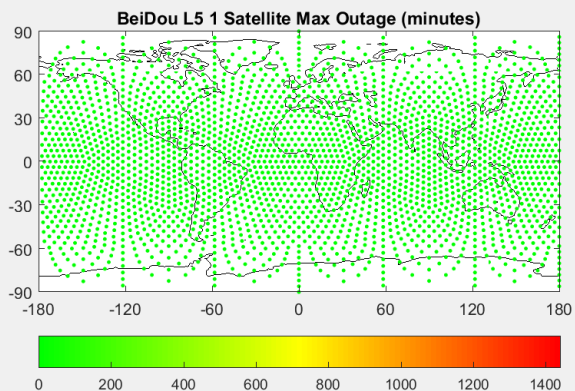
2D GRAPHICAL REPRESENTATIONS



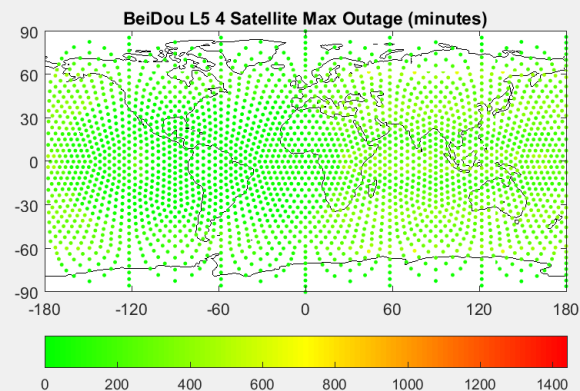
1 Satellite System Availability



4 Satellite System Availability

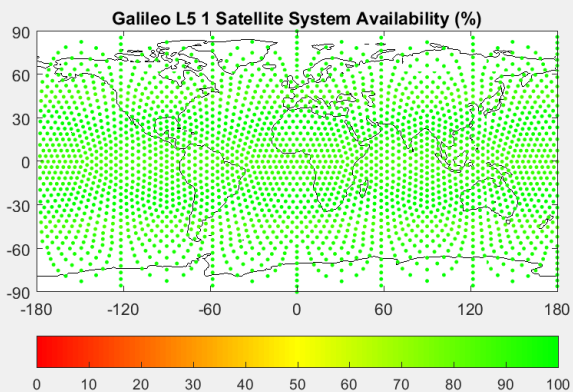


1 Satellite Maximum Outage

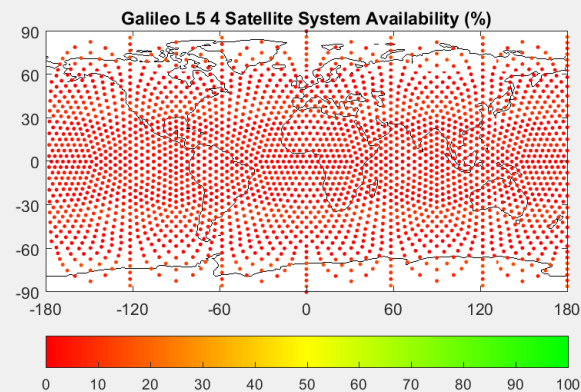


4 Satellite Maximum Outage

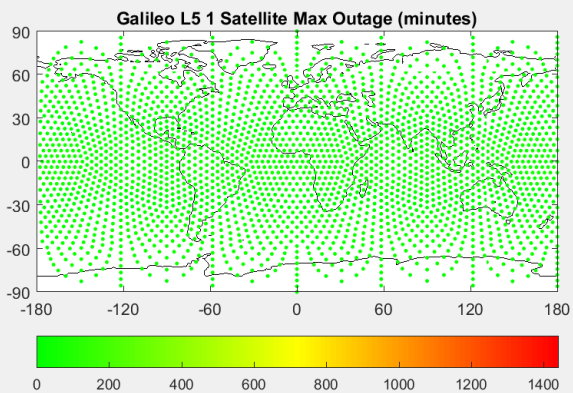
Galileo – L5



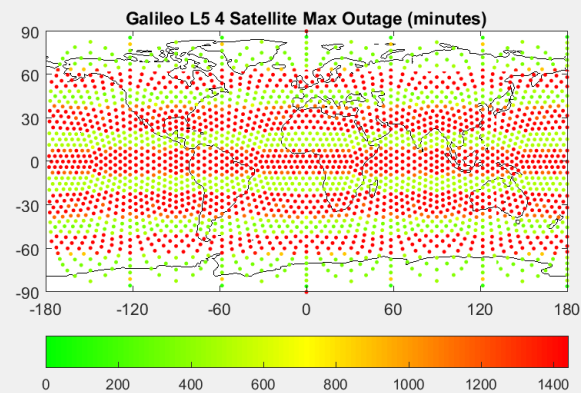
1 Satellite System Availability



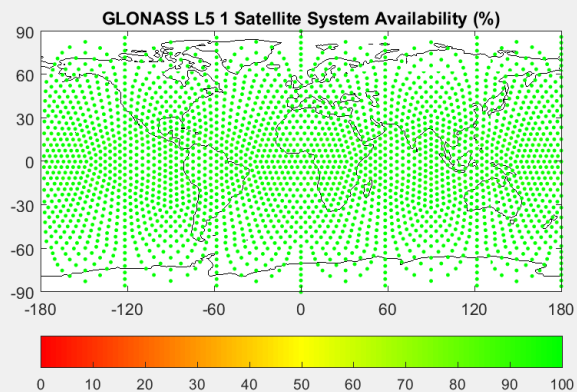
4 Satellite System Availability



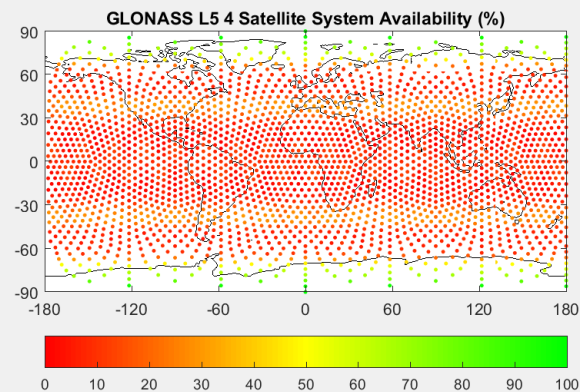
1 Satellite Maximum Outage



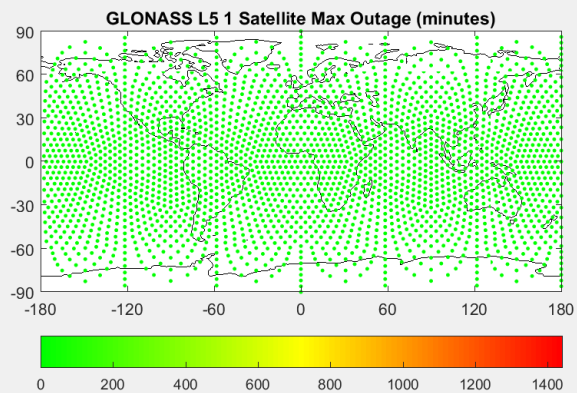
4 Satellite Maximum Outage



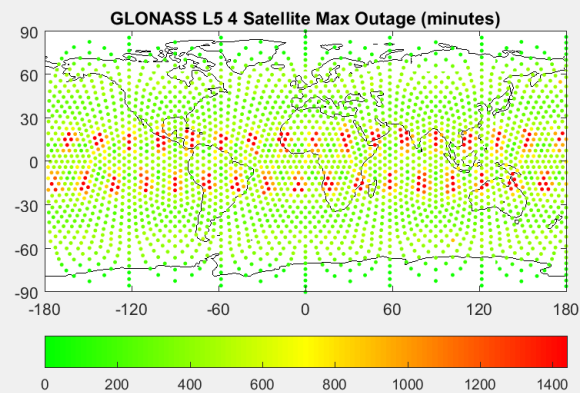
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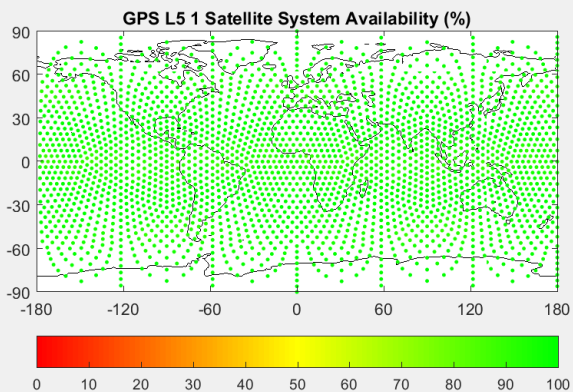
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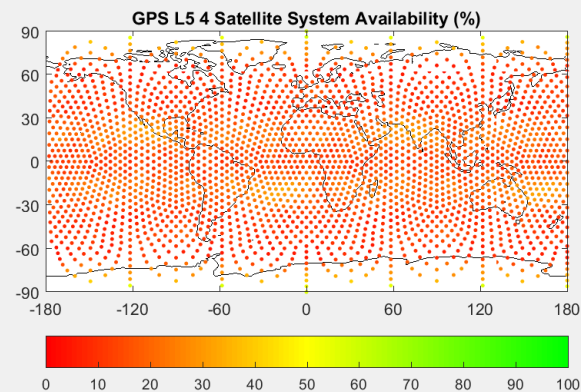
1 Satellite Maximum Outage



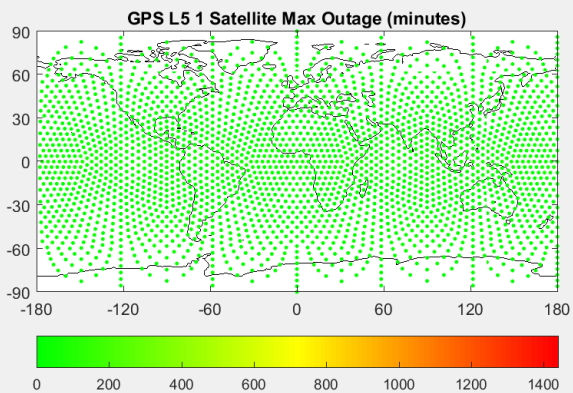
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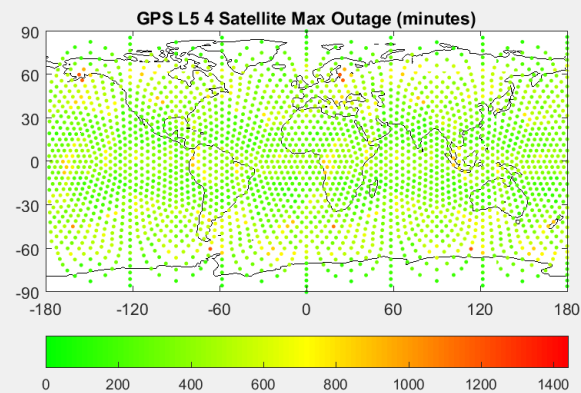
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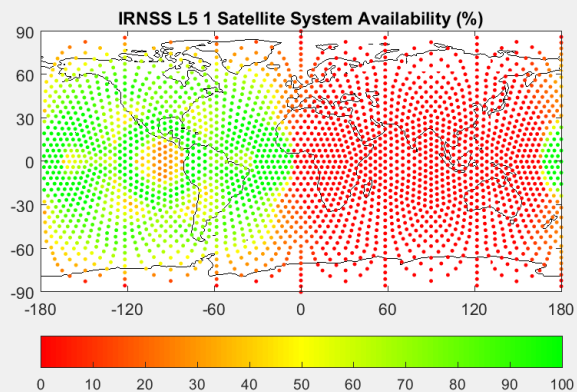
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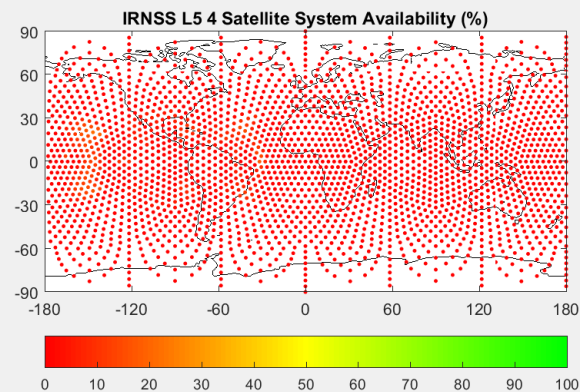
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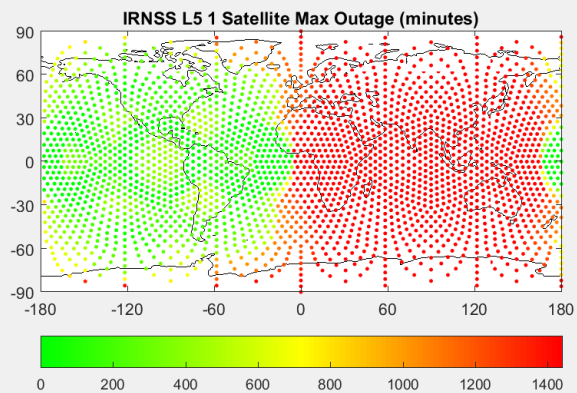
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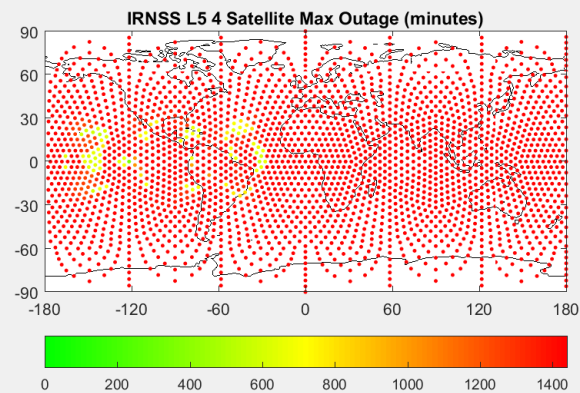
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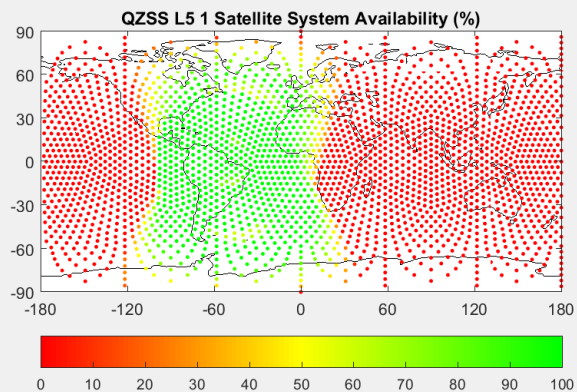
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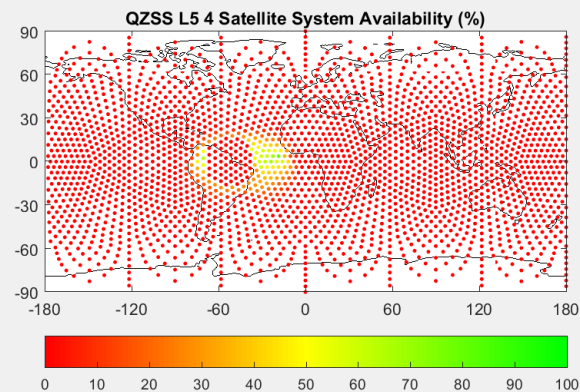
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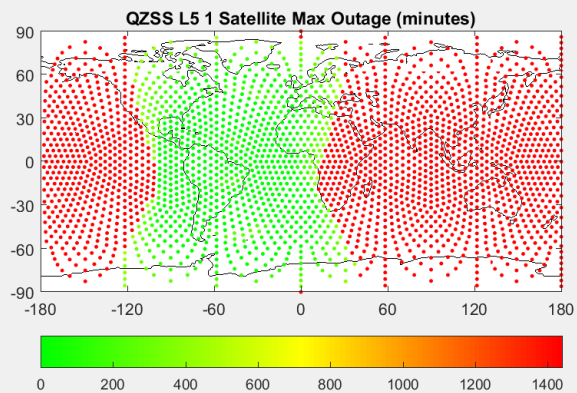
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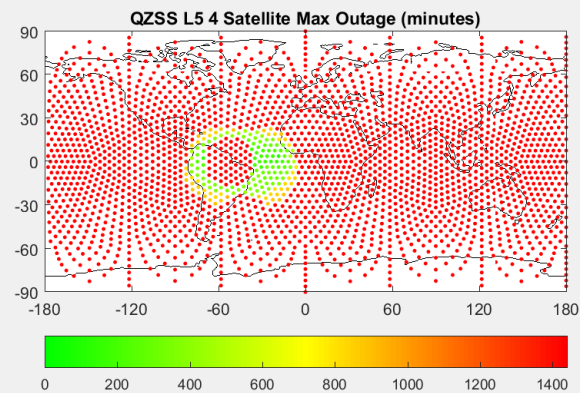
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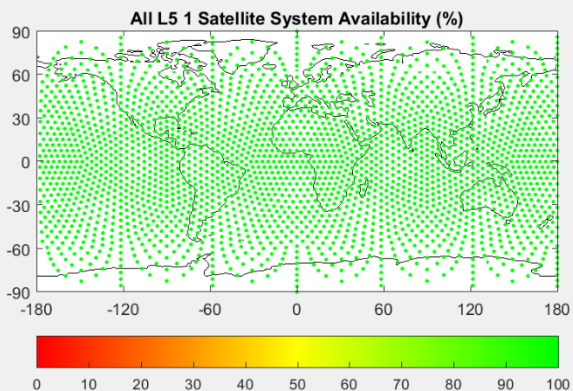
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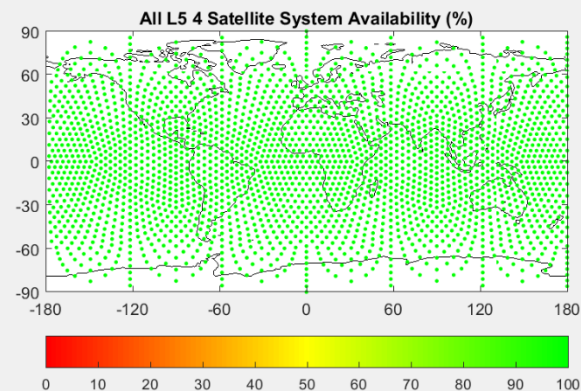
1 Satellite Maximum Outage



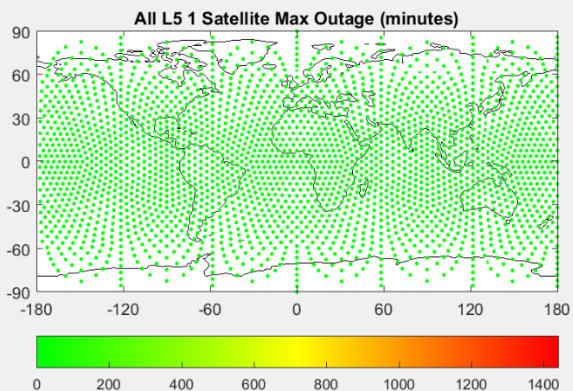
4 Satellite Maximum Outage



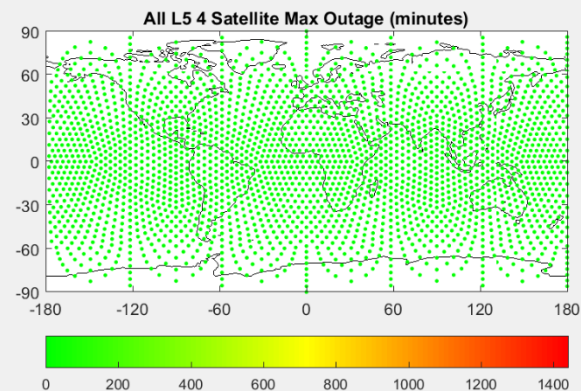
1 Satellite System Availability



4 Satellite System Availability



1 Satellite Maximum Outage



4 Satellite Maximum Outage



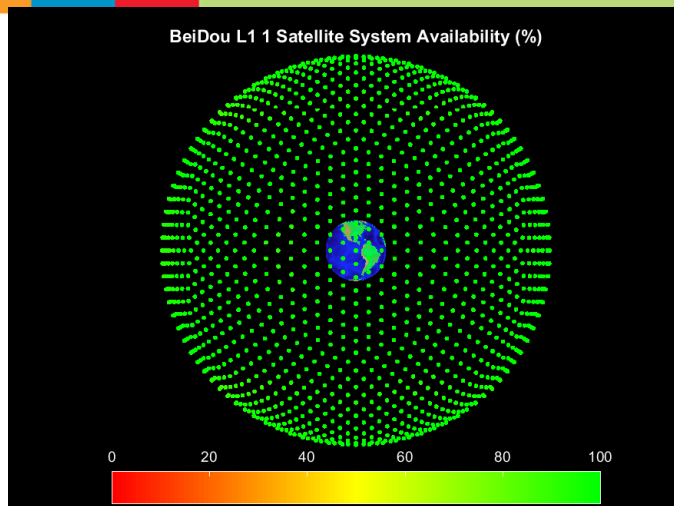
PHASE 1 FULL RESULTS

3D GRAPHICAL REPRESENTATIONS

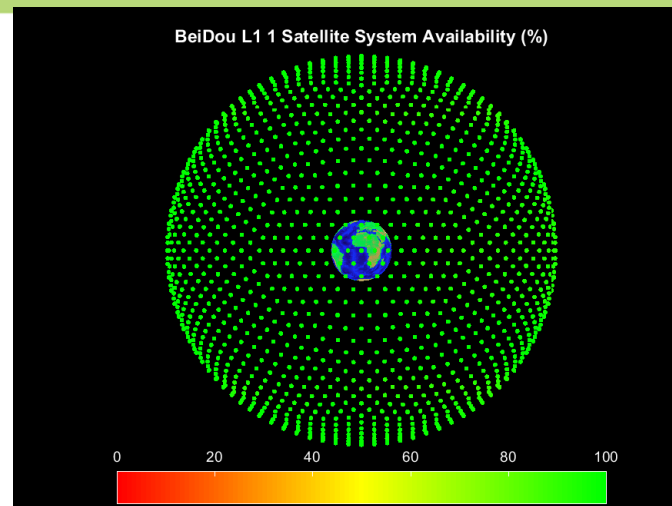


BeiDou – L1

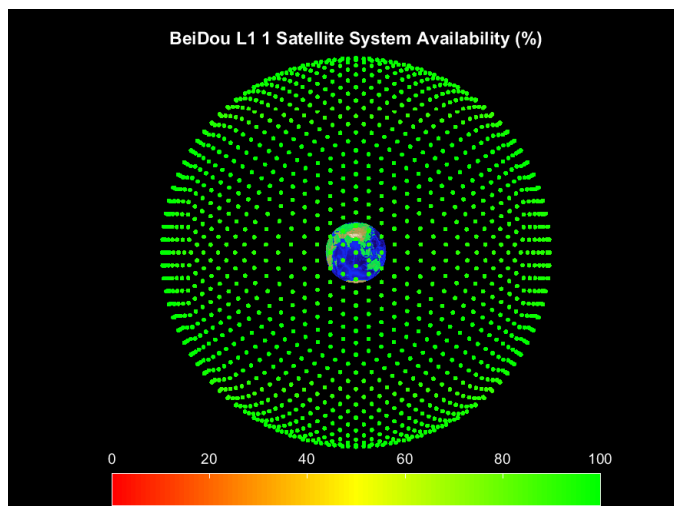
1 Satellite Grid Availability



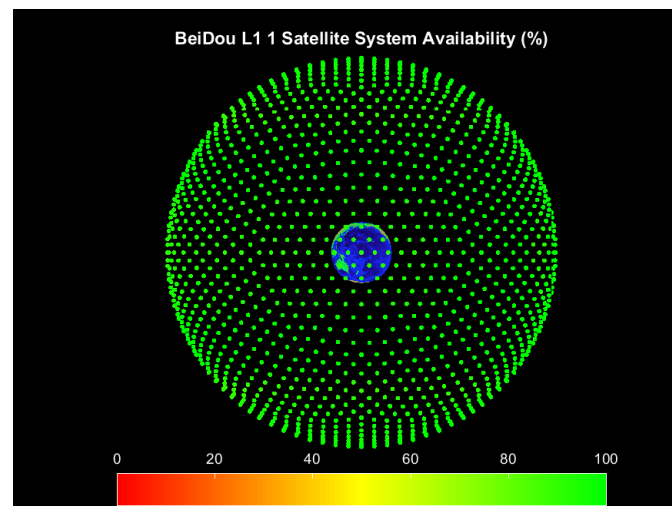
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

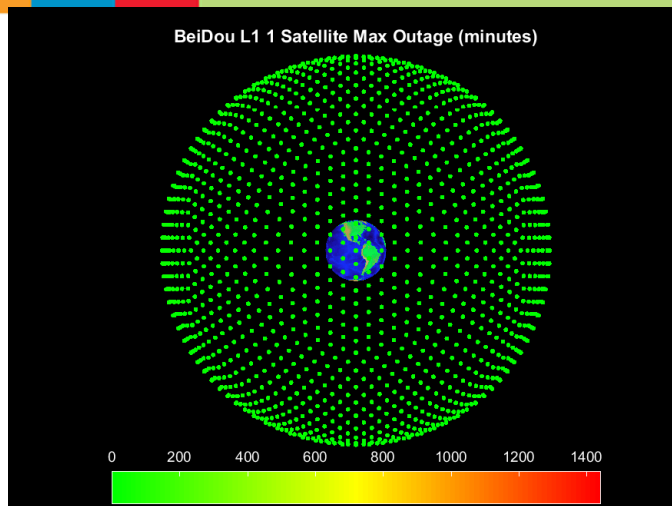


Viewed from 180E Longitude

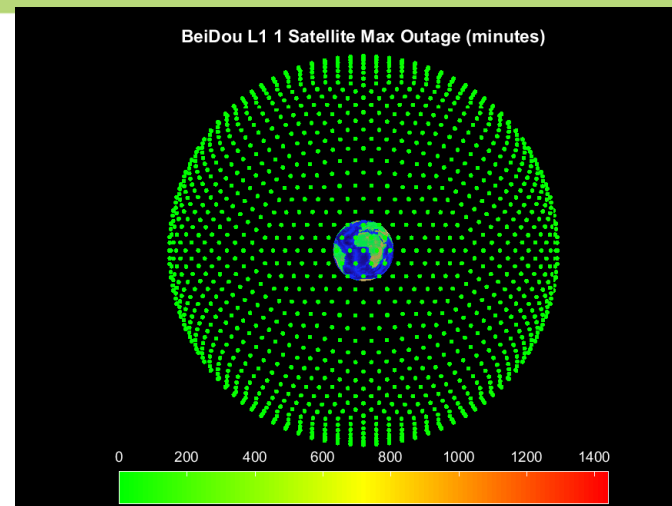


BeiDou – L1

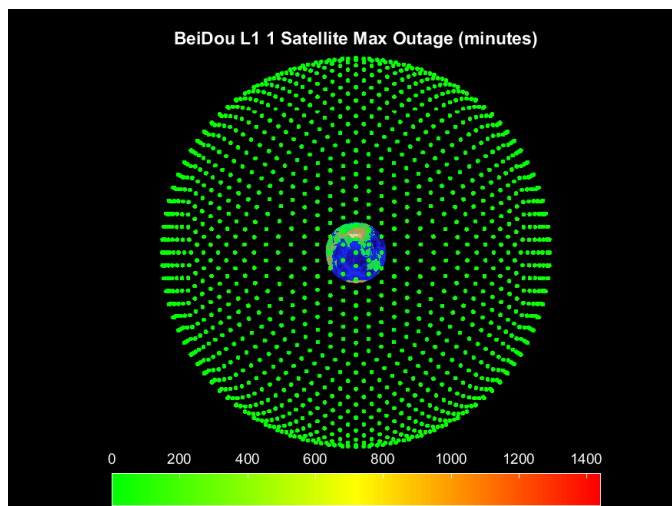
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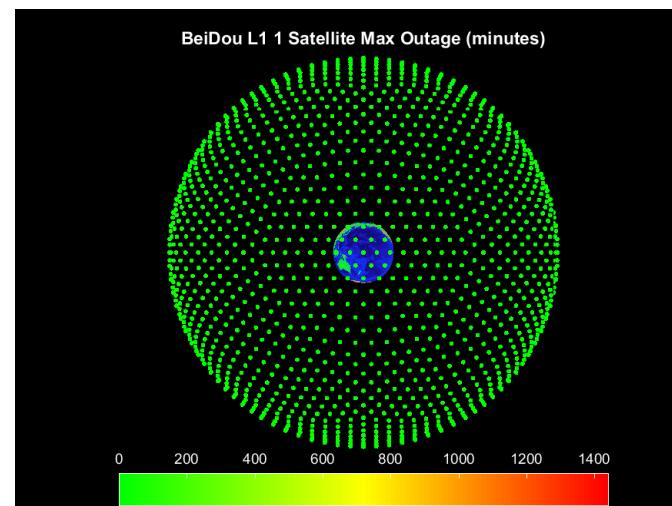
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Viewed from 0E Longitude



