Aircraft ASE and RVSM Collision Risk Analyses

Presented to: ASE Workshop
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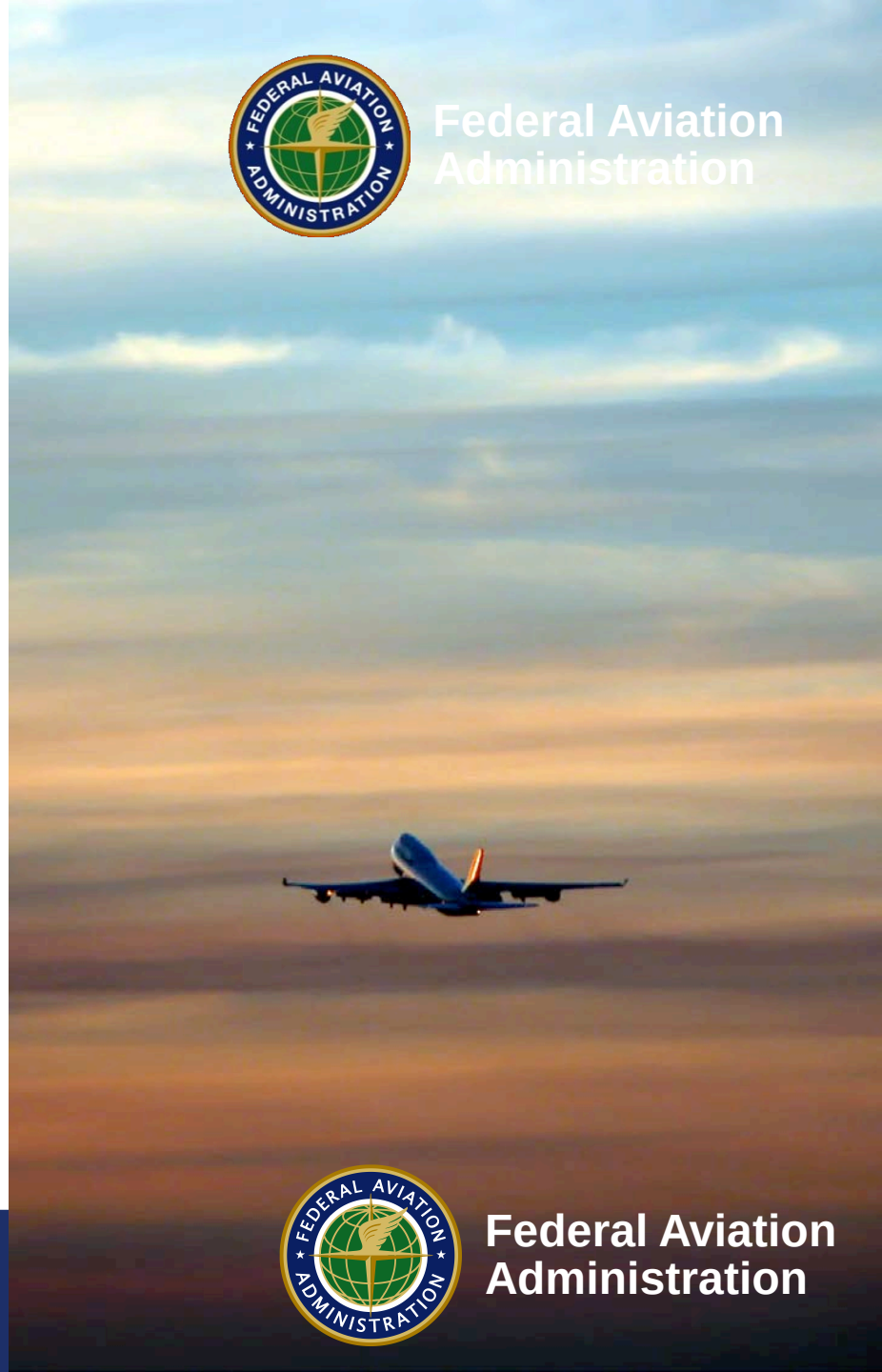
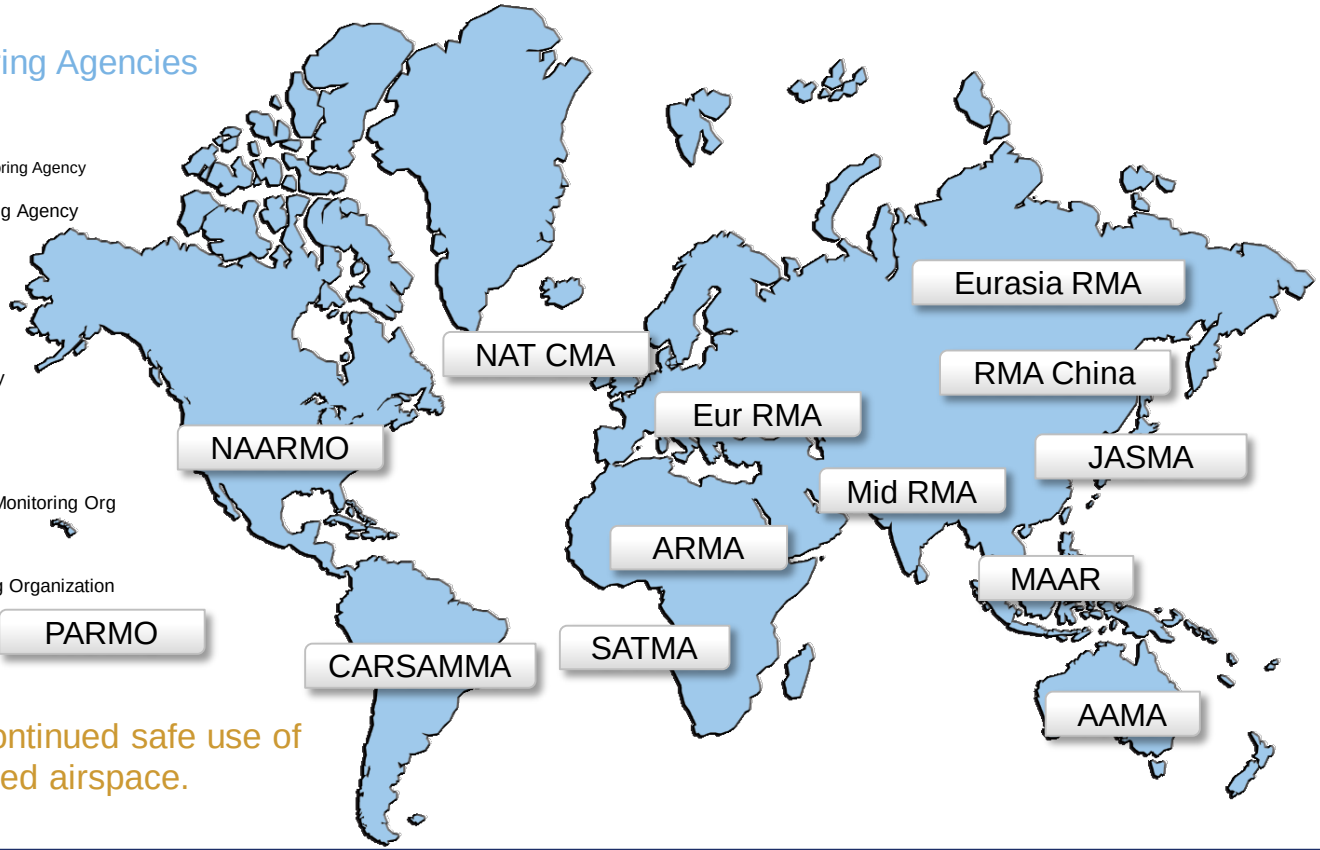


