Preliminary results from EGNOS Signal Verification Flights at Norwegian Airports

By Alexander Løvar
Manager CNS/ATM
Regional Airports division
AVINOR AS

Background

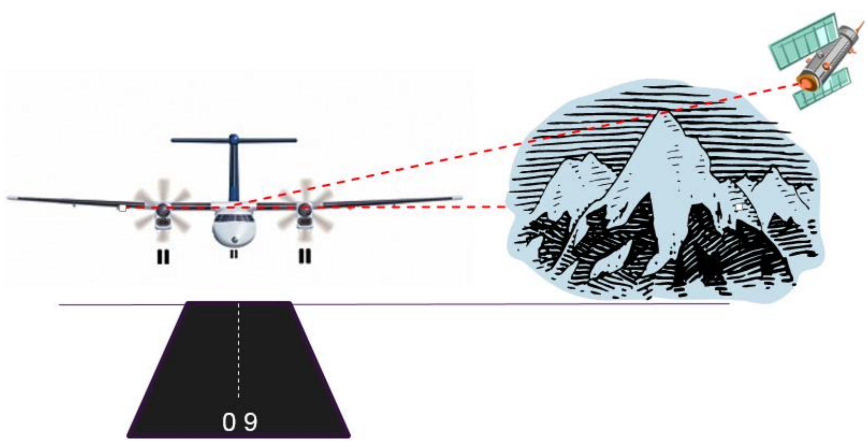
- Avinor has according to ICAO Res. A37-11; and as specified in BSL-G 4-1, started implementing PBN to all instrument runway ends…
  - LPV
  - LNAV/VNAV
  - LNAV

Background

- Some uncertainties are yet to be resolved relating to the practical use of the EGNOS signals:
  - Signal verification checks are required
    - Flight Validation/Inspection carried out at all locations where PBN procedures have been published (first validation at ENRS in 2013)
    - Signal verification (by ground measurements) carried out by Avinor at designated airports
    - As observers during In-flight Signal Verification Tests (by Norwegian Space Centre & Widerøe)

Theory

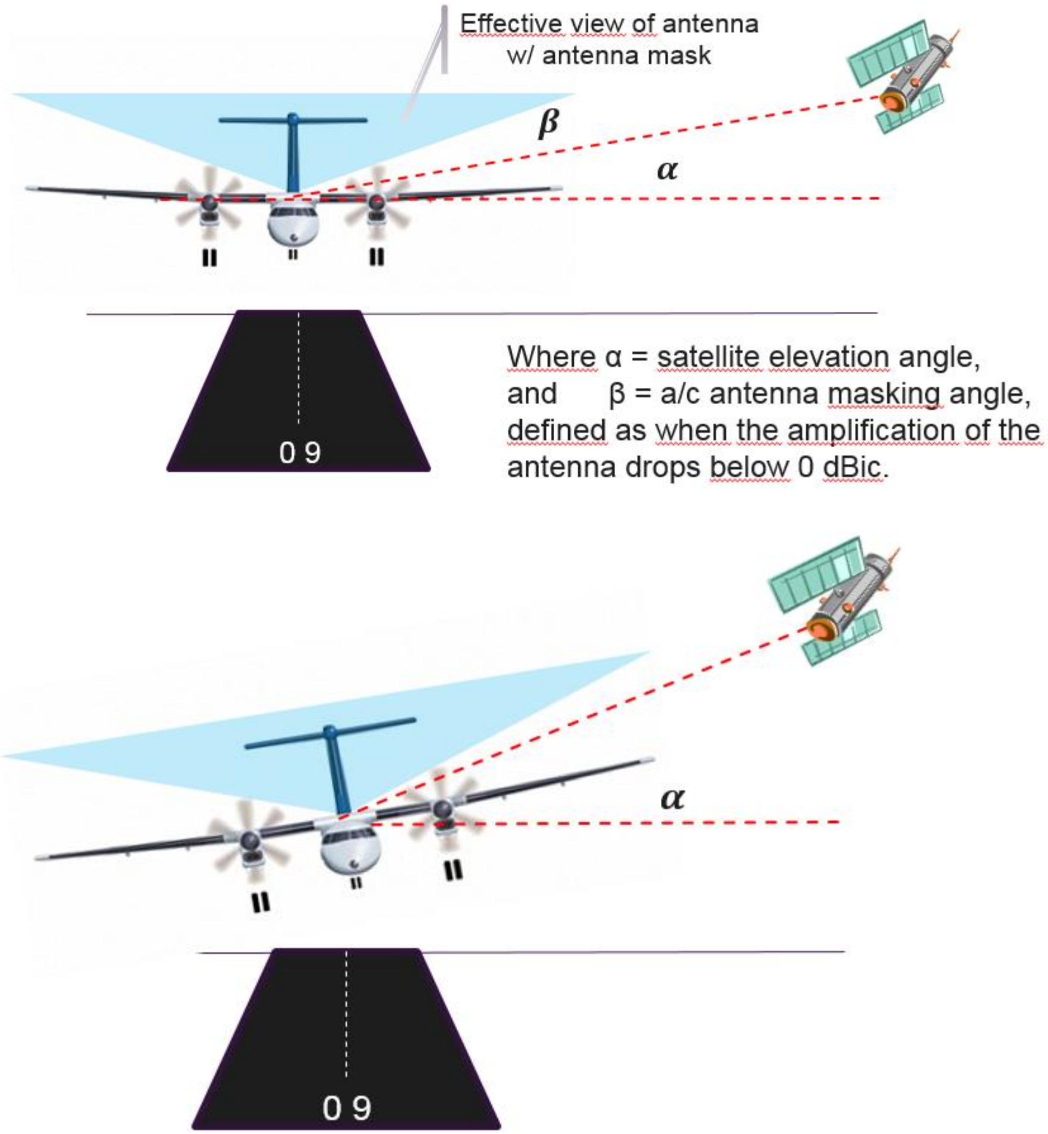
- The EGNOS satellites are GEO-stationary, resulting in low elevation angles at high latitude;
  - Signal is hence susceptible to terrain shadowing