Viewed from 90E Longitude

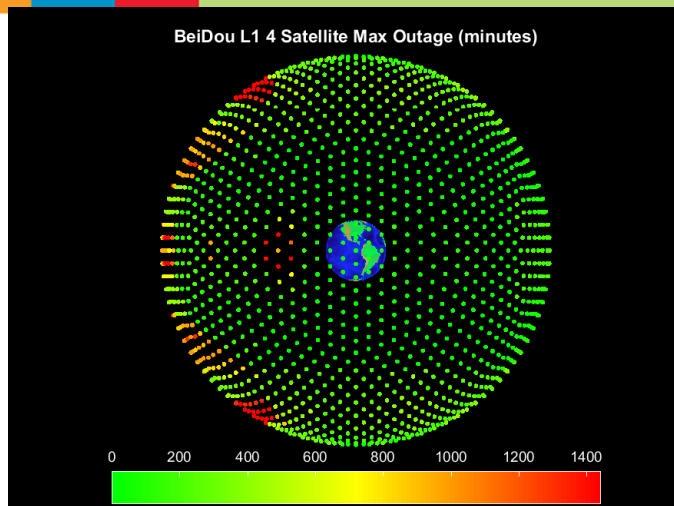


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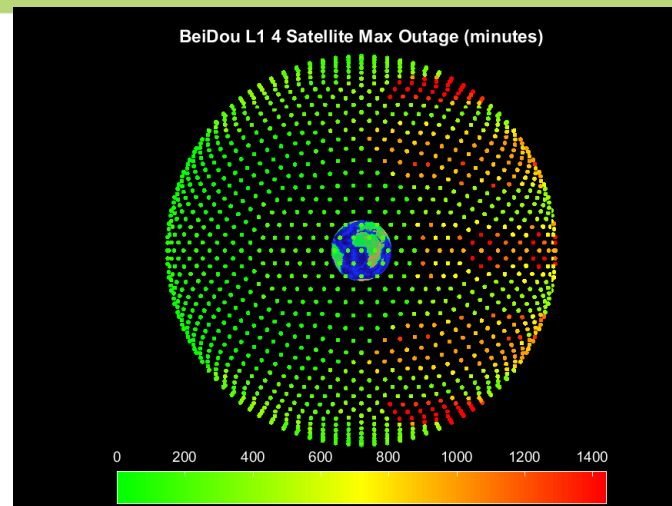


BeiDou – L1

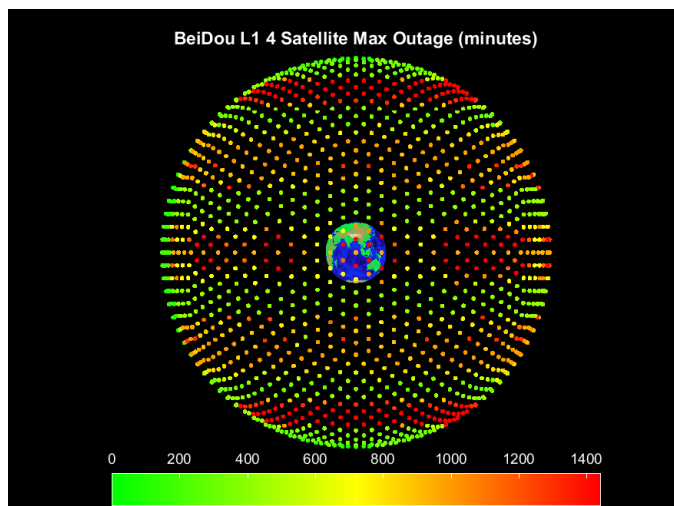
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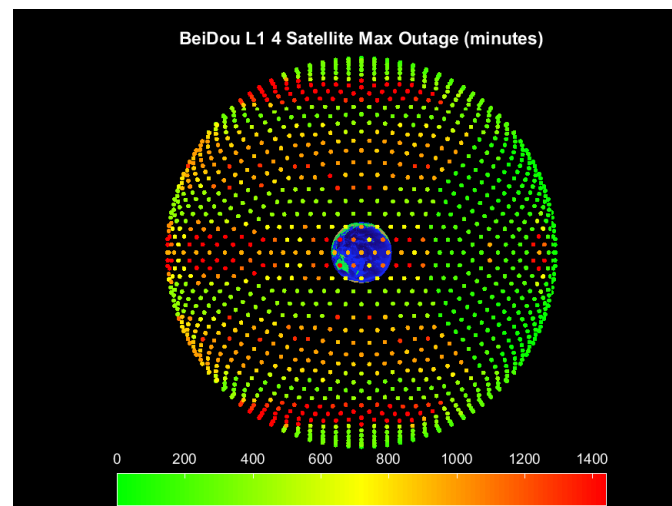
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

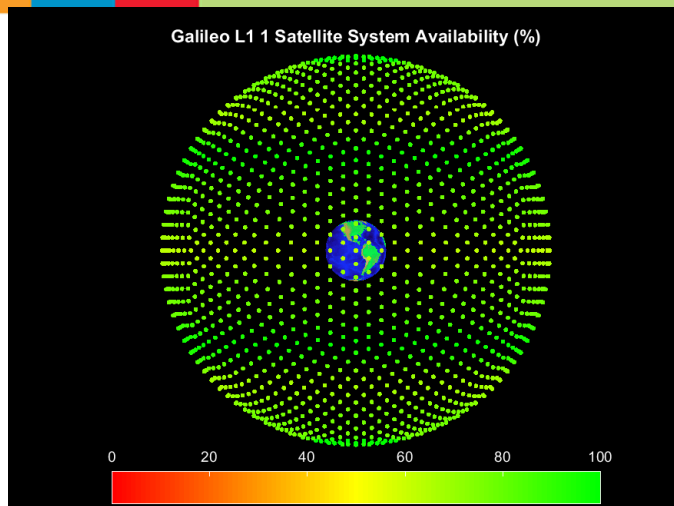


Viewed from 180E Longitude

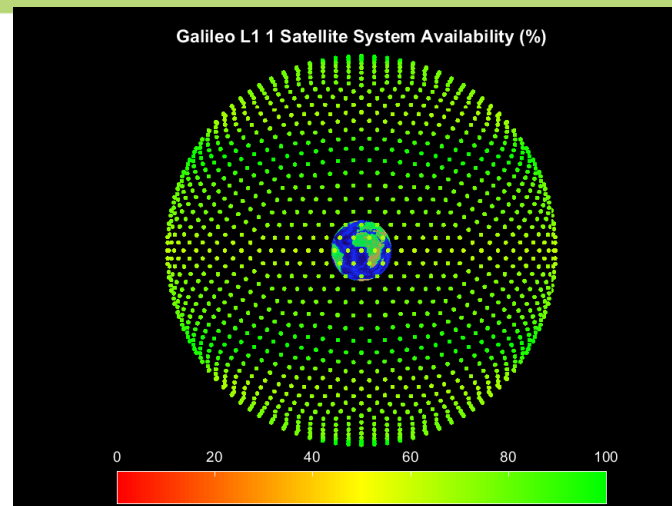


Galileo – L1

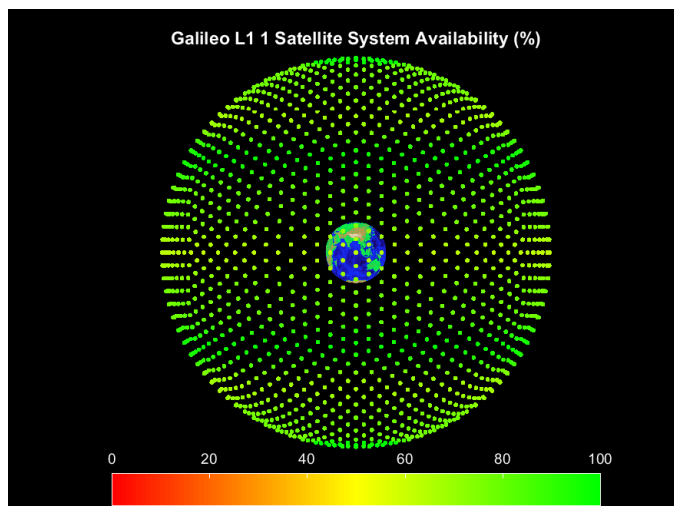
1 Satellite Grid Availability



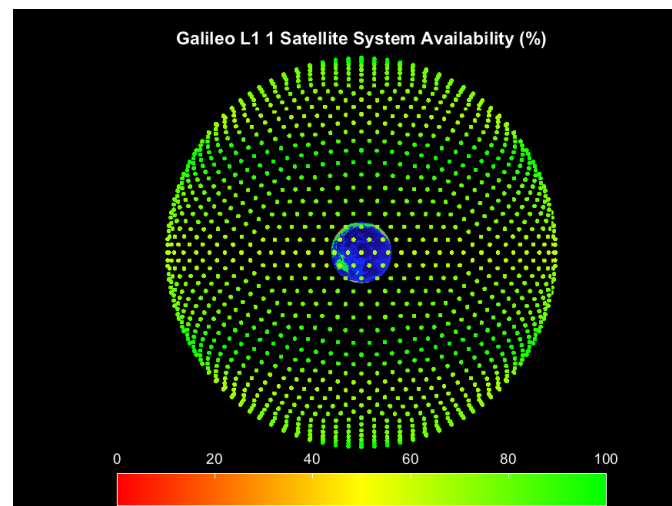
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

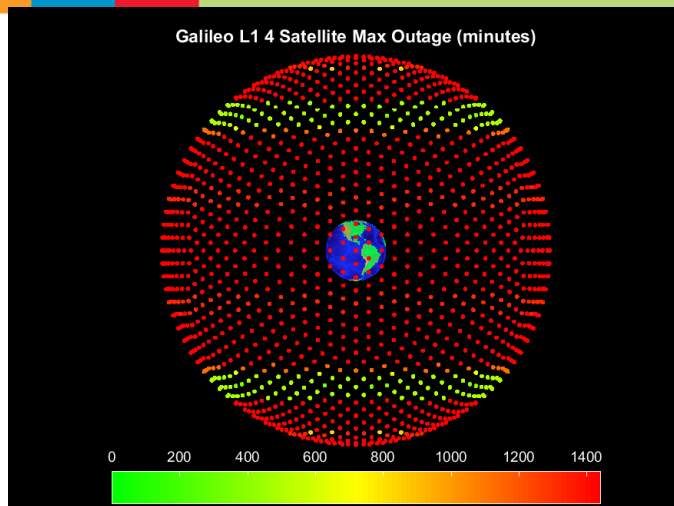


Viewed from 180E Longitude

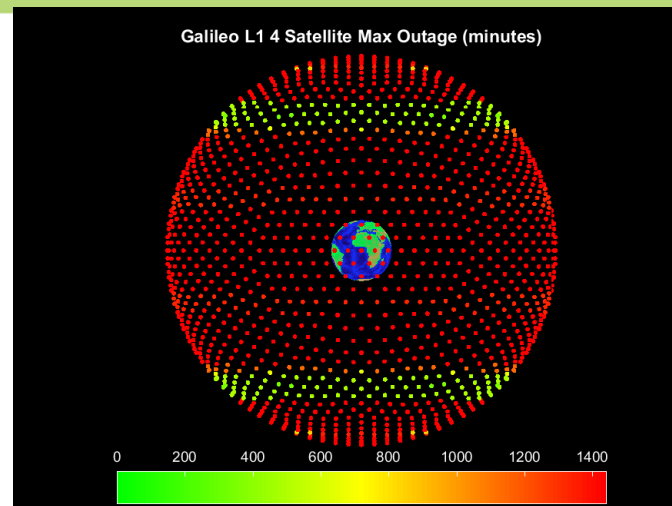


Galileo – L1

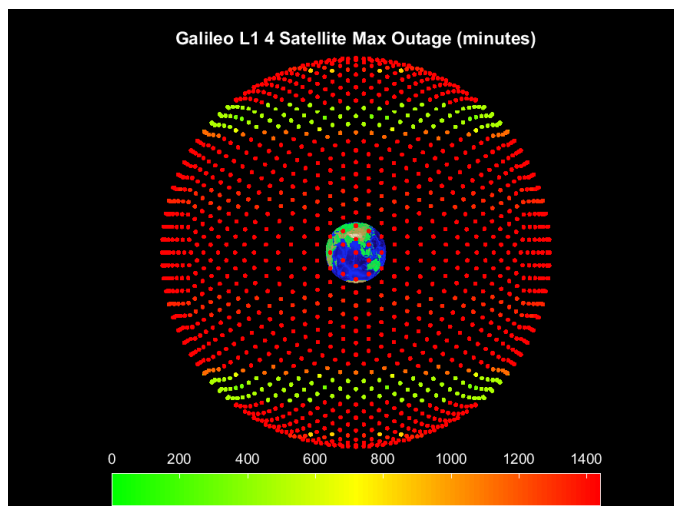
4 Satellite Grid Max Outage



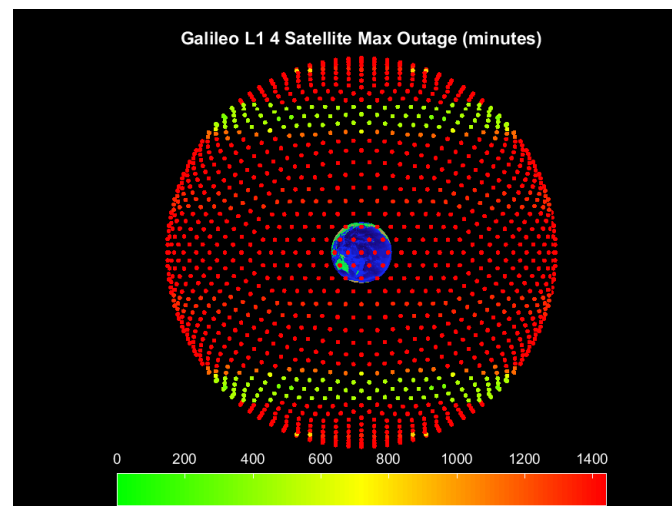
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

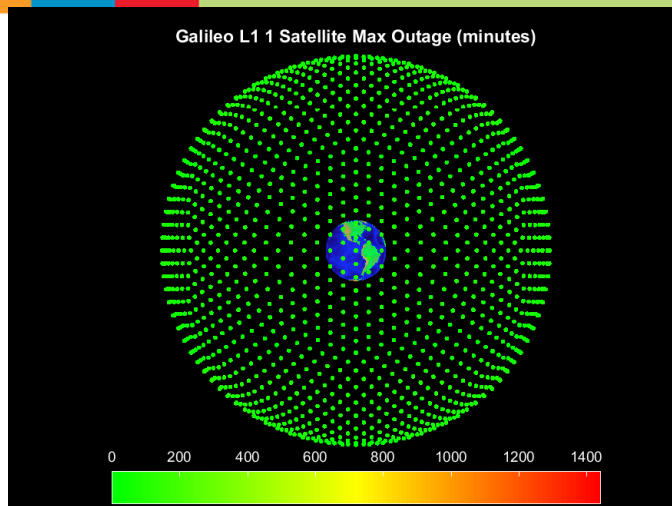


Viewed from 180E Longitude

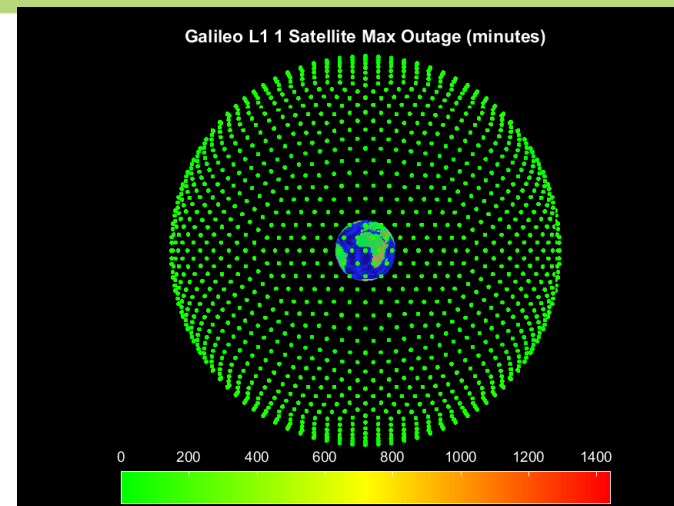


Galileo – L1

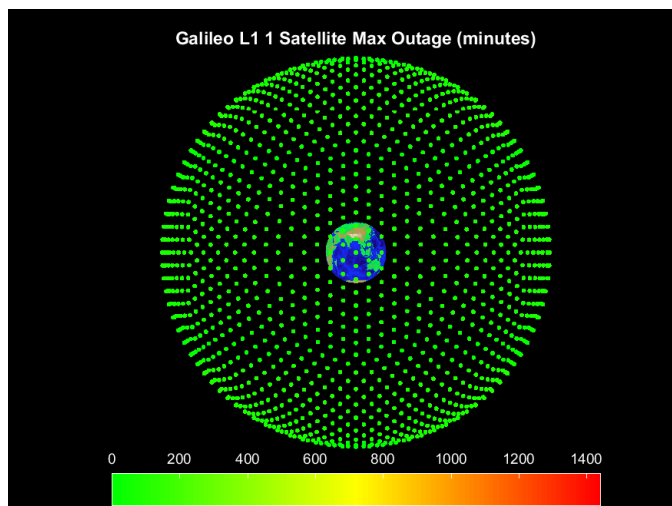
1 Satellite Grid Max Outage



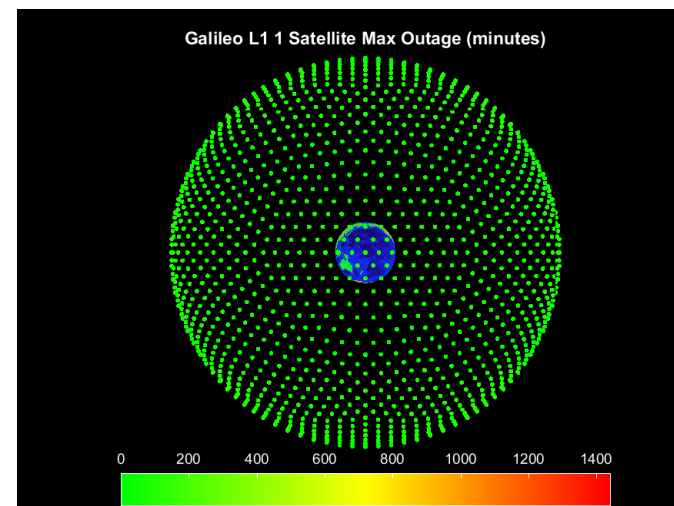
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

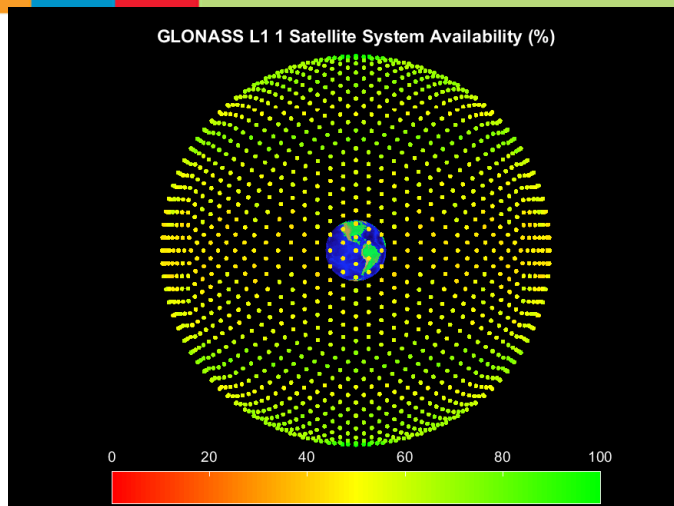


Viewed from 180E Longitude

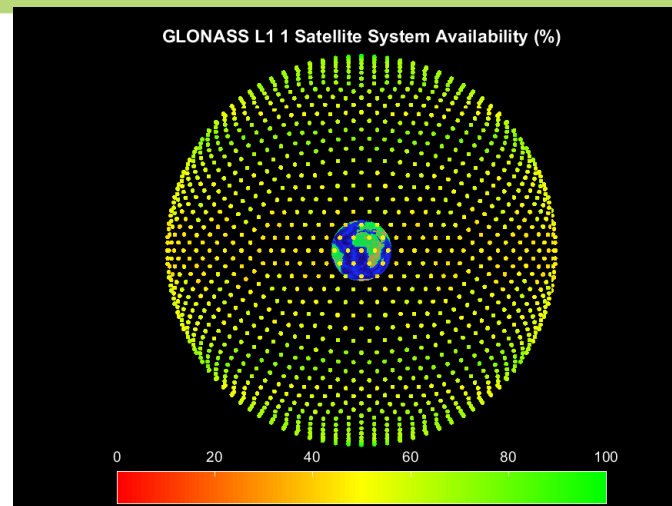


GLONASS – L1

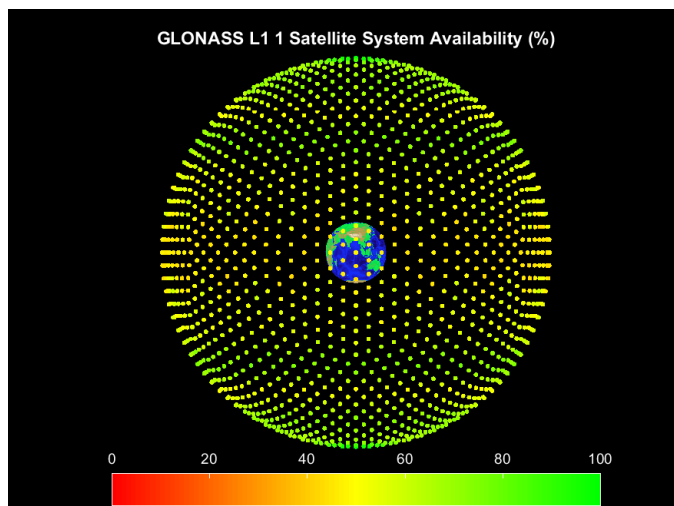
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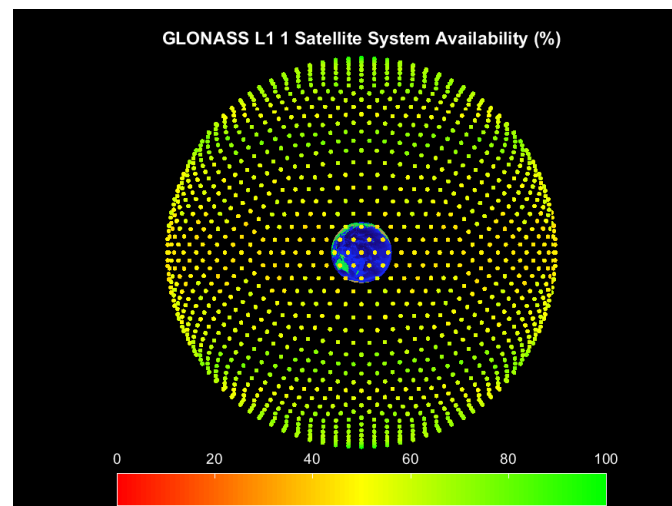
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

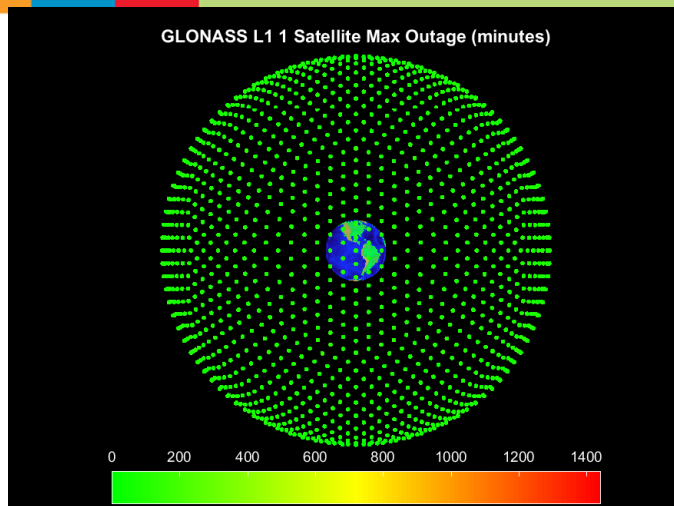


Viewed from 180E Longitude

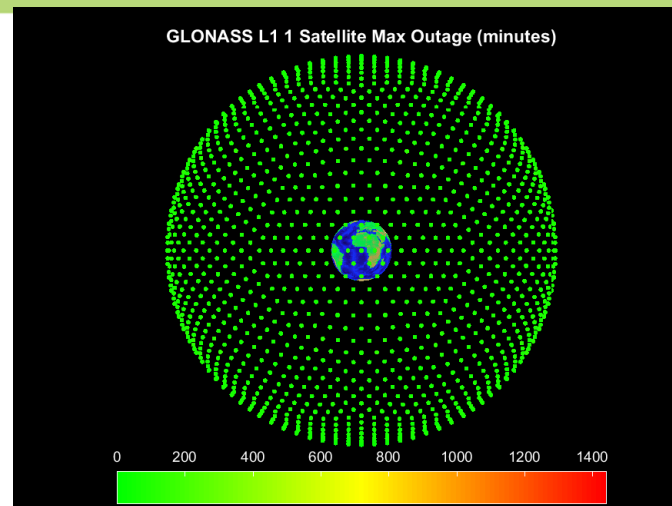


GLONASS – L1

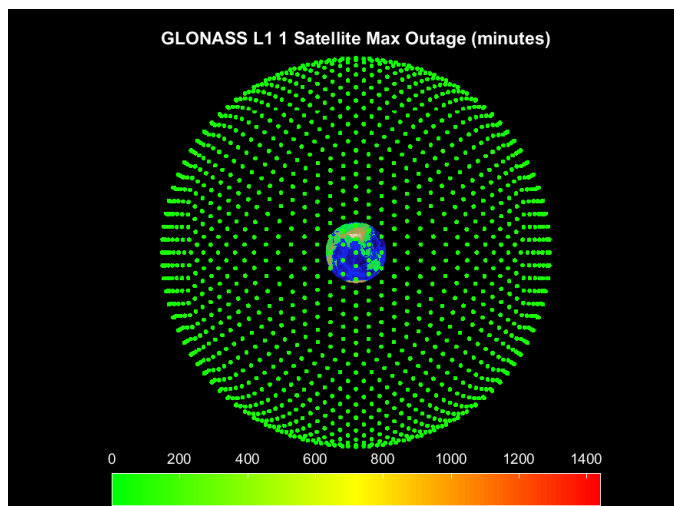
1 Satellite Grid Max Outage



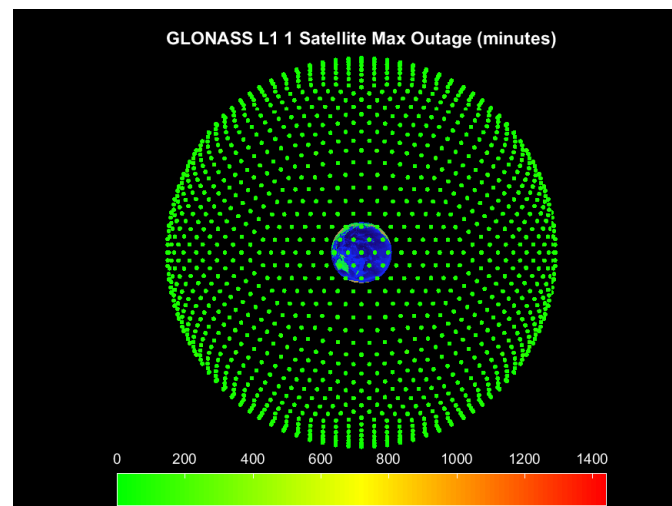
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

