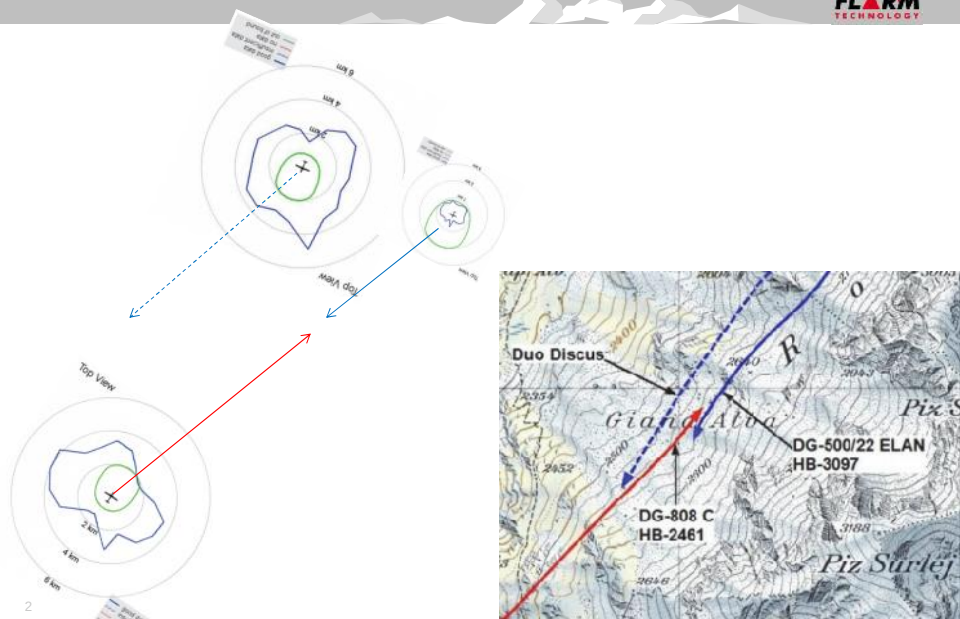




Collision Avoidance for General Aviation

SFVS Safety
Seminar 2016

SUST Airpox Juni 2014 @ Engadin



SUST Airpox Juni 2014 @ Engadin



Sicherheitsempfehlungen

Reichweitenanalyse von Flarm-Systemen

Sicherheitsdefizit

Die Reichweite (Sendeleistung und Empfangsempfindlichkeit) der in Luftfahrzeugen eingebauten Kollisionswarnsysteme Flarm kann am Boden nicht getestet werden. Auf der Website des Herstellers kann die Empfangsreichweite eines Flarm-Systems aufgrund von registrierten Daten im betroffenen Flarm-System einfach überprüft werden. Diese Daten können allerdings nur im Flug bei genügend Annäherungen mit anderen Luftfahrzeugen registriert werden.

Dieses Sicherheitsdefizit wurde auch im Rahmen der Untersuchung einer gefährlichen Annäherung zweier Helikopter vom 21. Juni 2013 festgestellt (vgl. Schlussbericht Nr. 2233 der SUST).

Sicherheitsempfehlung Nr. 500

Das Bundesamt für Zivilluftfahrt (BAZL) sollte sich für die Entwicklung eines technischen Verfahrens einsetzen, mit dem die Funktionstüchtigkeit der in Luftfahrzeugen eingebauten Kollisionswarnsysteme Flarm am Boden überprüft werden kann.

File-based Rx Range Analyzer by FLARM



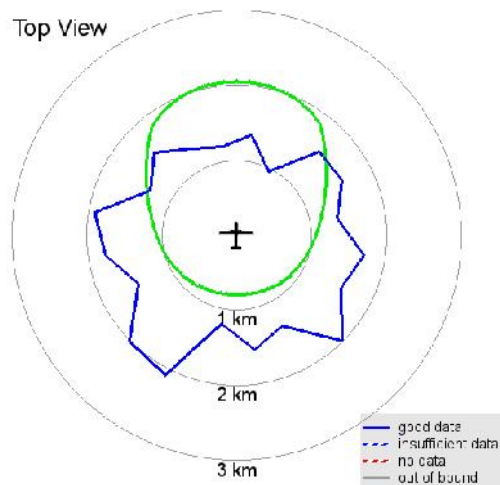
FLARM Radio Range Analysis

The green area is the minimum recommended range for speeds up to 200 km/h.
The blue area is the average receive range of the submitted flight data.

