

Current ILS Operations and Lessons for the Future

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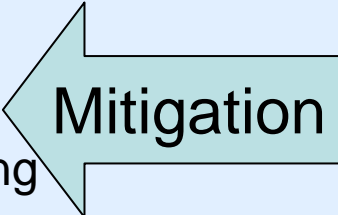
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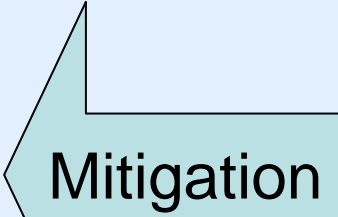



- Brief Introduction to ILS Sustainment (Localizer)
- Operational Flight Data Analysis using the EMS
- ILS Operations: Review of Approach Phases
 - Initial Approach – Entering ILS Coverage – ILS Capture & Tracking
- Lessons for the Future

ILS Localizer Challenges & Solutions

- Interference Mechanisms of Two Frequency Systems
 - Reflection and / or Diffraction from Static and / or Dynamic Objects

- Course → Course  Super Wide Aperture Arrays
 - Effect: Course scalloping

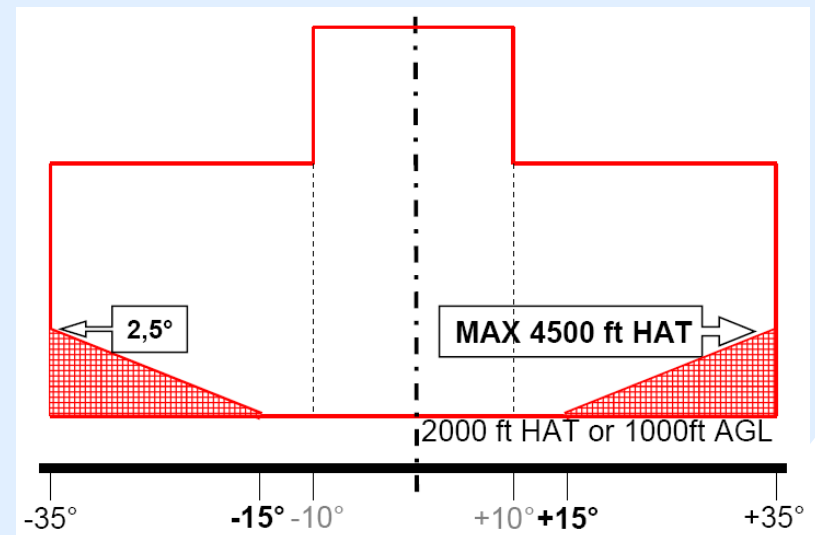
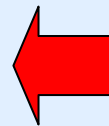
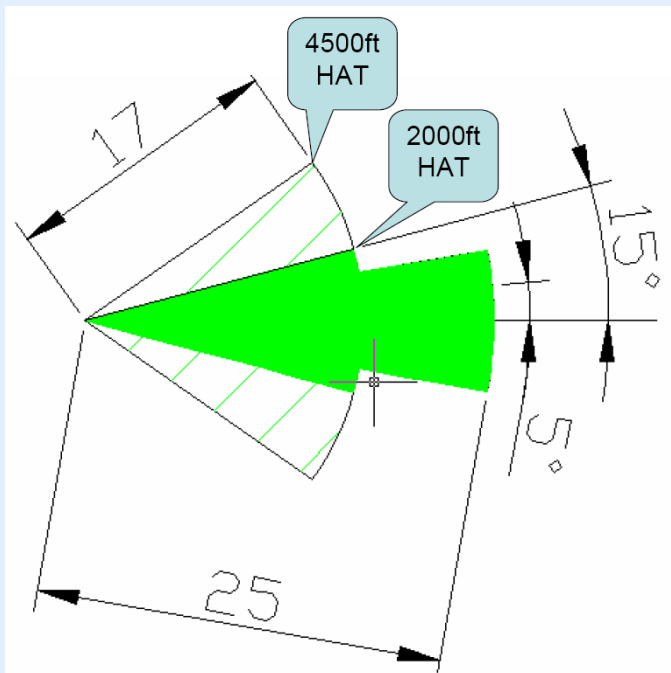
- Clearance → Course  Restricting Radiation
- Clearance → Clearance  Often Results in States Needing to File Deviation from ICAO Annex 10 SARPs
 - Effect: Scalloping & possible false axis

Raised Coverage Localizer Concept

- Limit Clearance Radiation outside ± 15 Degrees
 - Strong roll-off at 15° , but soft “shoulders” out to 35° to mask course sidelobes
 - Clearance Peak shifts inward from 12 to 7°
 - Mitigates typical “Hangar Reflectors” often found at 12 to 15°
- Consequence
 - Difficult / impossible to meet minimum field strength at 2000 ft HAT and 35°
 - However: low & far out coverage corners have *limited operational significance*
 - SARPs change: permit raising lower boundary up to defined maximum
- Benefits
 - More stable guidance signals where it matters (centerline and capture sectors)
 - No false axis in $\pm 35^\circ$ sectors, clean full scale deviations
- Goal
 - Enable ILS manufacturers and ANSP to implement ILS LOC that meets challenges by design (instead of accepting deviation from Annex 10)