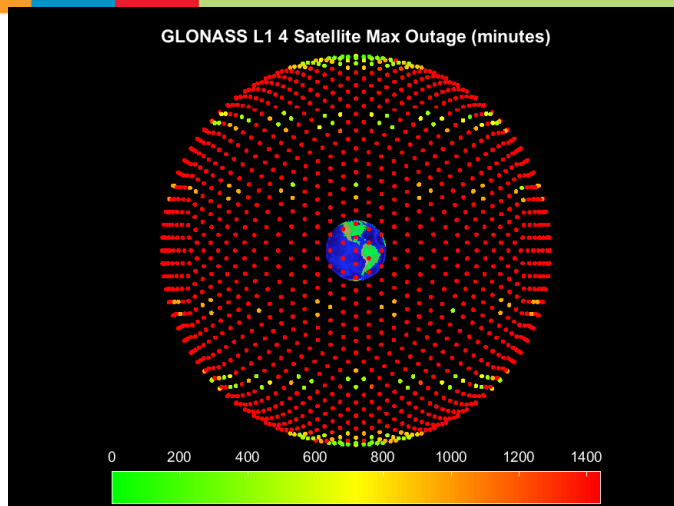


Viewed from 180E Longitude

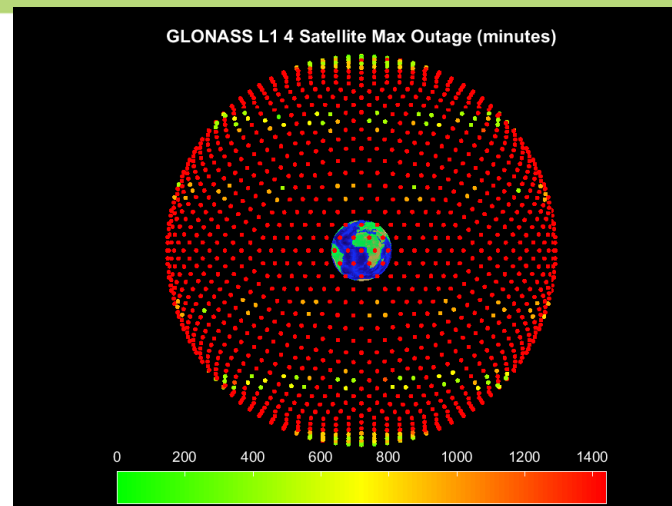


GLONASS – L1

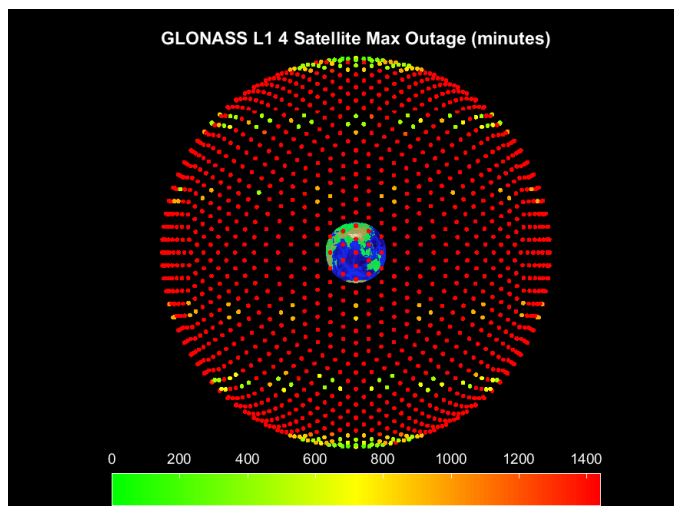
4 Satellite Grid Max Outage



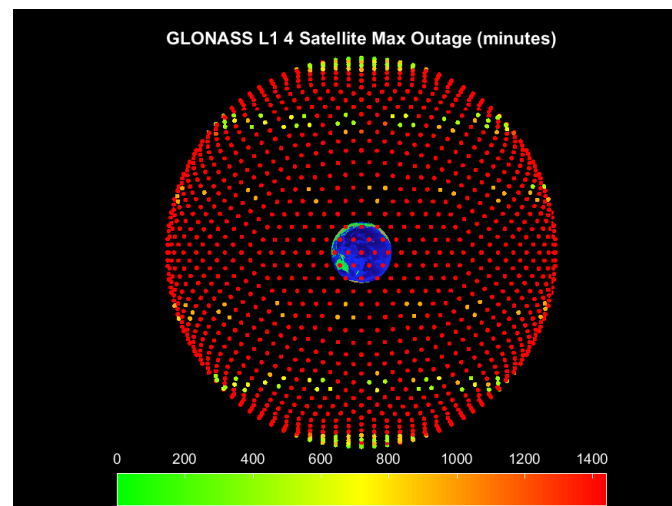
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

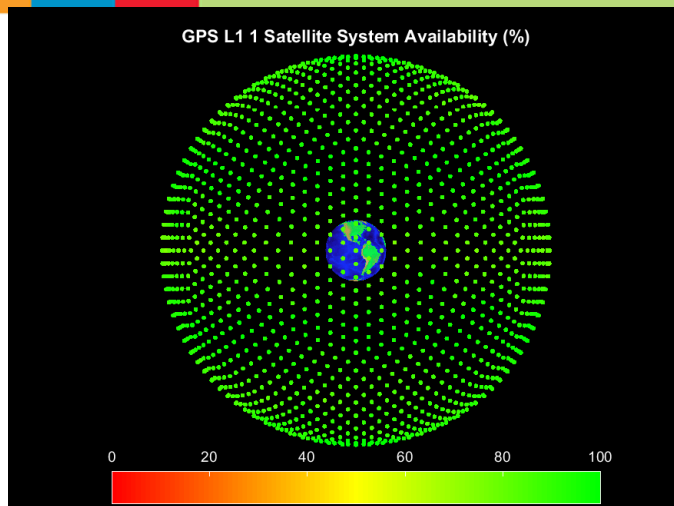


Viewed from 180E Longitude

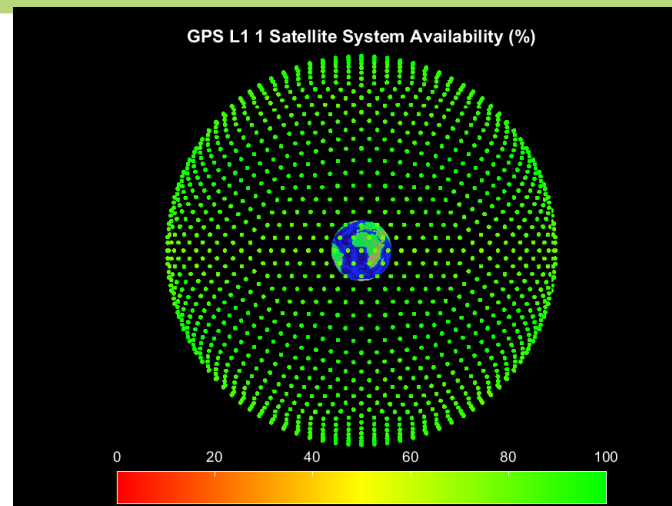


GPS – L1

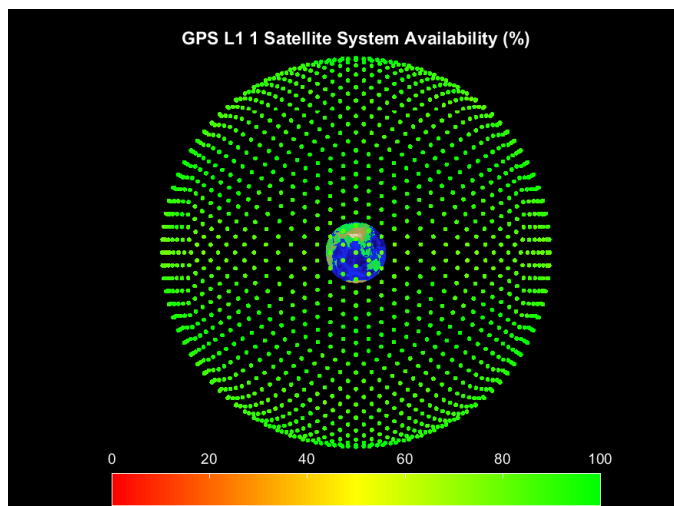
1 Satellite Grid Availability



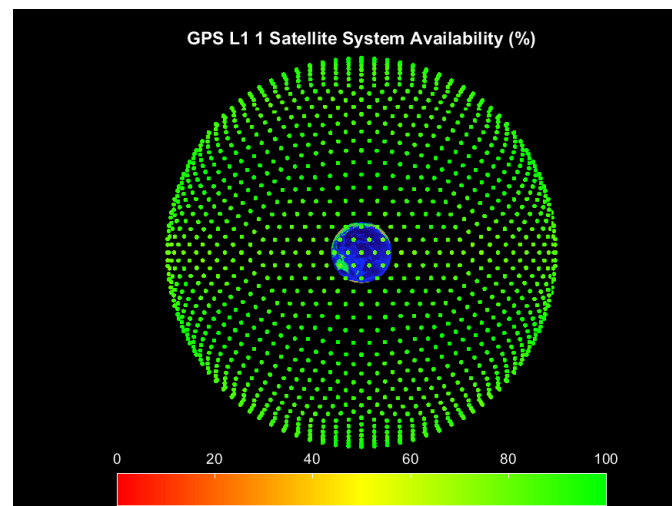
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

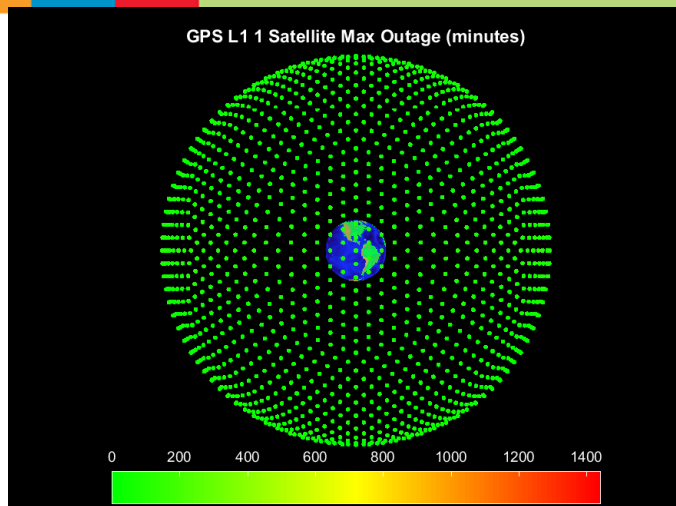


Viewed from 180E Longitude

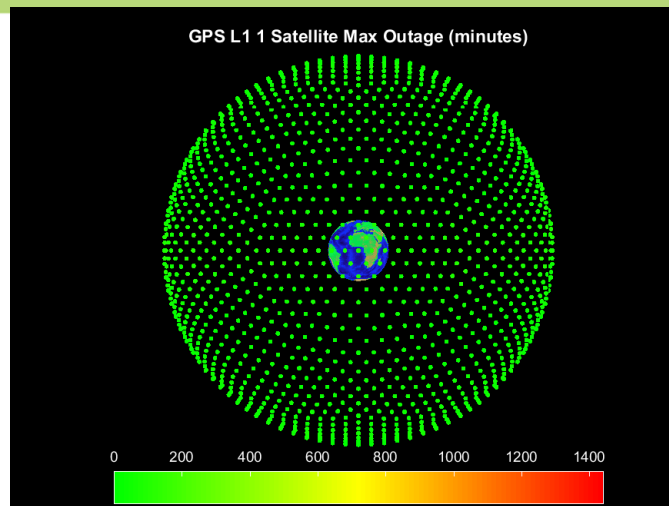


GPS – L1

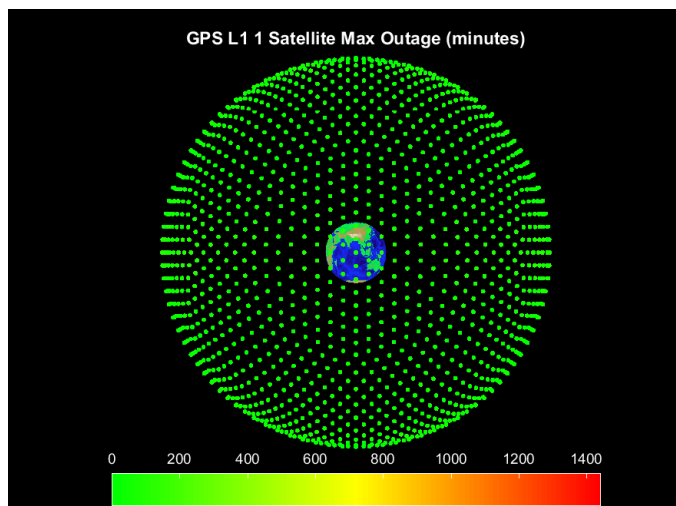
1 Satellite Grid Max Outage



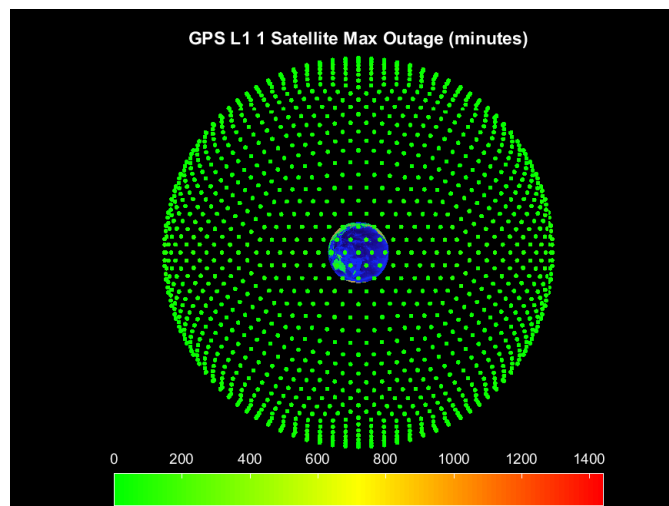
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

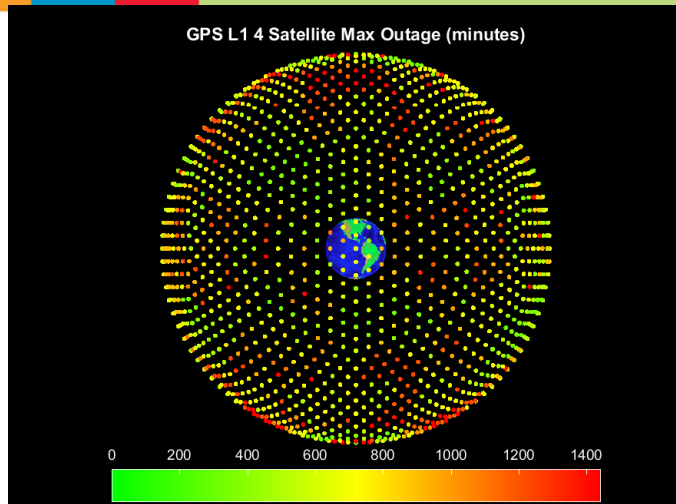


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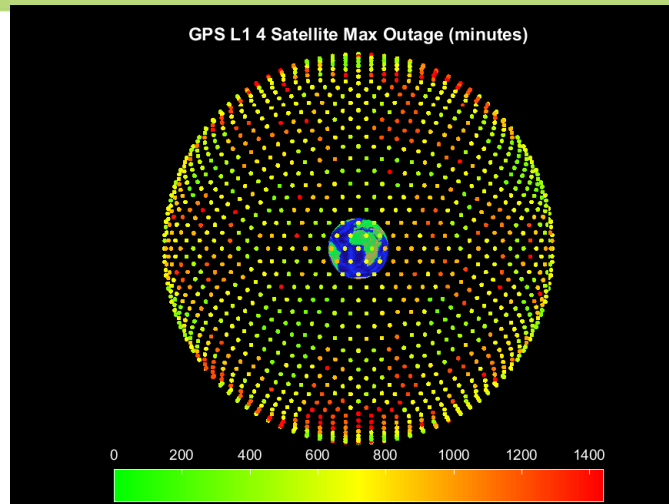


GPS – L1

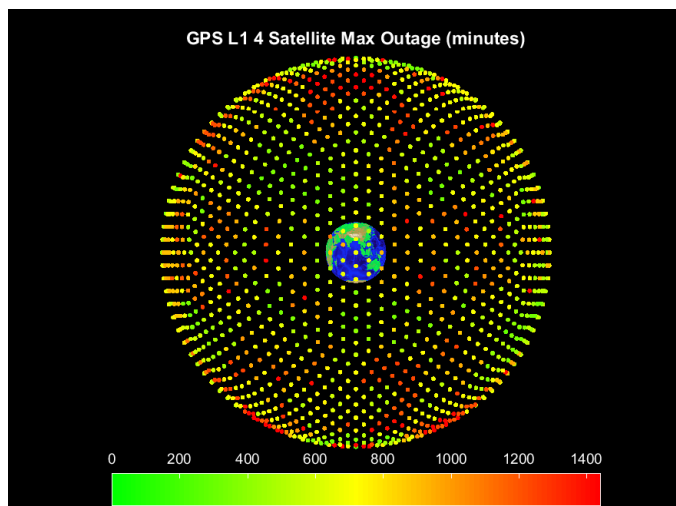
4 Satellite Grid Max Outage



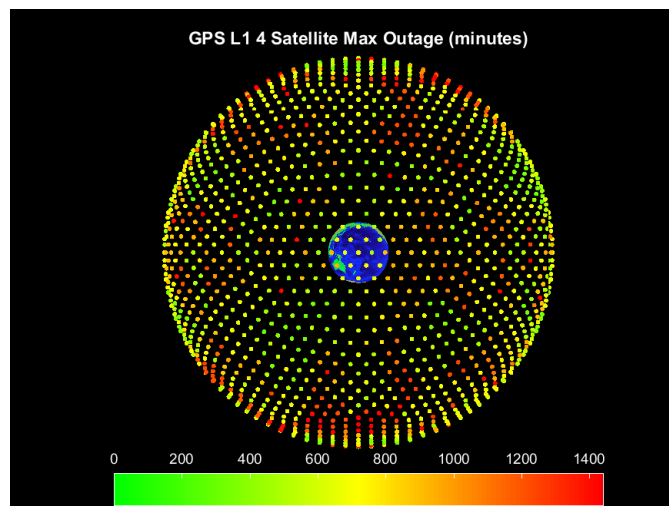
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

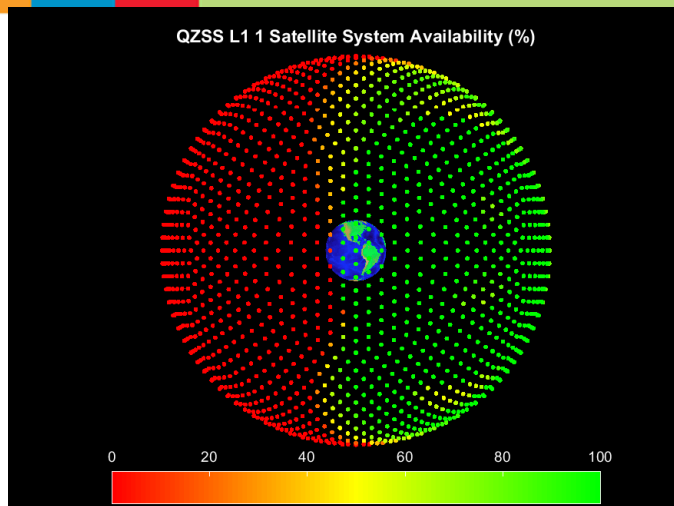


Viewed from 180E Longitude

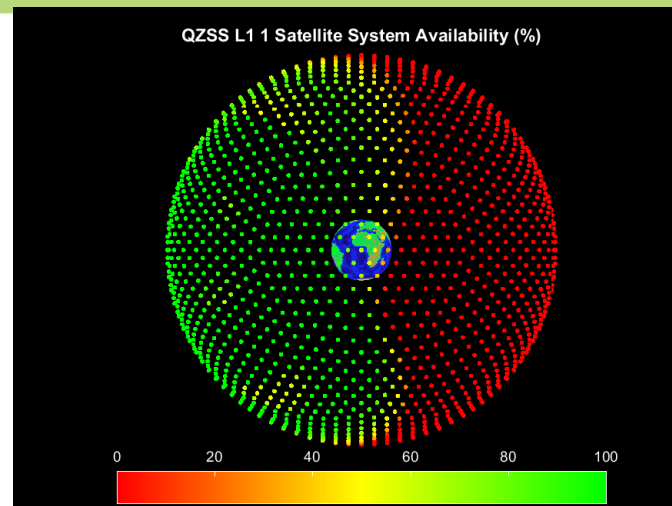


QZSS – L1

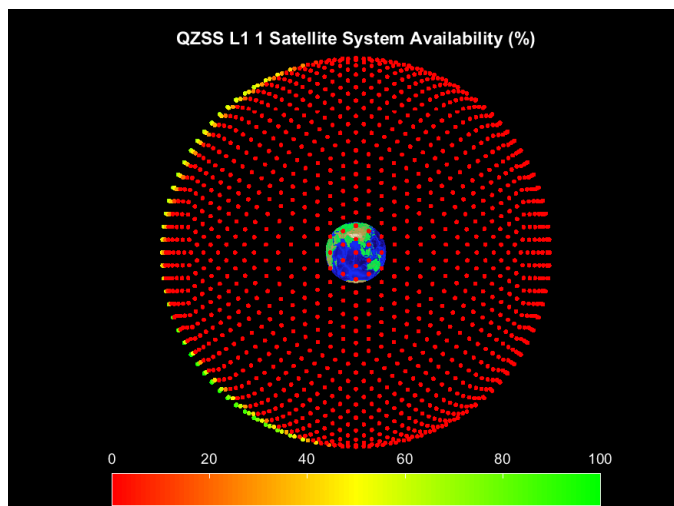
1 Satellite Grid Availability



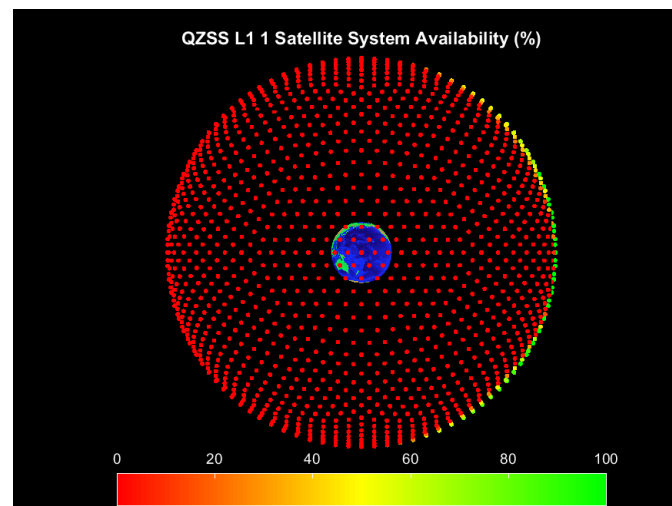
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

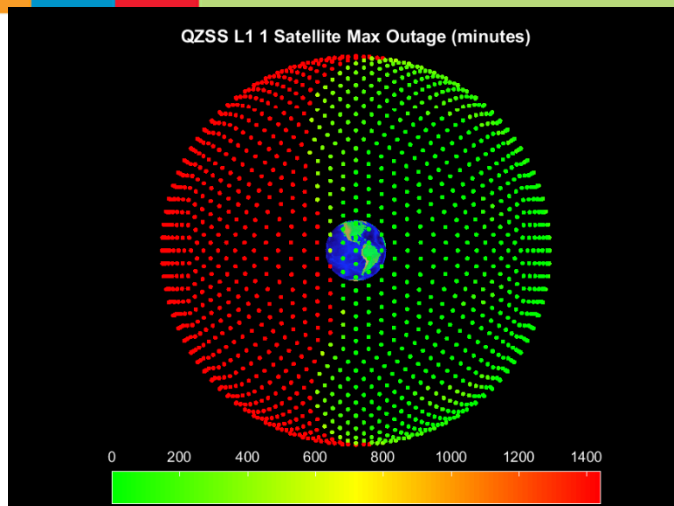


Viewed from 180E Longitude

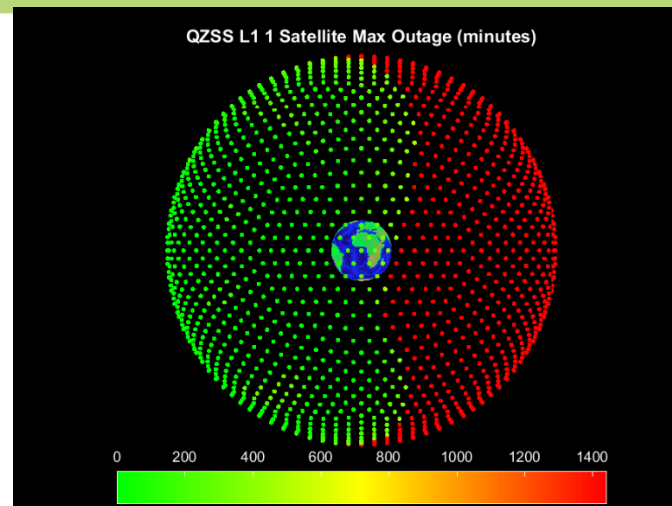


QZSS – L1

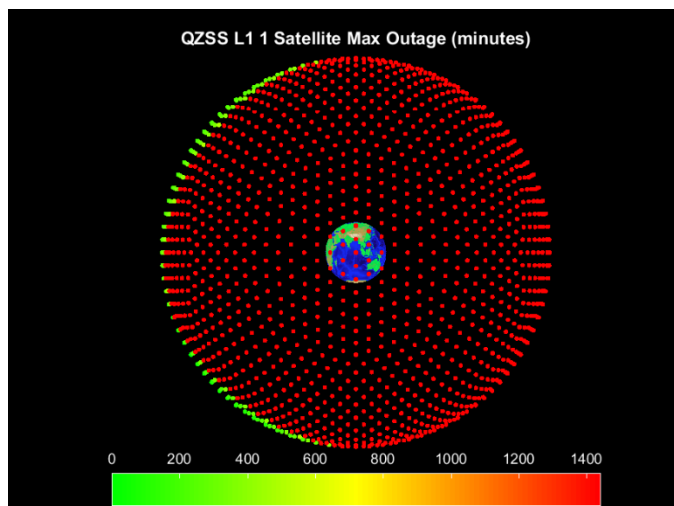
1 Satellite Grid Max Outage



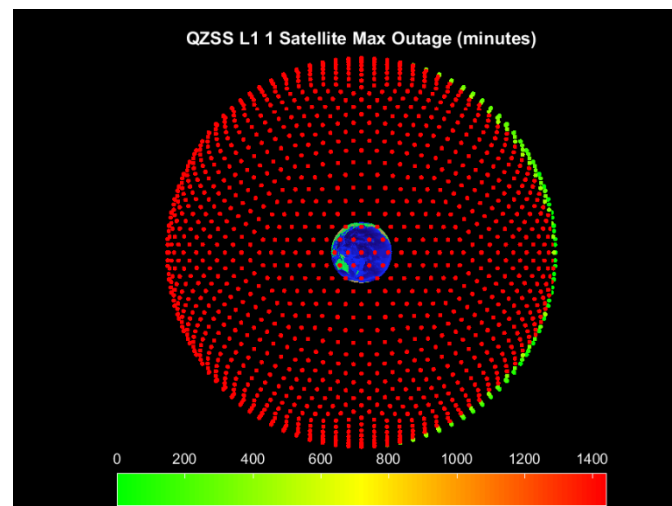
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

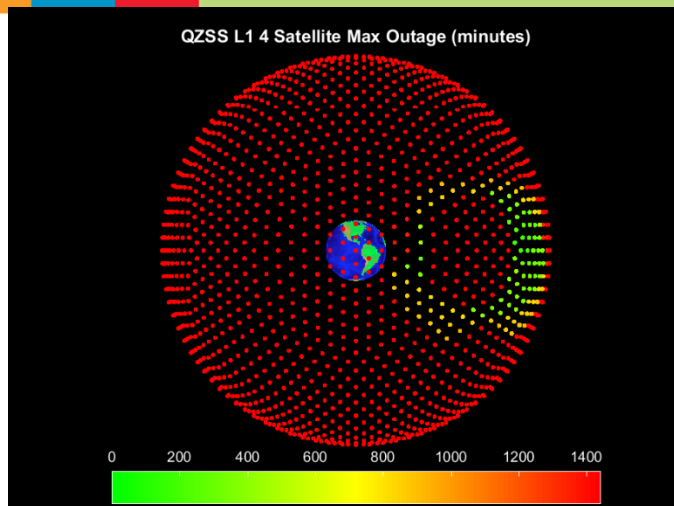


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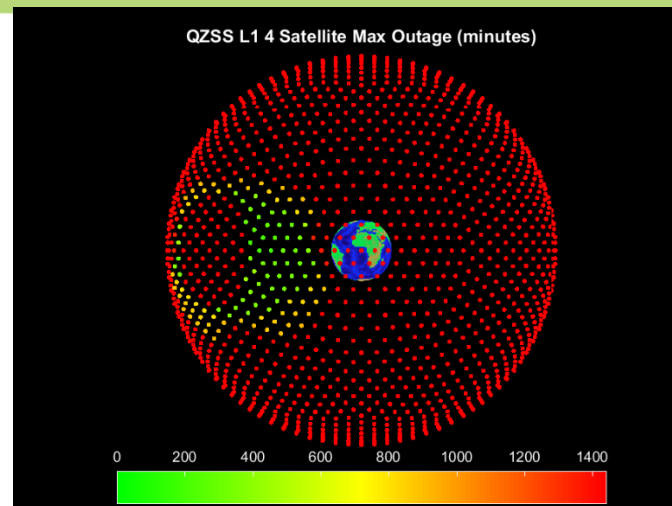