- Classic 8bit OEM
- LX RedBox
- Bad Rx
 - 1.4km Ø
 - 13km max
- Better on back side

File : 54602WV1.IGC
Pilot : RUTZEL BERND
Radio ID: DDB2C1
Recorder: LXN Red Box Flarm
HW Type: LXN-Flarm-IGC
FW Vers: 6.01
Stealth: OFF

Top View



Total points: 790
Average distance: 1440m
Maximum distance: 13276m



Version 1.0 Copyright (C) 2004-2015 FLARM Technology GmbH. Patents Pending

data processed on Wed, 02 Jun 16 14:24:13 +0100

File-based Rx Range Analyzer by FLARM



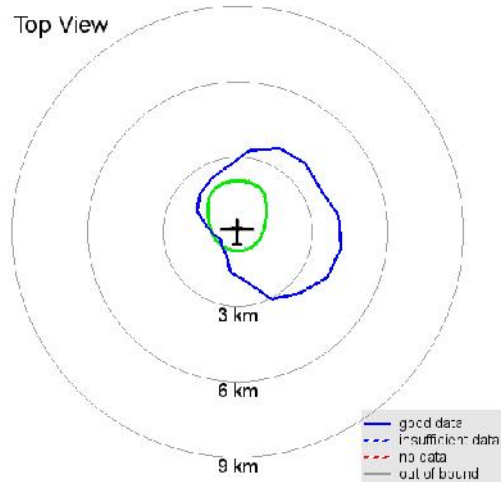
FLARM Radio Range Analysis

The green area is the minimum recommended range for speeds up to 200 km/h.
The blue area is the average receive range of the submitted flight data.

- Classic 8bit OEM
- LX RedBox
- Acceptable Rx
 - 3.3km Ø
 - 23km max
- Much better on right side

File : 57P031A1.IGC
Pilot : Graham Hoile
Radio ID: DDB365
Recorder: LXN Red Box Flarm
HW Type : LXN-Flarm-IGC
FW Vers : 6.01
Stealth : OFF

Top View



Total points: 1916
Average distance: 3297m
Maximum distance: 22671m



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data processed on Thu, 3 Dec 15 19:59 9 -0100

5

File-based Rx Range Analyzer by FLARM



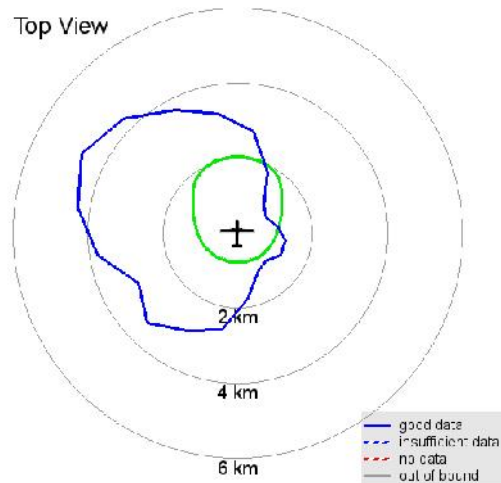
FLARM Radio Range Analysis

The green area is the minimum recommended range for speeds up to 200 km/h.
The blue area is the average receive range of the submitted flight data.

