# Aircraft performance-based redesign of airport obstacle limitation surfaces

## The horizontal obstacle limitation surfaces

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***Abstract* - Air traffic within highly frequented terminal manoeuvring areas is characterized by a high number of climbing and descending aircraft, varying in size, speed and distance between each other. So collision risk is increased compared to En-route airspace. Additional collision risk with ground based, fixed obstacles have to be taken into account. To protect aircraft from obstacle on ground during procedures in the vicinity of an aerodrome, the first obstacle limitation surfaces were implemented in the 1950's. From today's view current navigation procedures and actual aircraft performance are without clear correlation to the dimensions and shapes of the applied obstacle limitation surfaces. To avoid over and under protecting of specific terminal manoeuvring areas, obstacle limitation surfaces have to be redesign. We present a methodology of obstacle limitation surface redesign and focus on the horizontal surface. This area aims to protect aircraft on non-standardized flight procedures and is characterized by no nominal flight tracks. In consequence, here obstacle limitation surfaces design criteria focus on aircraft performance data, fitting to manoeuvres that can occur within this airspace. As result, new horizontal surfaces are designed and dimensioned in dependence to the ICAO's approach speed category and maximum cross wind components as key influencing parameters for aircraft turning radius. To ensure more practicability of obstacle limitation surface, the paper presents a 2nd optional iteration stage of the surface design. This stage takes local conditions into account, e.g. wind components. As a result, aerodrome-specific downsizing of the horizontal surfaces enables a benefit for urban planning.**

***Keywords - Obstacle Limitation Surfaces; OLS; TMA Safety; Performance-based Navigatio;, Flight Technical Error; Aircraft Performance; Wind Effect***

## I. INTRODUCTION

The high number of aircraft movements in a dense and complex airspace around the airport demands for a continuous optimization of the airspace capacity and designing of efficient flight operations. To ensure safe and collision-free flight operations with respect to obstacles on ground, regardless implemented navigation technology, the following condition has to be met: Compliance of navigation accuracy by keeping maximum allowable deviations from a desired flight path. However, a transfer of Performance-based Navigation (PBN) requirements to the previously static, conventional collision protection specifications - the obstacle limitation surfaces (OLS), e.g. according ICAO Annex 14 [1] or EASA CS-ADR-DSN [2], does not take place yet. In consequence, OLS dimensioning and alignment is still independent of the aircraft's navigation accuracy. As result, aircraft operating on beside straight in (e.g. ILS) and straight out approaches are not or only partly protected by OLS.

There is an immanent demand for OLS redesign with regard to navigation specification for conventional and performance-based navigation according [3] taking current and future aircraft performance into account.

This paper shows a systematic approach of a modular OLS redesign and focus on a methodology of horizontal surface dimensioning as subtask of the overall redesign process.

This paper is structures as follows: first, we introduce the state of art with a focus on currently valid OLS and two OLS redesign approaches. In section III, we focus on the methodology to redesign the horizontal surfaces as subtask during OLS redesign process. In section IV results of the first redesign stage are discussed. Additionally, results are extended by a second implementation stage using London Gatwick Airport as an example. Finally, the paper ends with a discussion and outlook on future research.

## II. State of the Art and Research Approaches

### *A. Obstacle Limitation Surface*

International specifications and dimensioning of the OLS according ICAO Annex 14 [1] respectively EASA CS-ADR DSN [2] support the purpose to assure conflict free procedure design within the TMA that take potential ground based obstacles into account. This is realized by a surface system (see Figure 1), which limits any kind of obstacle in its vertical dimensioning depending on its relative position to the aerodrome.

### *B. ICAO's OLS Task Force*

Introduced at the 12th air navigation conference in November 2012 and continued the 38th ICAO assembly in September 2013, ICAO has initiated a review of the existing obstacle limitation surfaces to analyze current problems and define solutions by the OLS task force (OLSTF).