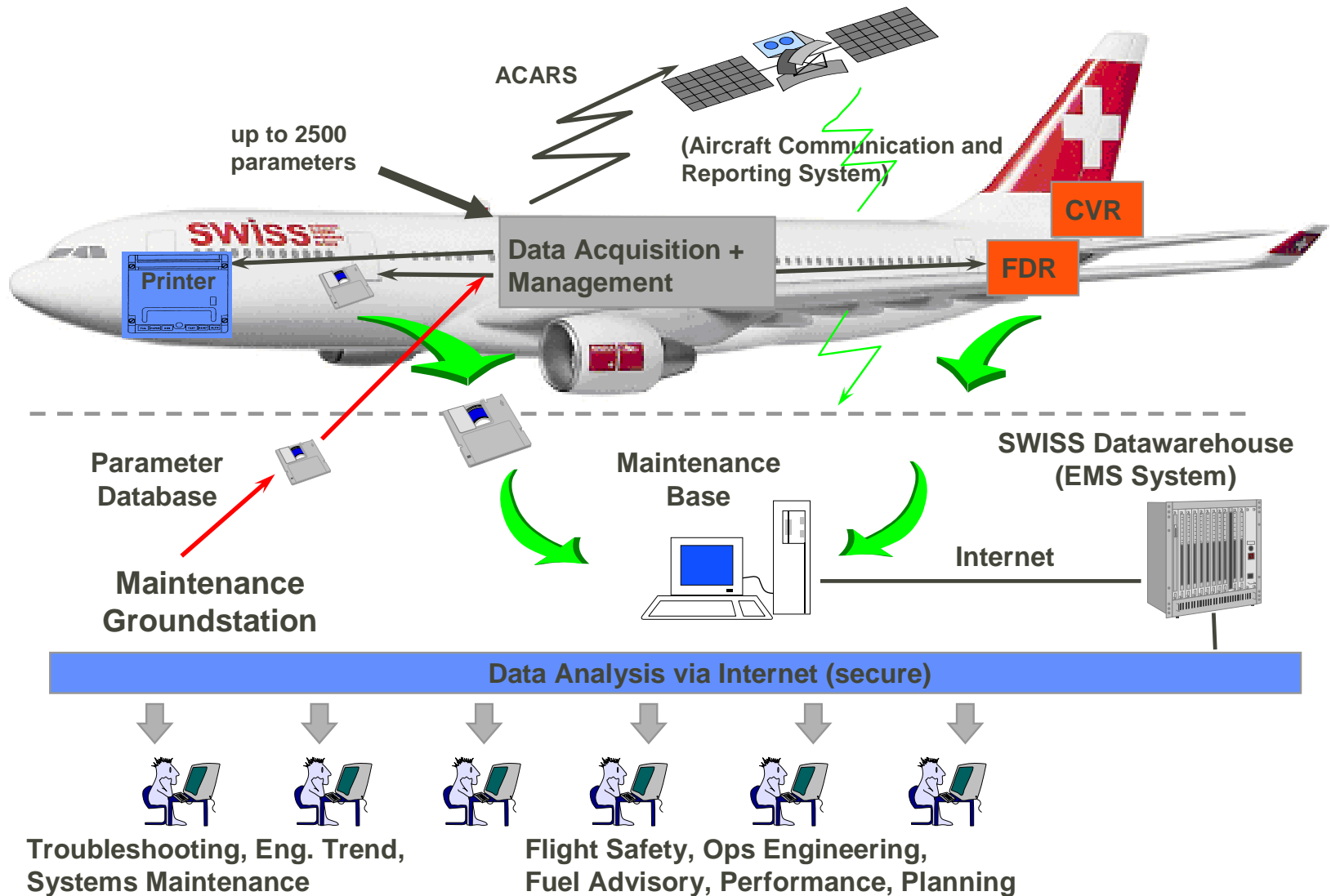
Current Status

- One Localizer meeting proposed requirements in operation
 - ZRH ILS16 Cat III certified since November 2007
- ICAO NSP finalizing changes in coverage requirements
 - Possible agreement at Fall 2008 meeting
 - Lower coverage boundary height function of *operational need* (vertical use)



Flight Data Recording System ADAS & EMS

Aircraft Data Acquisition System & Event Measurement System

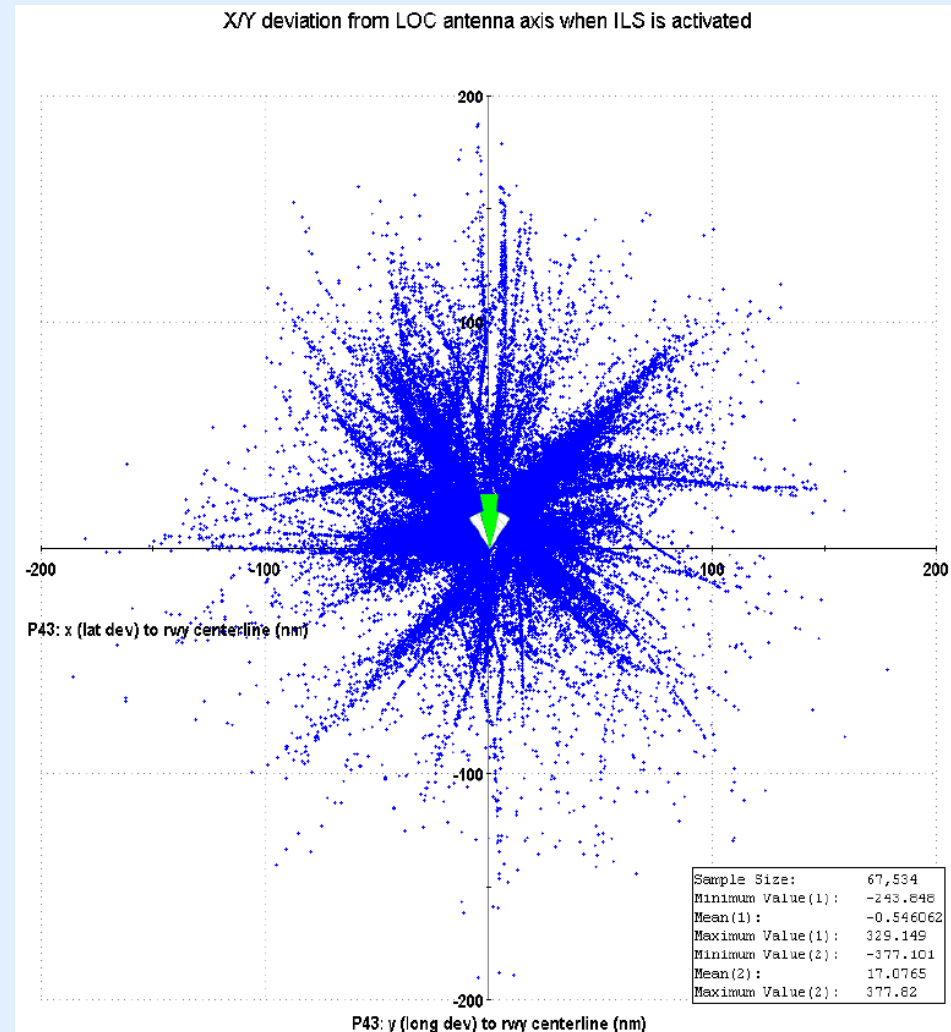


Supporting Operational Studies

- Check for Approach & IDENT
 - What the pilots do with ILS outside of coverage...
 - IDENT inside coverage and workload
- ILS Intercept and Capture
 - False capture issue and coverage
- ILS Tracking and Dynamic Multipath

Tuning of ILS (First Pilot Interest)

- First tuning usually in En-Route Phase
 - IDENT can be received well over 100NM out
- Pilots understand & expect that needles will be unreliable
 - Desired feature for some ('needles alive')
- IDENT check is normally done during Check for Approach
 - Around FL100
 - USUALLY well outside of coverage





Radar Vectoring

- Altitude 12000ft
- (Approach Brief)
- Approach Check
- IDENT Check

Crossing of 35 Deg LOC offset

LOC TRACK MODE (5 minute before)