- Classic 8bit Flarm
- F6
- Acceptable Rx
 - 3.0km Ø
 - 17km max
- Much better on left side

File : 58504WL1.IGC
Pilot : Matthias Haute
Radio ID: DDABDF
Recorder: Flarm-IGC
HW Type : Flarm-IGC06
FW Vers : 6.01
Stealth : OFF

Top View



Total points: 3997
Average distance: 3027m
Maximum distance: 17098m



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data processed on Thu, 14 Jan 16 12:17:56 +0100

6

File-based Rx Range Analyzer by FLARM



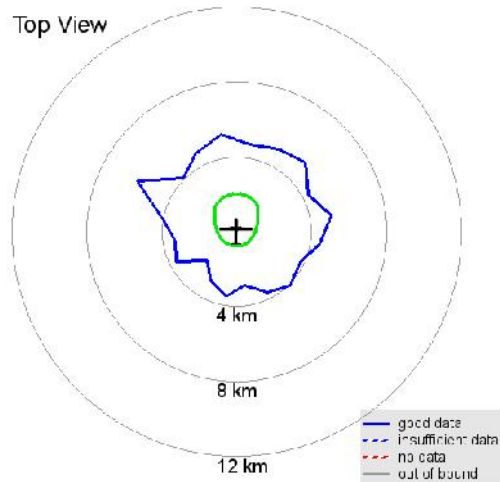
FLARM Radio Range Analysis

The green area is the minimum recommended range for speeds up to 200 km/h.
The blue area is the average receive range of the submitted flight data.

- Classic 8bit Flarm
- F5
- Good Rx
 - 4.4km Ø
 - 13km max
- Good surround rx

File : 58BXAY1.IGC
Pilot :
Radio ID: DD973A
Recorder: Flarm
HW Type : Flarm05
FW Vers : 6.00
Stealth : OFF

Top View



Total points: 374
Average distance: 4446m
Maximum distance: 12822m



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data processed on Wed, 20 Jan 10 06:23:20 +0100

7

File-based Rx Range Analyzer by FLARM



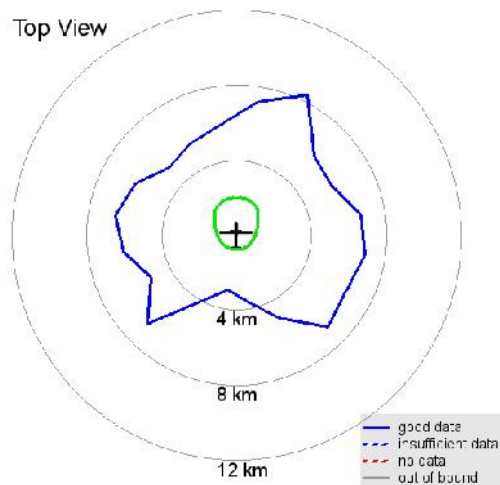
FLARM Radio Range Analysis

The green area is the minimum recommended range for speeds up to 200 km/h.
The blue area is the average receive range of the submitted flight data.

- Classic 8bit Flarm
- F6
- Good Rx
 - 6.1km Ø
 - 21km max
- Good surround rx

File : 55AXE9W1.IGC
Pilot :
Radio ID: DDADD4
Recorder: Flarm
HW Type : Flarm06
FW Vers : 6.01
Stealth : OFF

Top View



Total points: 2168
Average distance: 6083m
Maximum distance: 21374m



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data processed on Thu, 2 Dec 10 15:20:25 +0100

8

File-based Rx Range Analyzer by FLARM



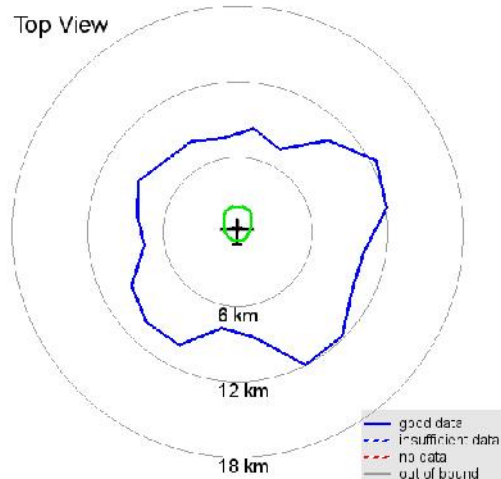
FLARM Radio Range Analysis

The green area is the minimum recommended range for speeds up to 200 km/h.
The blue area is the average receive range of the submitted flight data.