Since 2016 OLSTF published concepts and design description of new OLS, which are planned to find entrance to the chapter 4 of the Annex 14 from 2022 on [4]. Within the document "Aerodrome Obstacle Surfaces – The new concept", OLSTF published its objectives and design parameters of the new OLS [5]. The new concept presents two new categories of surfaces (Obstacle Free Surfaces - OFS and Obstacle Evaluation Surfaces - OES) to enhance safety and efficiency around aerodrome. [4]

The OFS "are surfaces that are applied within a defined airspace to maintain free from obstacles" [5]. The OES are "additional surfaces that are applied in a defined airspace, below and beyond the OFS, to be evaluated against obstacles [..] the OES act as trigger for an aeronautical study, [..] to evaluate potential impact of obstacles" [5].
OLSTF assigns the currently valid OLS to each category and provides updated design parameters for each surface. OLSTF does not currently provide any information to justify its categorization and dimensioning of the surfaces within the OFS/OES concepts.

### *C. IFL OLS redesign*

Our research approach pursues the target of a modular, aerodrome specific and two-stage OLS implementation. The specific OLS design criteria consider prevalent flight procedures, local obstacle occurrences, further parameter effecting the flight operation safety and local urban planning concepts. The dimensioning of the respective OLS is basically carried out by adapting the so-called iso-risk contours (according to ICAO PANS-OPS Vol II [7] and ICAO collision risk model – CRM [8]) as individual surfaces for obstacle protection. We thus pursue a dimensioning method that is essentially based on the procedure-dependent required navigation accuracies or performance-based requirements for the implementation of the procedures by operating aircraft.

As initial part of the research, an analysis was carried out to determine whether protection against obstacles is still relevant today. As a general rule, there is only a need for protection if an aircraft occupies these areas and then has to be protected against collisions with an obstacle.

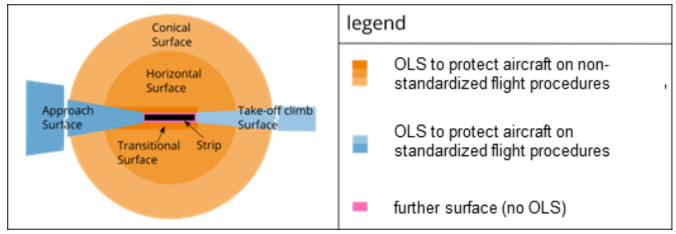


Figure 1 Simplified current OLS Design according [1], [2] amended by surface categories according flight procedures occurring within the scope of the single surfaces

As Figure 1 shows, the current OLS [1], [2] can be summarized by two target categories: The take-off and climb surface and the (inner) approach surface are to be allocated to the first category. Those surfaces aim to protect aircraft during approach or departure, specifiable by single procedure navigation accuracy requirements. Typically, these surfaces protect aircraft on its nominal flight tracks. The conical surface, horizontal surface and the transitional surface are to be allocated to the second category. Those surfaces aim to protect aircraft on non-standardized flight procedures with regard to navigation accuracy requirements, e.g. missed approach and circling. In consequence, those surfaces protect aircraft operating on no or not clearly assignable nominal flight tracks on or close to the ground level.

Depending on the category, the redesign process takes the following aerodrome specific parameter into account:

- implemented or potential flight procedures
- aircraft performance requirements
- external parameter influencing aircraft performance
- local obstacle occurrence
- global findings of aircraft accident investigation on the aerodrome

The dimensioning of the new surfaces as single, individual combinable modules follows a two-stage development process. Stage I defines general OLS, valid for all aerodromes. The surface dimensioning of stage I is based on minimum requirements for all specifying parameters, such as required navigation performance (RNP) values, minimum climb gradient (MCG) or maximum allowable wind components. As a result, stage I delivers a conservative surface dimensioning with spacious surfaces modules and significant safety buffers.

Since all input parameter are considered as worst case, local deviations of one or more parameter lead to an overestimation of the safety requirement of the OLS. At the same time, the use of the airport environment (urban planning) is sometimes severely restricted. Therefore, the (partial) application of stage II offers the possibility to reduce the dimensions of one or more modules to such an extent that the new safety buffers are adequate but not oversized. For this purpose, the actual input parameter (actual navigation performance (ANP), real wind components, typical gradient performance, etc.) must be documented over a period of time to be defined and used as a basis for the surface dimensioning. Since this stage II involves an enormous effort in terms of proof of equal safety level for each module to be reduced, it is optional if required and must be applied after operation of stage I.