Regional Monitoring Agencies

In all regions where RVSM has been implemented, regional monitoring agencies (RMAs) have been established by the appropriate planning and implementation regional groups (PIRGs) to satisfy the goals of the RVSM monitoring program.

ICAO-Endorsed Regional Monitoring Agencies

AAMA	Australian Airspace Monitoring Agency
ARMA	African and Indian Ocean (AFI) Regional Monitoring Agency
CARSAMMA	Caribbean and South American Monitoring Agency
China RMA	China Regional Monitoring Agency
EurAsia RMA	Regional Monitoring Agency Eurasia
Eur RMA	European Regional Monitoring Agency
JASMA	Japan Airspace Safety Monitoring Agency
MAAR	Monitoring Agency for Asia Region
Mid RMA	Middle East Regional Monitoring Agency
NAARMO	North American Approvals Registry and Monitoring Org
NAT CMA	North Atlantic Central Monitoring Agency
PARMO	Pacific Approvals Registry and Monitoring Organization
SATMA	South Atlantic Monitoring Agency



An RMA supports the continued safe use of RVSM within a designated airspace.

Annual Vertical Collision Risk Report

- **ICAO Doc 9574, paragraph 6.4.4 and 6.4.5, Responsibilities of an RMA**
  - One of the duties and responsibilities includes providing annual reports to the Planning and Implementation Regional Group (PIRG)
    - Reports contain assessments of risk in the system against the overall safety objectives to support the continued safe use of the RVSM
  - These reports are provided to the relevant groups within the ICAO Regions

Tools for Safety Assessment

- **ICAO Collision Risk Methodology**
  - Used to develop ICAO Doc 9574 global system performance specification, height keeping performance specification and aircraft height keeping performance requirements
  - Consists of:
    - Target Level of Safety (TLS) (=safety goal),
    - collision risk model (=risk estimation tool), and
    - agreed means to evaluate risk

Tools for Safety Assessment

- **ICAO Collision Risk Methodology**
  - Risk model was adapted to account for:
    - aircraft technical risk on same track and on intersecting tracks
    - effect of large height deviations on system risk
  - Same methodology is used by all RMAs worldwide

Safety Goals

- **The estimate of vertical collision risk associated with RVSM is compared to the agreed RVSM safety goals.**

Safety Goal 1: Technical risk, or the risk of collision associated with aircraft height-keeping performance, does not exceed a Target Level of Safety (TLS) of 2.5 x 10^{-9} fatal accidents per flight hour (fapfh).

Reference: ICAO Doc 9937, paragraph 2.3.1, 2.4.2

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Safety Goal 2: Overall risk, or the risk of collision due to all causes, which includes the technical risk and all risk due to operational errors, such as pilot/controller errors - does not exceed a TLS of 5 x 10^{-9} fapfh*.

For example the 2015 estimate of annual flight hours in continental United States is 9.8 million flight hours. A TLS of 5x10^{-9} fapfh equates to an acceptable value of risk of roughly 1 fatal accident every 20 years resulting from a loss of vertical separation

Reference: ICAO Doc 9937, paragraph 2.3.1, 2.4.2

Data Requirements

- **Results from aircraft height-keeping performance monitoring systems**
  - Both from regional monitoring systems and data-sharing with other RMAs
- **Collect reports of large height deviations (LHD) and traffic sample data (TSD) from Air Navigation Service Providers (ANSPs)**

Risk Categories

- **"Technical risk" is the term used to describe the risk of collision associated with aircraft height-keeping performance. Some of the factors which contribute to technical risk are:**
  a) errors in aircraft altimetry and automatic altitude control systems;
  b) aircraft equipment failures resulting in unmitigated deviation from the cleared flight level, including those where not following the required procedures further increases the risk; and
  c) responses to false collision avoidance resolution advisories.