- 32bit Flarm
- PowerFLARM
- Excellent Rx
 - 10km Ø
 - 37km max
- Better on right side

File : 55MDH4T1.IGC
Pilot :
Radio ID: DF0DD4
Recorder: PowerFLARM-IGC
HW Type : 1.1
FW Vers : 6.00
Stealth : OFF

Top View



Total points: 1971
Average distance: 9692m
Maximum distance: 36978m



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data processed on local, 18 Jan 15 10:20:55 -0100

9

File-based Rx Range Analyzer by FLARM



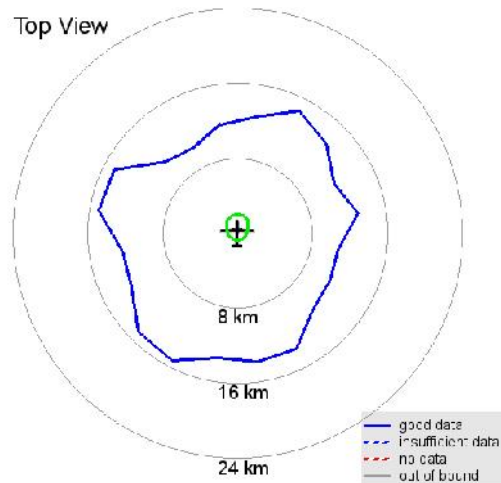
FLARM Radio Range Analysis

The green area is the minimum recommended range for speeds up to 200 km/h.
The blue area is the average receive range of the submitted flight data.

- 32bit Flarm
- PowerFLARM
- Excellent Rx
 - 13km Ø
 - 36km max
- Good surround rx

File : 49R2G3T1.IGC
Pilot : Wm_Kalle_Conni
Radio ID: 3B5D8D
Recorder: PowerFLARM
HW Type : 1.1
FW Vers : 6.00
Stealth : OFF

Top View



Total points: 1023
Average distance: 12862m
Maximum distance: 36392m



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data processed on local, 18 Jan 15 08:55:53 -0100

10

OGN-based Tx Range Analyzer by KISS Ktrax

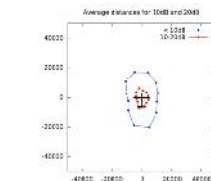
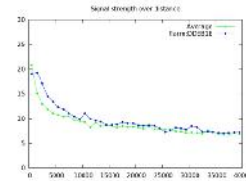


- Classic 8bit Flarm
- LX8000 / 9000
- Average Tx
- Weak Surround Tx



Signal strength and SAR report for flarm:DDEB1E

Processed by KISS Ktrax as a combined based on data from the Open Radar Network



Report date: Fri Jan 22 10:55:35 UTC 2016
 CallsignID: D KISS Ktrax DDEB1E
 Versions: 1 (Indoor: 05/Software: 6.01)
 Received by: 1 (OCN stations)
 Echoes used: 1 (OCN out of 19105)
 Average frequency deviation: 0.0071 kHz
 Average GPS accuracy: 4.3 m
 Position jumps: 0
 SAR: Timed out, not seen 2016-01-18 10:22:48Z

11

OGN-based Tx Range Analyzer by KISS Ktrax

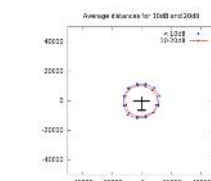
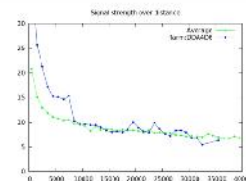


- Classic 8bit Flarm
- F6
- Average Tx
- Surround Tx



Signal strength and SAR report for flarm:DDA4D6

Processed by KISS Ktrax as a combined based on data from the Open Radar Network



Report date: Fri Jan 22 10:56:16 UTC 2016
 CallsignID: I CBB Ctrax DDA4D6
 Versions: 1 (Indoor: 05/Software: 3.01)
 Received by: 4 (OCN stations)
 Echoes used: 1 (OCN out of 12112)
 Average frequency deviation: 0.53 kHz
 Average GPS accuracy: 2.7 m
 Position jumps: 0
 SAR: Timed out, not seen 2016-01-18 11:00:18Z

