

# Are Our Landings Safe?

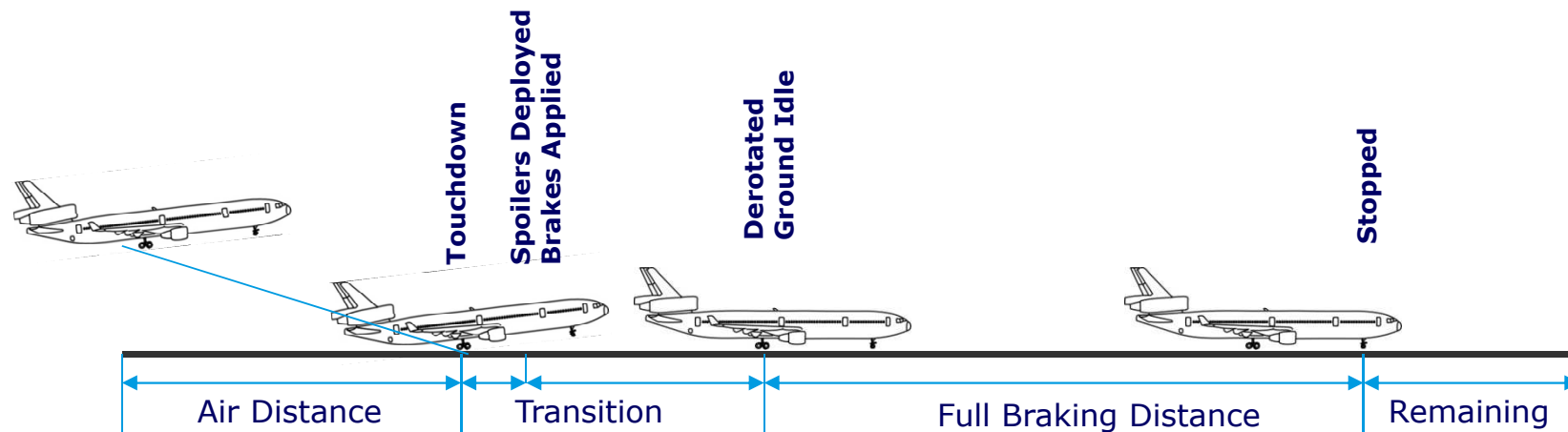
An analytical approach to  
landing performance  
risk assessments