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  c) responses to false collision avoidance resolution advisories.
- **The term "operational error" is used to describe any vertical deviation of an aircraft from the correct flight level as a result of incorrect action by ATC or the flight crew.**

Key Collision Risk Model Parameters

- **There are two vertical overlap probability parameters that take into account the ASE performance of the aircraft population**
- **To estimate Technical Risk, risk associated with aircraft technical height-keeping performance, specifically the performance affected by the avionics of the aircraft, not the flight crew.**
  - Pz(1000), is the probability that two aircraft nominally separated by 1 000 ft are in vertical overlap

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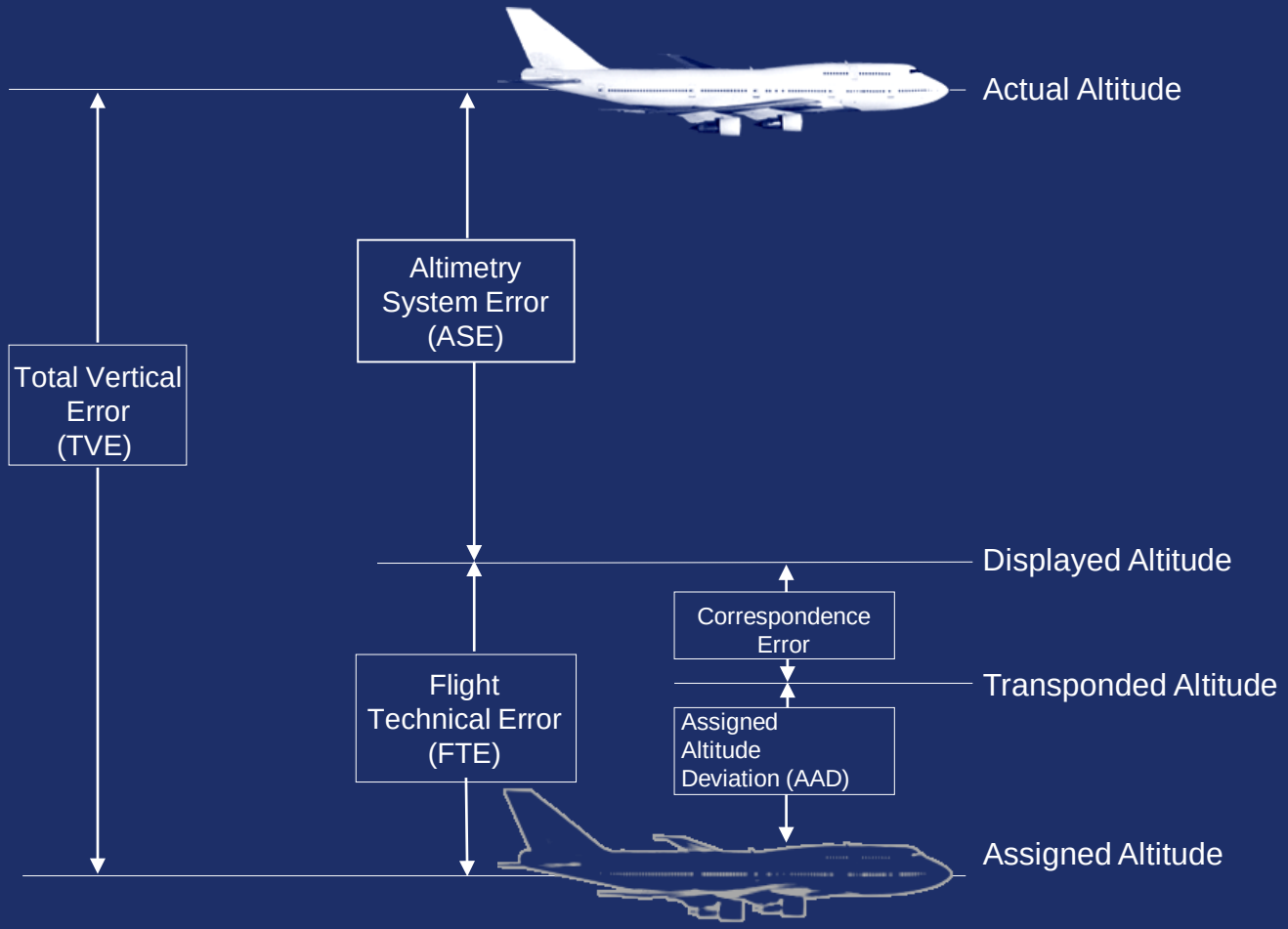
  - Pz(1000), is the probability that two aircraft nominally separated by 1 000 ft are in vertical overlap
- **To estimate Operational Risk, risk due to all other causes, including the risk due to operational errors**
  - Pz(0), is the probability that two aircraft flying at the same flight level are in vertical overlap