8.27 km

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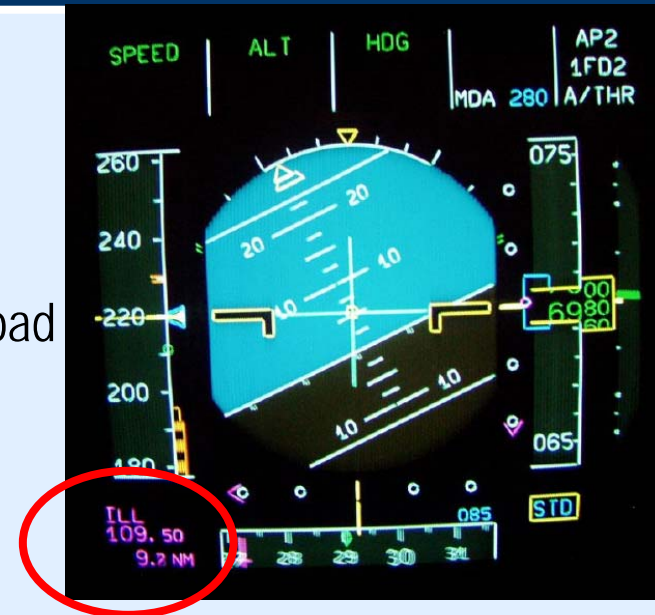
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IDENT – What's it for?

- Vital safety function especially at uncontrolled airfields
 - No IDENT = ILS signal shall not be used (ICAO Safety Campaign)
 - Confirmation of correct tuning of an operational facility
- Report “Established on Localizer” enables hand-back of NAV responsibility to Pilot and final *descent* on glidepath (FAP)
 - Good practice not to arm approach mode without IDENT
 - This “normal ops” function took some time to identify!
- *In THEORY*, Pilots would have to wait with IDENT until within coverage
 - Practice: Pilots want to get IDENT out of the way as early as possible to reduce *high workload flight phase* at localizer intercept

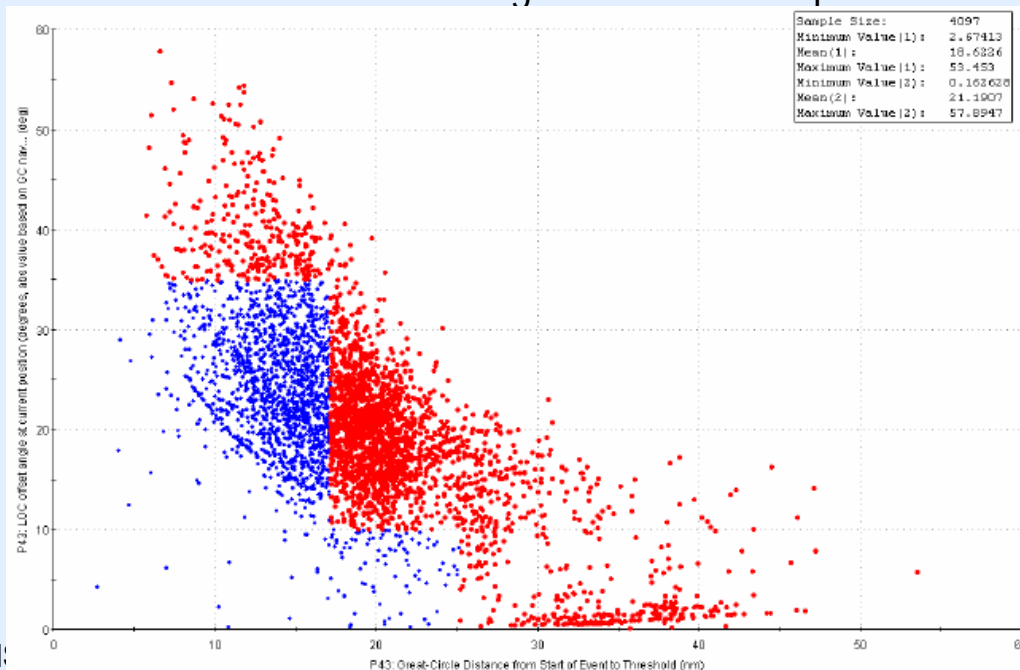
IDENT Study Approach

- Construct Worst-Case IDENT Scenario
 - If it had to be done within coverage
 - Determine if IDENT can be completed given workload
- Fleet Considerations
 - Focus on large air line operations
 - IDENT via PFD Display
 - Regional, Business and GA Fleet less critical:
 - Audio IDENT comes earlier than PFD
 - Higher dynamics correspond to aircraft capabilities (EMS Data, London City)
 - IDENT often also available via DME (ILS associated DME)