QZSS – L1

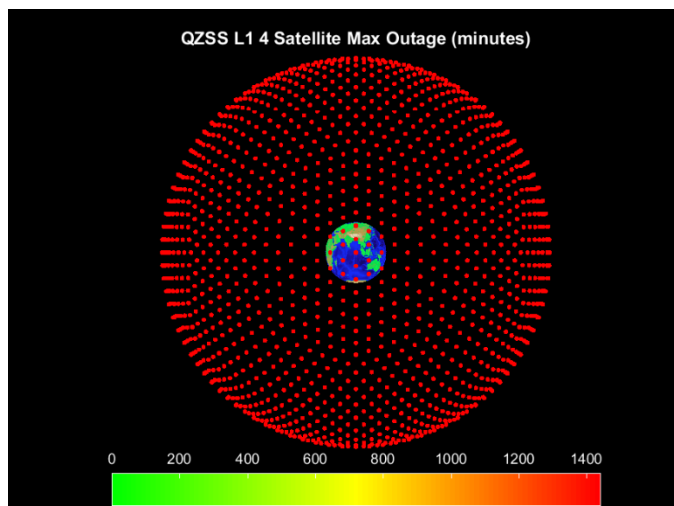
4 Satellite Grid Max Outage



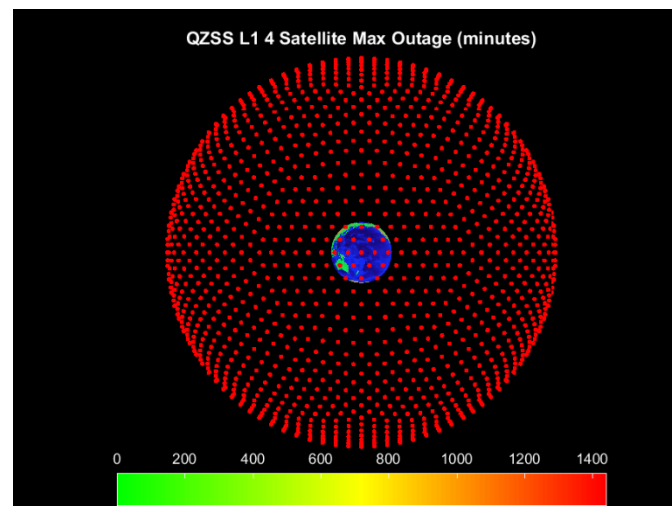
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

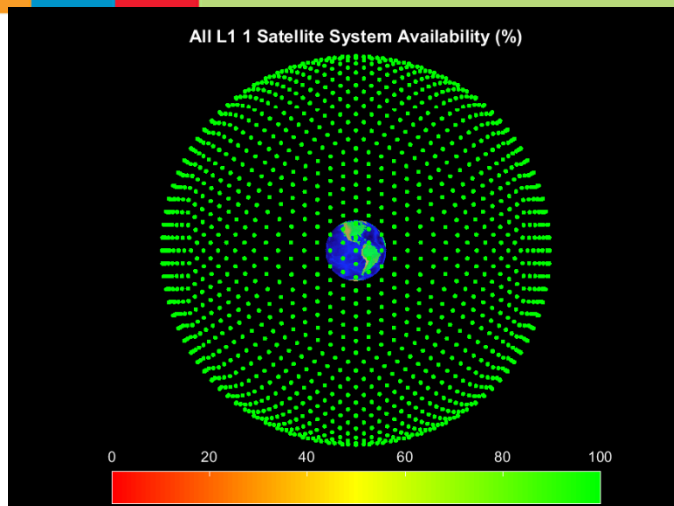


Viewed from 180E Longitude

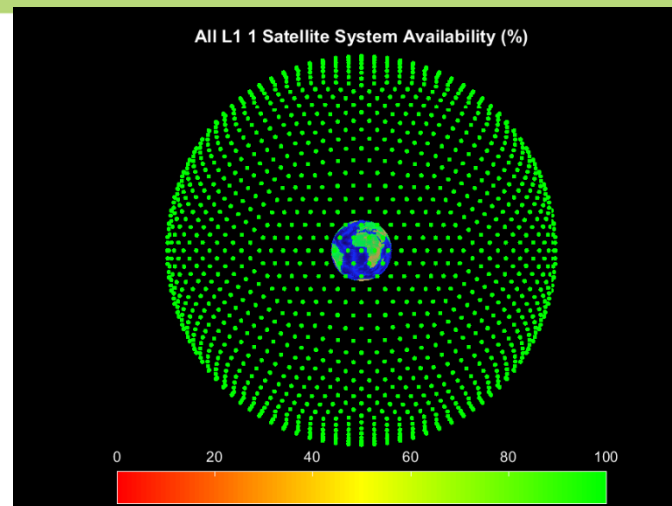


All – L1

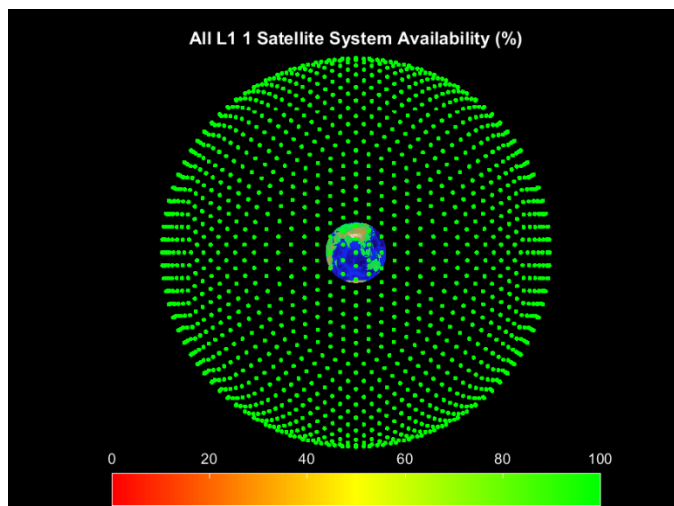
1 Satellite Grid Availability



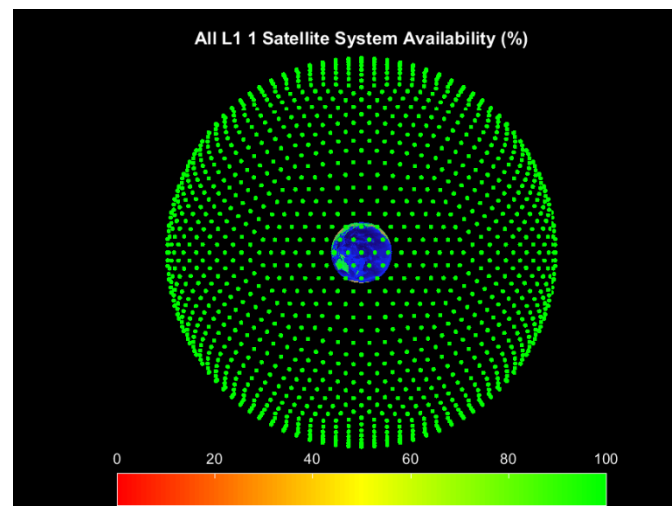
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

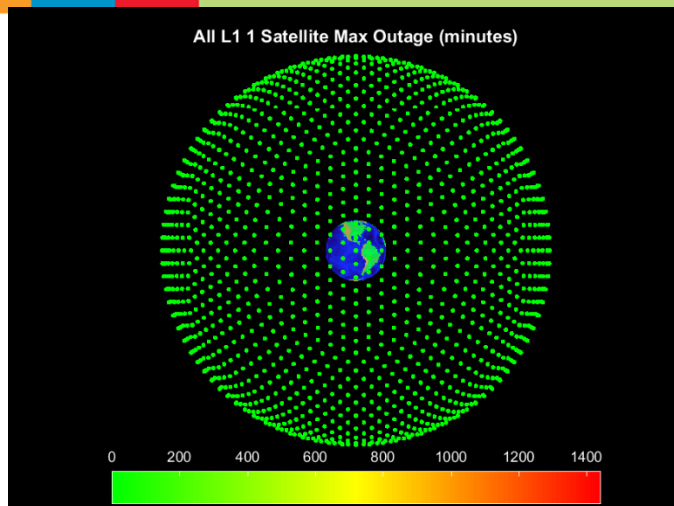


Viewed from 180E Longitude

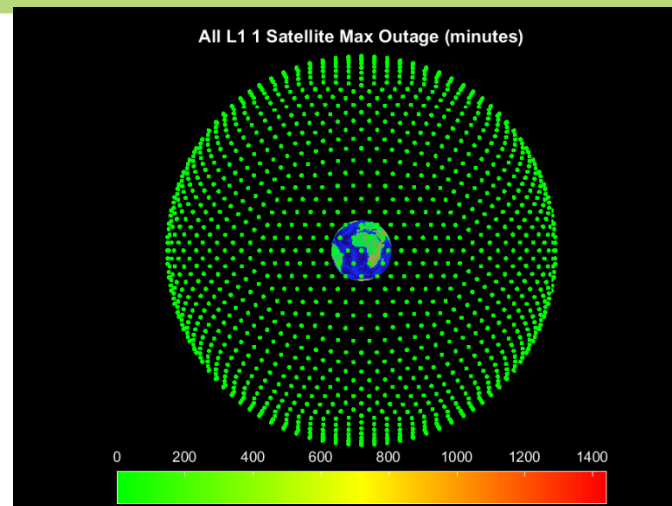


All – L1

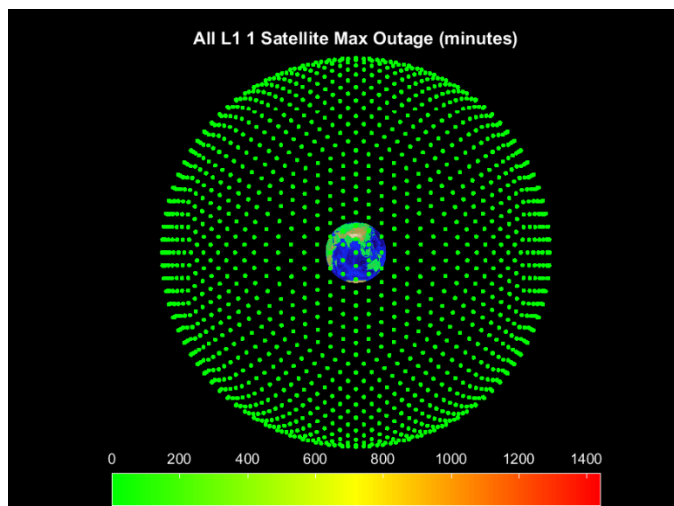
1 Satellite Grid Max Outage



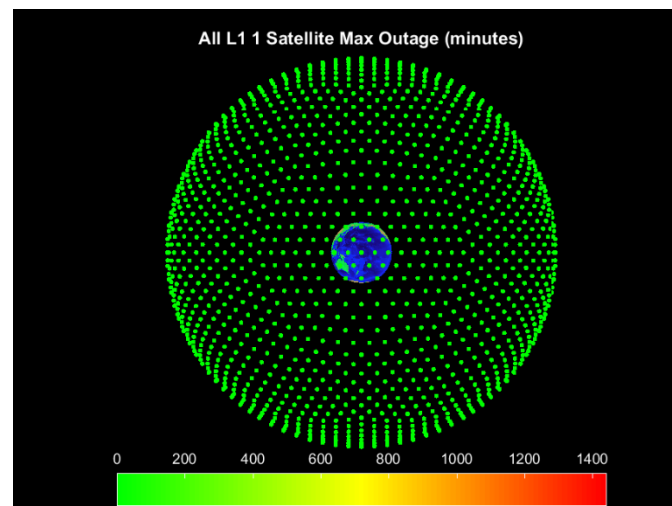
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

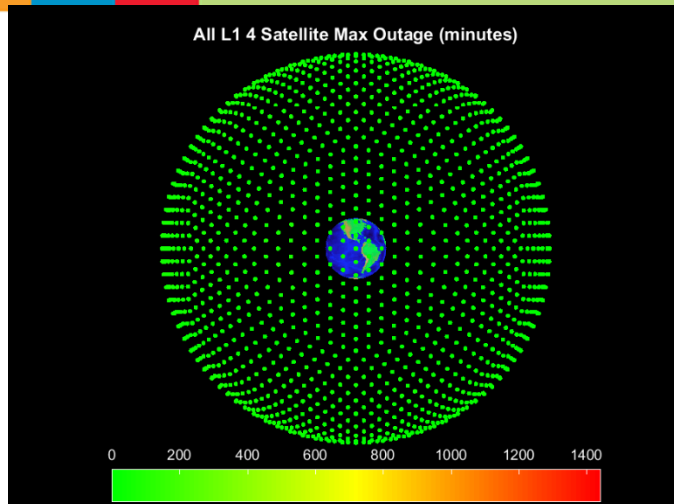


Viewed from 180E Longitude

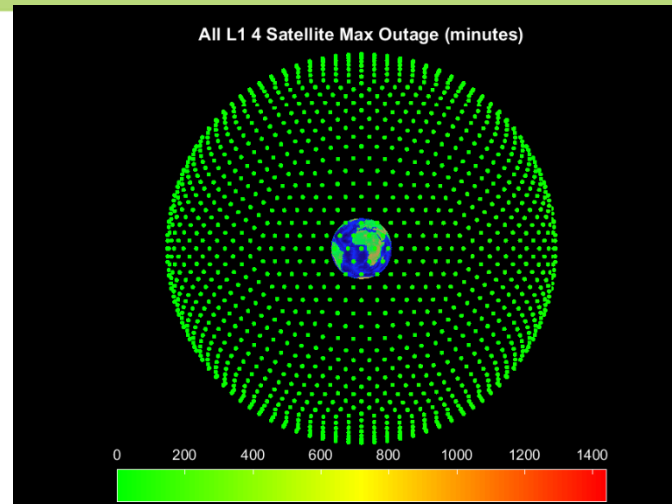


All – L1

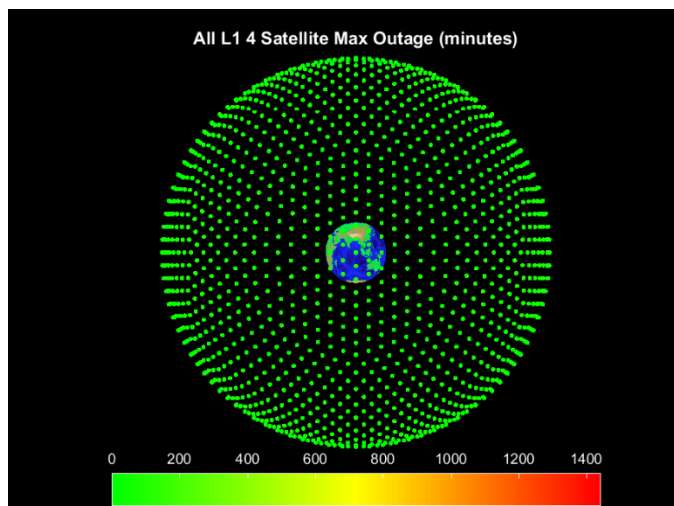
4 Satellite Grid Max Outage



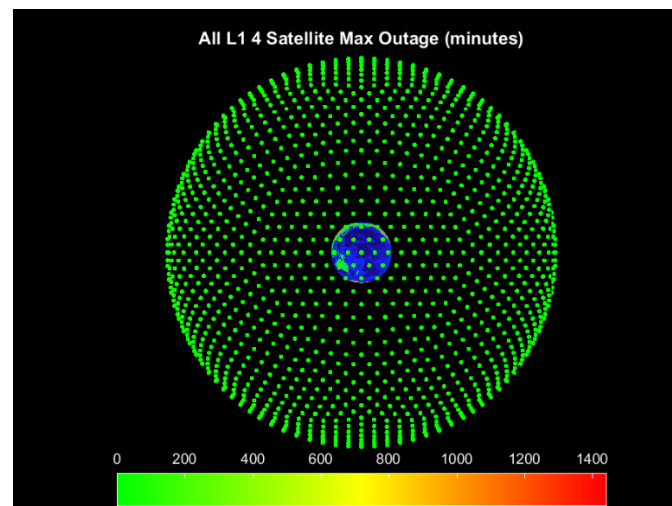
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

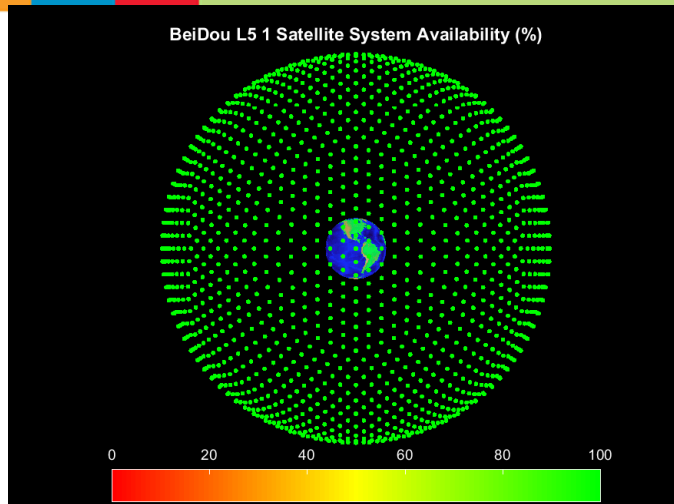


Viewed from 180E Longitude

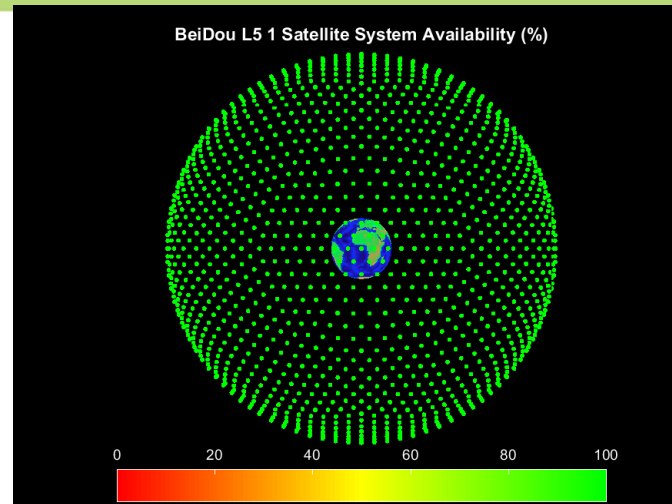


BeiDou – L5

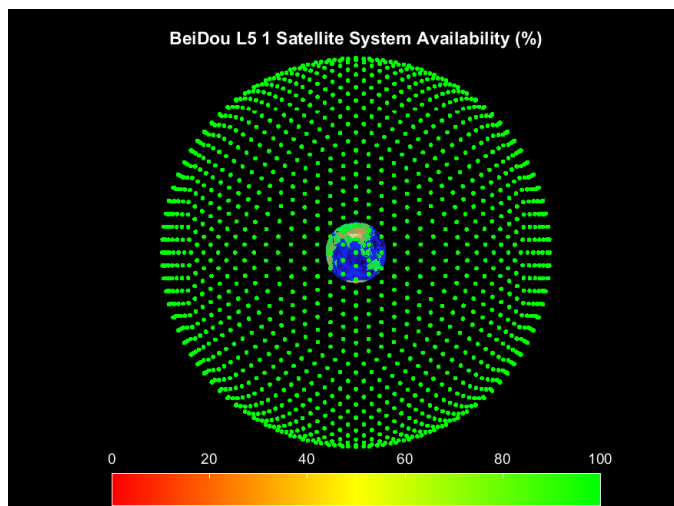
1 Satellite Grid Availability



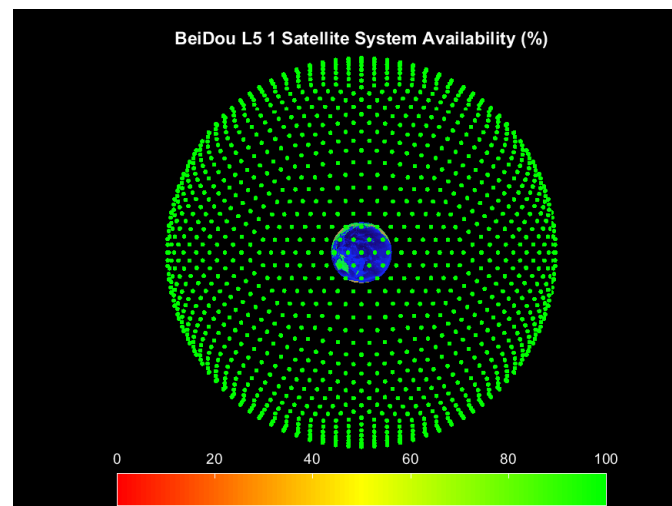
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

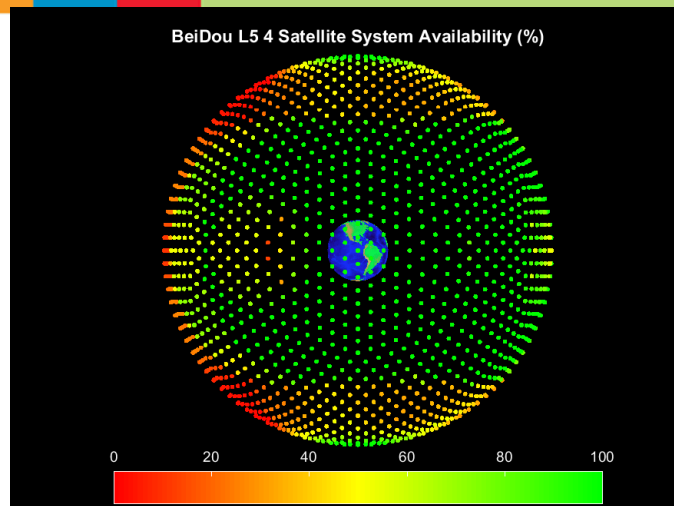


Viewed from 180E Longitude

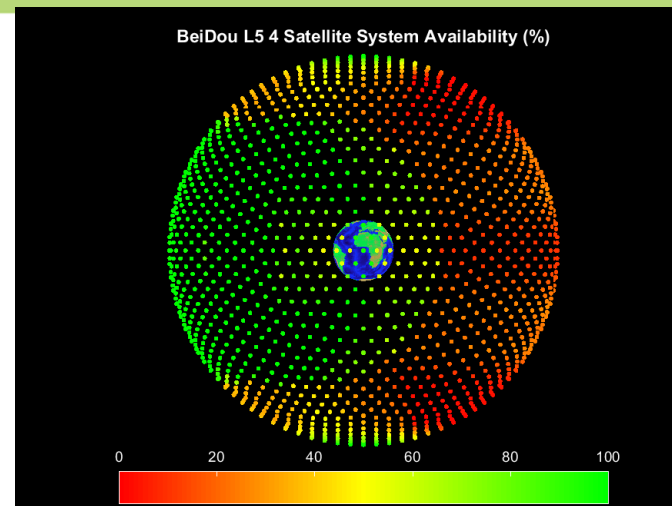


BeiDou – L5

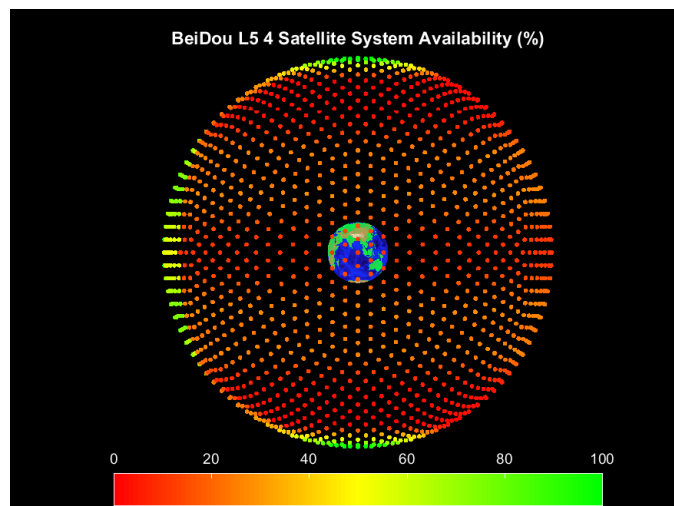
4 Satellite Grid Availability



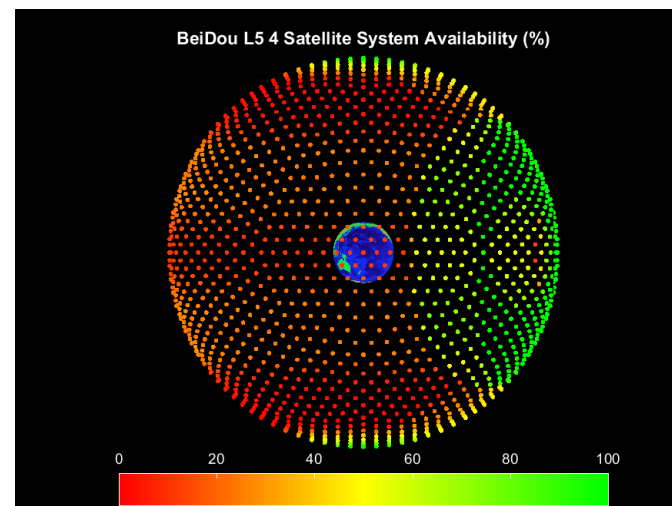
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

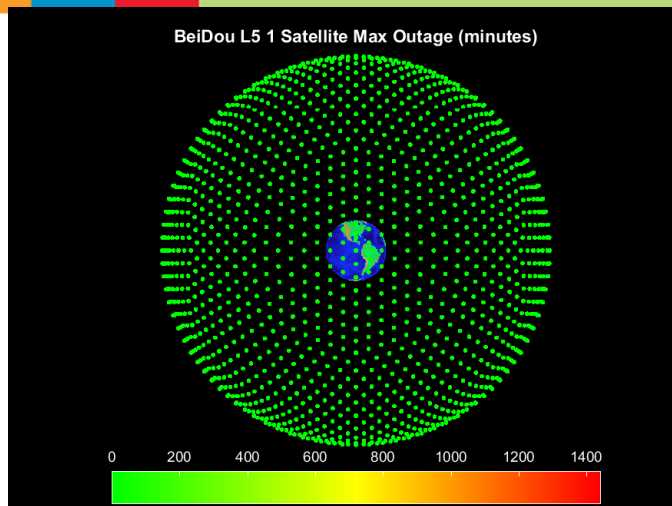


Viewed from 180E Longitude

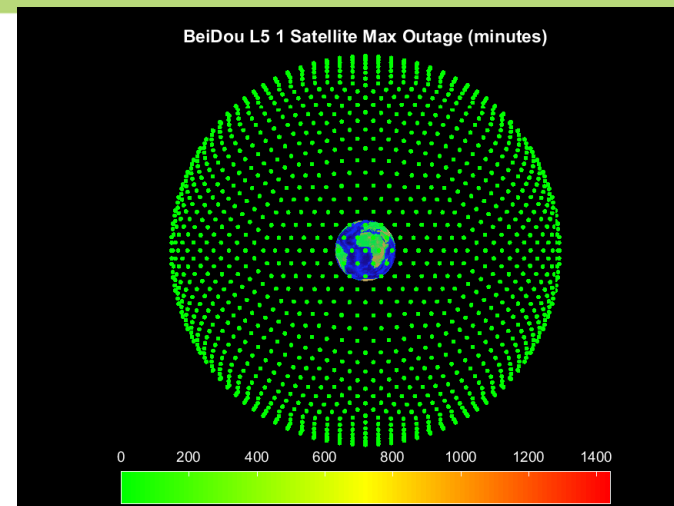


BeiDou – L5

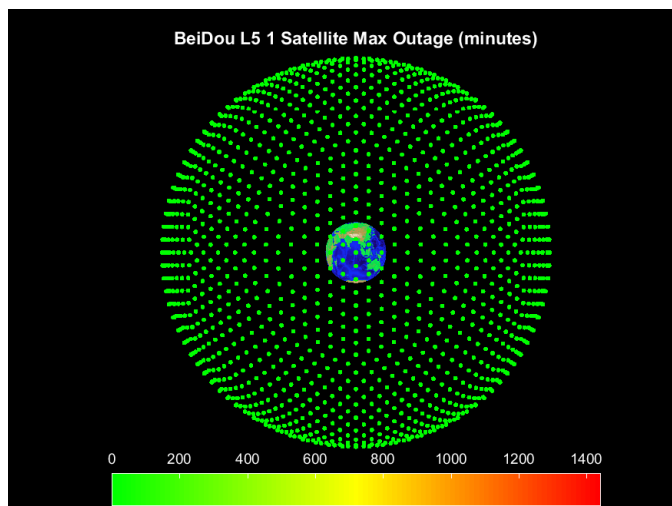
1 Satellite Grid Max Outage



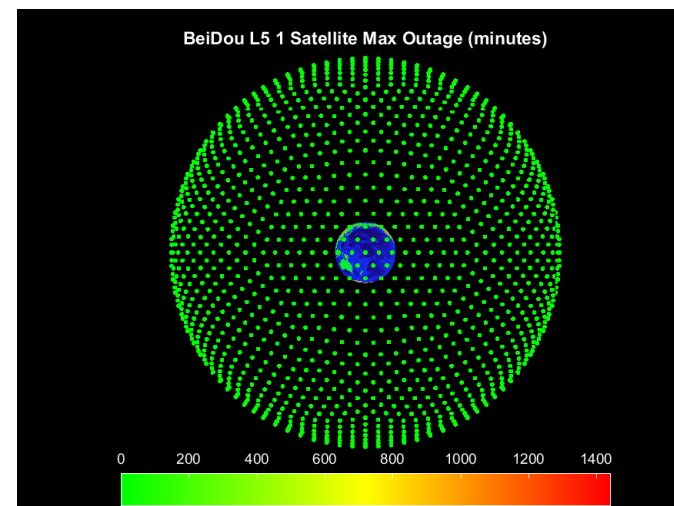
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