Lufthavn (ICAO)	Breddegrad (° N)	Lengdegrad (°Ø)	Justert Breddegrad (φ)		Teoretisk elevasjonsvinkel (α)	
			Inmarsat AOR-E (15,5° vest)	Inmarsat IOR (25,0° øst)	Inmarsat AOR-E (15,5° vest)	Inmarsat IOR (25,0° øst)
ENNM	64, 2820	011, 3443	67,22	65,06	14,43	16,68
ENRM	64, 5018	011, 4806	67,44	65,26	14,20	16,48
ENBN	65, 2740	012, 1303	68,25	65,94	13,36	15,76
ENMS	65, 4701	013, 1255	68,63	66,03	13,74	15,67
ENST	65, 5735	012, 2820	68,54	66,21	13,65	15,47
ENRA	66, 2150	014, 1805	69,49	66,66	12,08	15,01
ENBO	67, 1609	014, 2155	70,30	67,59	11,24	14,04
ENRS	67, 3140	012, 0612	70,01	67,92	11,54	13,70
ENLK	68, 0909	013, 3634	70,93	68,56	10,59	13,64
ENSH	68, 1436	014, 4009	71,17	68,54	10,34	13,65
ENNK	68, 2613	017, 2312	71,85	68,47	9,65	13,13
ENEV	68, 2920	016, 4042	71,70	68,55	9,80	13,64
ENSK	68, 3451	015, 0134	71,46	68,69	10,05	12,90
ENDU	69, 0325	018, 3225	72,71	69,18	8,76	12,39
ENAN	69, 1733	016, 0839	72,37	69,44	9,11	12,08
ENTC	69, 4053	018, 5504	73,06	69,54	8,41	12,02
ENSR	69, 4712	020, 5735	73,53	69,54	7,93	12,02
ENAT	69, 5834	023, 2218	74,21	69,59	7,23	11,97
ENNA	70, 0400	024, 5826	74,86	70,04	6,57	11,54
ENHK	70, 2912	022, 0823	74,50	70,32	6,93	11,54
ENHF	70, 4047	023, 4007	74,87	70,41	6,56	11,13
ENHV	71, 0035	025 ,5901	75,80	71,01	5,61	10,51
ENMH	71, 0147	027, 4936	76,24	71,05	5,17	10,47
ENBV	70, 5217	029 ,0203	76,24	70,57	5,17	10,96
ENSS	70, 2119	031, 0242	76,52	70,33	4,88	11,21
ENVD	70, 0355	029, 5041	76,03	70,10	5,38	11,45
ENKR	69, 4330	029, 5316	75,62	69,50	5,79	12,06