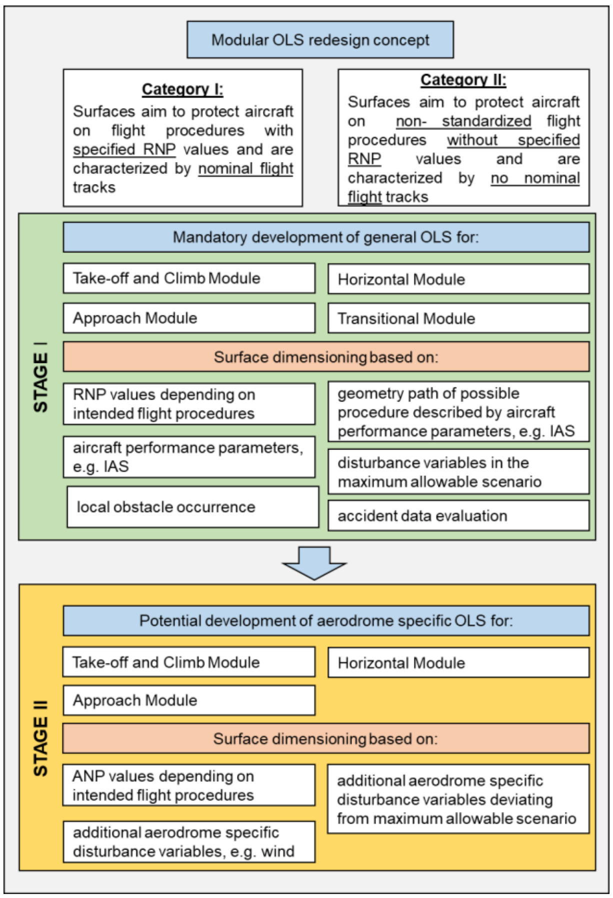


Figure 2 Scheme of the modular OLS design

Figure 2 summarize the introduced modular two-stage OLS redesign concept. Since the paper describes the methodology for dimensioning the horizontal surface module in detail within the following chapter, the input parameters of category I are only summarized here:

RNP values: Requirements to the navigation accuracy are defined within [3], [7], [6], etc. and have to be proven by the aircraft, its technical equipment and its cockpit crew. Via this so-called RNP, permissible deviations from the nominal flight track (lateral and vertical) are described as a probability of $1x10^{-7}$ per approach [7], [8]. Thus, a procedure-dependent expected location range is known and a risk to leave it is present. We convert these RNPs into OLS contours taking into account further safety buffers.

Aircraft performance parameter: The flight performance parameter speed represents an aerodrome independent safety buffer. Analogous to the procedure design process according to [7] the indicated airspeed (IAS) influences, among other things, turn radii and thus an area required for procedure implementation. We take this into account by introducing the ICAO speed classes according to [7] as a further categorisation level for dimensioning.

Local obstacle occurrence: The aerodrome-specific obstacle situation is taken into account by the procedure design gradient (PDG) during vertical OLS parameterization. If the PDG is increased according to [7] this is taken into account in the individual OLS.

The implementation stage II takes place in accordance with Eurocontrol's SAM (safety assessment methodology) [10] as SSA (system safety assessment) for safety monitoring during system's lifetime [10]. Here, real flight and environmental data is recorded at the respective airport as individual ANP key figures. If an airport can prove (e.g. by ANP) significantly higher navigation accuracies over a period of time to be defined, the RNP-based OLS can be downsized. This is done according to standardized area design analogous to the RNP methodology, but extended by specific safety buffers. These are factors to increase the ANP based OLS according to an extended airport categorization. The aim here is to define safety margins for classifiable influencing variables (e.g. wind components, elevation, etc.) for safe flight operations. Quantifying those variables is not the focus here.

## III. METHODOLOGY OF HORIZONTAL SURFACE REDESIGN

### A. *Procedures occuring within horizontal surface area*

Within the scope of the horizontal surface the following close to ground procedures (may) occur: approaches, missed approaches, departures and circling. Even if realization of those procedures may change in the future, they are going to be located in the same area. In fact, today the horizontal surface is of high importance for obstacle clearance. This fact will remain in future.

*B. Procedures properties as geometric input criteria of the horizontal surface*

According procedure design documents such as [7], [6] and [3] for all named procedures, design parameters are published. As result, it is possible to derive geometric design criteria's from procedure design requirements. The following Table 1 summarize the essential design requirements for procedures within the area of the horizontal surface.