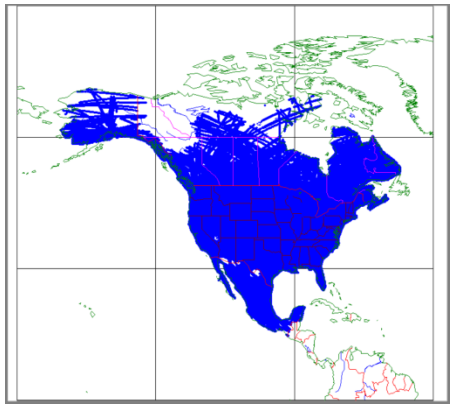
Aircraft Total Vertical Error (TVE)

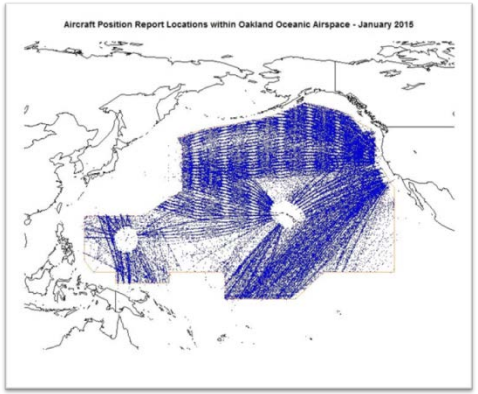


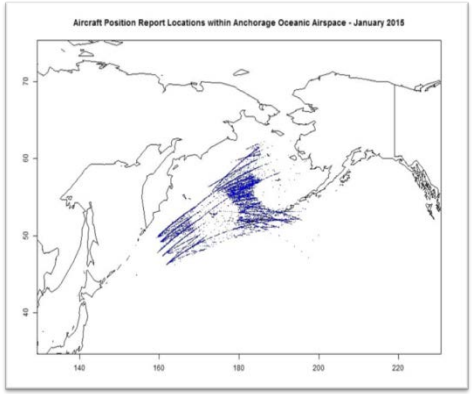
Vertical Overlap Probability Parameter

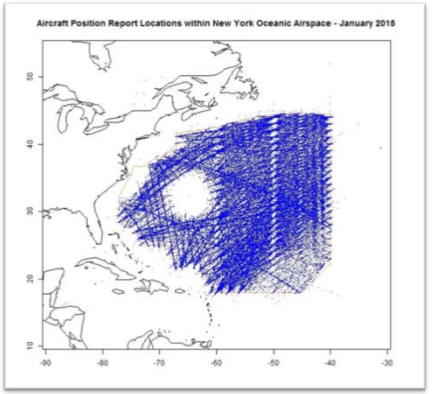
- **The process to assess aircraft total vertical error (TVE) and estimate $P_z(1000)$ and $P_z(0)$ is the same**
- **Data required:**
  - Assigned altitude deviation (AAD)
    - Radar data
  - Large Height Deviations (LHDs), including events due to turbulence and aircraft equipment failures
  - Aircraft type population
  - ASE performance for the aircraft observed in airspace

Top 10 Aircraft Types by Airspace (in terms of Flying Hours)