Theory

- The EGNOS satellites are GEO-stationary, resulting in low elevation angles at high latitude;
  - Signal may come from below the antenna receiption sector ..
  - Signal is susceptible to shadowing from wing, fuselage and control surfaces ..



EGNOS Signal Verification: Ground – July 2015

SV S120 C/No [dbHz]						
Antenna inclination	0°	10°	15°	20°	25°	30°
ENRA (localizer)	35	32	31	31	30	31
ENRA (airport)	39	36	34	31	27	27
ENBO	34	33	33	32	32	32
ENRS	36	30	30	30	31	31
ENSH	37	33	32	30.5	29,5	27
ENEV	39	35	34	33.5	33.5	33.5
ENTC	39	36	35	34	33	33
ENSR	-	-	-	-	-	-
ENKR	36	29	32	33	35	35
ENAT	38	36	35	34	33	33
ENHF	34	31	28	-	-	-
ENHV	-	-	-	-	-	-

SV S126 C/No [dbHz]						
Antenna inclination	0°	10°	15°	20°	25°	30°
ENRA (localizer)	39	36	35	34	33	-
ENRA (airport)	38	36.5	35	32	30.5	30
ENBO	37	35	34	33	32	28
ENRS	41	38	37	35	34	-
ENSH	39	34	33	33	34	34
ENEV	35	31	-	-	-	-
ENTC	40	37	35.5	34	34	33
ENSR	38	36	36	36	36	35
ENKR	37	34	34	35	35.5	34.5
ENAT	38	34	33	33	34	34
ENHF	38	31	-	-	-	-
ENHV	34	32	31	29	28	-

Theoretical assumptions verified:

- There is an EGNOS Signal in Space available...
- The signal have a usable C/No ratio, also North of 70N