TABLE I. LATERAL AND VERTICAL MINIMUM REQUIREMENTS PER PROCEDURE ACCORDING TO [6]

| **Procedure** | **Lateral parameters, influencing the procedure** | **Vertical parameters, influencing the procedure** |
|---|---|---|
| Final Approach | Approaches: straight in or curved approaches with latest point of intercept 1400 m before Threshold | Minimum/optimum descent gradient: 5.2 %<br><br>Maximum descent gradient: 6.5 % (Cat A, B aircraft) or 6.1% (Cat C, D, E aircraft) |
| Missed Approach | Phase dependencies:<br><br>initial phase : No track change<br><br>Intermediate phase: max track change 15°<br><br>Final phase: straight or turning missed approach possible | Phase dependencies<br><br>Initial phase: Initiated at DA/H (prec. App.) or at MAPt (non-prec. App.) to start of climb (SOC) → horizontal segment<br><br>Intermediate phase: SOC to 50 m obstacle clearance; min. climb gradient 2.5%<br><br>Final phase: extends to the point for new procedures (e.g. new approach from FAF): min. climb gradient 2.5% |
| Departure | Straight departures: Track change ≤ 15°<br><br>Turning Departure: Track change > 15° | Straight departures PDG of 3.3 % in case of no obstacles<br>In case of obstacles PDG + MOC |
| Visual Manoeuvering (Circling) | Visual procedure described by take-off, cross-wind leg, downwind-leg, base leg and final approach: size depends on the ICAO approach speed category | Aerodrome elevation + 1000 ft (300 m) |

Analogue to Table 1's structure, horizontal surface dimensioning follows lateral and vertical analysis of the flight procedures occurring within the area of interest. The analysis of lateral procedure characteristics can be categorized into straight and turning segments. However, vertical procedure characteristics are categorized into horizontal and sloped segments with requirements to descent or climb gradients.

Independent to the procedure, straight segments are located above the runway centerline. In addition, in case of circling procedures, straight segments are located parallel to the runway center line with a defined height above elevation. For horizontal surface design the location of the straight segments and the possible deviation of aircrafts cross to the straight segments have an impact on the dimensioning parameters. However, the shape and size determination of turning segments is more complexes, but relevant for horizontal surface design. The following chapters show variables influencing a turning segment and their effect to the size of turning area.

*C. Flight Performance for turing segments*

The lateral design of a turning segment is defined by the turning radius. To determine this aircraft performance-based value, the forces affecting an aircraft during turning procedures have to be considered (see Figure 3).

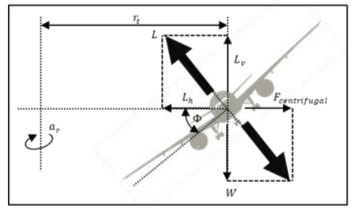


Figure 3 Forces during stationary horizontal turning procedures

Based on Figure 3, the following equilibrium of forces during stationary horizontal turning procedures can be established for forces acting in vertical and horizontal directions:

$$\sum F_{vertical} = 0: \quad L_v = W$$

$$L \cos \Phi = mg \quad (1)$$

$$\sum F_{horizontal} = 0: \quad L_h = F_{centrifugal}$$

$$L \sin \Phi = m a_r = m \frac{v^2}{r_t} \quad (2)$$

From Eq. 1 and Eq. 2 follows after transformation:

$$r_T = \frac{v^2}{g \cdot \tan \Phi} \quad (3)$$

With: $F_{vertical}$…vertical forces; $F_{horizontal}$…horizontal forces; $F_{radial}$…radial force; $L_v$…vertical lift share; $L_h$…horizontal lift share; $W$…weight; $L$…lift; $\Phi$…bank angle; $m$ ...aircraft mass; $g$…gravitational acceleration; $a_r$…angular acceleration; $v$…true airspeed; $r_t$…radius of turn

Acoording Eq. 3, the turning radius is described by to varring influencing variable: the airspeed v and the bank angle Φ. The following Figure 4 shows how those variables effect the turning radius in detail:

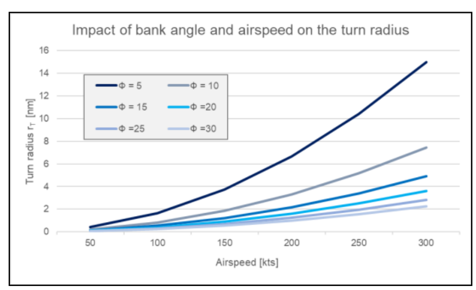


Figure 4 Relation between airspeed, bank angle and resulting turning radius

Figure 4 shows the turning radius decreases with increasing bank angel and increases with IAS. Within procedure design concepts, the bank angle for procedures until 1000 ft is fixed to Φ = 15° [7]. Thus the turn rate is between 2.6°/sec for the approach speed Cat A and 1.1°/sec for the approach speed Cat E for all categories below the maximum turn rate of 3°/sec. [7] As result Φ is fixed to 15° for the following approach.