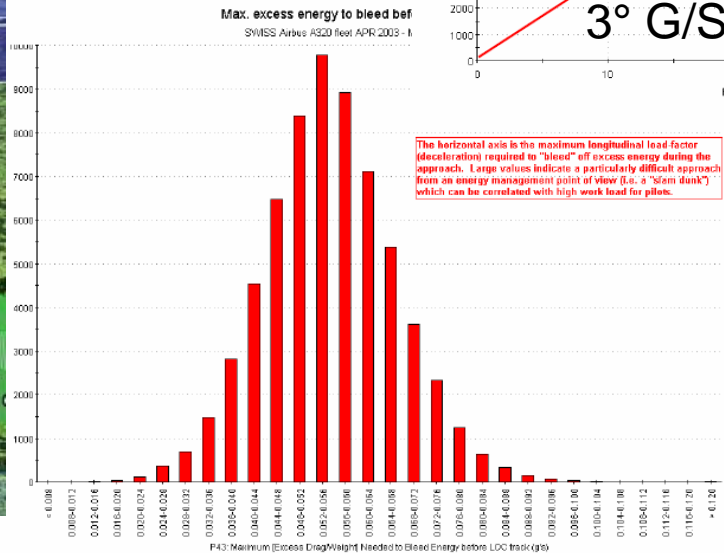
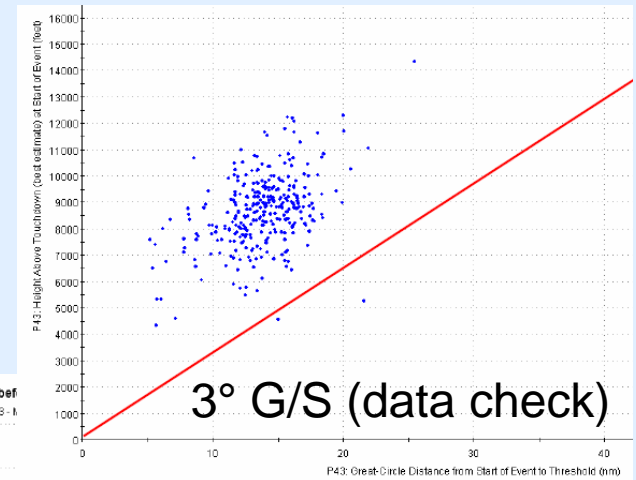
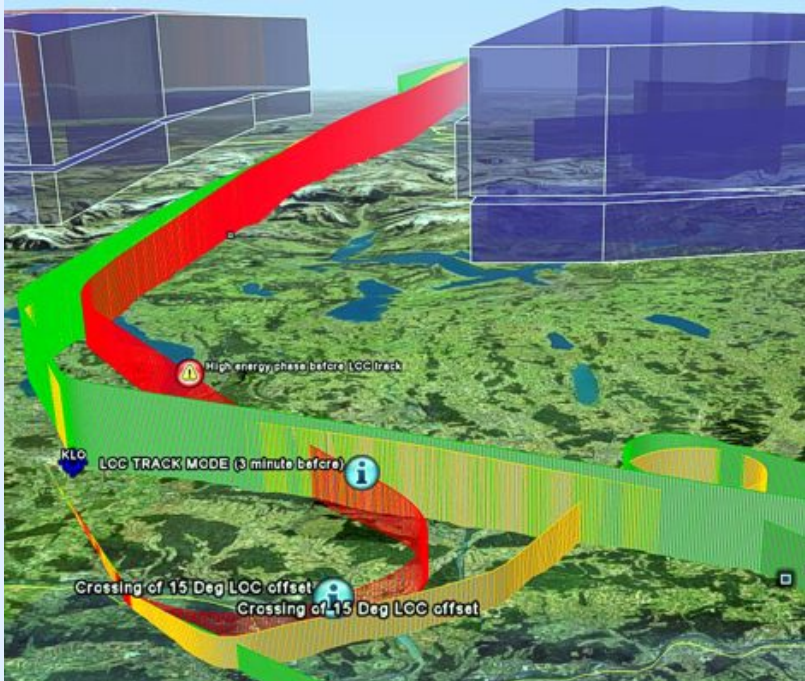
Worst Case Geometries & Timing

- Downwind Approach: close to LOC, many sidelobes
- Straight-In Approach: main signal lobe, time to acquire signal
- Most difficult are T-Approaches
 - least time b/w coverage & LOC intercept
- EMS shows distribution at 3 min to LOC Track Mode
 - 64% outside of coverage!
- Analyzed "Shortest time to LOC track after crossing 35° line"
- All flights have 120 seconds or more
- From 15° line, 71% still have 120+ sec
- 120 sec before LOC TRACK used as time window criteria



High Workload Approaches

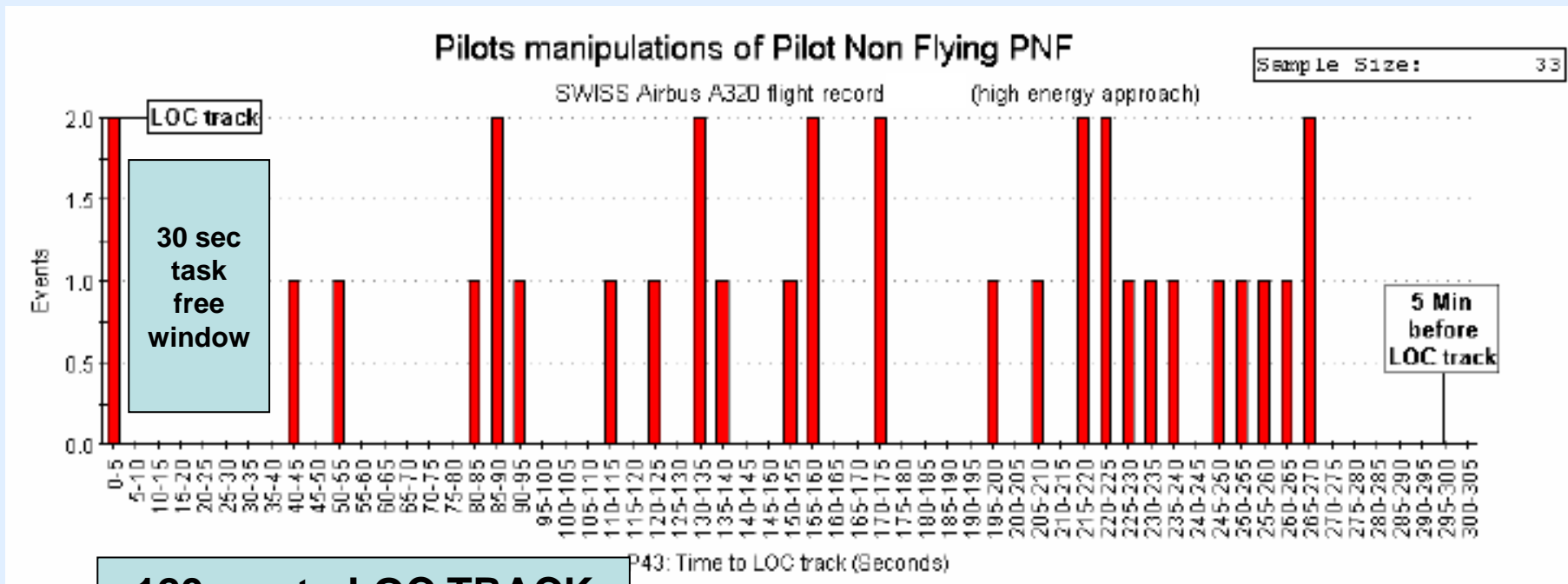
- Workload highest if pilot busy keeping up with ATC instructions (short-cuts)
- High energy state / steep descent
 - EMS: "Excess Energy to Bleed" Warnings



Taskload Analysis

- Difference between Workload (mental) and Taskload (actions)
- EMS can only measure Taskload – used as indirect measure of workload
- Split into Pilot Flying PF / Pilot Non Flying PNF
 - Each action triggers an event of 5 seconds (takes into account some initiation and feedback time)
- Function of Autopilot (A320 peculiarity)
 - Not possible to fully extend speedbrakes with AP ON
 - PNF takes over all FMS / AP manipulations while PF hand-flies
 - PF looks idle due to absence of events, but is fully tasked
- Analyzed Flights with Fast Intercept Geometry & High Workload