12

OGN-based Tx Range Analyzer by KISS Ktrax

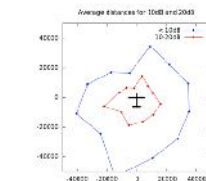
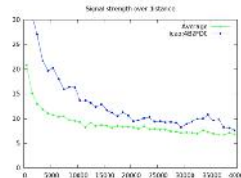


- 32bit Flarm
- PowerFLARM
- Good Tx
- Good Surround Tx



Signal strength and SAR report for Icao:4B2FD0

Processed by KISS Ktrax as a combined based on data from the Open Flarm Network



Report date: Friday 22 12 33 44 UTC 2016
 CallignID: H9 SCUN:40:4521 U6
 Versions: 43/Software: 6.02
 Received by: 13 OGN stations
 Echos used: 18/14 out of 11719
 Average frequency deviation: 7.05 MHz
 Average GPS accuracy: 1.4 m
 Position jumps: 0
 SAR: 41.444233, 8.2502839, UIC 2016 01 22 109247042

13

OGN-based Tx Range Analyzer by KISS Ktrax

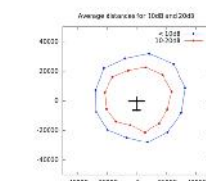
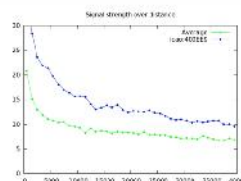


- 32bit Flarm
- PowerFLARM
- Good Tx
- Good surround Tx



Signal strength and SAR report for Icao:400EE9

Processed by KISS Ktrax as a combined based on data from the Open Flarm Network



Report date: Friday 22 12 33 53 UTC 2016
 CallignID: G-BVLU/c80:40:4521 U6
 Versions: 44/Software: 6.02
 Received by: 13 OGN stations
 Echos used: 18/14 out of 11719
 Average frequency deviation: 7.1 MHz
 Average GPS accuracy: 1.5 m
 Position jumps: 2
 SAR: 51.61176, 1.0952167, UIC 2016 01 22 116203862

14

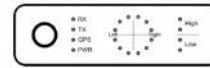
FLARM Darstellungs-Artefakte



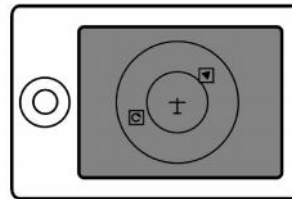
- Kontrastreiche, intuitive Darstellung für Ausnahmesituationen
- Kostengünstige Sensorik:
 - GNSS (u.a. für Ground-Track) + Baro (nur Cockpit-Static)
 - kein Kompass + IMU (Flz-Lage, Beschleunigungen, Rotationen)
- Flugweg-Prädiktion und Gefahren-Assessment in erdfestem Koordinatensystem, mit gewissen Korrekturen für externe Faktoren wie Wind
- Designannahmen für Darstellung:
 - Display-Heading = Flz-Heading = Ground-Track, d.h. weder Wind noch Schieben noch Seitenflug noch Rückenflug noch nach hinten schauend
 - Flz-Lage horizontal, d.h. weder rollen noch nicken