The equilibrium of forces shown in Figure 3 neglects any kind of external influencing factors on turning segment. In addition to bank angel and airspeed. The following parameters have an influence on the turn radius according to [7]: Altitude, wind (see III-E) and flight technical errors (FTE) (see III-D). In the affective area up to approx. 100 m above elevation, the influence of the height is neglected for the lateral dimensioning of the horizontal surface.

### *D. FTE as influencing parameter to the turn radius*

The FTE refers to the ability of crew or autopilot to follow a defined path. This also includes all types of visualization and display errors such as centering errors of the course deviation indicator (CDI). It can be monitored and corrected by the cockpit crew or by the autopilots.

Figure 5 the shows development of the lateral FTE during turning procedures, triggered by events causing lateral deviation from intended flight track.

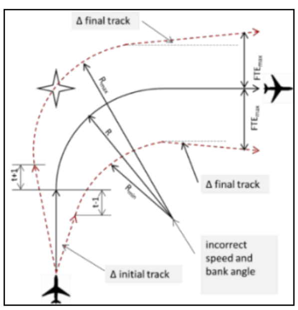


Figure 5 Development of lateral deviation during turn flight [11]

The identification of FTE trigger events is part of a SAM that is used to proof a specific target level of safety (TLS). Aim is to determine the risk of deviating from intended flight tracks and derive safety mitigation strategies to maintain TLS.

Here, methods of Eurocontrol's SAM [10] are used for first estimations. According to SAM Functional Hazard Assessment (FHA), events to determine the hazard of maximum lateral deviation have to be identified. With an Event Tree Analysis (ETA) those events were evaluated concerning their contribution to the FTE. Under consideration of the probability of occurrence ($P_E$), for each consequence of each ETA branch can be calculated. As result the worst case consequence reflects the maximum $FTE_{max}$.

Following events were identified as trigger events for lateral FTE during turning procedures:

**E1**: speed deviation as result of measuring and reading errors $[v_{min}; v;\ v_{max}]$; **E2**: deviation from initial track as result of measuring and reading error $[min; 0;\ max]$; **E3**: delay in initiating the turning procedure $[t - resposnse\ time; t;\ t + resposnse\ time]$; **E4**: deviation from bank angle as result of measuring and reading error $[\Phi_{min}; \Phi;\ \Phi_{max}]$; **E5**: deviation from final track as result of measuring and reading error $[min; 0;\ max]$; **E6**: visual reference available as potential risk mitigation strategy $[yes; no]$

### *E. Wind as influencing parameter to the turn radius*

According to [7], wind is identified as influencing parameter to the turn radius. Following the procedure design and worst case approach, the effecting wind is a continuous cross wind component a so called omnidirectional wind. The wind effect $E_\theta$ is calculated using the following formula:

$$E_\theta = \left(\frac{\theta}{R}\right) * \left(\frac{w}{3600}\right) \tag{4}$$

Where θ is the angle of turn, w is wind speed and R is turn rate:

$$R = \left(\frac{3431 \tan \Phi}{\pi * TAS}\right) \tag{5}$$

Figure 6 depicts wind effect $E_\theta$ in nautical miles for wind speeds between 5 and 33 kts, exemplary for the approach speed category D with a maximum approach speed of 240 kts (IAS) and Φ = 15° .

Figure 6 clearly shows, that without steering input of the pilot, the radius of turn is increasing during turn and wind speed. With Figure 7, the enlarging effect of this omnidirectional wind to the turning track is plotted for two exemplary wind speeds (15/33 kts). Under the worst-case assumption of a constant omnidirectional wind effect (track and wind direction show a constant 90° angle to each other) and without steering input, the flight path follows the geometric figure of a spiral, which opens with increasing angle of turn.