Taskplot Example



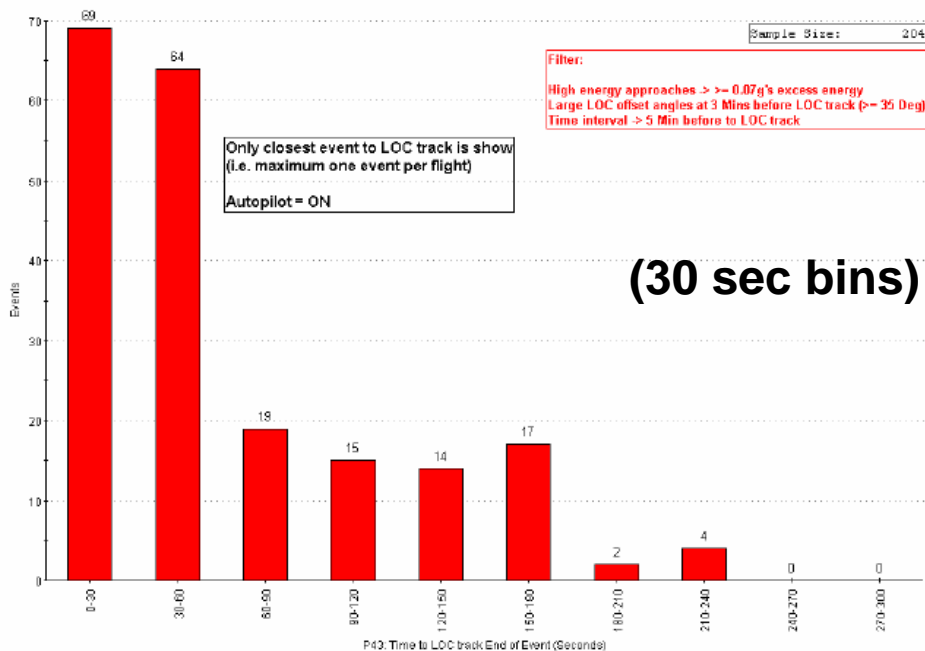
120 sec to LOC TRACK

- High Workload, Autopilot Off example
- Gear, flaps, speed brakes, VHF voice, FMS & Autopilot manipulations, etc...
- ASSUMPTION: If 30 sec task free window within 120 to LOC track, IDENT can be done

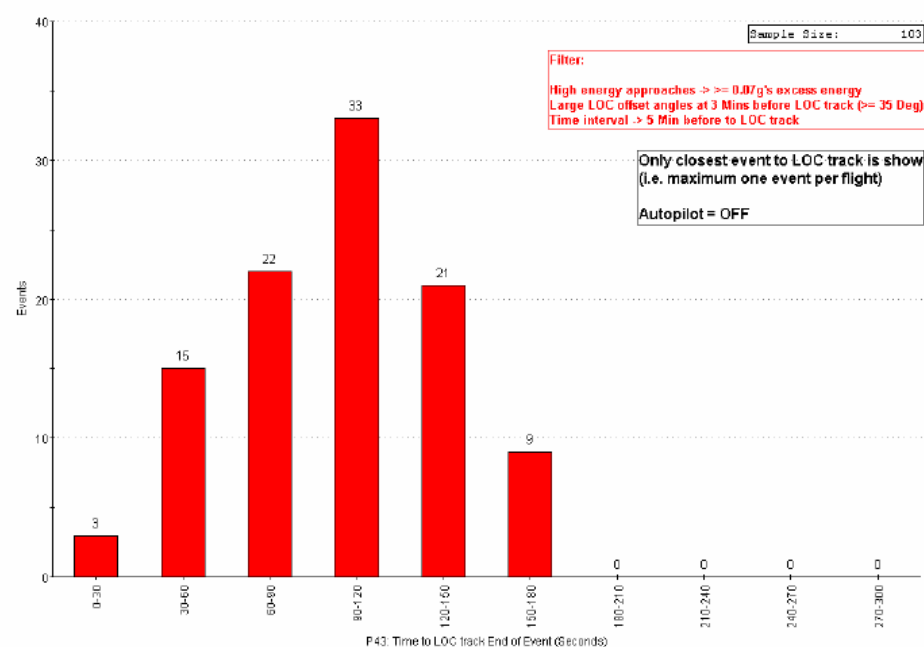
Results: Distribution of Task Free Windows

- Around 70% of flights meet the window criteria for either PF or PNF & AP on/off cases
 - As either pilot can do IDENT, cumulative probability is high
- Remaining most difficult cases reviewed by expert pilot
 - IDENT considered *possible* even in worst-worst cases
 - *But overall argument is a stretch!*

Distribution of "30 sec no manipulation" events for Pilot Non Flying PNF
 SWISS Airbus A320 fleet APR2003-MAR2007



Distribution of "30 sec no manipulation" events for Pilot Non Flying PNF
 SWISS Airbus A320 fleet APR2003-MAR2007



IDENT & Workload Lesson Summary

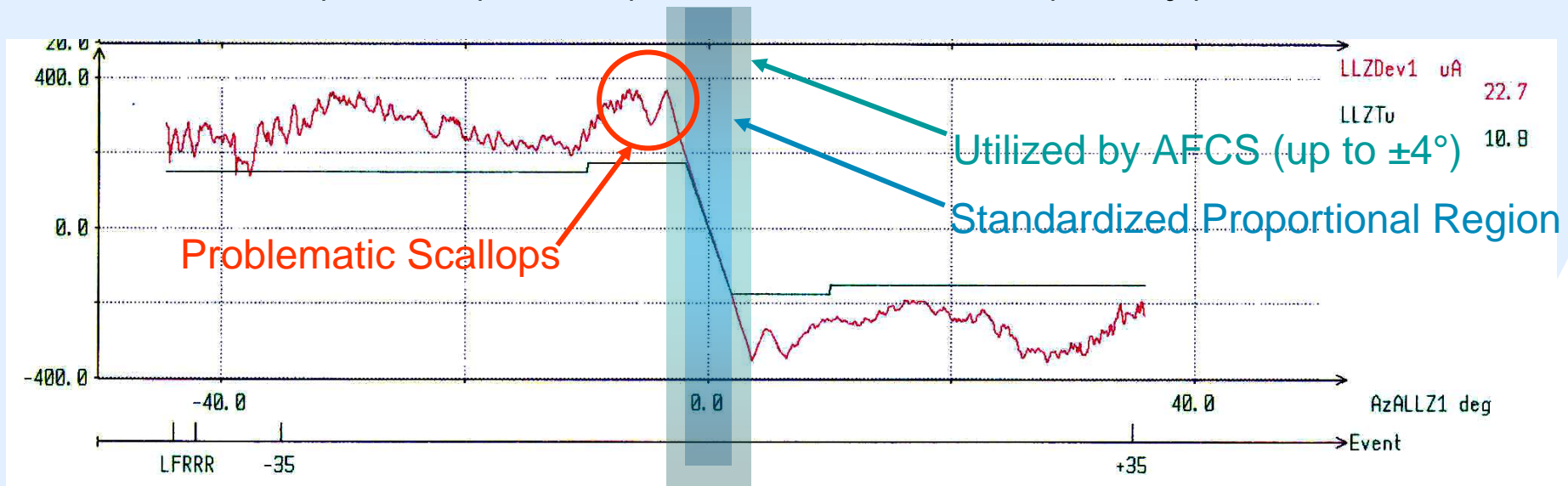
- Pilots *need* IDENT at check for approach near FL100
 - If pilots had to wait with IDENT until being inside, coverage requirements would be challenging to justify (would need to be larger)
- Not possible to remove this technical over-performance once pilots have gotten used to it!
 - Even if wrong IDENT is possible (co-channel / spectrum)
- High Workload caused by high energy state / ATC shortcut
 - Conversely, pilots aiming for low workload come in low on purpose (long-haul)