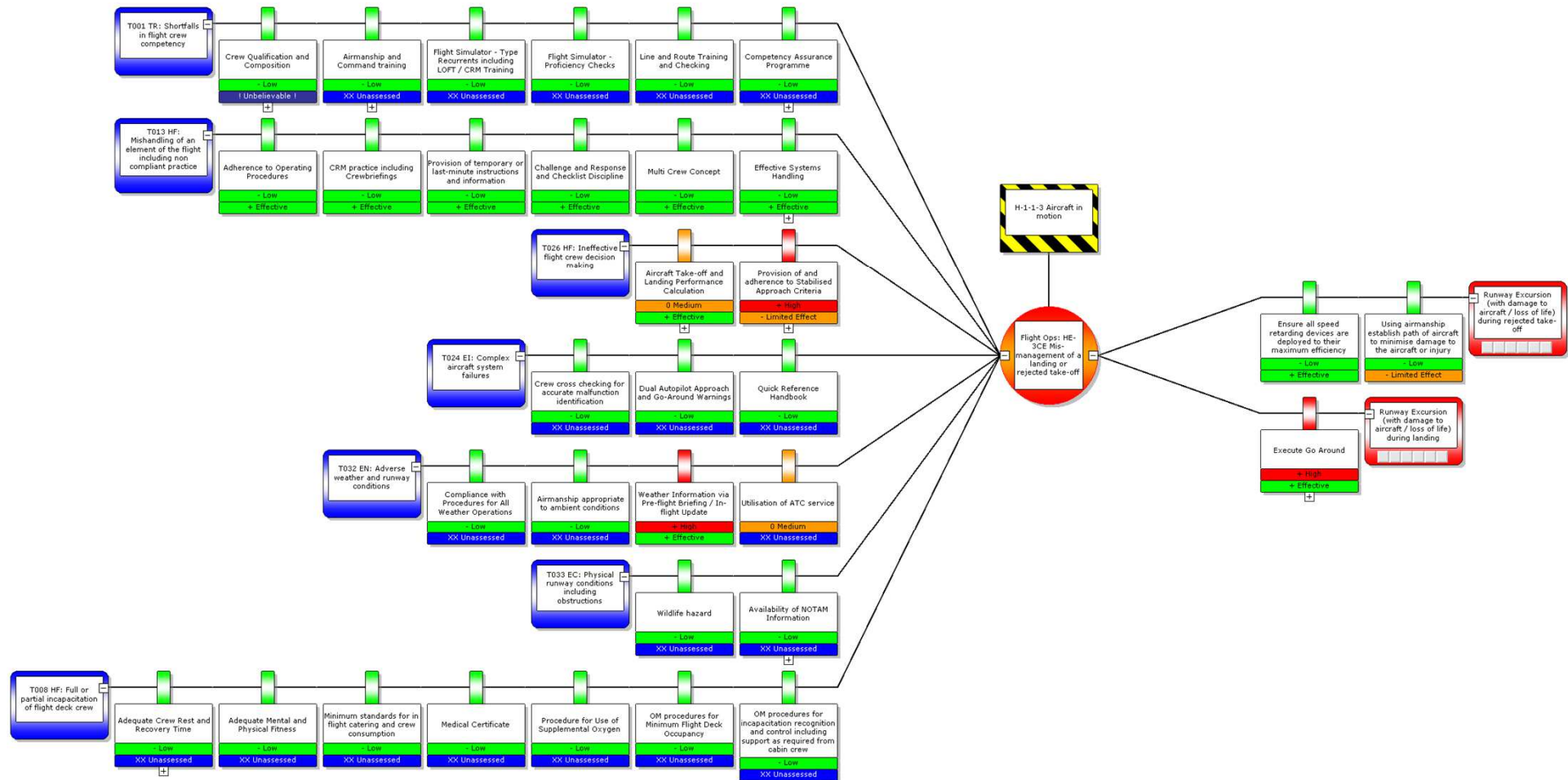
# Transition to **Risk Based** Safety Assurance

- Need for a sensible representation of risk
- Need to look for “small signals”
- Wish to use (much) more data from operation

# Landing Phases



# Sensible Representation of Risk (Bowtie)

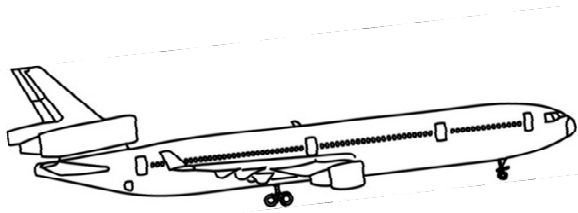


# Runway Overrun Risk

- First attempt at “filling in” all bow tie elements
- We need “something” for:
  - Flight Crew Planning
  - Landing Manoeuvre
  - Touchdown Location
  - Touchdown Speed
  - Remaining Stopping Distance
  - EGPWS intervention rates
  - Go-Around Rates
  - Etc. etc.
- For **all** flights!

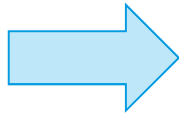
} simple

# Data collection



01001100  
00110110  
11100001  
11110001

FDM  
data

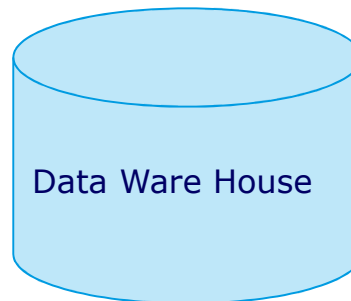
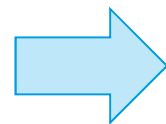


Aircraft	Flaps	Airport Runway	Touchd. location	Touchd. Mass	Touchd. speed	60kts location	Rwy state	Planned QRH-LD	Actual QRH-LD	Distance 60-0 kts
B737-700	30	ESGG 03	602	53.27	138	1714	Good	1512	2088	242
B737-700	40	EHAM 18C	611	53.6	112	1751	Dry	1780	1615	121
B737-800	30	LFPG 27R	680	59.7	148	2473	Dry	2094	2159	121
B737-800	30	LHBP 13R	704	59.2	131	2864	Dry	2263	2178	121
B737-900	30	EHAM 22	555	62.4	125	1816	Dry	1660	1490	121