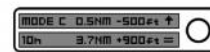
Figure 1: FLARM display



(a) Low-complexity dedicated traffic display



(b) High-complexity dedicated traffic display



(c) Alphanumeric dedicated traffic display

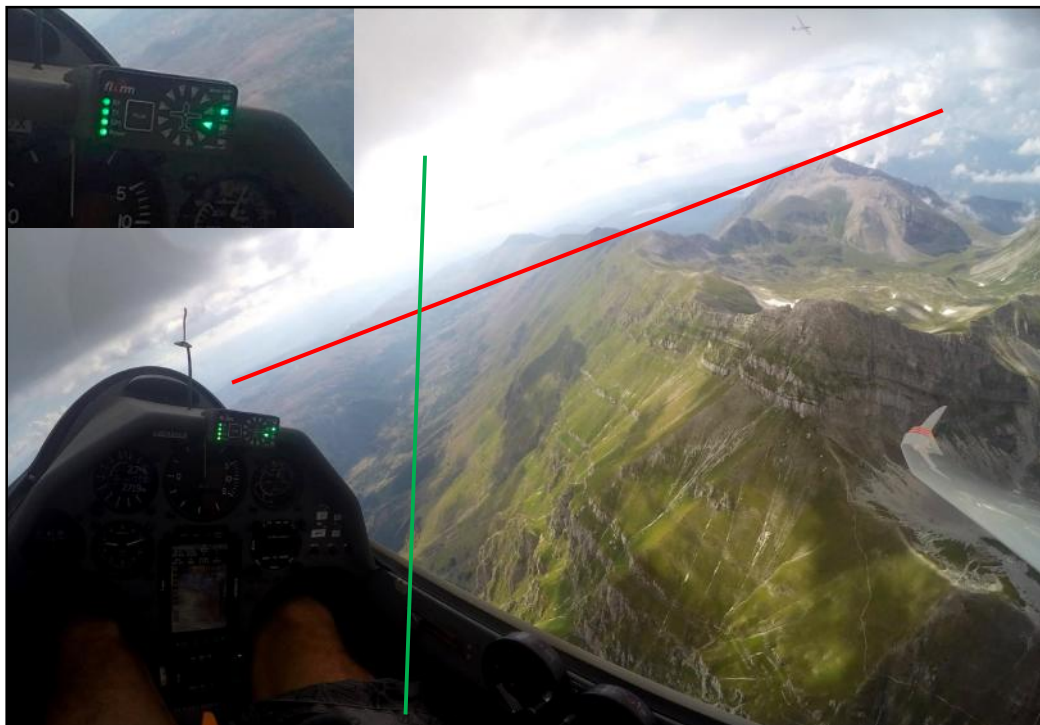
15

FLARM Darstellungs-Artefakte



Flight condition	Straight and level flight	Horizontal flight with crosswind from left	Left-hand turning flight	Climbing flight
Cockpit visual scene				
Orientation of FLARM coordinate system				
Orientation of ownship-fixed coordinate system				
Bank angle Φ =	0°	0°	-30°	0°
Pitch angle Θ =	0°	0°	0°	10°
Drift angle ν =	0°	-12°	0°	0°

16



SAR Schanis – Prättigau, Juli 2015



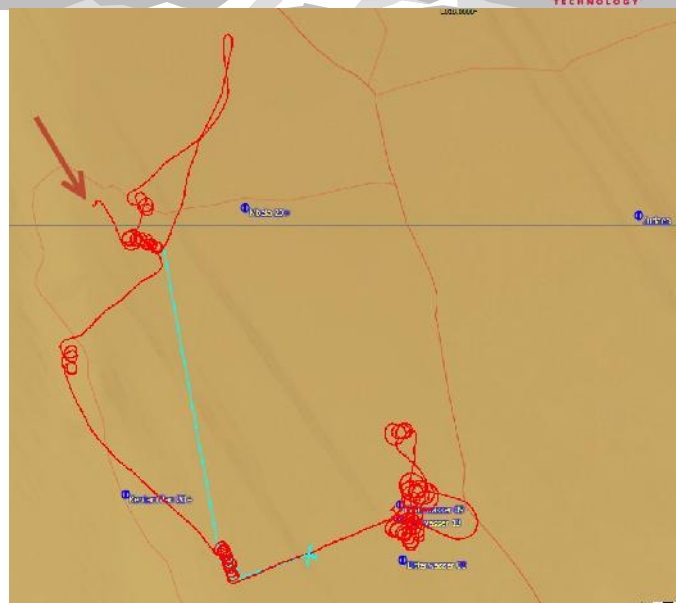
- Synthetische FLARM-Rekonstruktion
- OGN Daten (letzte Posi sofort verfügbar)