Supporting Operational Studies

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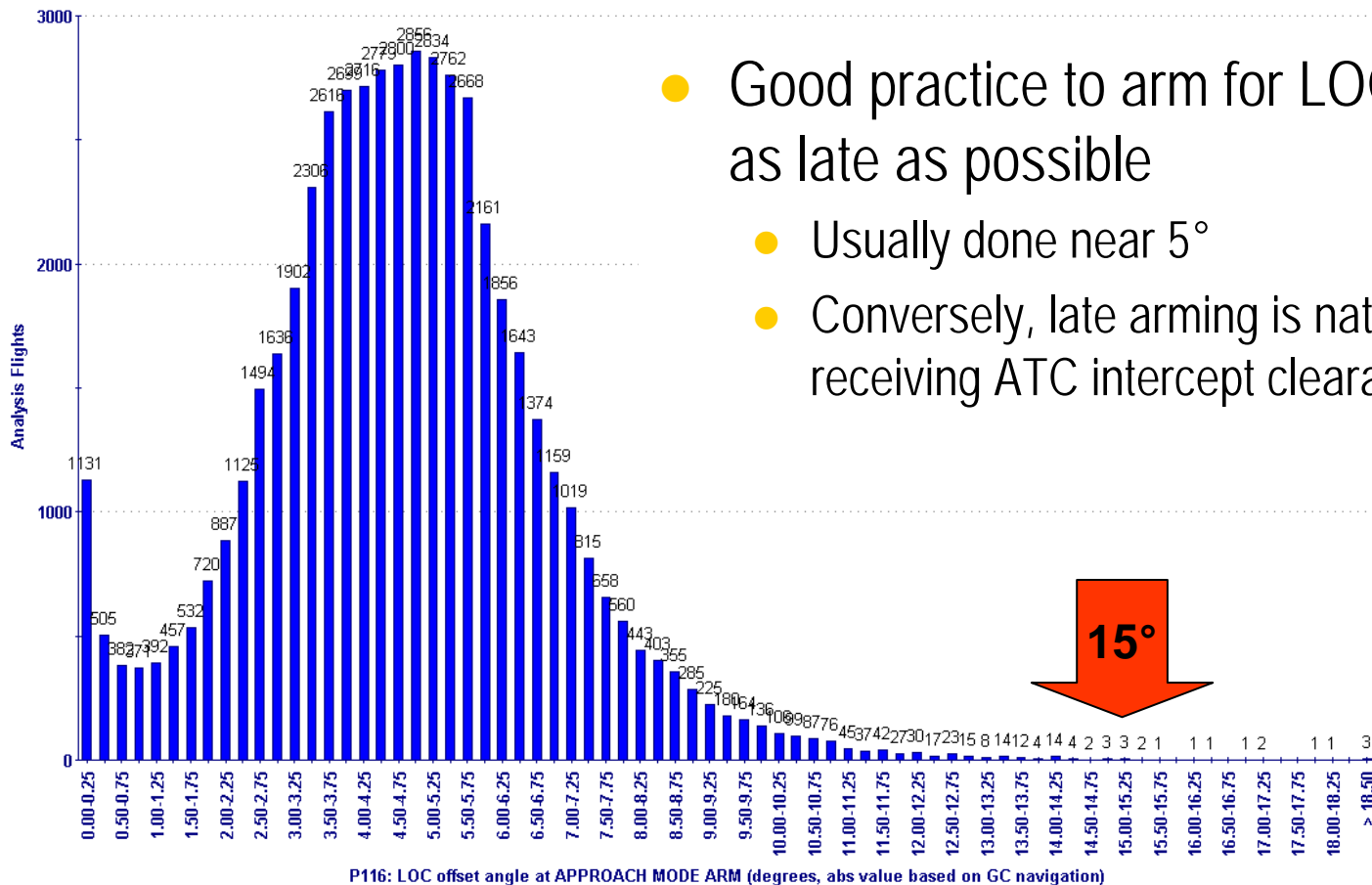
Intercept Turn Initiation

- Course guidance is on the order of $\pm 2^\circ$ (FSD, function of runway length)
- DDM's typically keep increasing up to $\pm 4^\circ$
 - This system margin is intended to give installation flexibility to the ANSP
- Reliable intercept turn initiation without overshoot needs at least $\pm 5^\circ$
 - More in strong tailwind situations
 - Has resulted in some avionics that make use of non-standardized region
 - Natural response to operator expectation, but leads to interoperability problems



False Capture Mitigation (Partial)

ILS LOC offset angle at timepoint of APPROACH MODE ARM activation (degrees)



- Good practice to arm for LOC intercept as late as possible
 - Usually done near 5°
 - Conversely, late arming is natural result of receiving ATC intercept clearance

