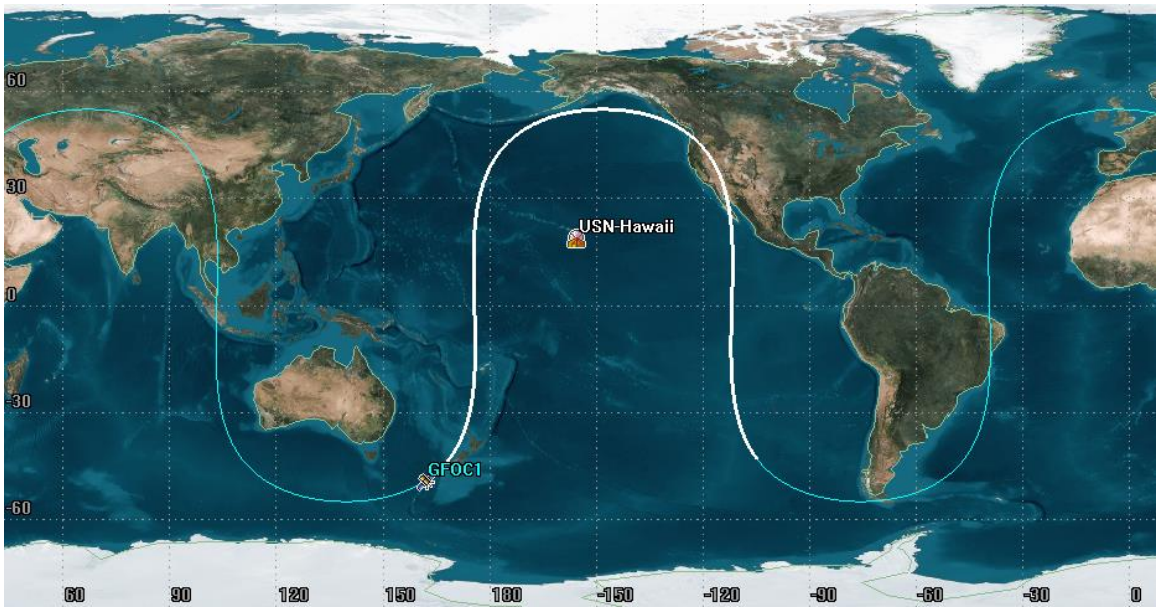
LEOP support of Galileo Constellation (FOC3 and FOC4) from USN's Hawaii ground station

Galileo FOC3 and FOC4 are the third and fourth spacecraft of the "Full Operational Capability" of the Galileo navigation constellation for the EU. The launch consists of 2 spacecraft (FOC3 and FOC4) that will be launched from French Guiana on a Soyuz vehicle on March 27th, 2015 at 21:46:18 UTC. USN has been contracted to support the Galileo spacecraft LEOP(s) for a period of up to 14 days.

The spacecraft(s) are a Medium Earth Orbiting (MEO) spacecraft in a high mid-latitude orbit (55 degrees) with a near circular orbit of altitude of 23400 Km. This orbit allows a nominal 1 visibility over the USN Hawaii station every day. Each spacecraft contact is on the order of 1 to 16 hours.



FOC3 and FOC4 nominal orbit and Hawaii coverage

The spacecrafts will be supported from injection and three subsequent orbital maneuvers for spacing of FOC3 and FOC4. The below analysis covers all possible visibilities from USN Hawaii, but not all visibilities will be supported.

FOC3 and FOC4 injection and coverage of pass #1-5

Both spacecraft are still in same antenna beamwidth after injection for the first several passes and then begin to drift apart. For the first several passes FOC3 and FOC4 are supported by selecting different RF frequencies. Subsequent to the first several hours the spacecraft(s) are supported separately. Post maneuver TLE's and maximum visibilities are shown below for each event and each spacecraft.

	Downlink	Uplink
FOC3	2228.094 MHz	2051.703 MHz
FOC4	2234.232 MHz	2057.355 MHz

GFOC3-injection
1 99935 14999A 15087.06545139 +.00000000 +00000-9 +73172-3 2 00008
2 99935 055.0630 094.9122 0004840 254.6556 347.3149 01.67807181000002

GFOC4-injection
1 99790 14999B 15087.06545139 +.00000000 +00000-9 +73174-3 2 00009
2 99790 055.0629 094.9122 0003715 045.1545 196.8159 01.68014372000001

FOC3

Access	Start Time (UTCG)	Stop Time (UTCG)
1	27 Mar 2015 01:33:00	27 Mar 2015 05:33:21
2	28 Mar 2015 03:53:04	28 Mar 2015 15:21:38
3	29 Mar 2015 13:32:20	29 Mar 2015 21:09:36
4	29 Mar 2015 22:44:28	30 Mar 2015 04:54:51
5	31 Mar 2015 03:17:34	31 Mar 2015 06:43:00*

*** Note that spacecraft stays in view of Hawaii during TLE update V1 below, therefore visibility continues into pass #6.**

FOC4

1	27 Mar 2015 01:33:00	27 Mar 2015 05:35:20
2	28 Mar 2015 03:53:07	28 Mar 2015 15:20:00
3	29 Mar 2015 13:27:52	29 Mar 2015 21:06:36
4	29 Mar 2015 22:44:50	30 Mar 2015 04:48:51
5	31 Mar 2015 03:10:35	31 Mar 2015 06:43:00*