SAR Bitterwasser, Dezember 2015



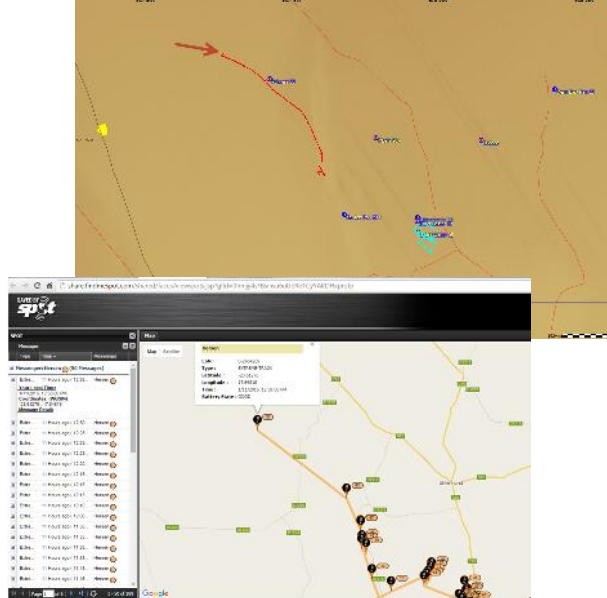
- Synthetische FLARM-Rekonstruktion
- IGC Daten aus Wrack
- Keine OGN Daten (Empfänger seit 4 Wochen defekt)
- SPOT abgestellt
- Altes ELT, ohne Daten
- Gefunden 2 Tage danach vom Boden her, zufällig



SAR Bitterwasser – Pokweni, Januar 2016



- Synthetische FLARM-Rekonstruktion aus OLC
- OGN Daten ab Kiripotib (letzte Posi sofort verfügbar)
- SPOT alle 2.5 Minuten, letztmals 640m und 2' von OGN entfernt
- Kein ELT
- Beide PLB nicht aktiviert
- Gefunden am Morgen danach aus der Luft



21

Empfänger @ Flplz oder zuhause



- Gute Experimentierplattform: Zugänglich, bequem, warm, harmlos, Infrastruktur, Kontrolle
- Gute Abdeckung für Platzverkehr (Voltenkontrolle, Startliste, ID-Matching via Webcam)
- Geringeres Datenvolumen für rechenintensive Auswertung
- Mässige Reichweite

22

Empfänger @ Rigi-Kulm

- Installiert Ende Sept 2015
- Nur wenige Tage in Betrieb
- Operativ seit Mitte Nov
- Tägliche Reichweiten 100-200km
- Ständig @ Top 2%

