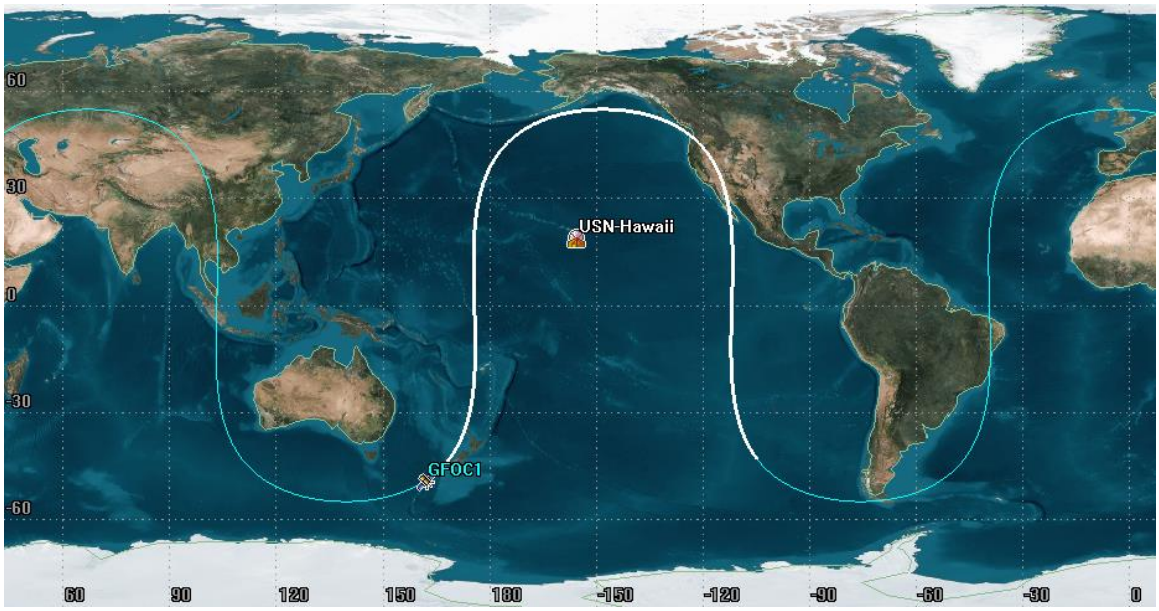
LEOP support of Galileo Constellation (FOC1 and FOC2) from USN's Hawaii ground station

Galileo FOC1 and FOC2 are the first and second spacecraft of the "Full Operational Capability" of the Galileo navigation constellation for the EU. The launch consists of 2 spacecraft (FOC1 and FOC2) that will be launched from French Guiana on a Soyuz vehicle on August 21st , 2014 at 12:31:13 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.



FOC1 and FOC2 nominal orbit and Hawaii coverage

The spacecrafts will be supported from injection and three subsequent orbital maneuvers for spacing of FOC1 and FOC2. The below analysis covers all possible visibilities from USN Hawaii, but not all visibilities will be supported.

FOC1 and FOC2 injection and coverage of pass #1-3

Both spacecraft are still in same antenna beamwidth after injection for the first several hours and then begin to drift apart. For the first several hours FOC1 and FOC2 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
FOC1	2221.995 MHz	2046.051 MHz
FOC2	2225.024 MHz	2048.887 MHz

GFOC1-injection
1 99997 51999A 14233.67998611 +.00000000 +00000-9 +69797-3 2 00001
2 99997 055.0288 100.8659 0004838 254.7598 347.2647 01.67807170000005

GFOC2-injection
1 99998 51999B 14233.67998611 +.00000000 +00000-9 +69797-3 2 00002
2 99998 055.0288 100.8659 0003707 045.1785 196.8459 01.68014387000000

FOC1

Access	Start Time (UTCG)	Stop Time (UTCG)
1	21 Aug 2014 18:20:59	22 Aug 2014 06:24:18
2	23 Aug 2014 03:55:09	23 Aug 2014 19:57:46
3	24 Aug 2014 17:45:14	25 Aug 2014 05:45:59

FOC2

1	21 Aug 2014 18:21:02	22 Aug 2014 06:22:43
2	23 Aug 2014 03:50:28	23 Aug 2014 19:51:40
3	24 Aug 2014 17:38:08	25 Aug 2014 05:36:06