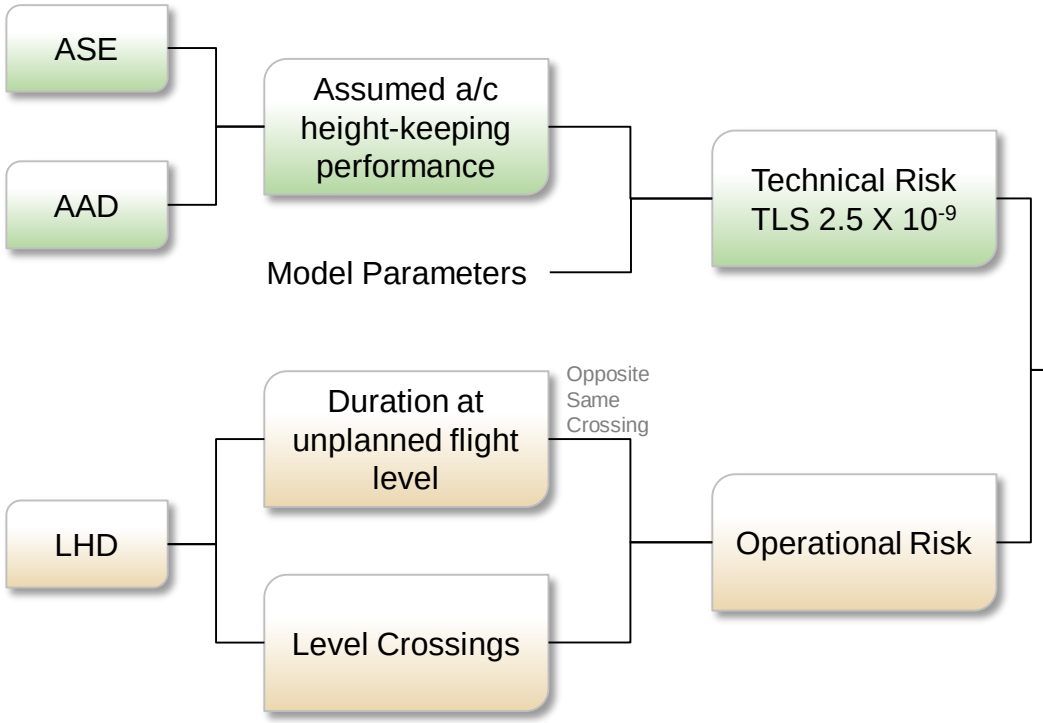


US NAS		Oakland Oceanic		Anchorage Oceanic		New York Oceanic	
B738	12.07%	B77W	16.21%	B744	22.00%	A332	14.87%
B737	11.57%	B772	12.79%	B77W	19.69%	A333	14.26%
A320	9.98%	A332	9.62%	B772	12.85%	B763	13.54%
A319	5.90%	B763	8.54%	B748	10.07%	B772	11.23%
B752	5.33%	B744	8.29%	B788	8.28%	B744	8.59%
CRJ7	3.45%	B738	8.25%	B77L	6.84%	B77W	7.31%
B739	3.39%	B752	6.05%	B763	5.59%	B788	7.24%
A321	3.01%	B788	4.80%	MD11	3.12%	A346	5.25%
E170	2.83%	A388	3.55%	A388	3.05%	A343	3.83%
E145	2.61%	B77L	3.22%	A332	2.69%	B77L	2.16%
	60.14%		81.32%		94.20%		88.29%

ZAN Oceanic Airspace

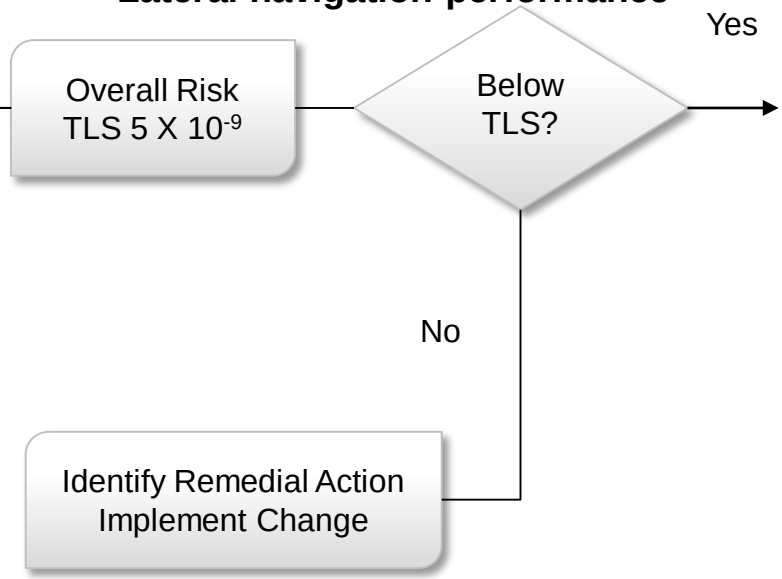
Aircraft Type	Relative Proportion in ZAN	ASE Mean	ASE Standard Deviation
B744	22.00%	-85.46	48.13
B77W	19.69%	29.43	37.84
B772	12.85%	14.51	34.62
B748	10.07%	18.66	25.51
B788	8.28%	27.89	34.43
B77L	6.84%	14.51	34.62
B763	5.59%	-74.01	51.17
MD11	3.12%	-68.80	49.06
A388	3.05%	-29.33	36.08
A332	2.69%	29.23	43.47