*** Note that spacecraft stays in view of Hawaii during TLE update V1 below, therefore visibility continues into pass #6.**

FOC3 Maneuvers and possible support times pass # 6 - 17

GFOC3-V1
1 99935 14999A 15091.28150463 +.00000000 +00000-9 +73196-3 2 00005
2 99935 055.0659 094.8004 0008735 262.0833 006.9010 01.67709650000006

Access	Start Time (UTCG)	Stop Time (UTCG)
6	31 Mar 2015 06:43:00	31 Mar 2015 14:41:40
7	1 Apr 2015 12:50:09	1 Apr 2015 16:33:00*

***Note that spacecraft stays in view of Hawaii during TLE update V2 below, therefore visibility continues into pass #8.**

GFOC3-V2
1 99935 14999A 15092.69589120 +.00000000 +00000-9 +73220-3 2 00005
2 99935 055.0671 094.7623 0006062 286.6487 116.3026 01.67610303000003

Access	Start Time (UTCG)	Stop Time (UTCG)
8	1 Apr 2015 16:33:00	1 Apr 2015 20:40:10
9	1 Apr 2015 22:34:54	2 Apr 2015 04:16:45

GFOC3-V3
1 99935 14999A 15093.87583333 +.00000000 +00000-9 +73222-3 2 00008
2 99935 055.0680 094.7304 0005993 288.0570 106.8867 01.67605180000004

Access	Start Time (UTCG)	Stop Time (UTCG)
10	3 Apr 2015 02:44:58	3 Apr 2015 14:06:22
11	4 Apr 2015 12:13:09	4 Apr 2015 20:14:53
12	4 Apr 2015 22:25:46	5 Apr 2015 03:45:53
13	6 Apr 2015 02:16:56	6 Apr 2015 13:33:06
14	7 Apr 2015 11:36:33	7 Apr 2015 19:49:10
15	7 Apr 2015 22:17:25	8 Apr 2015 03:14:59
16	9 Apr 2015 01:49:08	9 Apr 2015 12:58:36
17	10 Apr 2015 10:57:39	10 Apr 2015 19:23:07

FOC4 Maneuvers and possible support times pass # 6 - 19

GFOC4-V1
1 99790 14999B 15090.70934028 +.00000000 +00000-9 +73295-3 2 00007
2 99790 055.0645 094.8164 0021704 097.1699 188.8742 01.68513690000005

Access	Start Time (UTCG)	Stop Time (UTCG)
6	31 Mar 2015 06:43:00	31 Mar 2015 14:32:02
7	1 Apr 2015 12:29:52	1 Apr 2015 16:33:00*

***Note that spacecraft stays in view of Hawaii during TLE update V2 below, therefore visibility continues into pass #8.**

GFOC4-V2
1 99790 14999B 15092.17795139 +.00000000 +00000-9 +73430-3 2 00009
2 99790 055.0653 094.7762 0000151 292.1454 164.8527 01.69070070000002

Access	Start Time (UTCG)	Stop Time (UTCG)
8	1 Apr 2015 16:33:00	1 Apr 2015 20:27:11
9	1 Apr 2015 22:38:34	2 Apr 2015 03:52:53

GFOC4-V3
1 99790 14999B 15093.29023148 +.00000000 +00000-9 +73437-3 2 00004
2 99790 055.0662 094.7459 0001208 235.9601 178.0499 01.69098115000003

Access	Start Time (UTCG)	Stop Time (UTCG)
10	3 Apr 2015 02:10:11	3 Apr 2015 13:05:36
11	4 Apr 2015 10:31:19	4 Apr 2015 19:18:04
12	4 Apr 2015 22:46:53	5 Apr 2015 02:21:19
13	5 Apr 2015 18:15:17	5 Apr 2015 20:21:44
14	6 Apr 2015 00:55:31	6 Apr 2015 10:47:48
15	7 Apr 2015 07:43:08	7 Apr 2015 18:05:06
16	7 Apr 2015 23:34:23	8 Apr 2015 00:13:48
17	8 Apr 2015 16:32:02	8 Apr 2015 20:44:02
18	8 Apr 2015 23:43:37	9 Apr 2015 08:05:57
19	10 Apr 2015 05:43:34	10 Apr 2015 16:49:31

Flux Density impinging on the ground in Hawaii from Galileo FOC3 and FOC4

The Flux density is calculated as:

$$\boldsymbol{Flux\ density = EIRP \div (4\pi\, Rse^2)}$$

Where $\boldsymbol{Rse}$ is the distance from spacecraft to the ground?
Where $\boldsymbol{EIRP}$ is the Effective Isotropic Radiated Power of the spacecraft?

Data from the spacecraft vendor indicates that the nominal EIRP of each FOC spacecraft is -1.10 dBW. Being a near circular orbit, the altitude (and thus the closest distance to earth during an overhead pass) is = 23,400 Km.

Converting -1.10 dBW to scalar watts = 0.776 watts transmitted at 2221.9 MHz

Therefor:

$$\boldsymbol{Flux\ density = 0.776 \div (4\pi * 23{,}400{,}000\ meters^2)}$$

Flux density = 1.127 x 10^{-16} Watts/meter^2
Or
Flux density = 1.127 x 10^{-17} mW/cm^2