FOC1 Maneuvers and possible support times pass #4 - 13

GFOC1-V1
1 99997 51999A   14237.02208681 +.00000000 +00000-9 +69797-3 2 00005
2 99997 055.0307 100.7748 0005390 259.1868 201.8854 01.67822712000002

No passes visible from this maneuver

GFOC1-V2
1 99997 51999A   14237.84883218 +.00000000 +00000-9 +69797-3 2 00000
2 99997 055.0312 100.7528 0005223 261.0177 339.5876 01.67847990000002

Access	Start Time (UTCG)	Stop Time (UTCG)
4	26 Aug 2014 03:09:47	26 Aug 2014 18:30:00

Note that spacecraft stays in view of Hawaii during the maneuver #2 below, therefore this continues to be pass #5.

GFOC1-V3
1 99997 51999A   14238.77173264 +.00000000 +00000-9 +69797-3 2 00006
2 99997 055.0318 100.7277 0004761 263.8557 174.4649 01.67858931000008

Access	Start Time (UTCG)	Stop Time (UTCG)
5	26 Aug 2014 18:30:00	26 Aug 2014 19:18:22
6	27 Aug 2014 17:08:21	28 Aug 2014 05:04:27
7	29 Aug 2014 02:17:31	29 Aug 2014 18:38:05
8	30 Aug 2014 16:31:13	31 Aug 2014 04:20:59
9	1 Sep 2014 01:18:12	1 Sep 2014 10:58:21
10	1 Sep 2014 12:22:49	1 Sep 2014 17:57:41
11	2 Sep 2014 09:29:17	2 Sep 2014 10:56:26
12	2 Sep 2014 15:54:11	3 Sep 2014 03:34:58
13	4 Sep 2014 00:08:36	4 Sep 2014 10:16:21

FOC2 Maneuvers and possible support times pass #4 - 14

GFOC2-V1
1 99998 51999B 14237.59188542 +.00000000 +00000-9 +69797-3 2 00001
2 99998 055.0310 100.7594 0039449 266.0046 182.2510 01.69086769000000

Access	Start Time (UTCG)	Stop Time (UTCG)
4	26 Aug 2014 02:42:22	26 Aug 2014 11:47:00

Note that spacecraft stays in view of Hawaii during the maneuver #2 below, therefore this continues to be pass #5.

GFOC2-V2
1 99998 51999B 14238.49128009 +.00000000 +00000-9 +69797-3 2 00003
2 99998 055.0316 100.7230 0003340 144.8635 131.0338 01.70208670000000

Access	Start Time (UTCG)	Stop Time (UTCG)
5	26 Aug 2014 11:47:00	26 Aug 2014 18:43:53
6	27 Aug 2014 10:00:48	27 Aug 2014 11:17:38

GFOC2-V3
1 99998 51999B 14239.47820023 +.00000000 +00000-9 +69797-3 2 00007
2 99998 055.0371 100.6932 0001961 060.3046 100.4545 01.70341875000009

Access	Start Time (UTCG)	Stop Time (UTCG)
7	27 Aug 2014 16:13:58	28 Aug 2014 03:30:55
8	28 Aug 2014 22:56:26	29 Aug 2014 09:42:52
9	29 Aug 2014 13:21:11	29 Aug 2014 16:23:15
10	30 Aug 2014 07:17:34	30 Aug 2014 12:19:29
11	30 Aug 2014 14:09:21	30 Aug 2014 23:33:31
12	31 Aug 2014 20:01:52	1 Sep 2014 07:42:36
13	2 Sep 2014 05:03:08	2 Sep 2014 20:37:58
14	3 Sep 2014 17:49:43	4 Sep 2014 05:37:35

Flux Density impinging on the ground in Hawaii from Galileo FOC1 and FOC2

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 -15.5 dBW. The altitude (and thus the closest distance to earth during an overhead pass) is = 23,400 Km.

Converting -15.5 dBW to scalar watts = 0.028 watts transmitted at 2221.9 MHz

Therefor:

$$\boldsymbol{Flux\ density = 0.028 \div (4\pi * 23{,}400{,}000\ meters^2)}$$

Flux density = 4.239 x 10^{-15} Watts/meter^2
Or
Flux density = 4.239 x 10^{-16} mW/cm^2