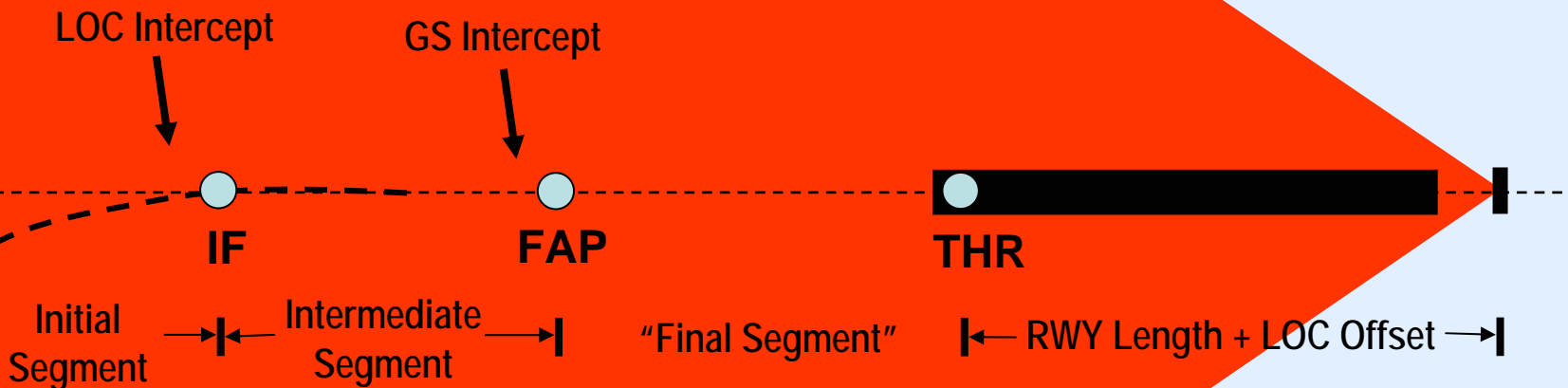


P116: LOC offset angle at APPROACH MODE ARM (degrees, abs value based on GC navigation)

Analysis processed at 8:28 AM Jan 19, 2006



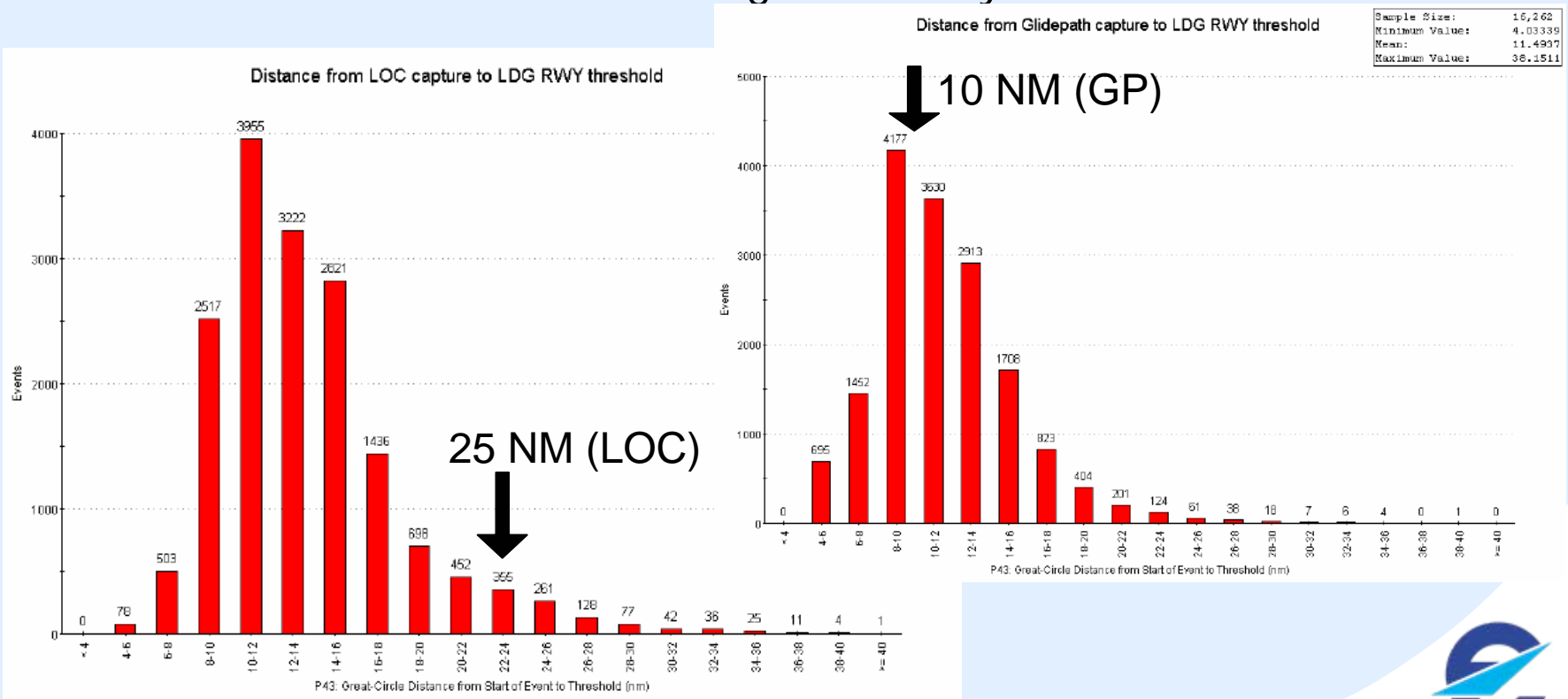
Localizer Intercept Procedure



Interaction of PANS-OPS, Flight Ops & Vectoring...

ILS Capture Points

- Majority of Glide Path captures and significant portion of LOC capture occur well outside of formal coverage
- OK because centerline coverage is usually best



Intercept and Capture Lesson Summary

- Operational need for deviation guidance enabling reliable ILS intercept turn initiation is at least 5°
 - Pilot crews have gotten used to finding alternate means
 - RNAV or Airport VOR
 - Current interoperability issues (false capture) due to operational need
- Operational use of ILS has evolved
 - Advances in aircraft and associated aerodynamics, as well as ATC factors (vectoring practices) contribute to need for centerline guidance well outside of coverage ranges
- Advances in Continuous Descent Approach (CDA) Implementation
 - Will increase desire for far out captures (LOC and especially GP)