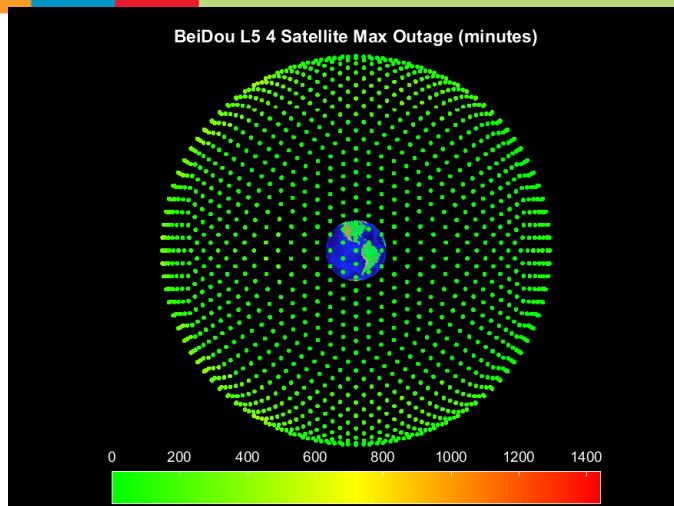


Viewed from 180E Longitude

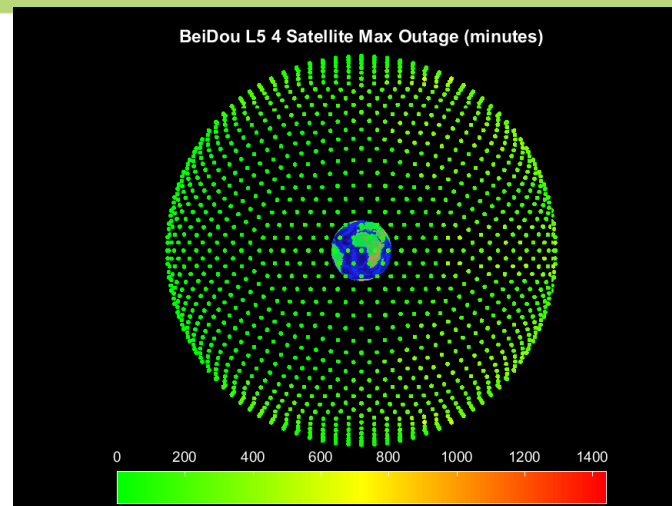


BeiDou – L5

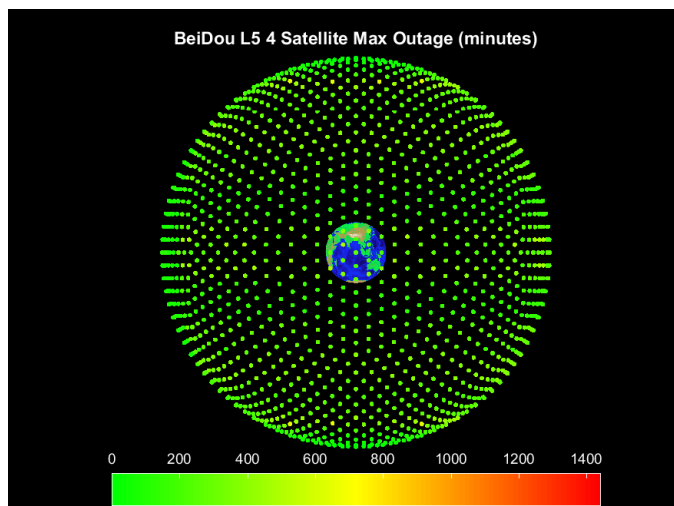
4 Satellite Grid Max Outage



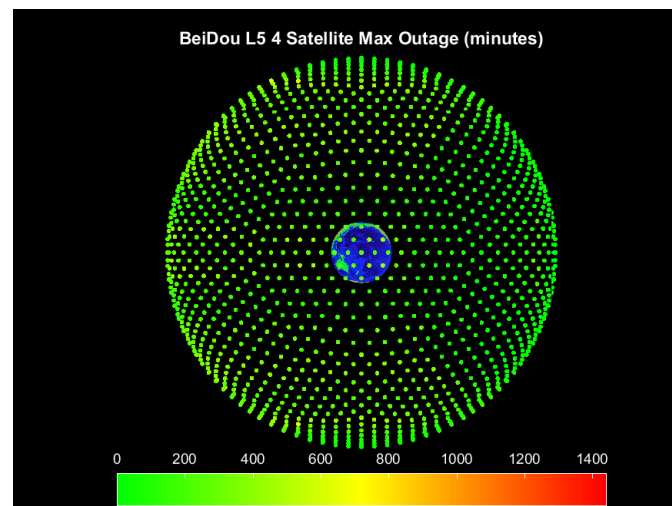
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

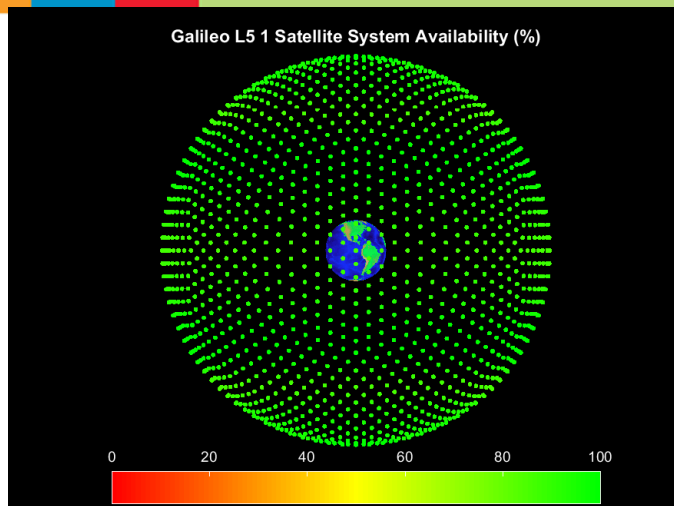


Viewed from 180E Longitude

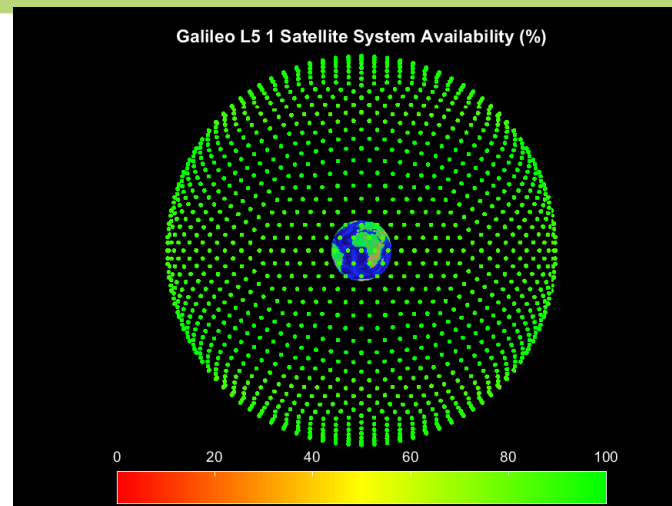


Galileo – L5

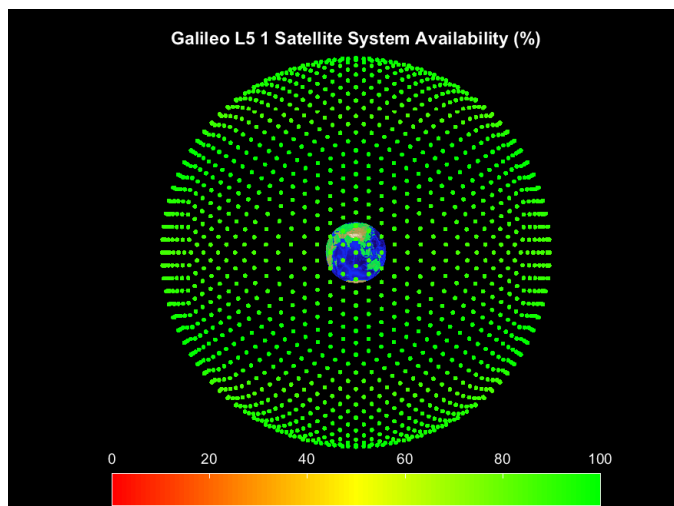
1 Satellite Grid Availability



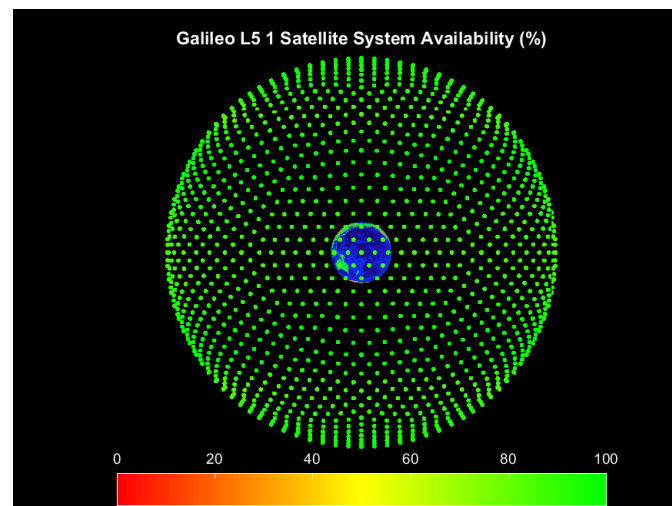
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

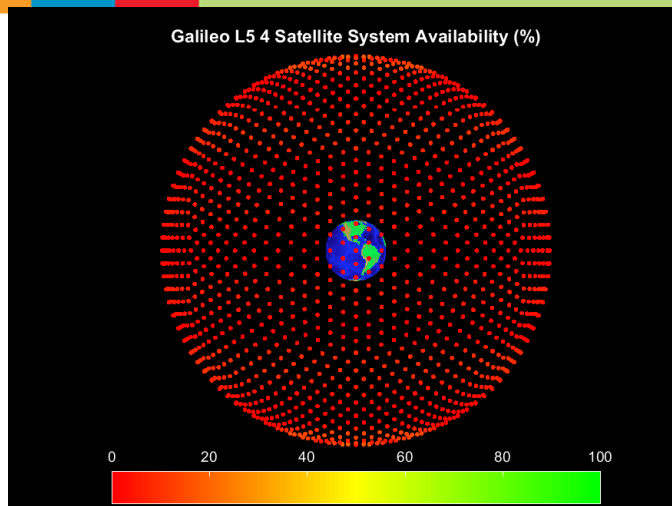


Viewed from 180E Longitude

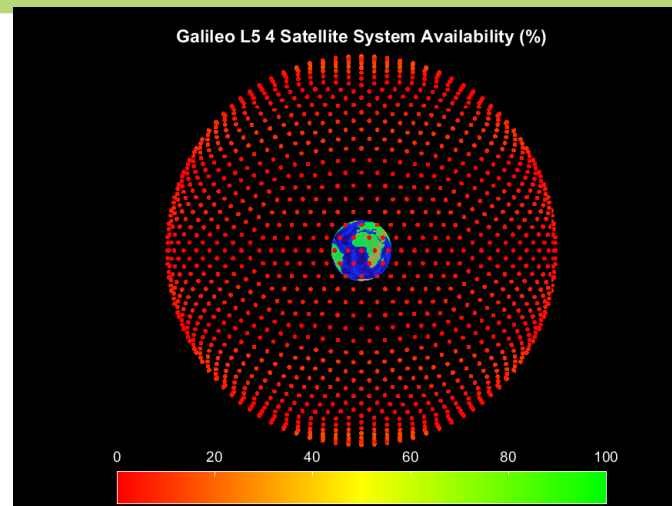


Galileo – L5

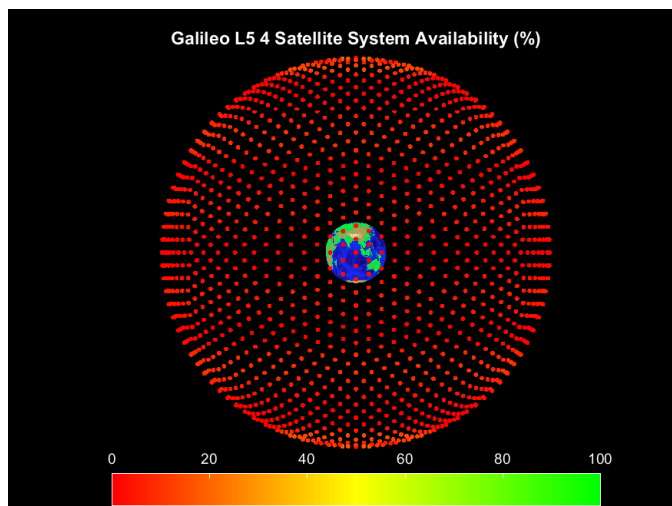
4 Satellite Grid Availability



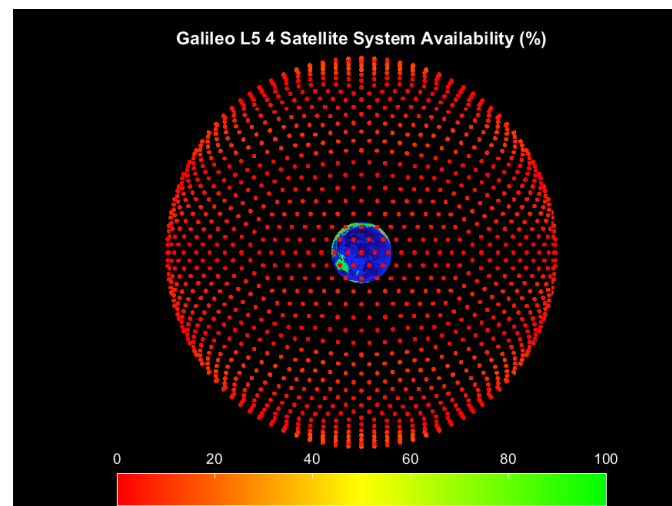
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

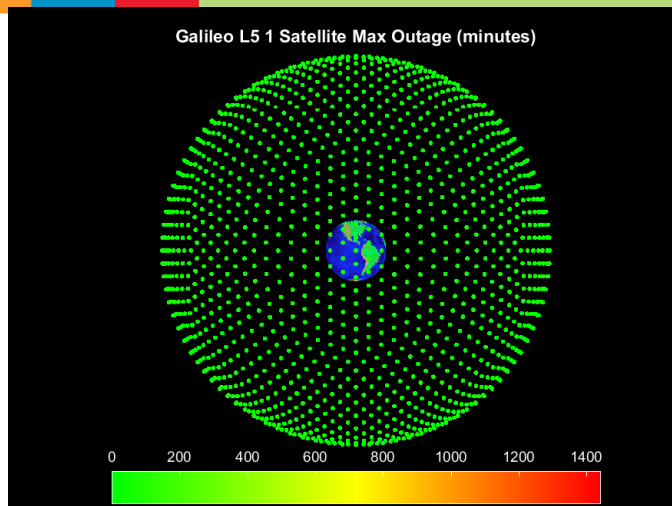


Viewed from 180E Longitude

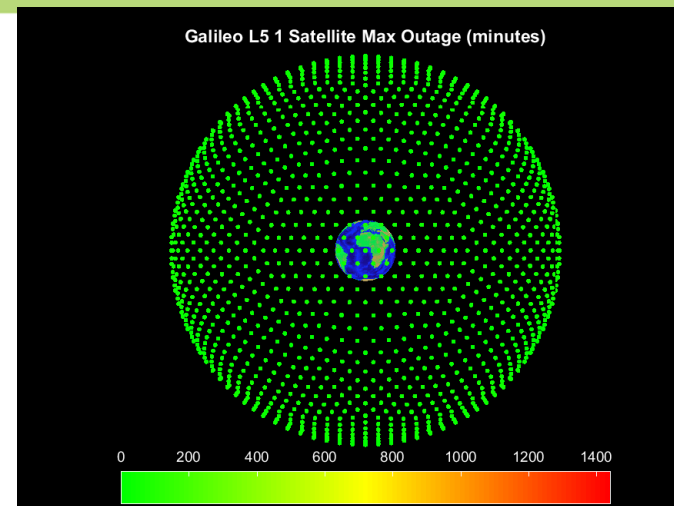


Galileo – L5

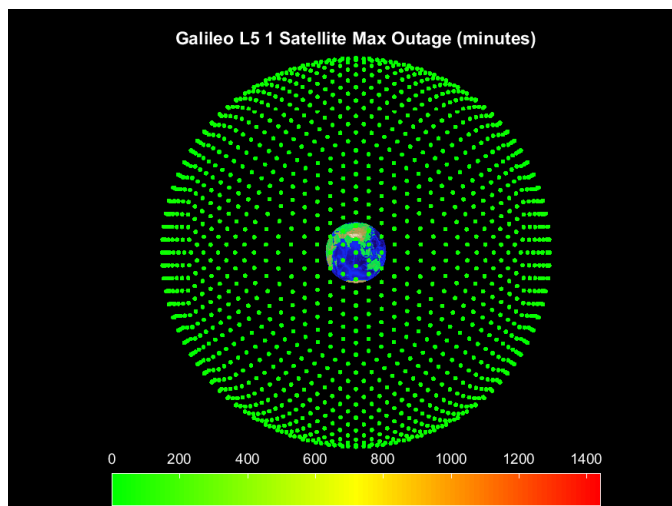
1 Satellite Grid Max Outage



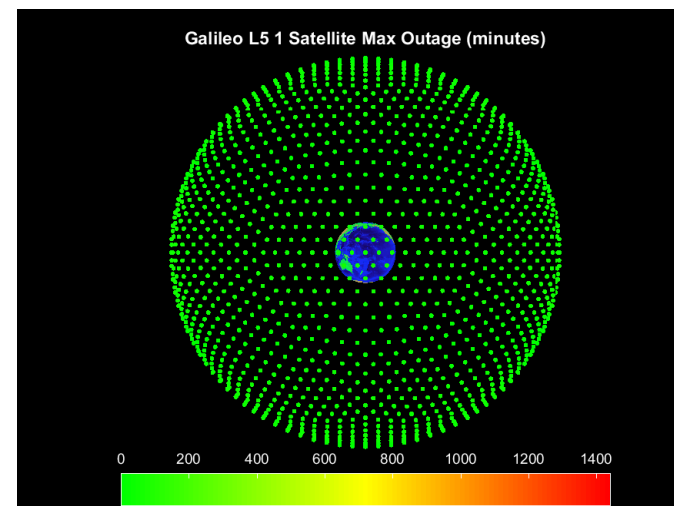
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

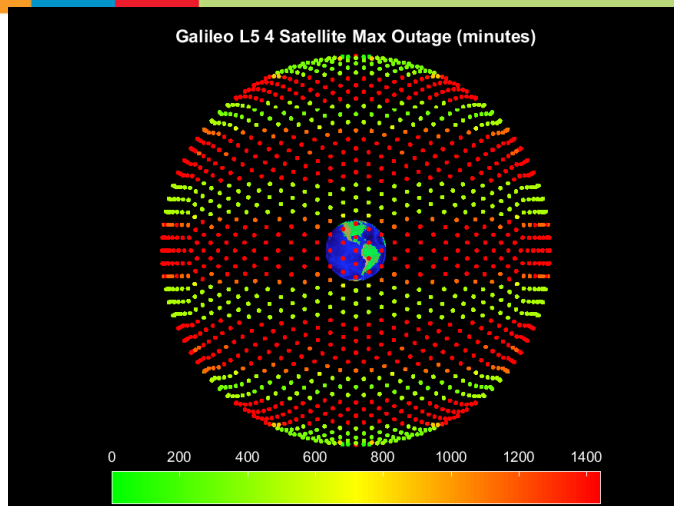


Viewed from 180E Longitude

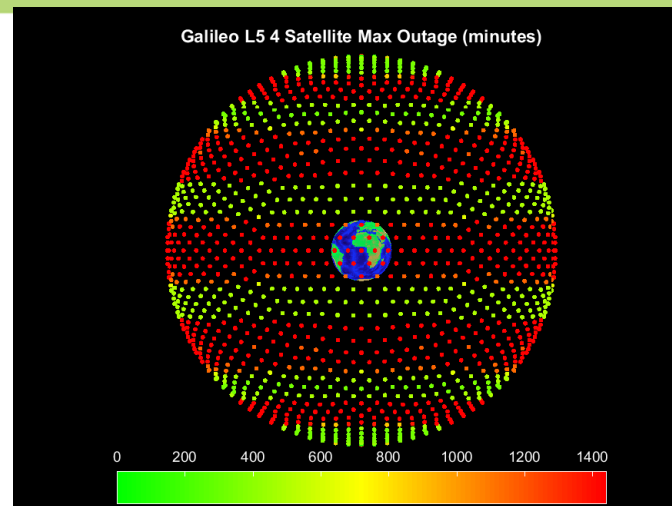


Galileo – L5

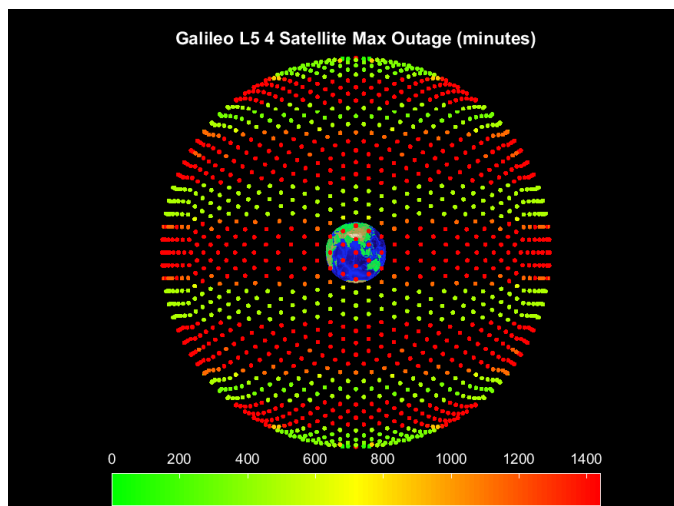
4 Satellite Grid Max Outage



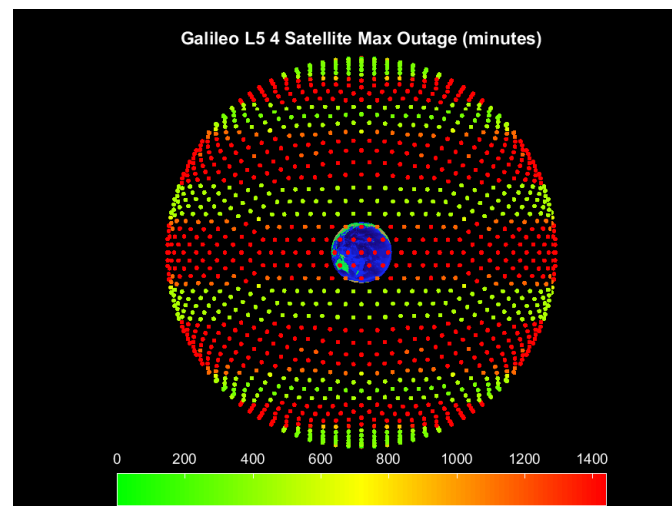
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

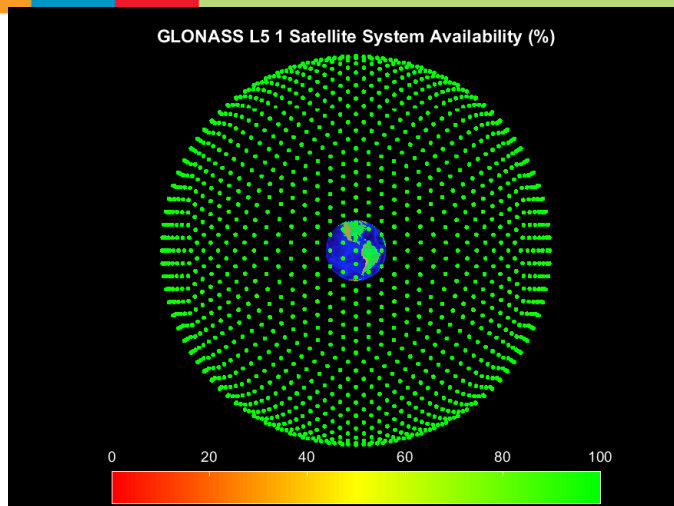


Viewed from 180E Longitude

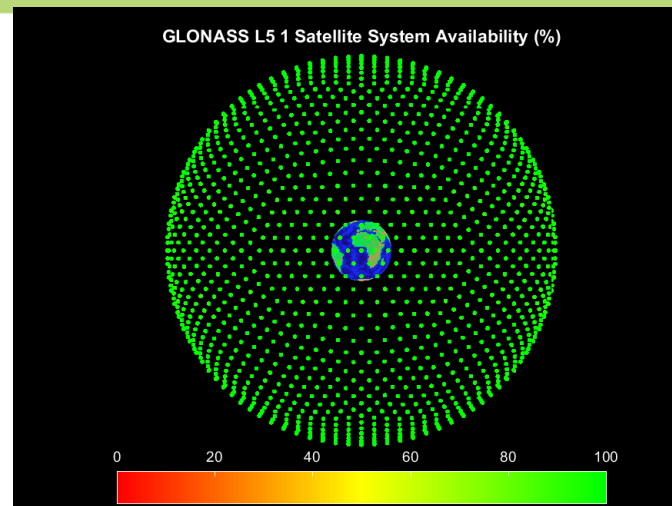


GLONASS – L5

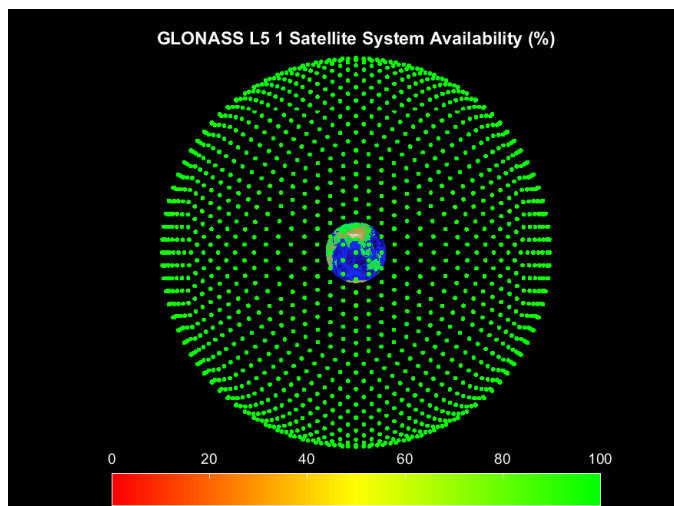
1 Satellite Grid Availability



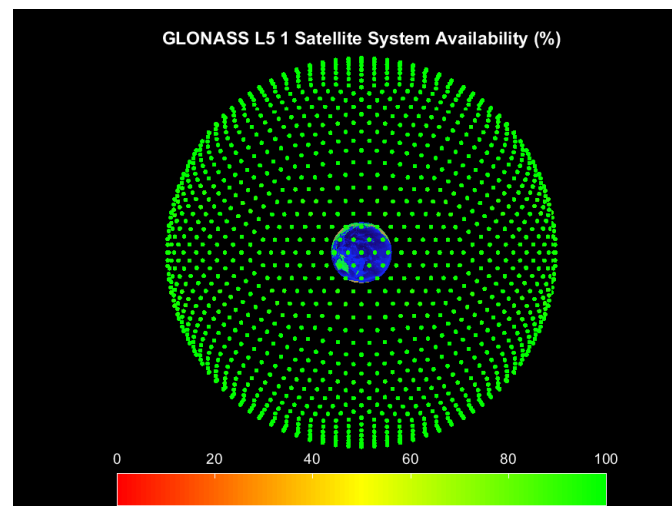
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