EGNOS Signal Verification : Flight – Oct 2015

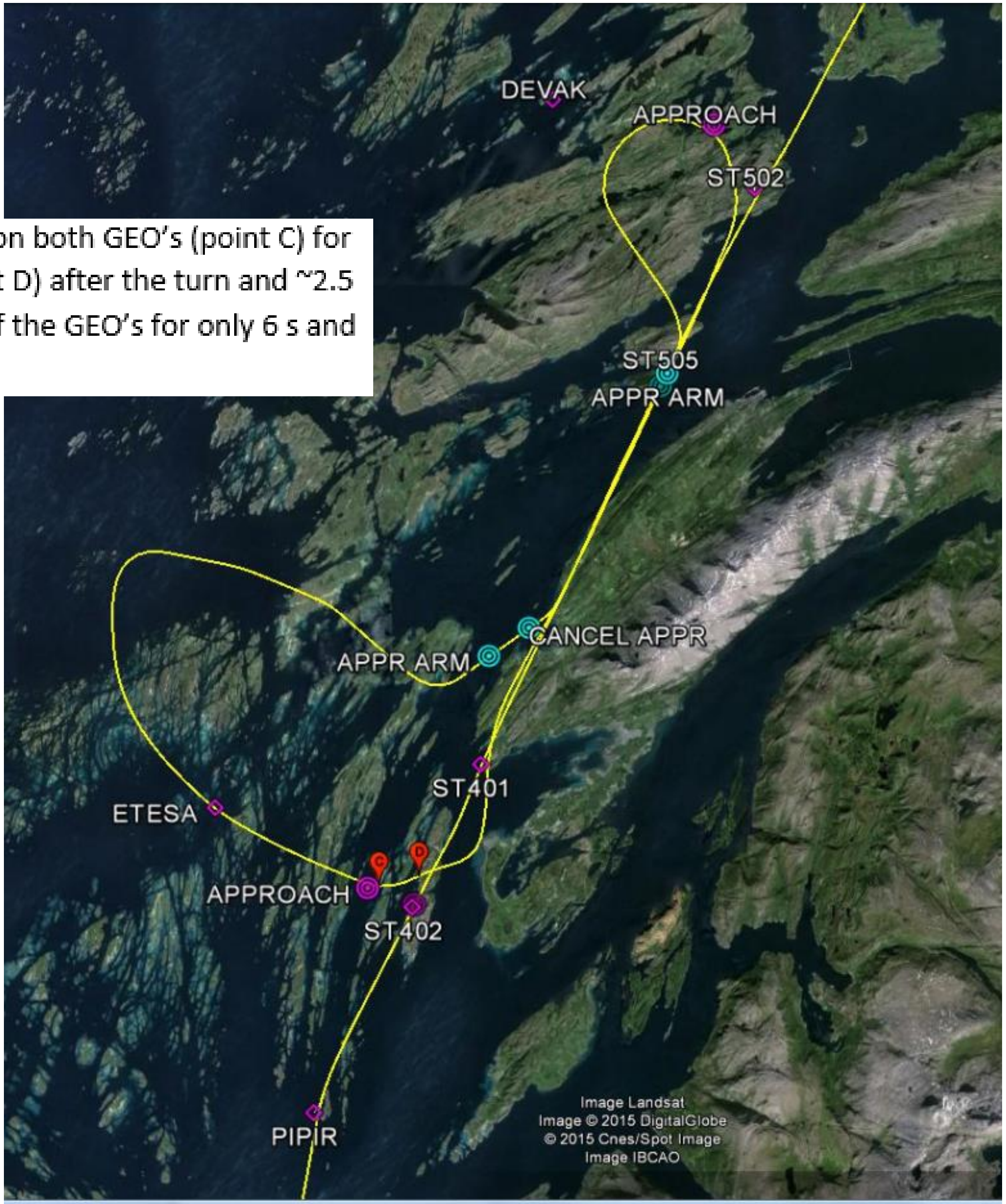
Airport	LAT	Successful LPV Apch?	Comment
Namsos (ENNM)	64.3	1 of 2	Lost track during turn onto «final» during approach from north.
Sandnessjøen (ENST)	65.6	1 of 3	Lost track whilst manouvering prior to final approach.
Stokmarknes (ENSK)	68.3	1 of 2	Lost track whilst manouvering prior to final approach.
Andøya (ENAN)	69.2	1 of 2	Lost track whilst manouvering prior to final approach.
Tromsø (ENTC)	69.4	1 of 2	NOTE; only one GEO available. Lost track whilst manouvering prior to final approach.
Hammerfest (ENHF)	70.4	---	Signals not received continiously.
Mehamn (ENMH)	71.1	---	Signals not received continiously.
Kirkenes (ENKR)	69.4	1 of 2	Lost track during turn onto «final» during approach from north.