Ongoing Safety Monitoring



Collision risk model (CRM) key parameters

- **Rate of LHD occurrences**
- **Growth in traffic and congestion (reflected in passing frequency and occupancy**
- **Lateral navigation performance**



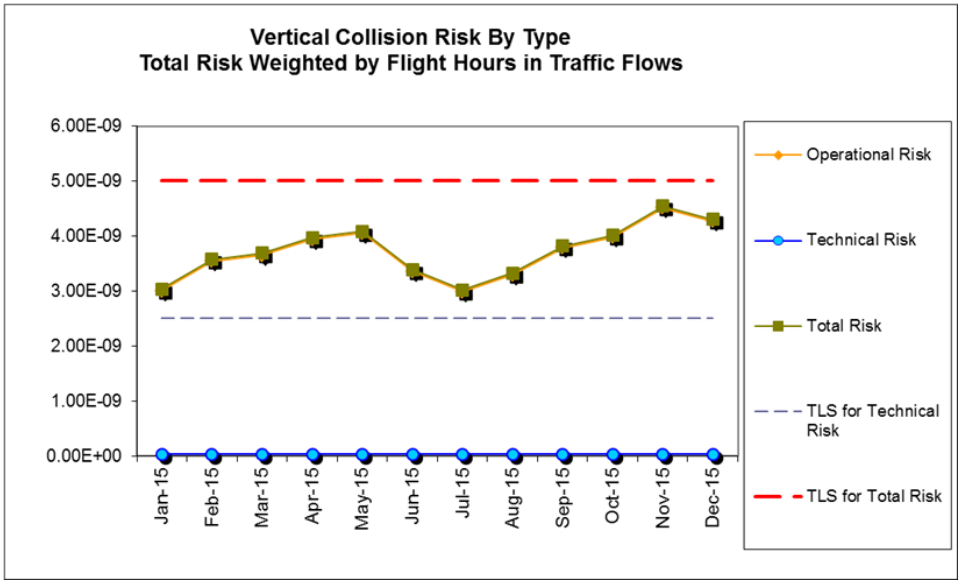
Example: Pacific Airspace Performance Specification: Pre-Implementation and Today

- **Target Level of Safety N_{az} = 2.5 x 10^{-9} fapfh**

Parameter	Pre-Implementation Value	Today
Vertical Overlap Probability Pz(1000)	2.46 x 10^{-8}	4.7 x 10^{-9}
Vertical Overlap Probability Pz(0)	0.42	0.538
Lateral Overlap Probabilty Py(0)	0.0263	0.150
Passing Frequency N_x(equivalent)	0.251	0.170

PARMO Vertical Report to RASMAG/21

Pacific Airspace – estimated annual flying hours = 1,670,790 hours (note: estimated hours based on Dec 2015 traffic sample data)			
Source of Risk	Risk Estimation	TLS	**Remarks**
RASMAG/20 Total Risk	$3.86\ 10^{-9}$	5.0×10^{-9}	**Below TLS**
Technical Risk	0.03×10^{-9}	2.5×10^{-9}	**Below Technical TLS**
Operational Risk	4.26×10^{-9}	-	**-**
Total Risk	**4.30×10^{-9}**	**5.0×10^{-9}**	**Below TLS**



Federal Aviation Administration