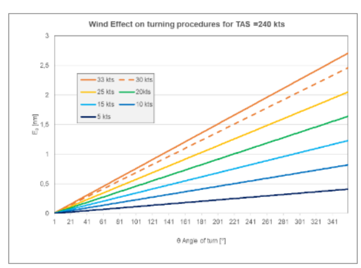


Figure 6 Wind effect during turning segments with omnidirectional influencing wind

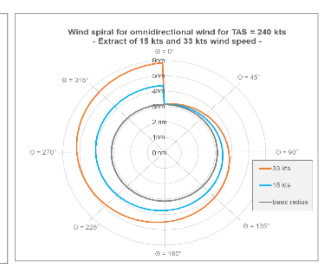


Figure 7 Wind spiral for exemplary wind speeds and TAS = 240 kts

In Table 1 introduced TMA procedures show a maximum turn of 180° for a procedure section (e.g. circling). So, for the following analysis, a maximum wind effect is t taken into account at θ = 180°.

*F. Exemplary FTE Determination*

To gain results as absolute deviation values, the ETA has to be performed under specified conditions and for each aircraft type. To show the method working, one example was executed with the following constrains and assumptions:

<u>ETA constrains and assumptions:</u>

- Observation area: 0 – 100 m AGL
- Observation aircraft: Airbus 320 | CFM56-5A3 engines[1]
- Track deviation: between min -2.5° to max 2.5° [2]
- Bank angle deviation: between min -5° to max 5°[2]
- Indicated Airspeed: 151.6 kt (approach),
  155.5 kt (departure)
- Reaction time: 1 s (approach) | 3 s (departure) [7], [6]

<u>$FTE_{max\_lat}$ as lateral deviation during turn flight:</u>

The ETA detects maximum lateral deviation with effect to enlarged turn radius during departures, mainly caused by higher airspeeds and reaction time.
$FTE_{max\_lat}$ is calculated as maximum deviation to enlarge the turn radius at the angle of turn θ =180: 1620 m (0.87 nm).

*G. Geometric design parameters of the horizinrtal surface*

To derive all influencing parameter for horizontal surface design and dimensioning, Figure 8 summarizes potentially occurring procedures in this close to ground airspace including already identified geometrical parameter.

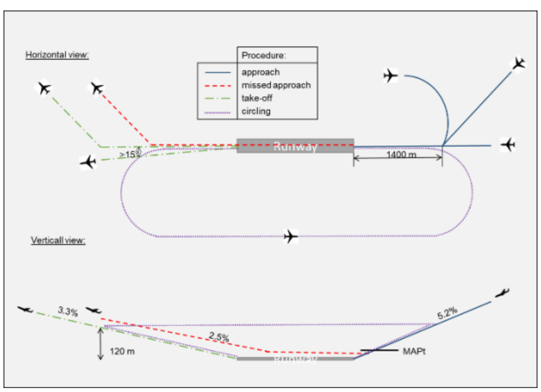


Figure 8 Procedures potentially occurring close to ground level

Deriving a surface design from procedures according Figure 8, the lateral dimensioning has to take care for straight and turning procedure segments. To protect turning segments, the OLS has to follow the turning path (radius), with a radius center has to be defined as distance to the threshold location. As result, the following parameter has to be defined for horizontal surface dimensioning:

- radius,
- centre of the radius and
- surface height

<u>Radius determination</u>:

As described in III - C, the radius of turning segments depends on the turn radius (see Eq. 3), $FTE_{max\_lat}$ and wind effect (see Eq. 4). To consider all three parameter per approach speed category (app spd cat) according to describe methods is equal to reflect the worst case scenario. So safety buffers for deviating from this radius are already included. As result, surface radii per app spd cat are calculated as follows:

$$r_{hor_{Surf}} = r_t + FTE_{\max\_lat} + E_\theta(180°)_{app\_CAT}$$

<u>Centre of the radius determination</u>

According [7][3] "…Straight flight is assumed until reaching of at least 120 m (394 ft)…above the elevation of the DER…" In the first iteration, a conservative approach is chosen to ensure the safety level. According to this, aircraft climb in obstacle-free areas with minimum requirements and follow the PDG of 3.3%. Calculating the center as a distance to the runway threshold, a gradient of 3.3 % to 120 m (394 ft) results to a distance of 3.6 km (2.0 nm).