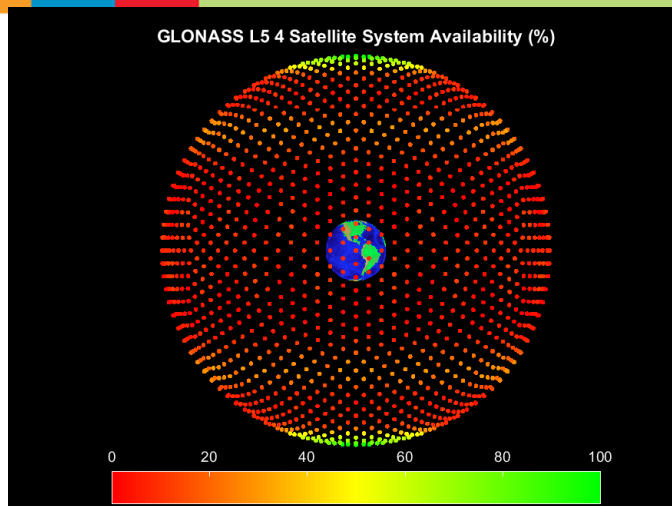


Viewed from 180E Longitude

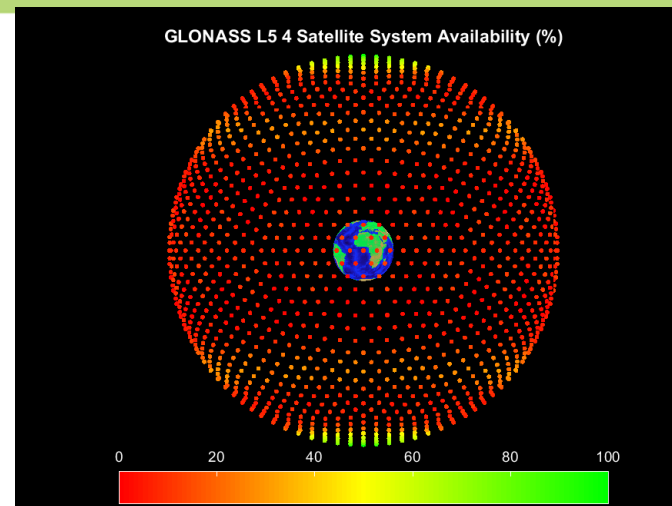


GLONASS – L5

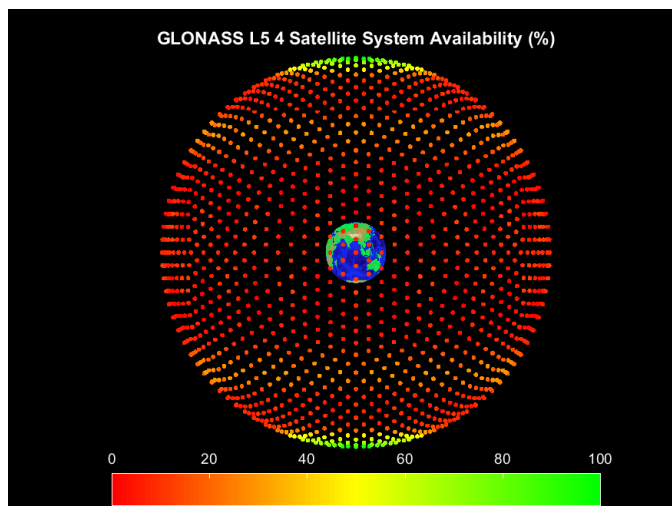
4 Satellite Grid Availability



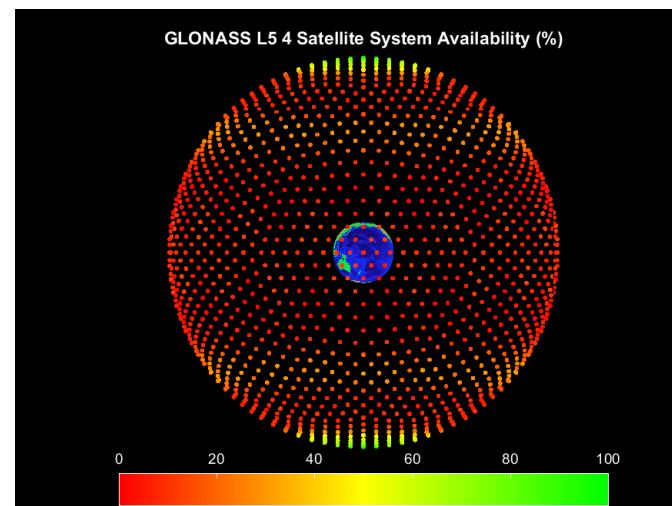
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

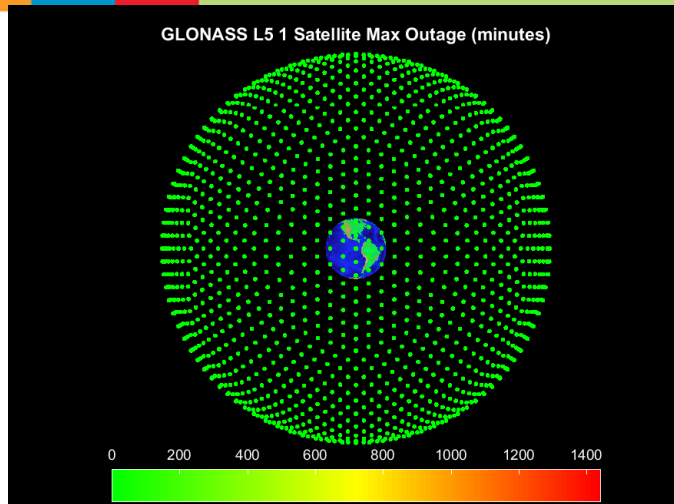


Viewed from 180E Longitude

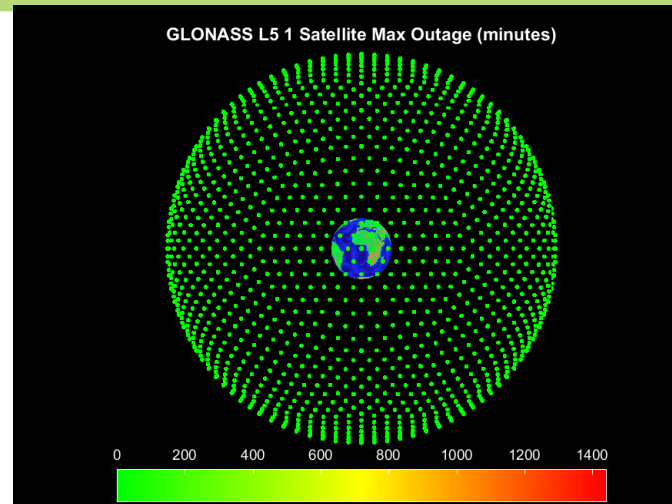


GLONASS – L5

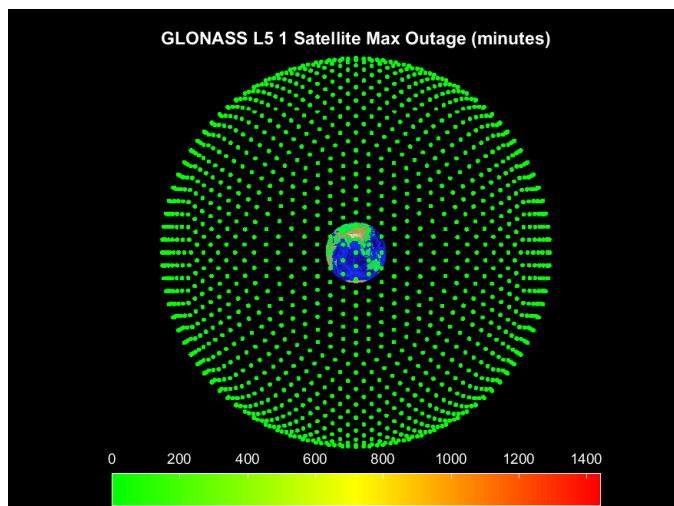
1 Satellite Grid Max Outage



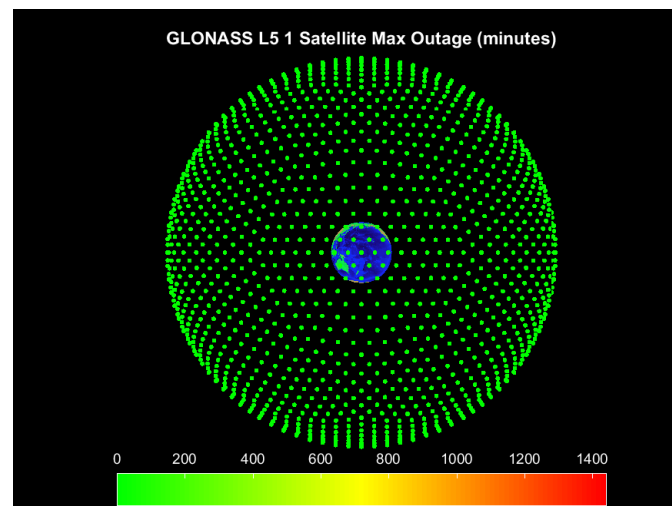
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

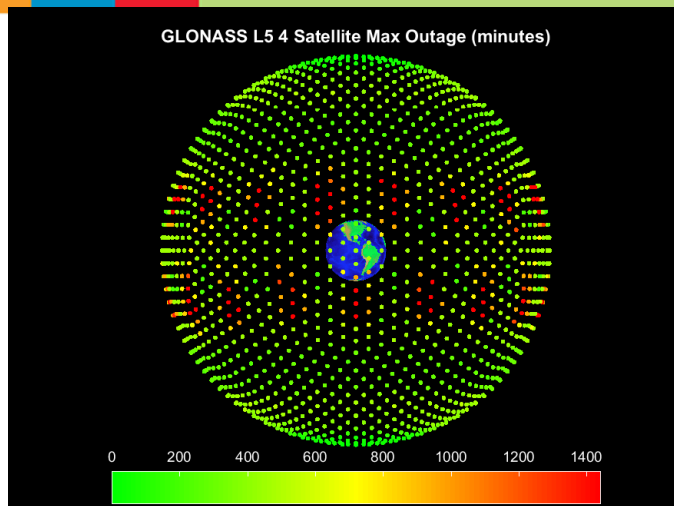


Viewed from 180E Longitude

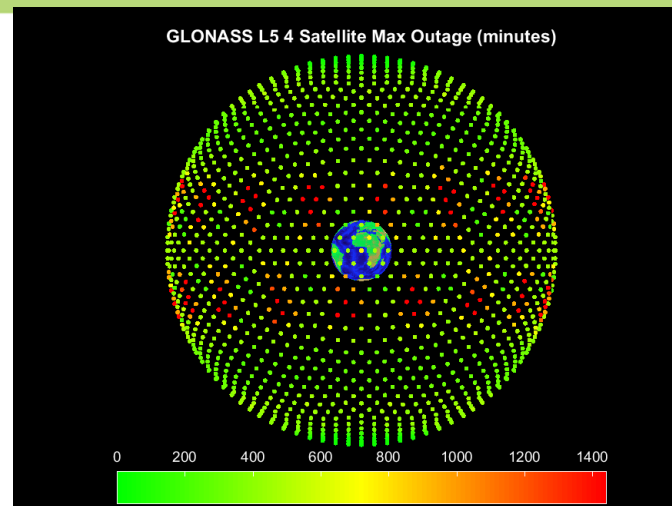


GLONASS – L5

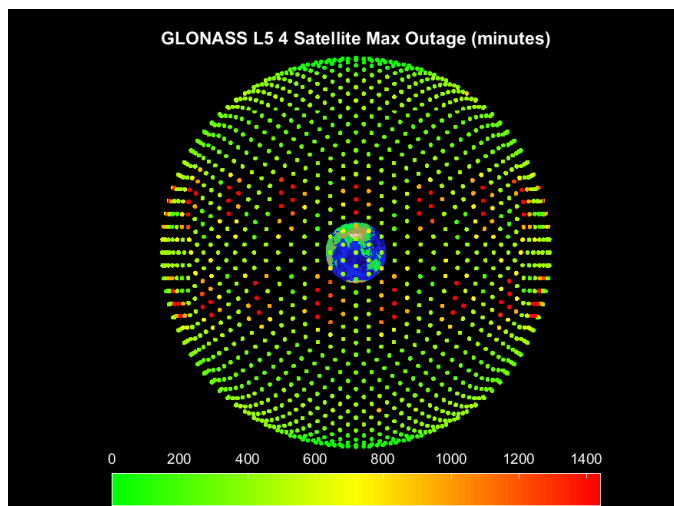
4 Satellite Grid Max Outage



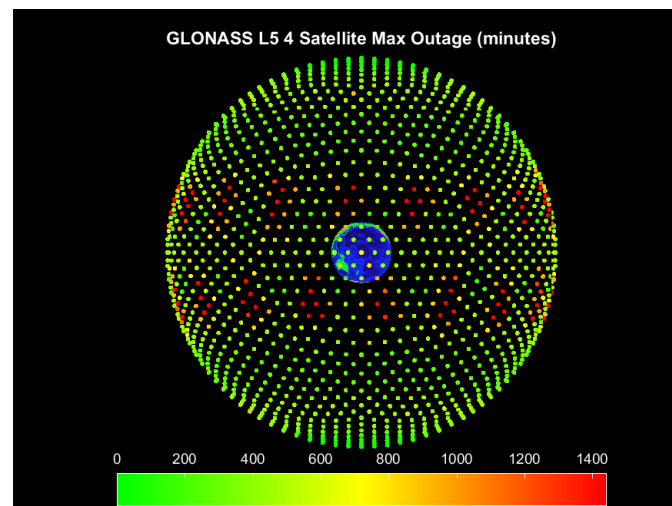
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

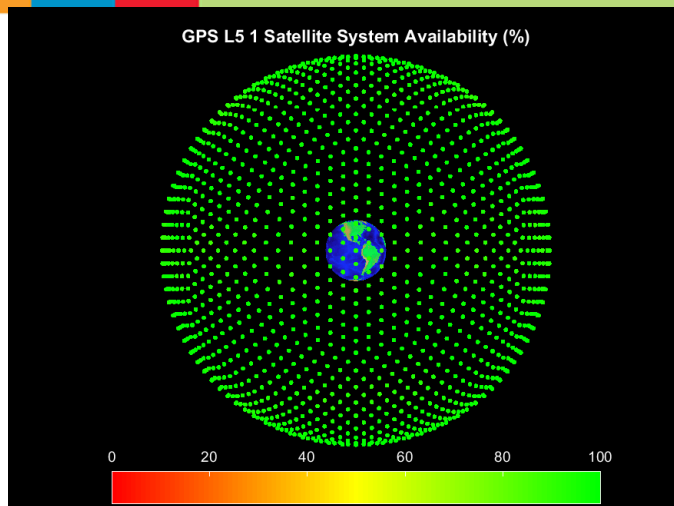


Viewed from 180E Longitude

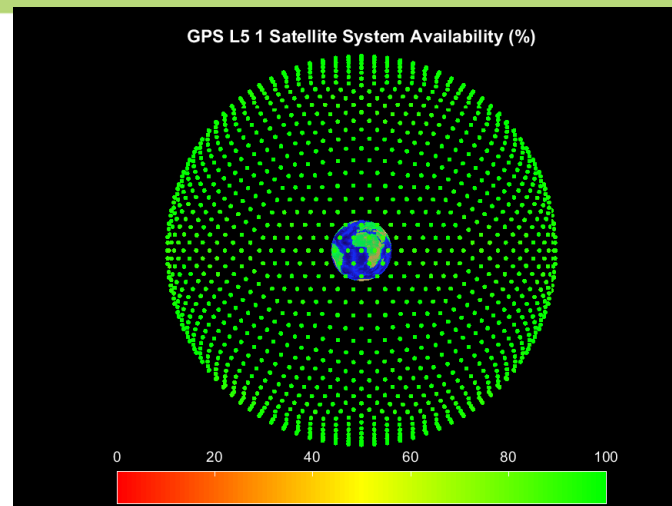


GPS – L5

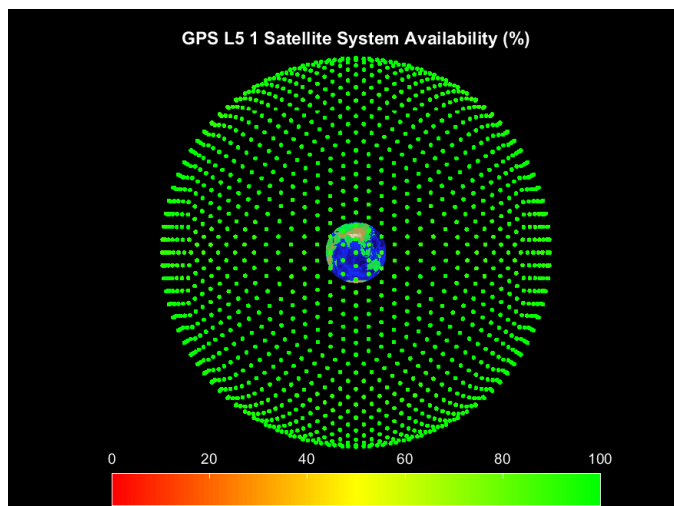
1 Satellite Grid Availability



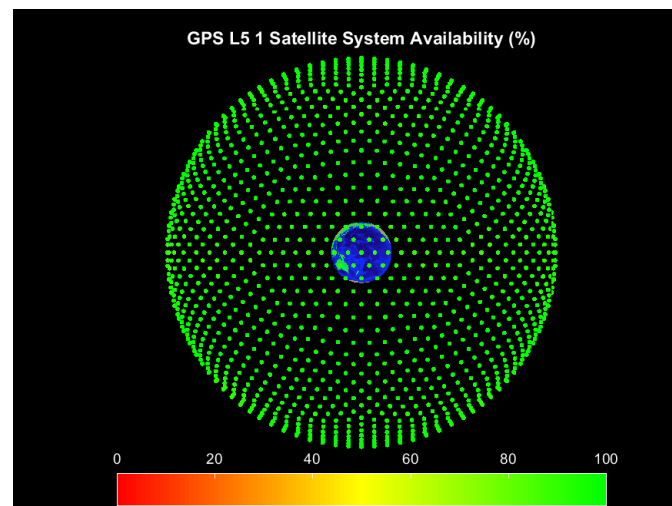
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

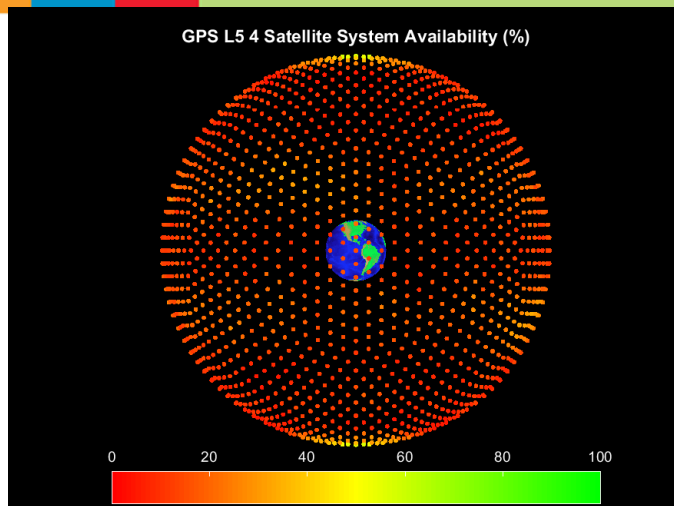


Viewed from 180E Longitude

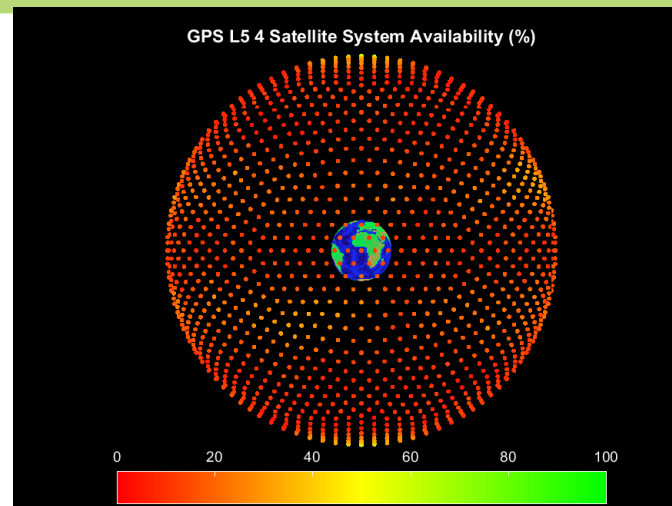


GPS – L5

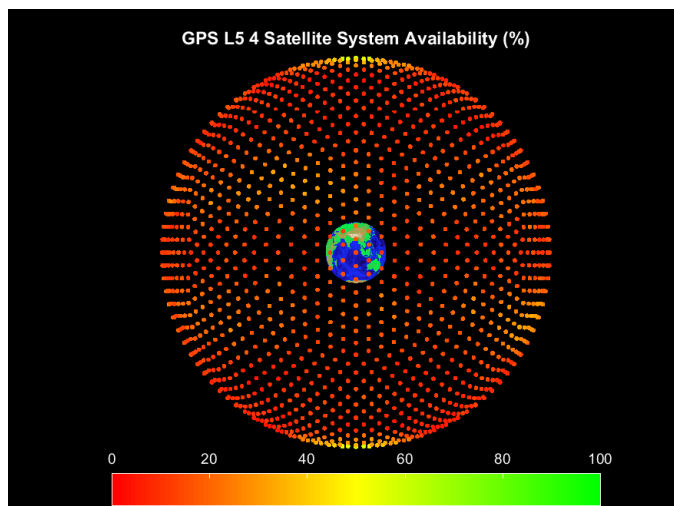
4 Satellite Grid Availability



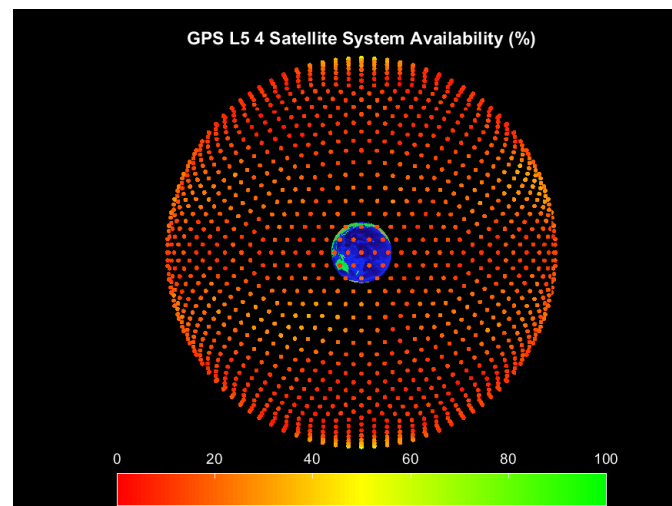
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

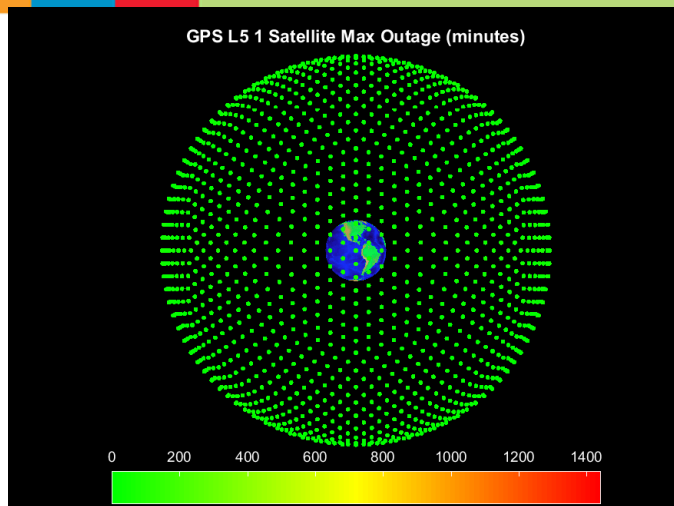


Viewed from 180E Longitude

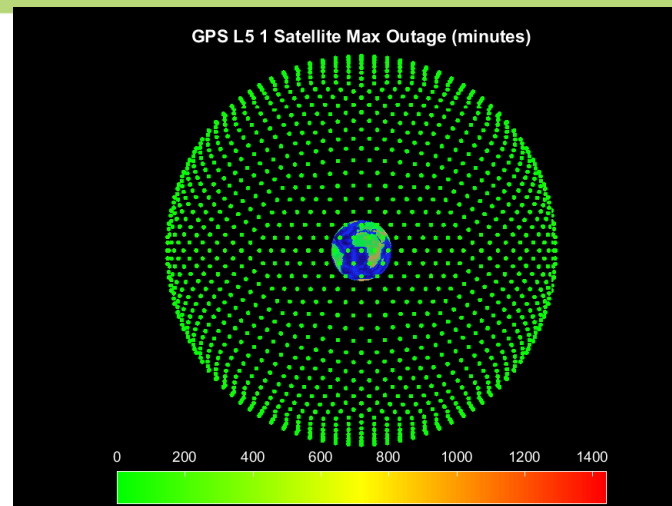


GPS – L5

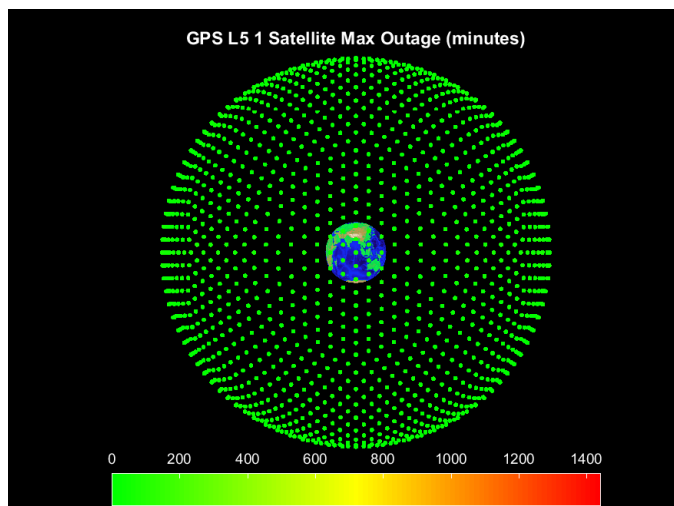
1 Satellite Grid Max Outage



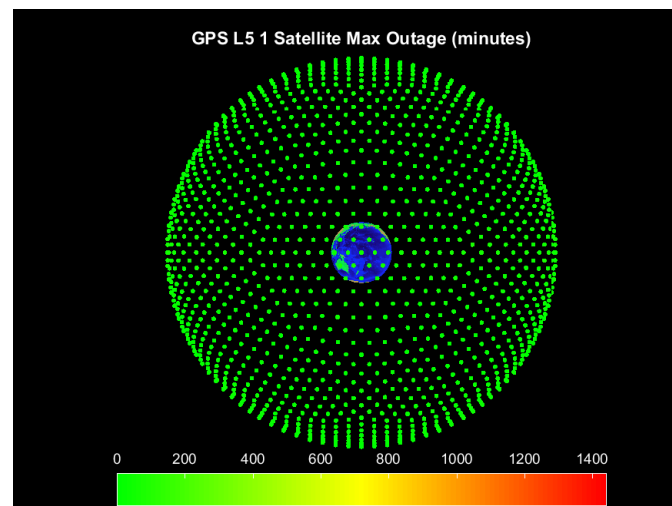
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

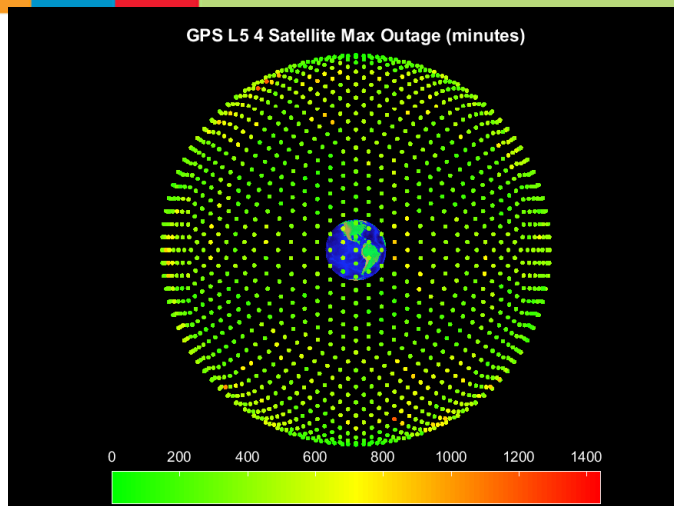


Viewed from 180E Longitude

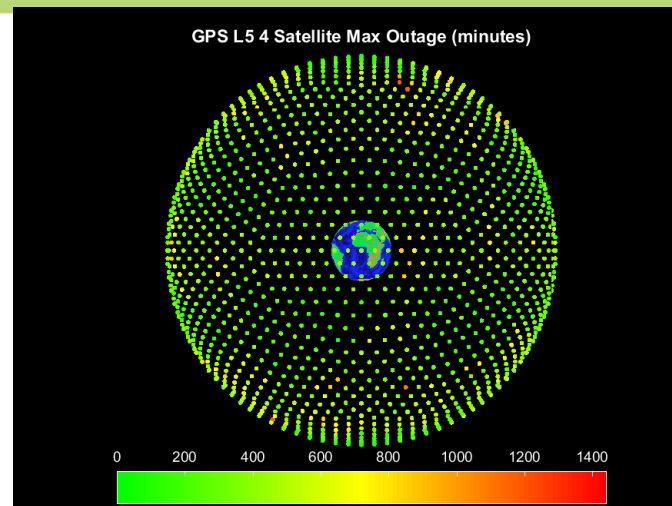


GPS – L5

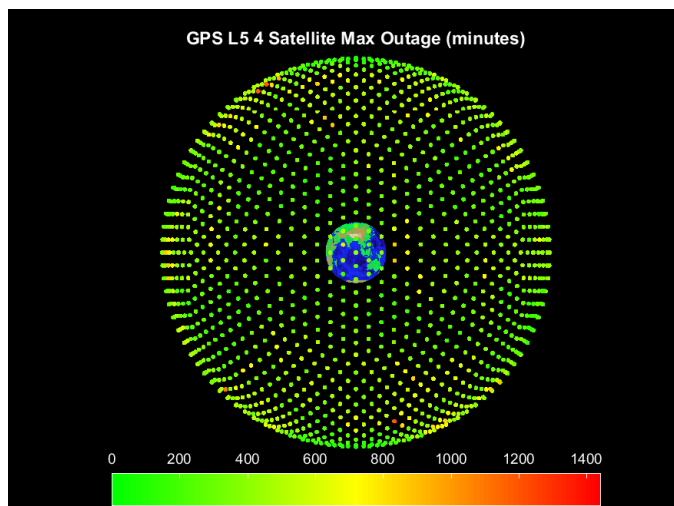
4 Satellite Grid Max Outage



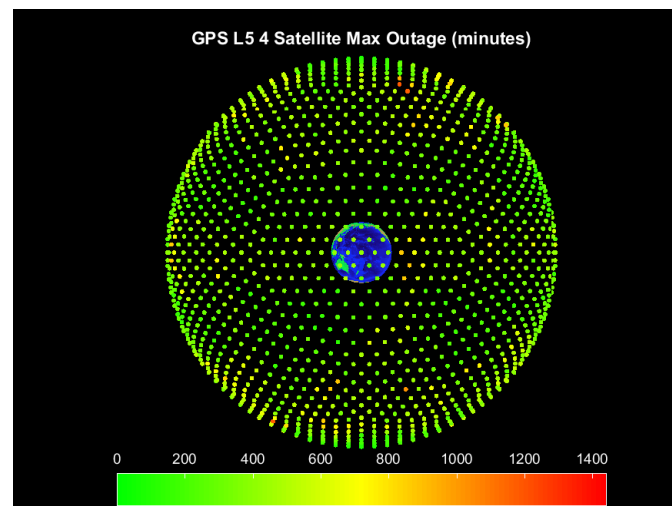
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