Airport data



METAR Airport Weather data



$$\frac{dV_{GS}}{dt} = \frac{T - \frac{1}{2}\rho V_{IAS}^2 C_{DS} - \mu(W - \frac{1}{2}\rho V_{IAS}^2 C_{LS}) - W\phi}{W/g}$$

# Safety Performance Indicators

- Flight Crew Planning
  - *QRH CLD versus LDA*
- Touchdown Location/Consumed Safety Margin
  - *With respect to threshold and LDA*
- Touchdown Speed
  - *With respect to VREF*
- Landing Manoeuvre
  - *QRH CLD for actual TD location/speed versus LDA*
- Remaining Stopping Distance
  - *60 kts GS Location + Max. Manual Braking*
- Criticality categories **HIGH MED LOW**

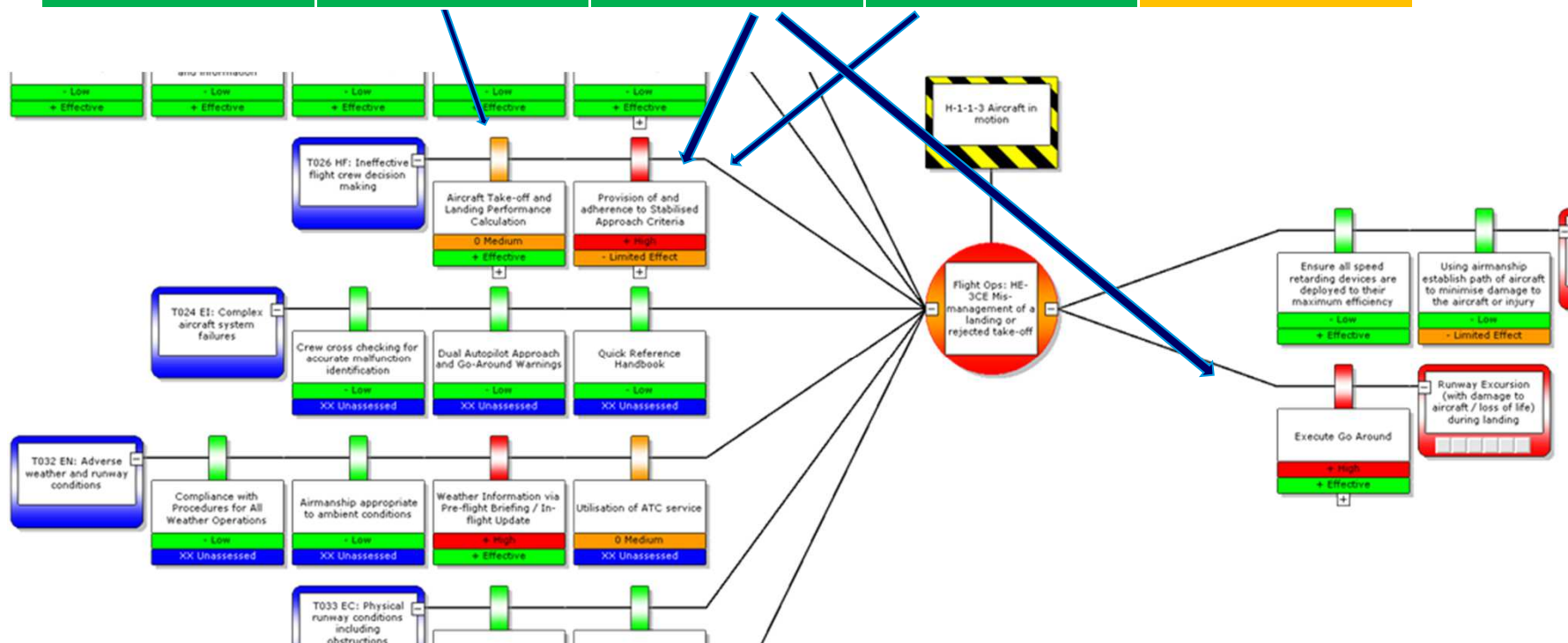
# Risk Analysis Based On SPI's

A/C	Flaps	Airport Rwy/ LDA	Bra kes	Actual QRH-LD unfactor ed	Planned QRH-LD unfactor ed	TD loc	TD Mass	TD speed	60kts location	Rwy state (META R)	Distance 60-0 kts	Rem. LD
B737-700	40	EGPD 16 1953 m	3	1564 m	1285 m	666 m	48400 KG	111 kts	1265 m	Good	457 m	230 m
B737-700	30	EGNT 25 2125 m	2	2114 m	1904 m	600 m	55300 KG	127 kts	1372 m	Dry	238 m	514 m
B737-900W	30	EHAM 18R 3530 m	2	2345 m	1887 m	493 m	63900 KG	159 kts	2405 m	Good	109.4 m	687 m
B737-900W	30	EHAM 18R 3530 m	1	2974 m	2261 m	1103 m	58500 KG	137 kts	2563 m	Dry	235 m	642 m
B737-900W	30	LIML 36 2442 m	2	1846 m	1676 m	556	54540 KG	131 kts	1878 m	Dry	221 m	342 m

Planning Criticality (QRH) Vs LDA	Air Distance/ Consumed Safety Margin Criticality Vs. LDA	TD Speed criticality (FDM)	Landing Manouvre Criticality (QRH+FDM) vs LDA	Overrun Criticality (FDM+QRH+ Engineering)
LO	MED	LO	MED	MED
HI	LO	LO	HI	LO
LO	LO	HI	LO	LO
LO	MED	LO	LO	LO
LO	LO	LO	LO	MED



Planning Criticality (QRH) Vs LDA	Air Distance/ Consumed Safety Margin Criticality Vs. LDA	TD Speed criticality (FDM)	Landing Manoeuvre Criticality (QRH+FDM) vs LDA	Overrun Criticality (FDM+QRH+ Engineering)