<u>Surface height determination</u>

Regarding the horizontal surface height, currently only assumptions can be met. As Figure 8 shows, the worst case procedure with regard to vertical requirements are missed approaches with their horizontal initial phase and the potential vertical FTE during intermediate phase with a minimum climb gradient of 2.5%. As result, the horizontal surface height has a strong dependency to the height of the MAPt and the maximum vertical FTE per approach speed category. Here, the horizontal surface height evaluations are out of scope.

*H. Implementation stage I*

The methodology to define a horizontal surface by aircraft performance parameters, wind influence and FTE are described in III. Even, if general quantification of the FTE did not happened yet, interim results to define the horizontal surface could be generated (see Table 1 and Figure 9).

[1] Randomly selected example aircraft, compatible to aircraft performance model represents performance specifications.
[2] As half of the smallest readable scale unit.

[3] Section 3, Chapter 3, 3.3 Turning Departures

TABLE 1 DIMENSIONING OF THE HORIZONTAL SURFACE MODULE

| **Basic module of the horizontal surface – stage I** | | | | | |
|---|---|---|---|---|---|
| approach speed category | A | B | C | D | E |
| surface radius [km] / [nm] | 2.4/ 1.3 | 3.8/ 2.1 | 8.3/ 4.5 | 9.8/ 5.3 | 10.5/ 5.7 |
| center of the arc as distance to threshold [km] / [nm] | 3.6/2.0 | | | | |
| height above aerodrome elevation [m] / [ft] | evaluation is still in progress | | | | |

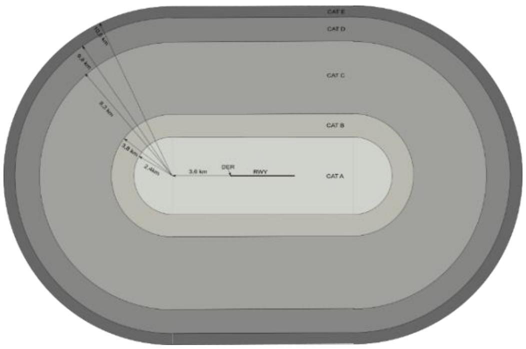


Figure 9 Geometric structure of the horizontal surface module according the approach speed category

As demonstrated in Figure 9 and Table 1, the geometric design of the new horizontal surface looks very similar to the current surface according to [1] or [2]. But there is clear difference in the dimensioning and the categorization. Even, if the presented results have an interim status, this horizontal surface are clearly defined by the requirements of the aircraft.

### *I. Implementation stage II*

Even if the FTE is not yet considered during horizontal surface dimensioning, the requirements for obstacles in the vicinity of the airports are very conservative with current dimensioning parameters (see Table 1). The dimensioning is based on worst case scenarios for each influencing parameter. Due to the fact that this generally means an overestimation on areas to be protected, the stage II was introduced for the OLS redesign concept.

To adopt the horizontal surface to real conditions some dimensioning parameter are particularly suitable for:

- the real wind conditions on the airport
- the real location of positions were turning procedures are initiated (late turns have an impact to the dimensioning of the approach and take-off surface, early turns with lower heights impact the location of the centre of the horizontal surface radius)

The following example focuses only on the dimensioning effect of real wind data. If those are known with a defined reliability, expressed by continuous data sets over a period, the wind effect ($E_\theta$) can be reduced by the maximum real wind components. To demonstrate this, the airport London Gatwick (ICAO Code: EGKK) was randomly chosen as airport of investigation.

Meteorological Aerodrome Reports (METAR) provided on [12] were selected for seven years from 2012 January 1st to 2018 December 31st. These reports are standardized weather reports that are updated every 30 minutes. Due to the standardized structure, the message on wind direction and speed is located after ICAO aerodrome code and observation time. The wind speed and direction information was filtered of the total data set of 121772 single reports. Thereof 105897 wind data could be considered for further analysis. About 10 % could not be evaluated, because there was no clear assignment of the wind direction for wind speeds between 0 kts and 7 kts. Therefore, the further analyses only refer to entire wind forces > 7 kts.

Figure 11 shows the result of this wind data analysis of London Gatwick displayed as a wind rose. Besides a clearly identifiable main wind direction from 200°-240°, total wind speeds between 25 and 35kts occur only as single events (less than 0.1% of the evaluated data) .