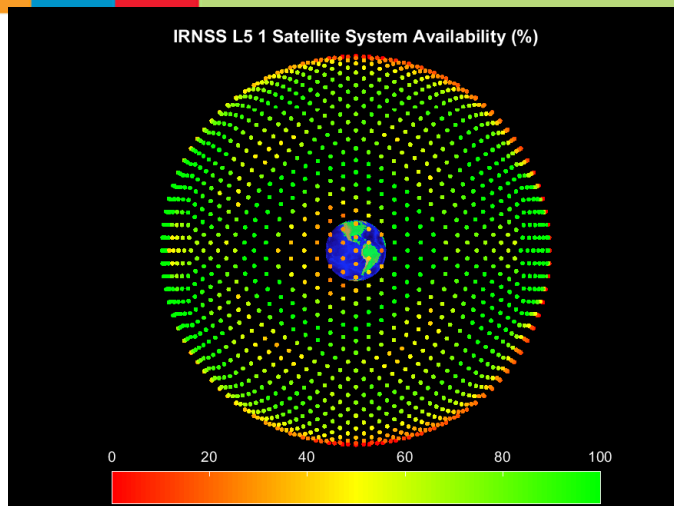


Viewed from 180E Longitude

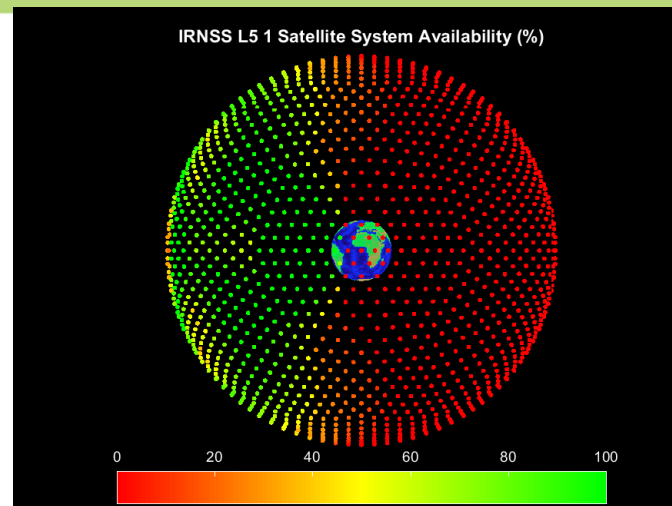


IRNSS – L5

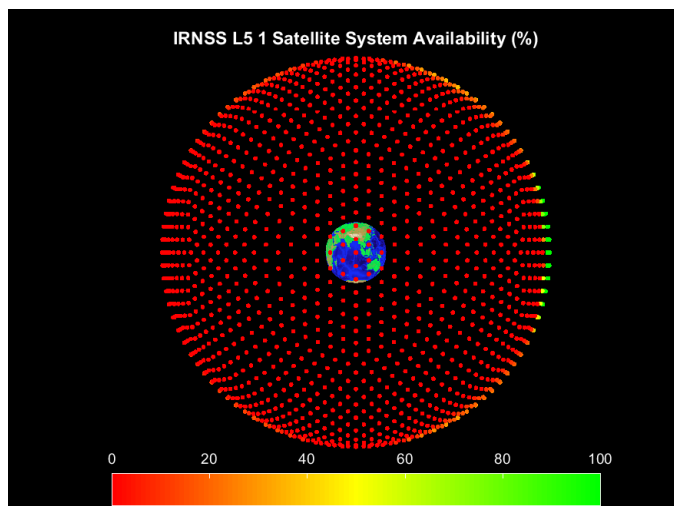
1 Satellite Grid Availability



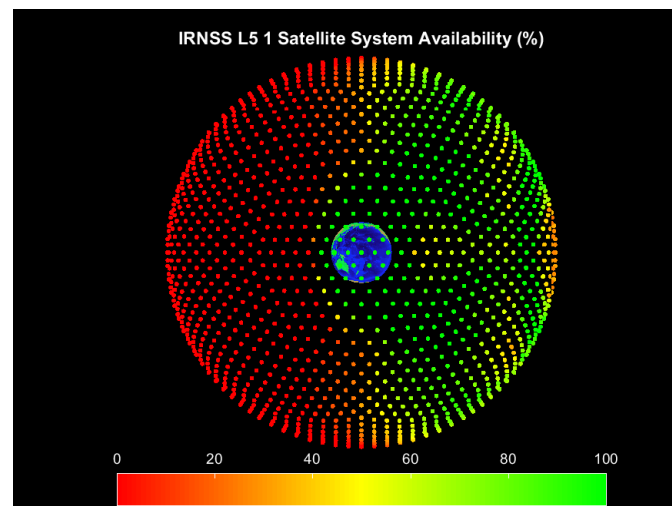
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

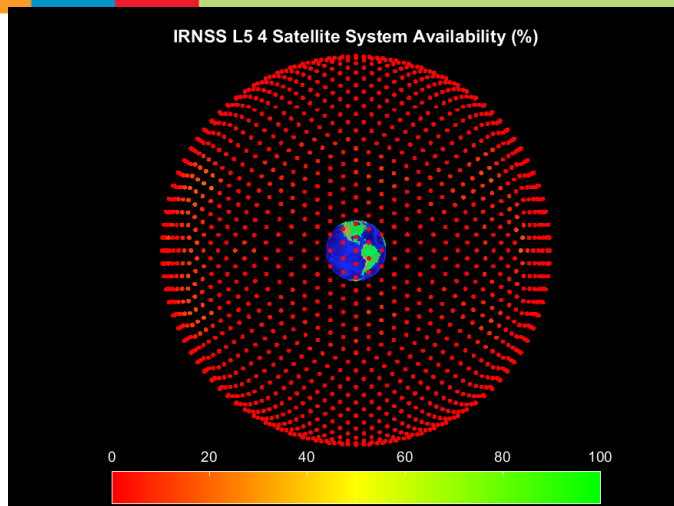


Viewed from 180E Longitude

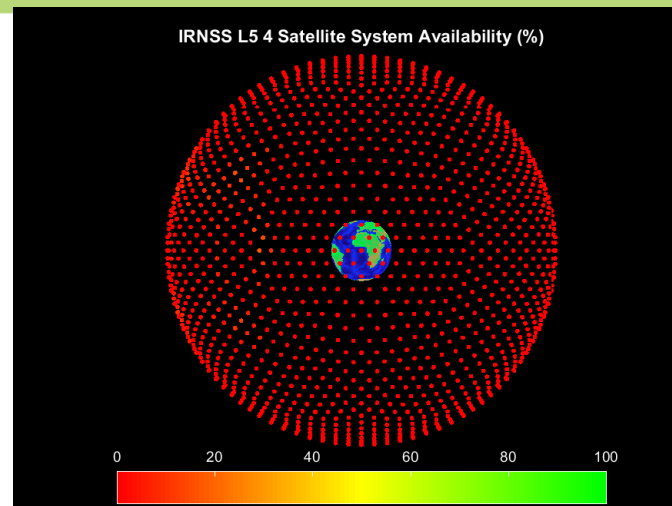


IRNSS – L5

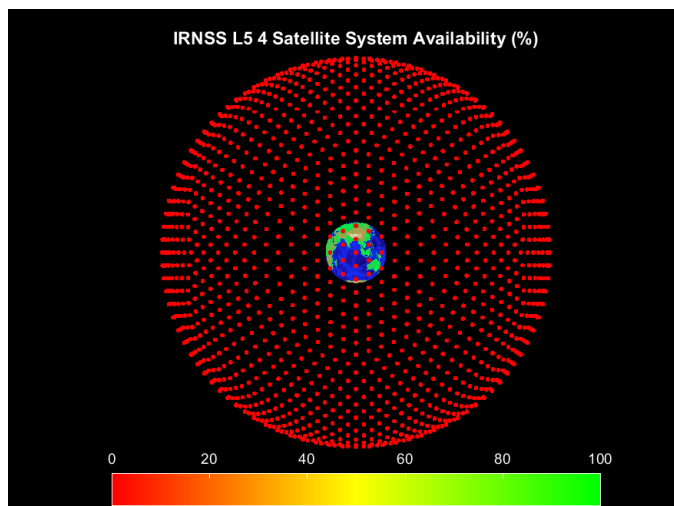
4 Satellite Grid Availability



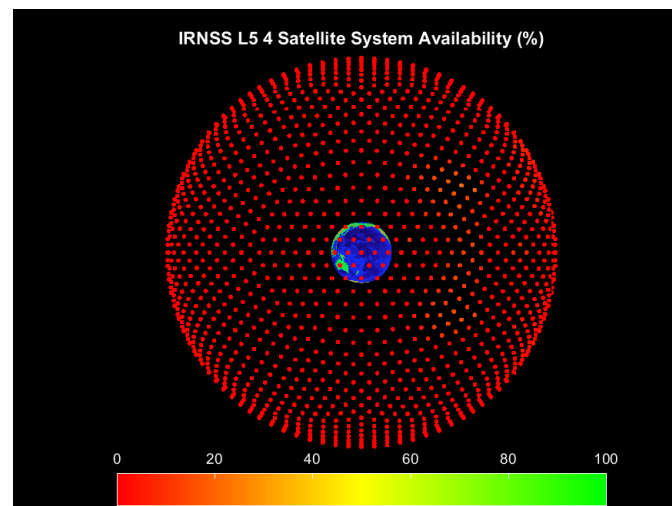
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

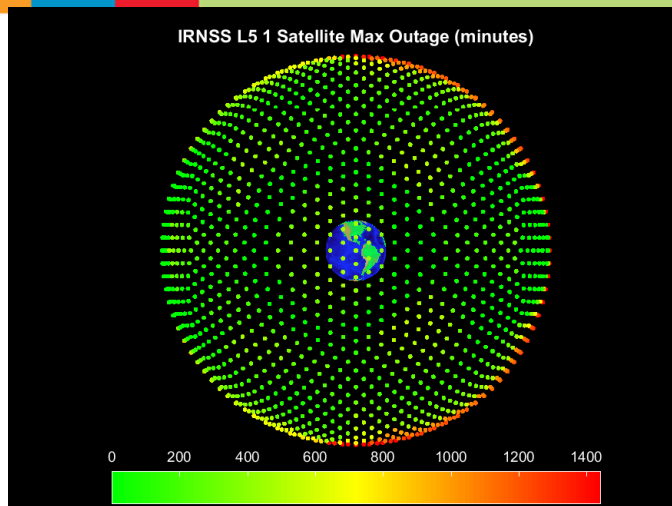


Viewed from 180E Longitude

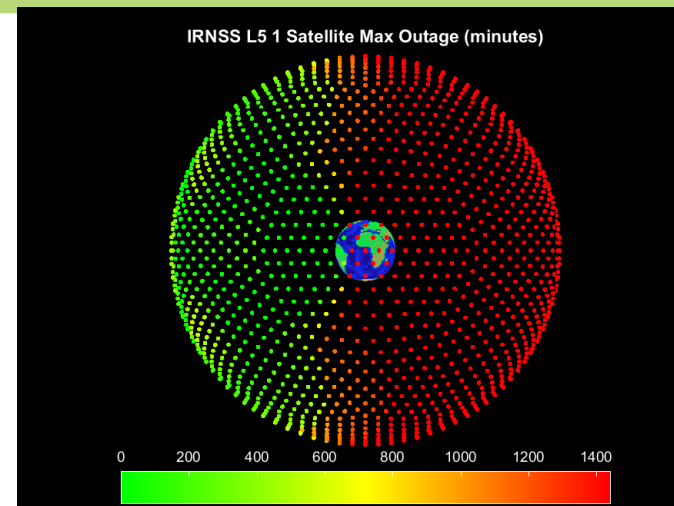


IRNSS – L5

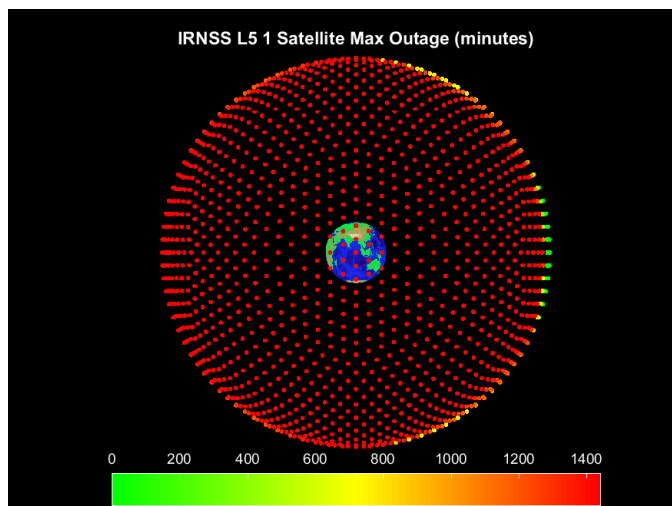
1 Satellite Grid Max Outage



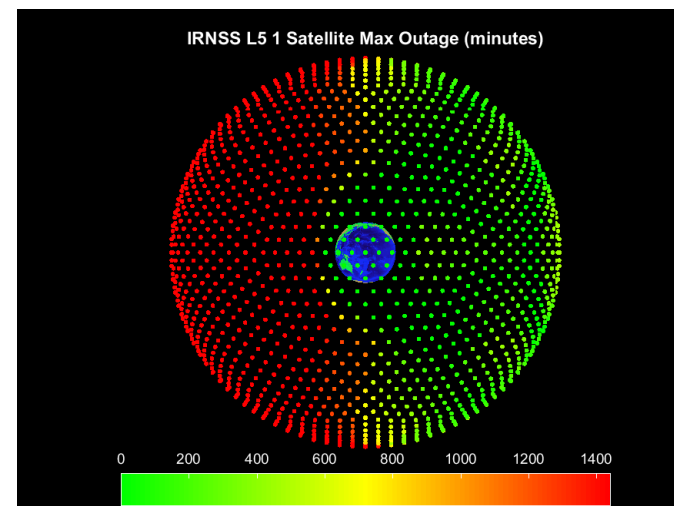
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

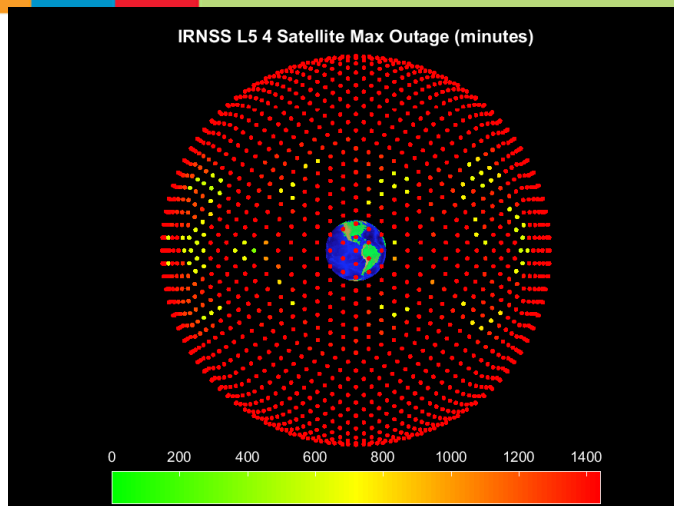


Viewed from 180E Longitude

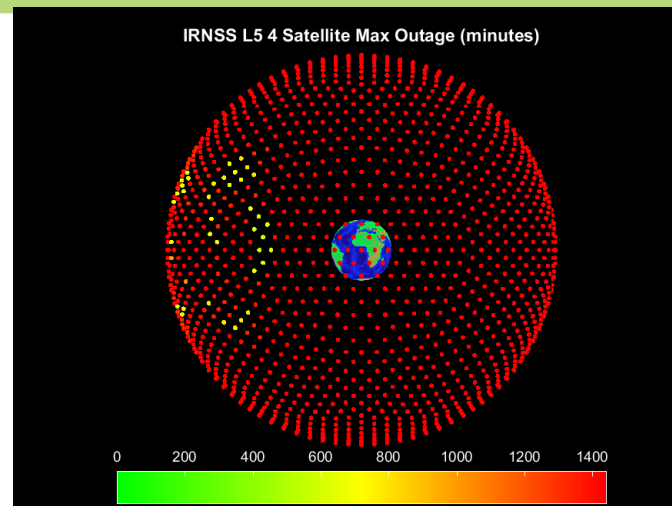


IRNSS – L5

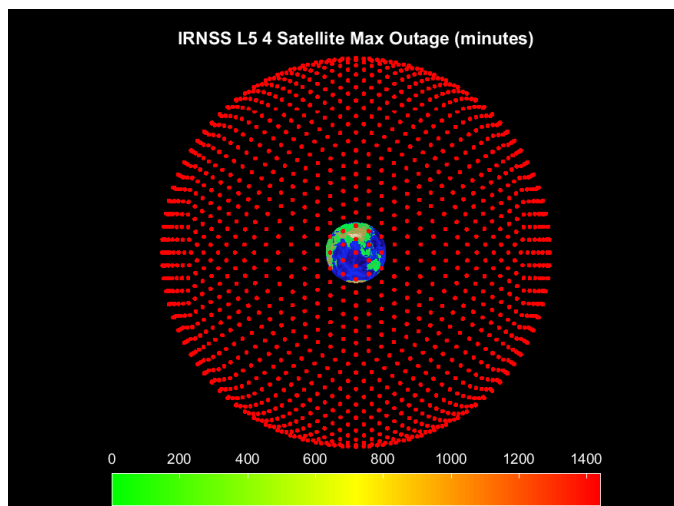
4 Satellite Grid Max Outage



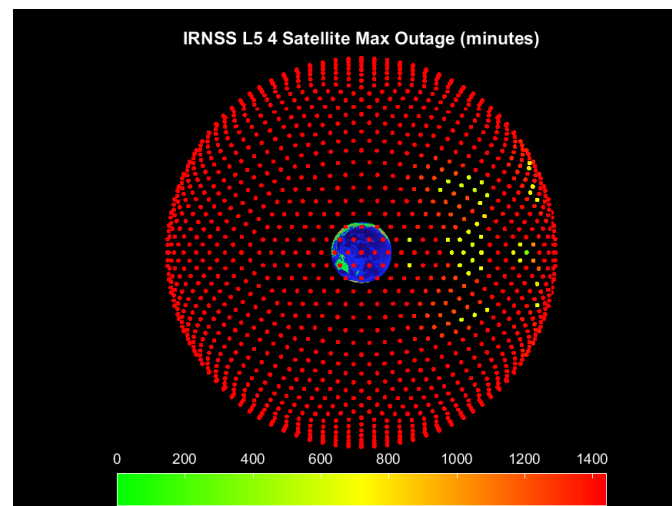
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

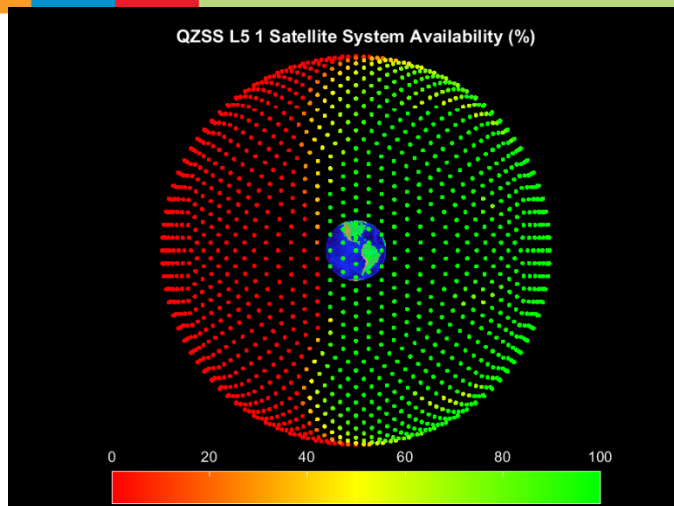


Viewed from 180E Longitude

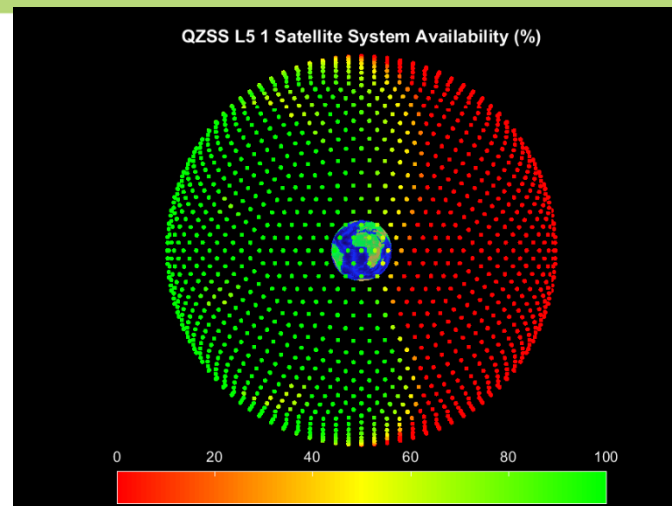


QZSS – L5

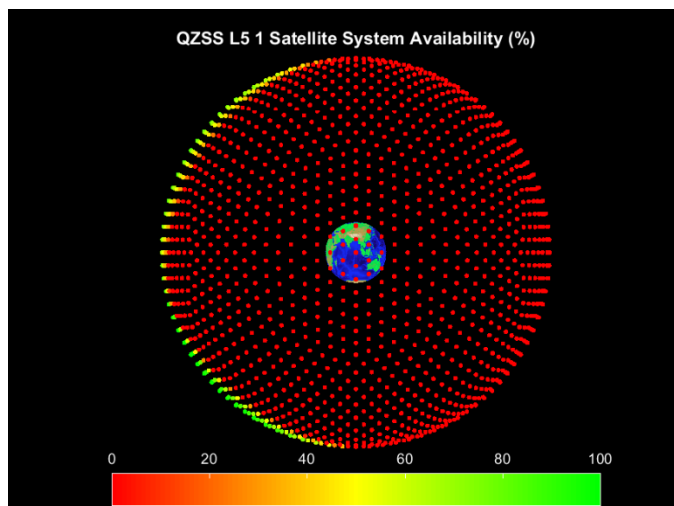
1 Satellite Grid Availability



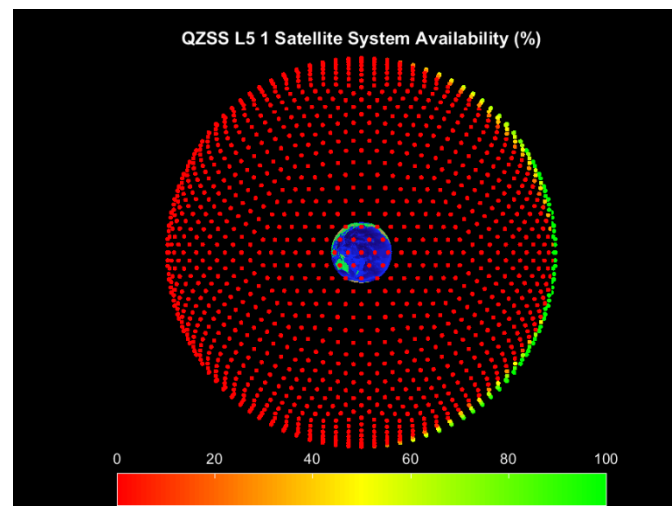
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

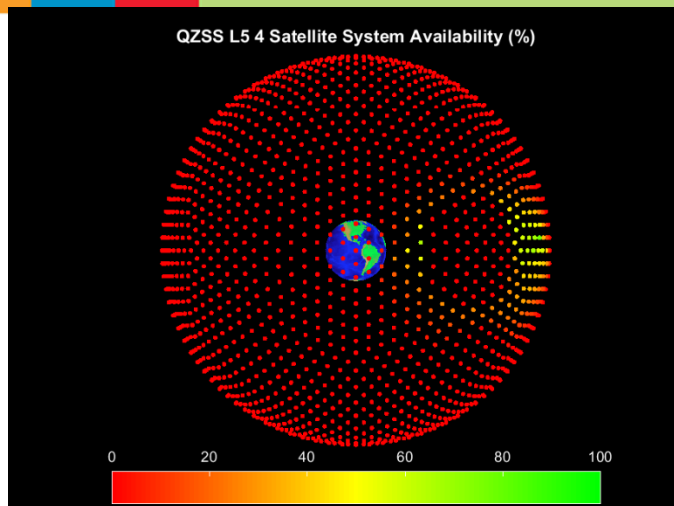


Viewed from 180E Longitude

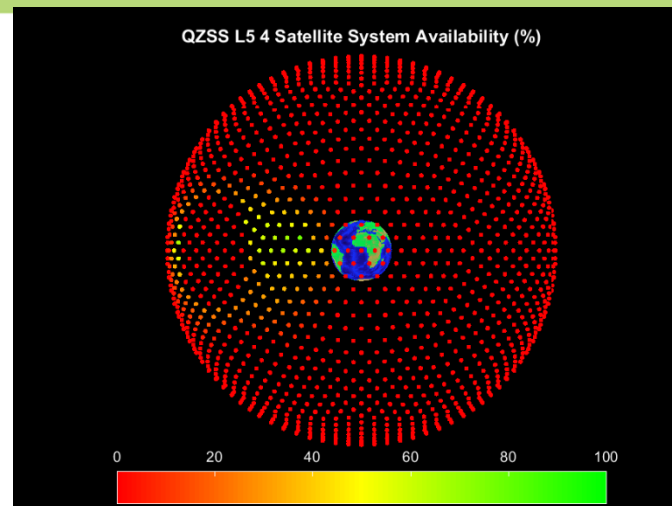


QZSS – L5

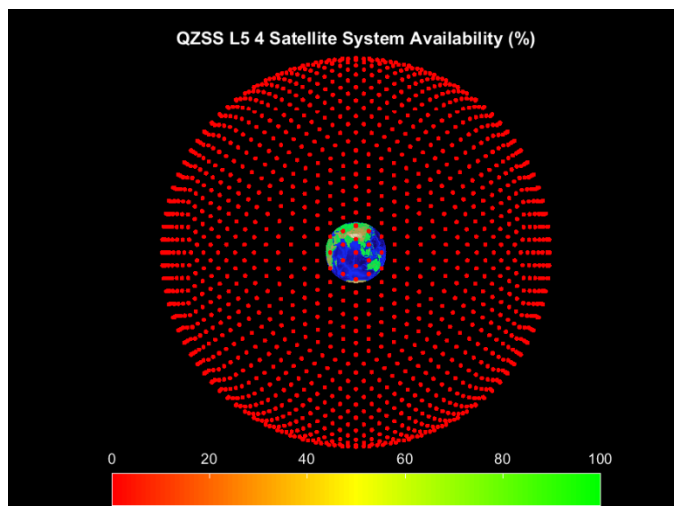
4 Satellite Grid Availability



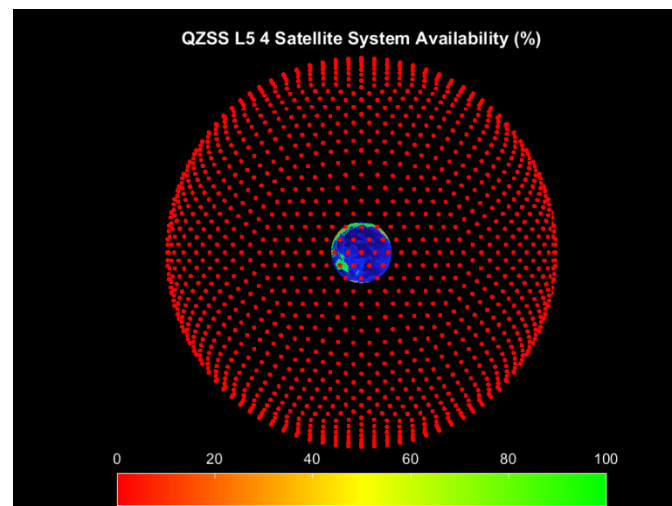
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