EGNOS Signal Verification Flight – ENNM

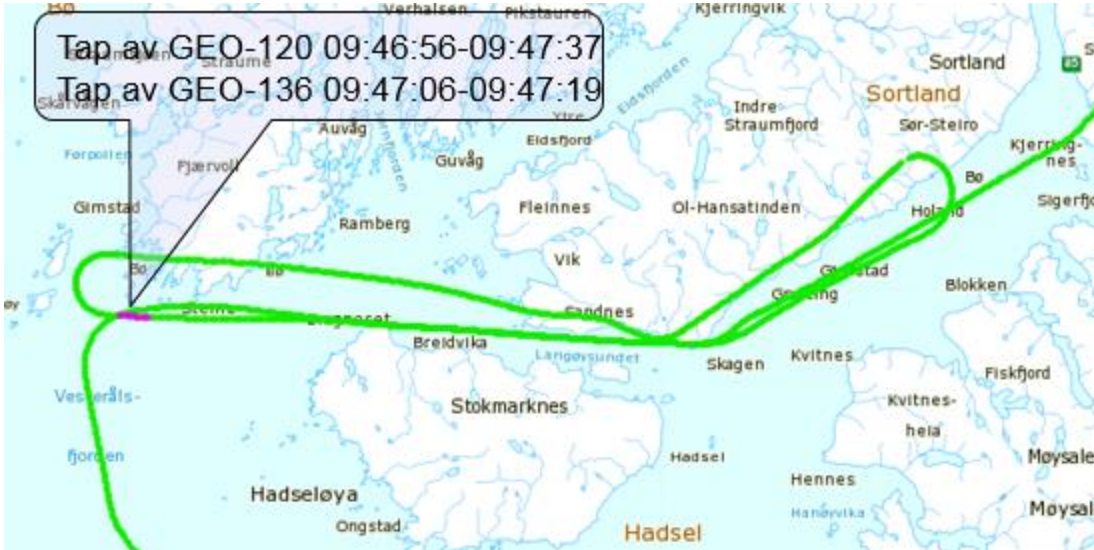
During the LH-turn @ ULROP the WAAS1 sensor lost track on both GEO's (point A) for ~20 s and SBAS mode for ~ 15 s, but reacquired them (point B) after the turn and ~2.3 nm before the FAF (KOSUN). The WAAS2 sensor lost track of the GEO's for only 5 s and remained in SBAS mode.

EGNOS Signal Verification Flight – ENST

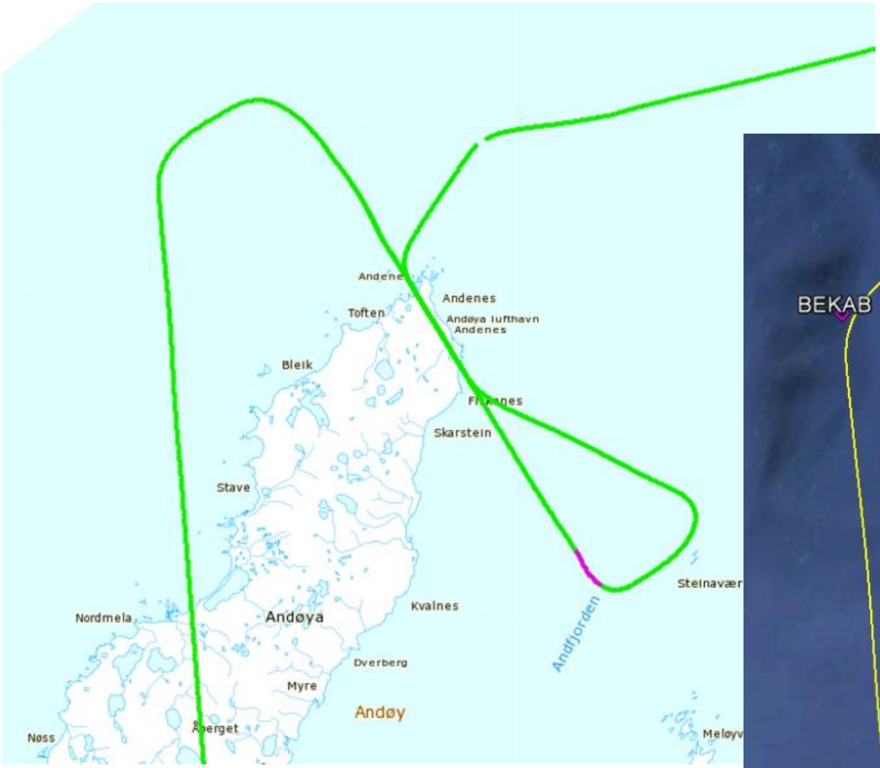
During the LH-turn @ ST402, the WAAS1 sensor lost track on both GEO's (point C) for ~17 s and SBAS mode for ~10 s, but reacquired them (point D) after the turn and ~2.5 nm before the FAF (ST401). The WAAS2 sensor lost track of the GEO's for only 6 s and remained in SBAS mode.