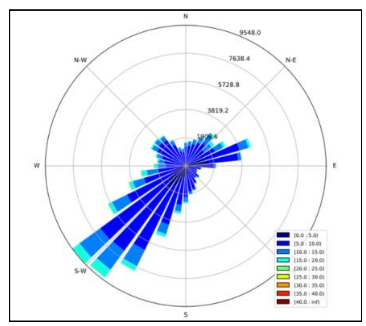


Figure 10 EGKK wind rose with METAR wind data (Jan 2012 to Dec 2018)

In order to evaluate the effect of wind on turning procedures specifically in EGKK, the alignment of the RWY system (25R/08L and 25L/08R) is taken into account. Afterwards, the head/tailwind or crosswind components are determined via the RWY alignment and the wind direction.

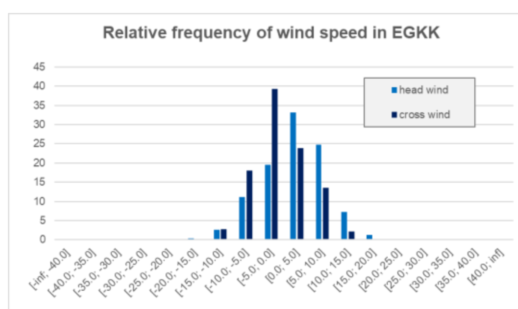


Figure 11 EGKK head and cross wind frequencies

Figure 12 shows the relative frequency of head and cross wind components whereas negative headwind is equal to tailwind and negative crosswind is main operating runway alignment (25R/L) + 90° (wind from 340°). The cumulated real wind frequencies per cluster are summarized in Table 2:

TABLE 2 CUM. RELATIVE FREQUENCIES OF WIND COMPONENTS IN EGKK

| **Range of value for wind speed [kts]** | **Cum. rel. freq. [%]** | |
|---|---|---|
| | **Head wind component** | **Cross wind component** |
| [-5.0;5.0] | 52.6 | 63.1 |
| [-10;10] | 88.5 | 94.6 |
| [-15;15] | 98.2 | 99.5 |
| [-20;20] | 99.8 | 100.0 |

According the results of Table 2 we would recommend a reduction of maximum wind speed within the wind effect calculation from 33 kts omnidirectional wind to 15 kts omnidirectional. From statistical view 15 kts wind speed (max.) cover 98.2 % of all head wind components and 99.5 % of all cross wind components. The further uncertainties are almost negated by the consideration as omnidirectional wind. The consequence of this reduction is shown in Figure 7. The surface radius category can be reduced by 15% (CAT C- E), 21% for CAT B and 29% for CAT A.

TABLE 3: REDUCTION POTENTIAL ON THE RADIUS OF HORIZONTAL SURFACE CAUSED BY EGKK REAL WIND COMPONENTS

| **Local wind analysis effect to the radius of the horizontal surface – stage II** | | | | | |
|---|---|---|---|---|---|
| approach speed category | A | B | C | D | E |
| Stage I: surface radius [km] / [nm] | 2.4/ 1.3 | 3.8/ 2.1 | 8.3/ 4.5 | 9.8/ 5.3 | 10.5/ 5.7 |
| Stage II: surface radius [km] / [nm] | 1.7/ 0.9 | 3.0/ 1.6 | 7.0/ 3.8 | 8.3/ 4.5 | 8.9/ 4.8 |

## IV. CONCLUSION & OUTLOOK

The redesign of OLS also pursues the target to protect todays and future aircraft from collisions with obstacles on the ground. To achieve this, it is necessary to know the position of the aircraft, including its deviation. Depending on the flight phase or procedure, the position is determined on the basis of different parameter. Here a methodology was presented which provides the design and dimensioning of the horizontal surface. Due to the procedures occurring here, a position estimation is carried out by analysis of the aircraft performance parameters. Turning procedures and their disturbance variables such as FTE and wind have the largest impact on the surface design. As a result, parameter for dimensioning the horizontal surface can be determined depending on air speed. However, the determination of the lateral FTE for all speed categories and the exact specification of the height of the surface using vertical FTE is still open.

Nevertheless, the second implementation stage of the horizontal surface has already been demonstrated with an example airport for one downsizing factor. An adaptation of the OLS to the local conditions of the airports can be developed to an optimum between safe airport environment (regarding max. allowable obstacle heights) and economic use (building development) of urban planning.

In conclusions the introduced method is feasible for horizontal surface redesign but further method development is indispensable for general usage.

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