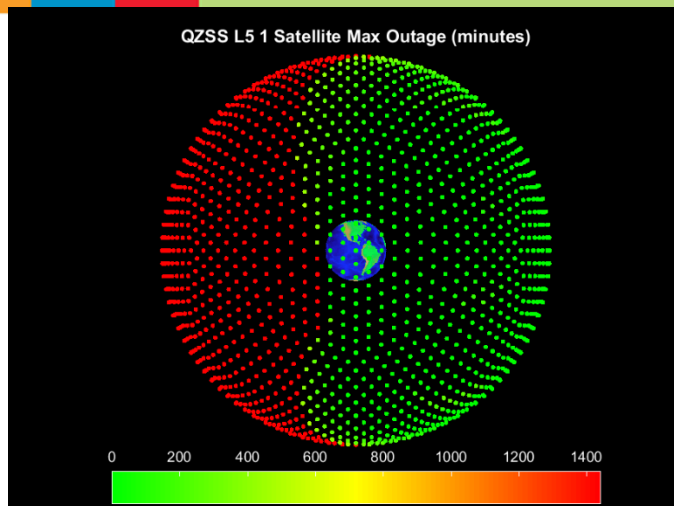


Viewed from 180E Longitude

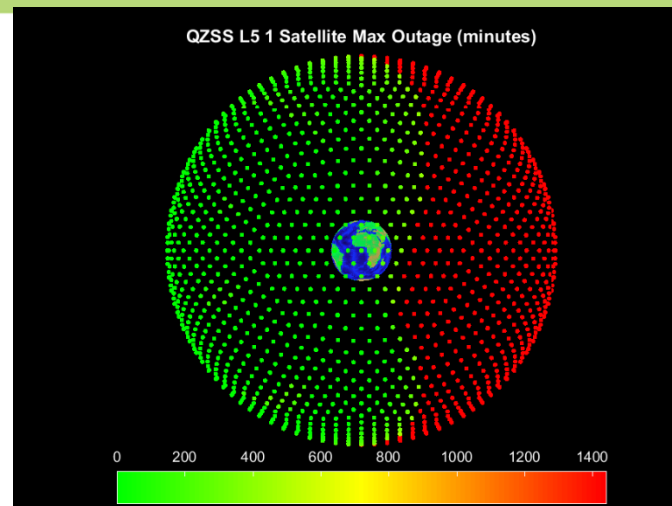


QZSS – L5

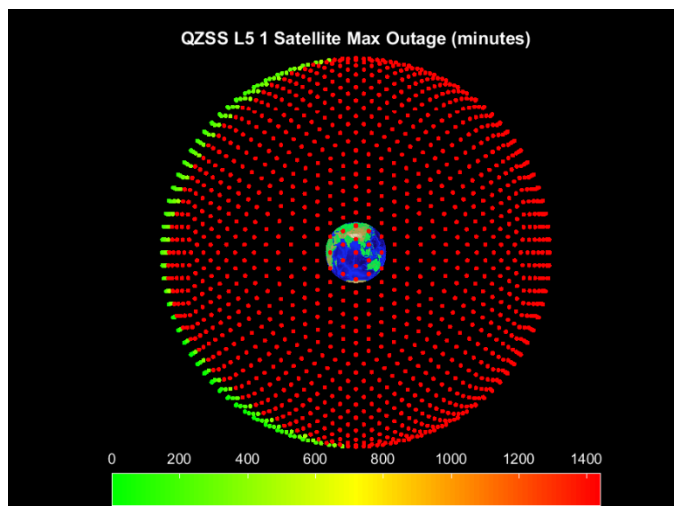
1 Satellite Grid Max Outage



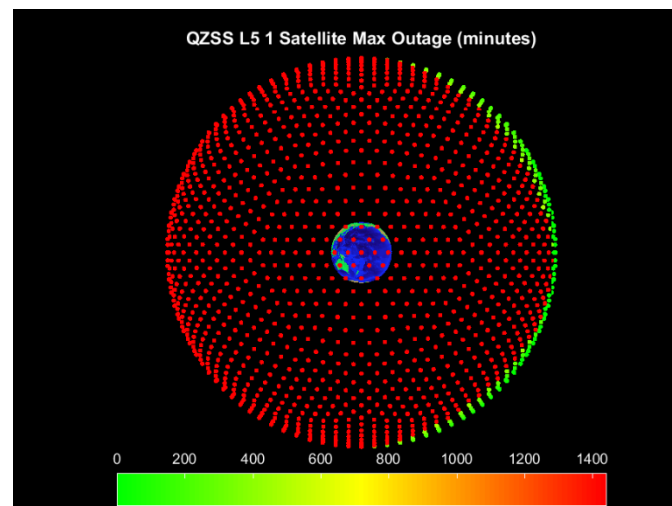
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

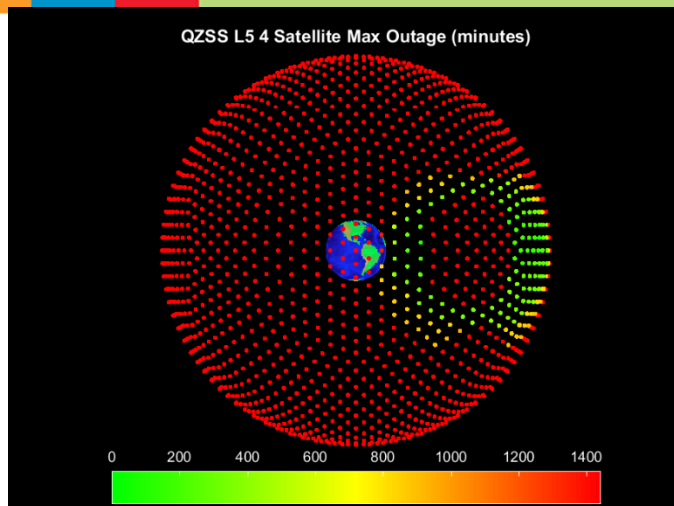


Viewed from 180E Longitude

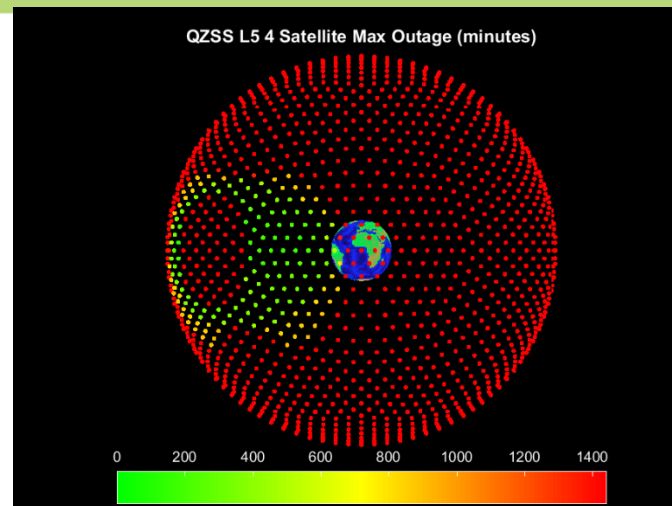


QZSS – L5

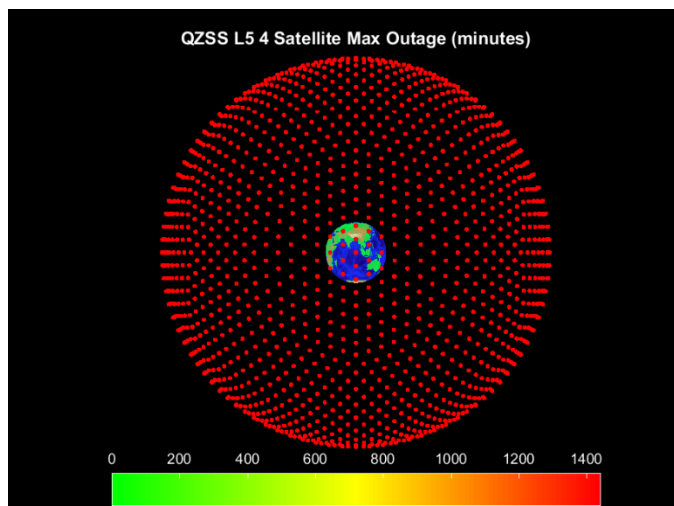
4 Satellite Grid Max Outage



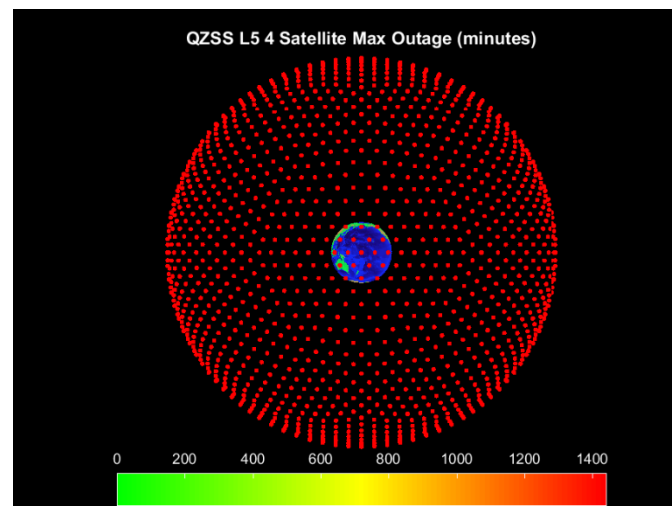
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

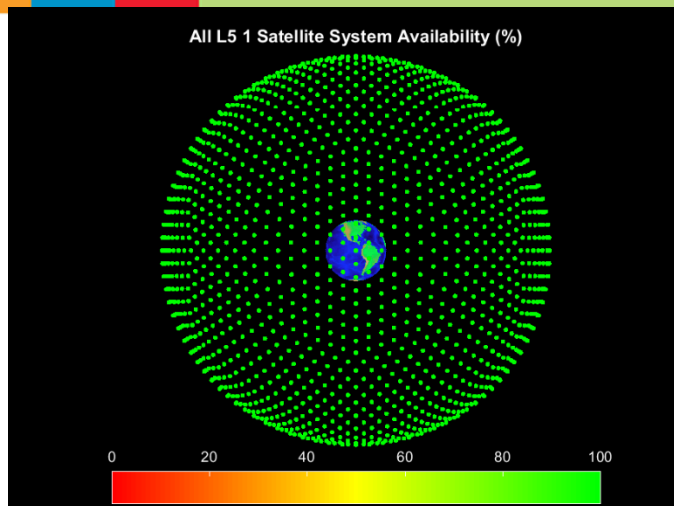


Viewed from 180E Longitude

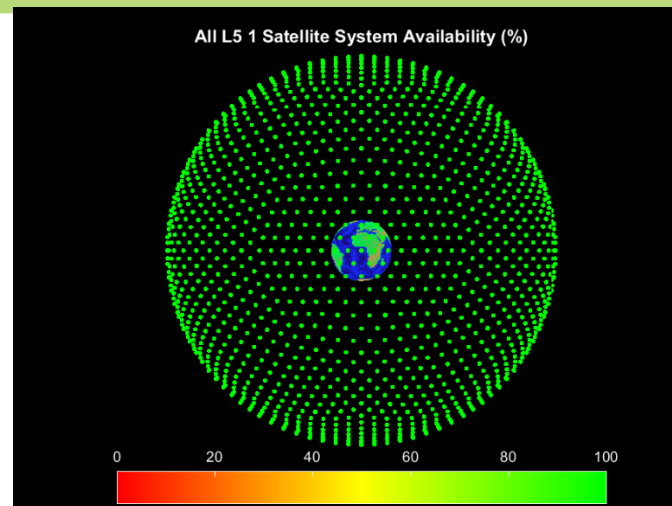


All – L5

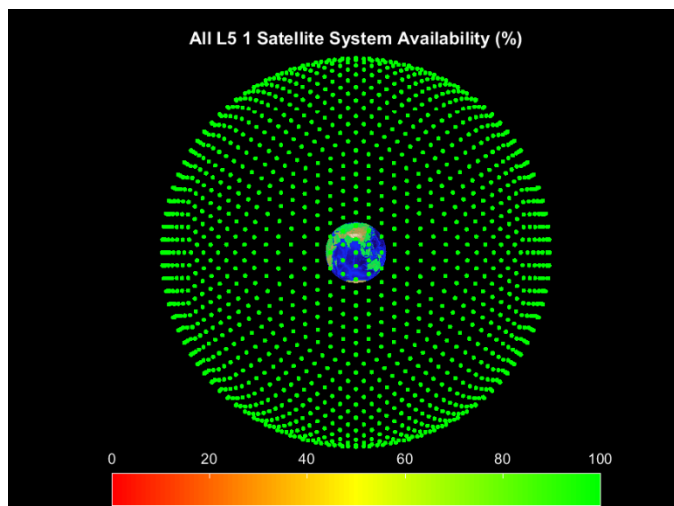
1 Satellite Grid Availability



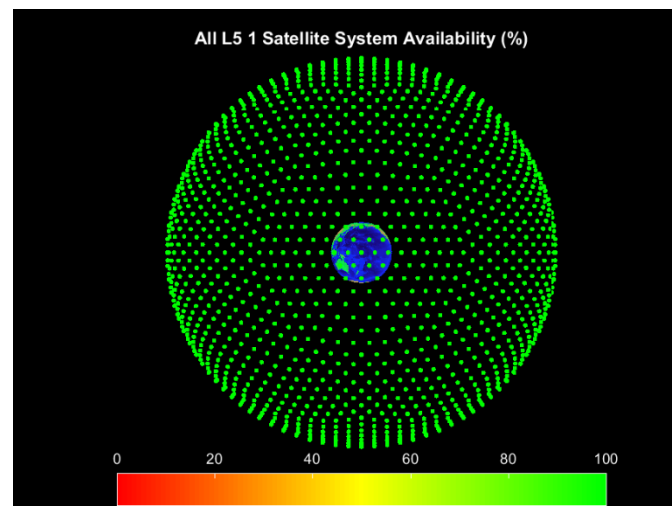
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

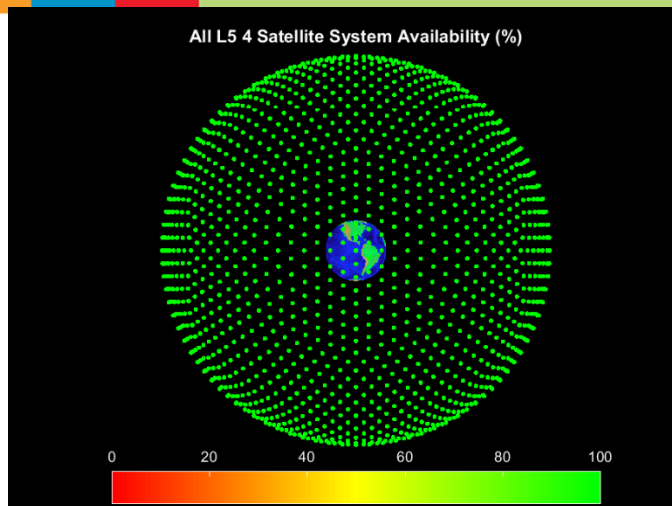


Viewed from 180E Longitude

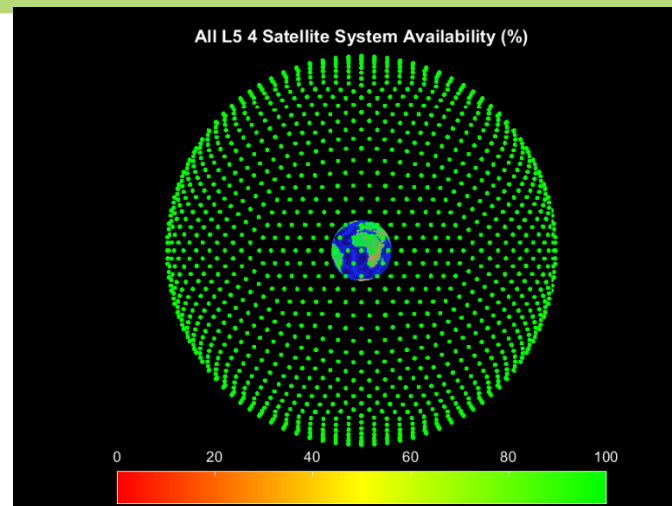


All – L5

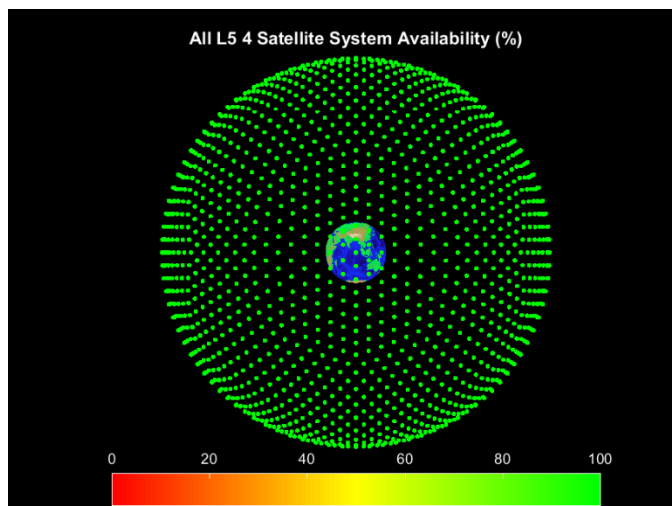
4 Satellite Grid Availability



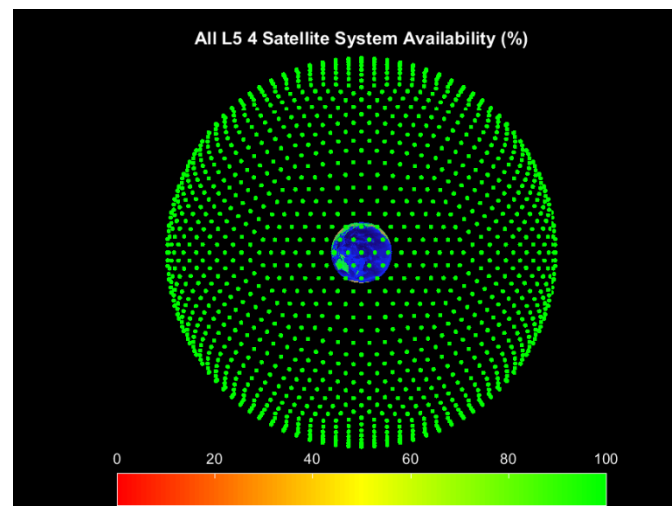
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

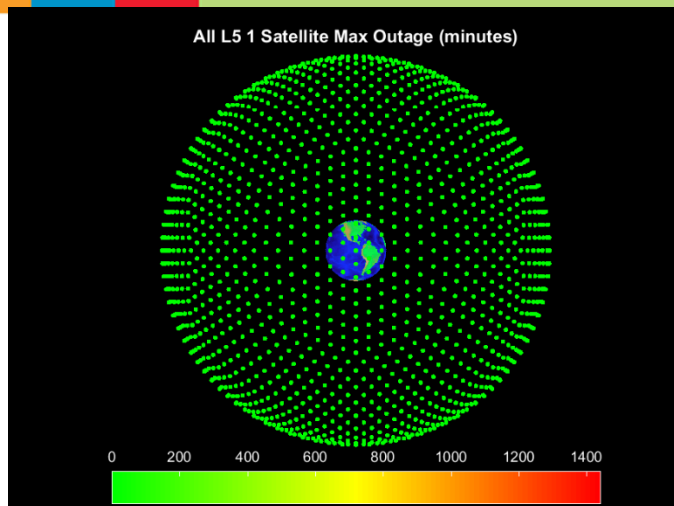


Viewed from 180E Longitude

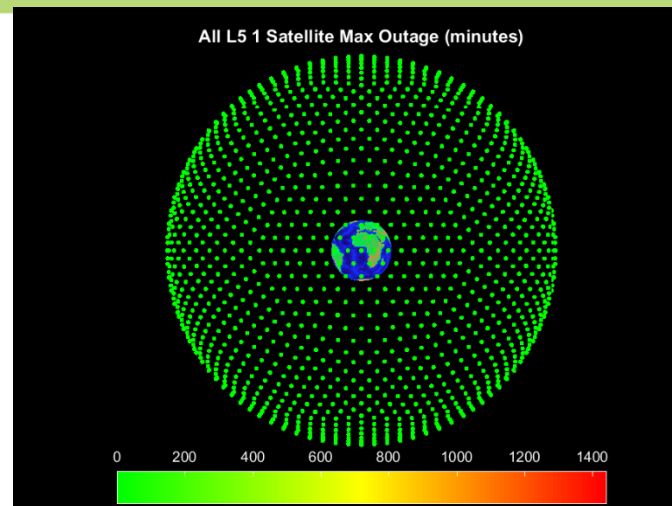


All – L5

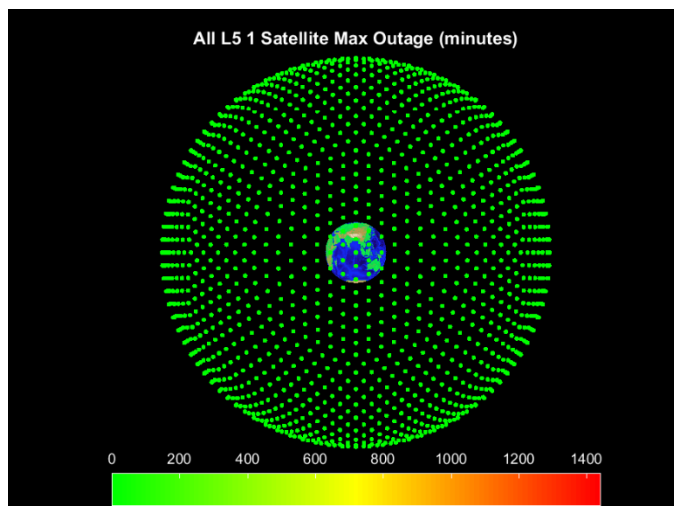
1 Satellite Grid Max Outage



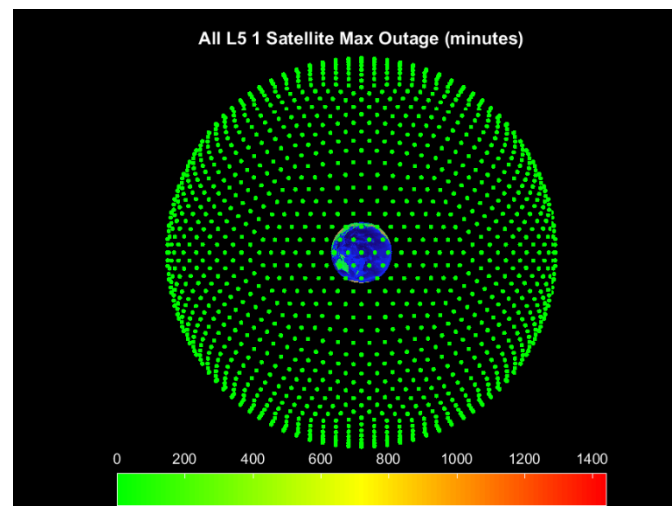
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude

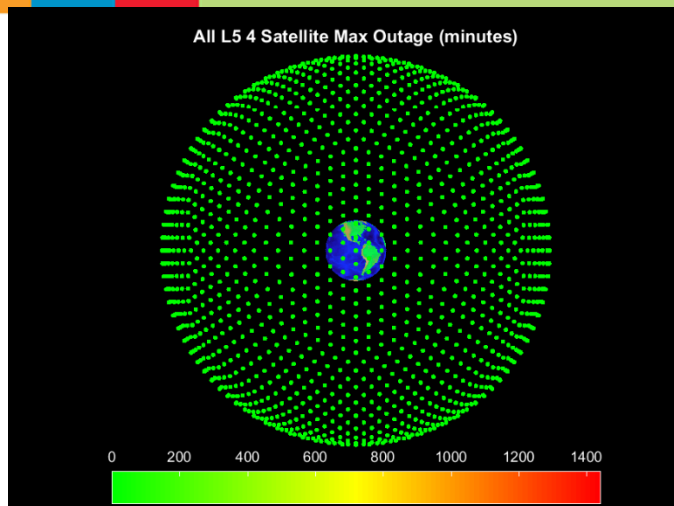


Viewed from 180E Longitude

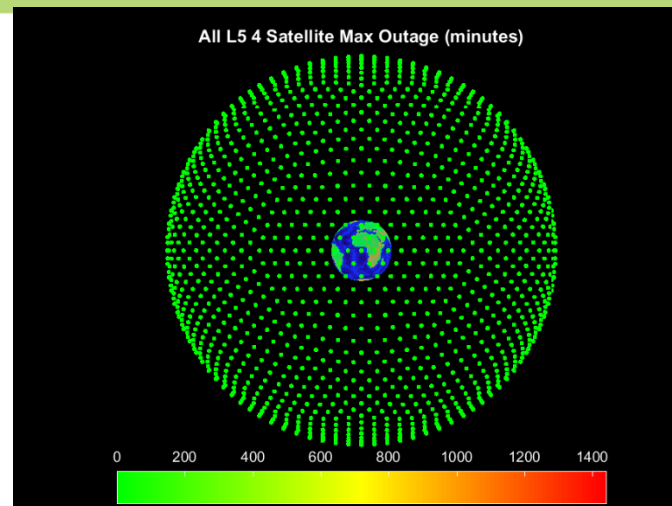


All – L5

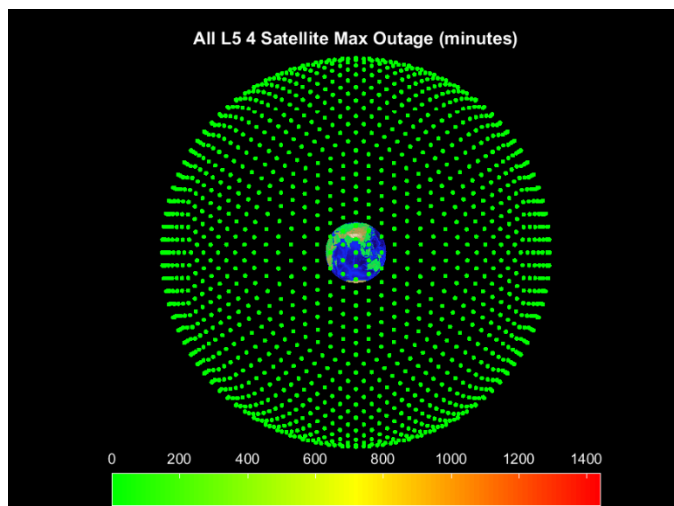
4 Satellite Grid Max Outage



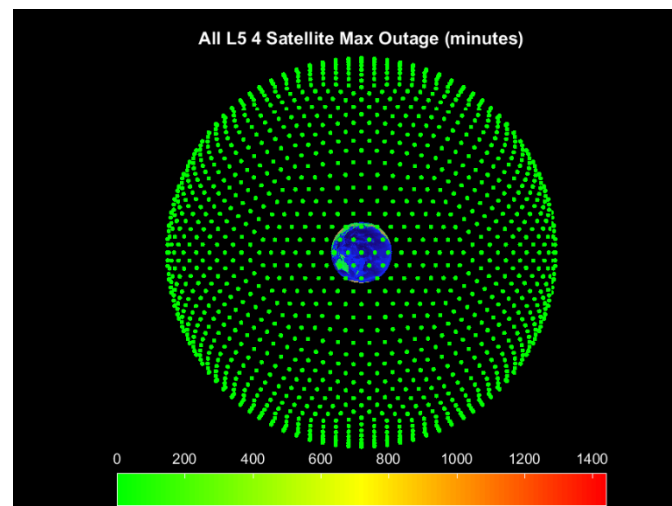
Viewed from 90W Longitude



Viewed from 0E Longitude



Viewed from 90E Longitude



Viewed from 180E Longitude



Example omni antenna pattern data



```
% OMNI.TXT (0 dB peak)
% Zero degrees corresponds to boresite
% angle [deg] gain [db]
-5.0000    0.0
  0.0      0.0
  5.0000    0.0
 10.0000    0.0
 30.0000    0.0
 60.0000    0.0
 90.0000    0.0
120.0000    0.0
150.0000    0.0
180.0000    0.0
```