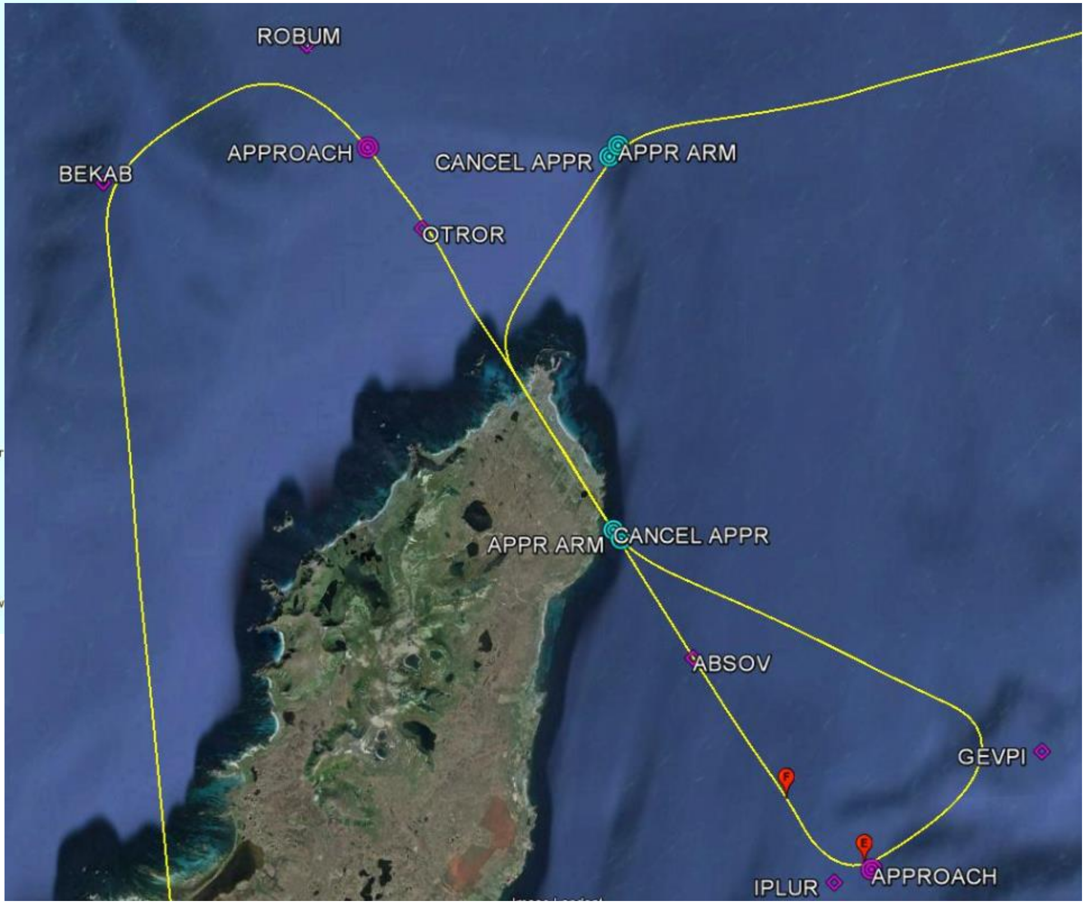


EGNOS Signal Verification Flight – ENSK

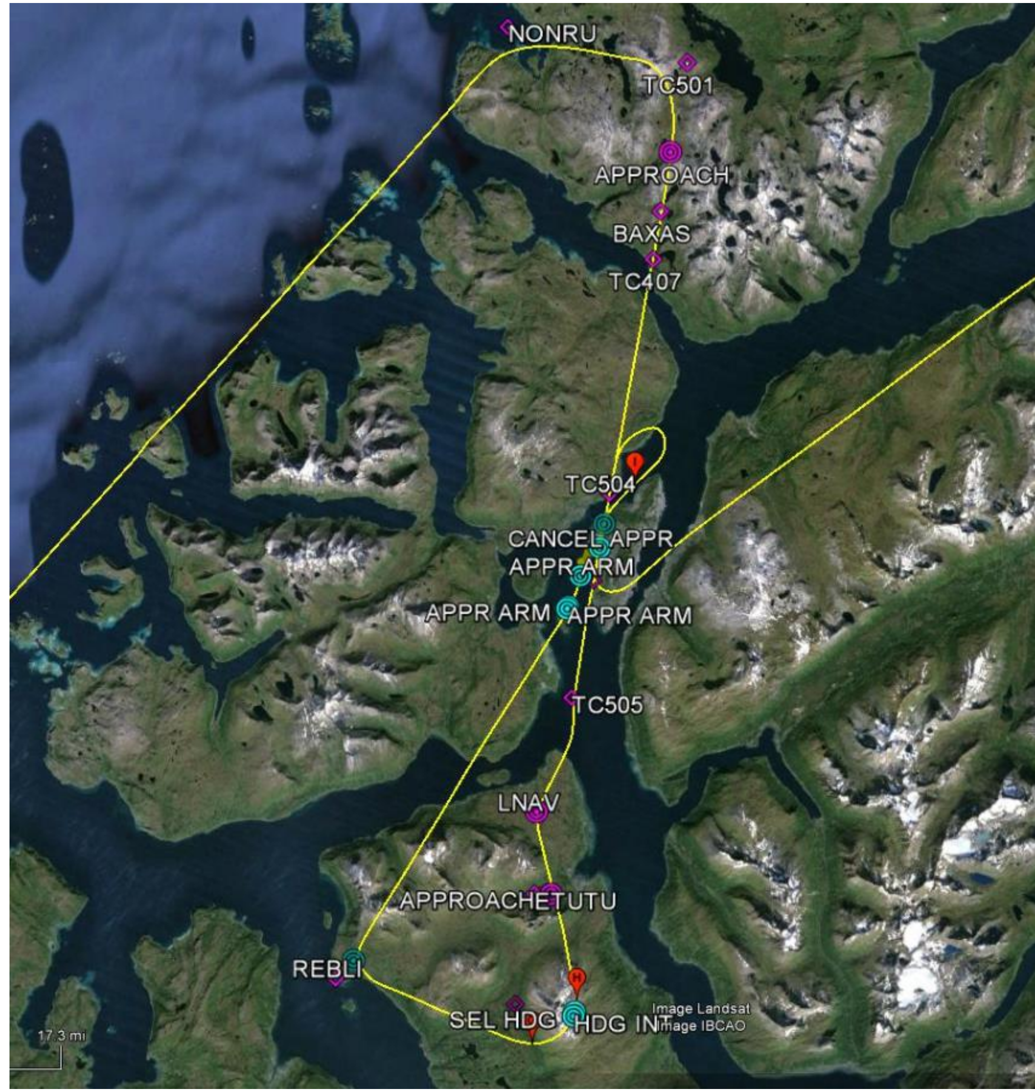


EGNOS Signal Verification Flight – ENAN





EGNOS Signal Verification Flight – ENTC



EGNOS Signal Verification Flight – ENKR

PRELIMINARY Conclusions

- Some uncertainties are yet to be resolved relating to the practical use of the EGNOS signals:
  - Signal is available "in space" also at the most northerly airports
  - Signal seems not disrupted by terrain shadowing at low altitude
  - Signal reception seems dependent on aircraft structure relative to the location of the antenna(e)
  - Signal reception seems dependent on aircraft maneuvering, as all temporary interruptions seems to originate from movements in the roll-axis
  - Signal is received, and normal operations resumed, short time after the aircraft return to a «wings level» flightpath
  - An extended coverage of EGNOS to 72N will likely not help with the problem, as the issue arises due to low elevation angles.

PRELIMINARY Conclusions

- Solutions & work arounds:

  - Could cockpit procedures allow for the approach not to be terminated (not initiate a «go-around») even though signals are temporarily lost? [when signal is lost at 10+ n.m. and 4000 ft.?]

  - EGNOS signal transmitted from other sources than GEO's

- Operational implications:

  - The long term strategy for navigation in the ECAC is PBN-only at smaller local airports. However, this is not a solution that covers the needs in Norway. The consequence seems to be a navigation network that deviates from European standards, with the implications that has for interoperability and economy versus safety and punctuality.