Supporting Operational Studies

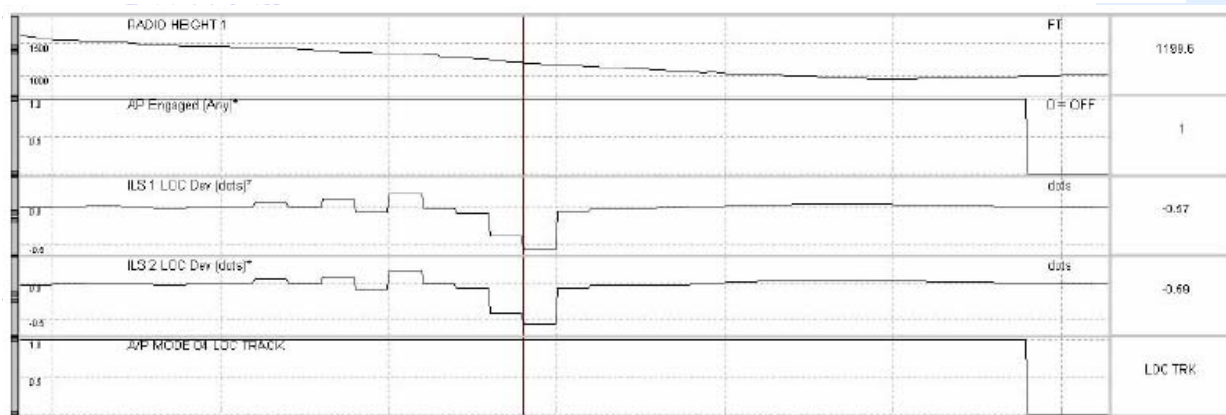
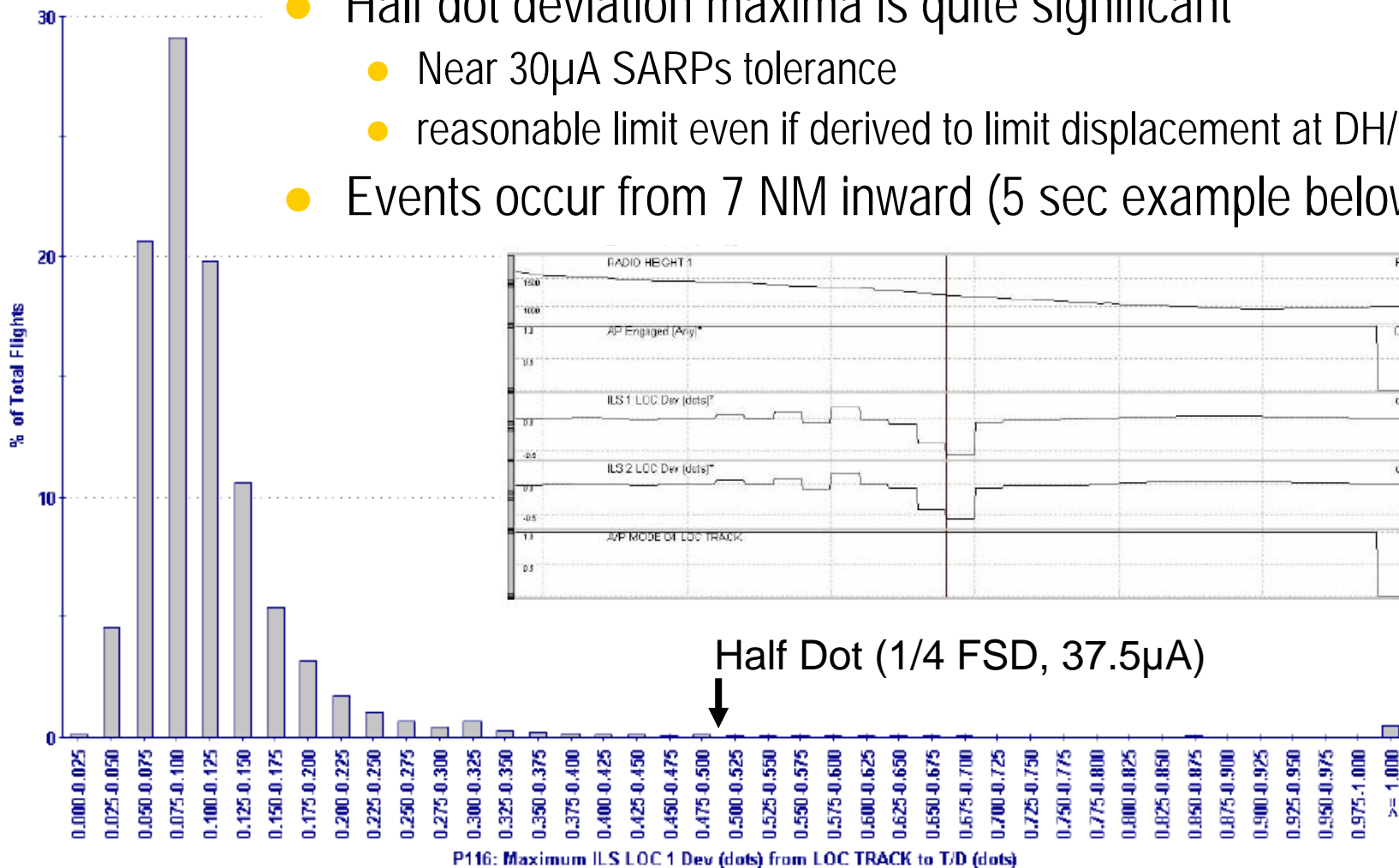
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 - What level of deviations & disturbances is operationally relevant?

ILS Tracking - in Presence of Multipath

- Supports ongoing Critical & Sensitive Area (CSA) work
- Avionics have implemented additional filters to limit effect of transients (due to maneuvers on airport)
 - One OEM using 7 second window
- Loss of LOC tracking is very rare (go-around or other maneuver)
 - Prior to FAP (>> 7 NM to THR), significant maneuvers and recapture possible (operational reasons - flock of birds, etc. but extremely rare)
 - Roughly 1 or 2 in 300 go-around's can be attributed to ILS
- Transient deviation disturbance usually tolerable when visual
 - Go-around likely in Instrument Met Conditions

ILS Deviations – How much is significant?

- Half dot deviation maxima is quite significant
 - Near 30 μ A SARPs tolerance
 - reasonable limit even if derived to limit displacement at DH/DA
- Events occur from 7 NM inward (5 sec example below)



Tracking & Overall Coverage Lesson Summary

- Once aircraft is established on ILS, landing success highly likely
 - ILS is a “minority cause” for rare approach interruptions and go-around’s
 - Many ILS operations each day → pilots handle these cases regularly
 - Airline ¼ dot go-around criteria reflects operational experience
- Pilots are NOT expected to know about coverage volumes and associated implications
 - ANSP notion of responsibility limit not relevant to pilot
 - To pilot, avionics are to indicate any limitations
- A signal will be used wherever it is received
 - ANSP also has a desire to maximize utility of investment
 - Pilots aware of limitations mostly from operational experience
 - It can also be viewed as a *detriment to safety* to not use an available signal

Conclusions

- ILS is considered a standard of operational suitability
 - Does not mean that there isn't room for improvement
 - New landing systems should try to alleviate current limitations (esp. coverage)
 - "ILS look-alike" includes the non-standardized features...!
- **All such development requires an open dialogue between technical and operational communities**
- **EMS Essential to Provide Quantitative, Data-Driven Analysis**
 - Large sample statistics → global credibility
 - Provides filtering to enable expert analysis of small sample data

Questions?