LO	MED	LO	MED	MED
HI	LO	LO	HI	LO
LO	LO	HI	LO	LO
LO	MED	LO	LO	LO
LO	LO	LO	LO	MED



# Safety Intelligence Consolidation

Questions to be answered:

- What are the correlations between the criticalities (Which situations eventually may lead to overruns)
- How to connect the overrun SPI's to the barriers in the Landing Performance Bowtie
- Which parameters, trends and/or abrupt changes in trends determine the barrier performance
- In case of (abrupt changes in) trend: Which barriers in the bowtie are playing a role
- In which barriers do we invest our \$\$\$ to improve safety (In order of effectiveness)
- Each barrier has an owner within KLM who is responsible for corrective action



# Runway Conditions

The following speed averaged aircraft braking actions are used (Boeing methodology)

- Dry runway -> Type dependent  $\mu \approx 0.38 - 0.43$
- Braking Action GOOD (wet runway)  $\mu = 0.2$
- Braking Action MEDIUM  $\mu = 0.1$
- Braking Action POOR  $\mu = 0.05$



# Safety Performance Indicators

- Flight Crew Planning  
(*QRH LD versus LDA*)
  - > 30% margin LOW
  - 15% < margin < 30% MEDIUM
  - < 15% margin HIGH
- Touchdown Location/ Consumed Safety Margin
  - TD < 600 m OR CSM < 30% LOW
  - 600 m < TD < 900 m or 15% < CSM < 30% MEDIUM
  - TD > 900 m OR CSM > 15% HIGH
- Touchdown Speed
  - VTD < Vref+10 kts LOW
  - Vref+10 < VTD < Vref+20 MEDIUM
  - VTD > Vref+20 HIGH
- Landing Manoeuvre  
(*QRH LD for actual TD location/speed versus LDA*)
  - > 30% margin LOW
  - 15% < margin < 30% MEDIUM
  - < 15% margin HIGH
- Remaining Stopping Distance  
(*60 kts GS Location + Max. Manual Braking*)
  - RSD > 500 LOW
  - 200 < RSD < 500 MEDIUM
  - RSD < 200 HIGH