rigi
KULM HOTEL

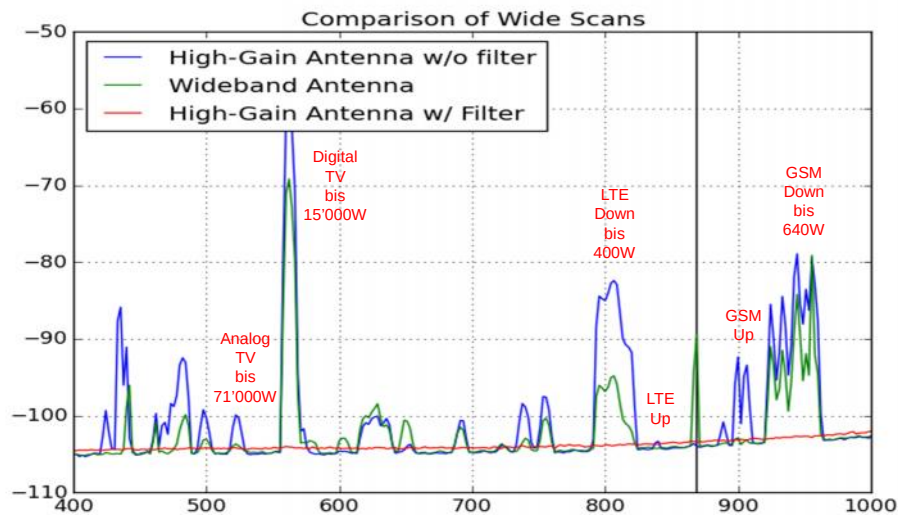


Installation @ Rigi

FLARM
TECHNOLOGY



Funkbelastung @ Rigi



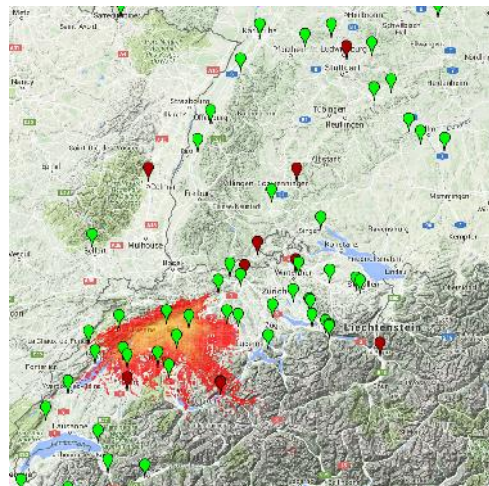
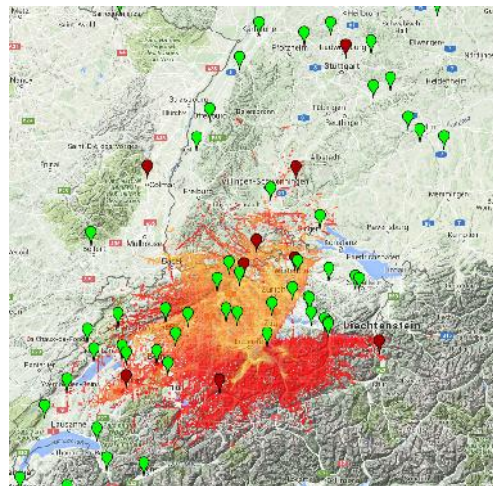
Empfänger @ Rigi-Kulm



- PC ab 50.- (Board, Box, SD-Karte, WiFi-Modul, Kühlkörper, Netzgerät)
- DVB-T SDR Rx ab 10.-
- Antenne ab 50.- (Antenne, Halterung, Kabel, Adapter, Verstärker, Netzgerät)
- Erlaubnis, Zugang + Präsenz
- Brauchbares Netzwerk und –zugang
- Brauchbare Stromversorgung
- Zuverlässiger PC
- Umweltfeste Antennen- und Kabelinstallation
- Brauchbare HF-Filter
- Ausreichendes Schutzgehäuse
- Tastatur, Monitor, Maus im Feld, oder KVM-Adapter
- Zeit + Flexibilität
- Material-, Versand- und Transportkosten
- Know-how
- Frustrationstoleranz
- Rechtsrisiko



- Solothurn

[illegible]

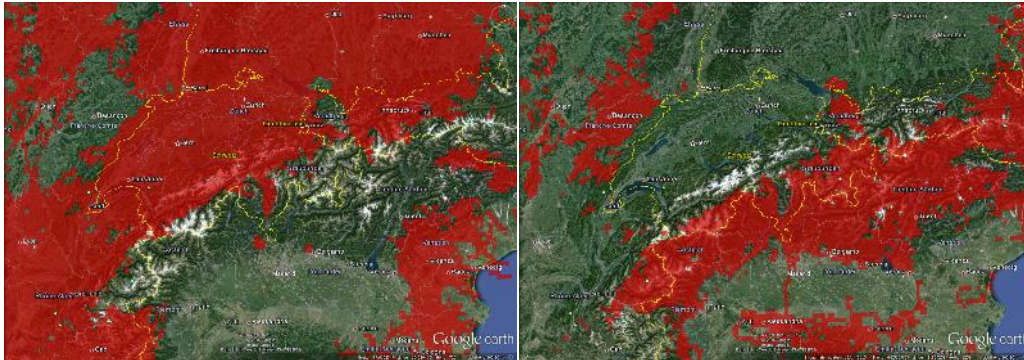
- Materialbezugskosten um 700.- bei 50 Stück
- Exkl. Zusammenbau, Montage, Wartung
- Zusätzlich Natel-Datenabo um 100.-/Jahr
- Langzeiterfahrung steht aus, allenfalls werden robustere Komponenten benötigt
- Dafür: viel Reichweite + Nutzen



OGN Abdeckung



- Optimistic Maximal Coverage
- Missing Coverage vs. Gliding



29

OGN Abdeckung @ tiefste Höhenwerte

