FLIGHT SAFETY FOUNDATION

2009 Annual C-FOQA Statistical Summary Report

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Enclosed is a statistical summary of Flight Operations Quality Assurance (FOQA) results for flight data processed through the Austin Digital Inc. eFOQA Event Measurement System (EMS). By opening this packet you indicate your acceptance in protecting the proprietary and confidential information of Austin Digital Inc. and The Flight Safety Foundation. The enclosed information cannot be distributed, data manipulated in any manner, or otherwise reproduced.

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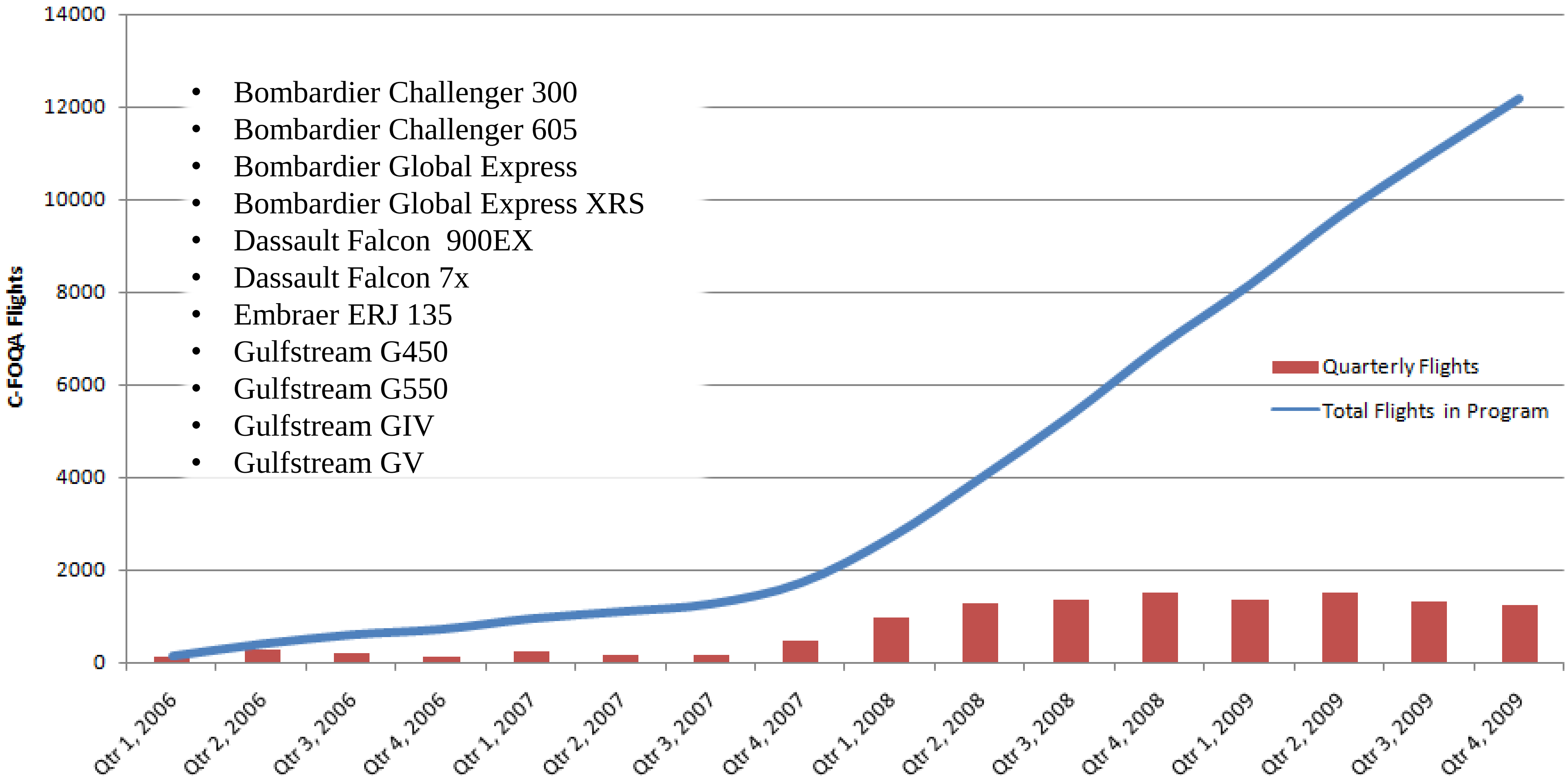
C-FOQA Enrollment

As of Q4 2009, 27 aircraft of the following types contributed to the aggregated C-FOQA data set:

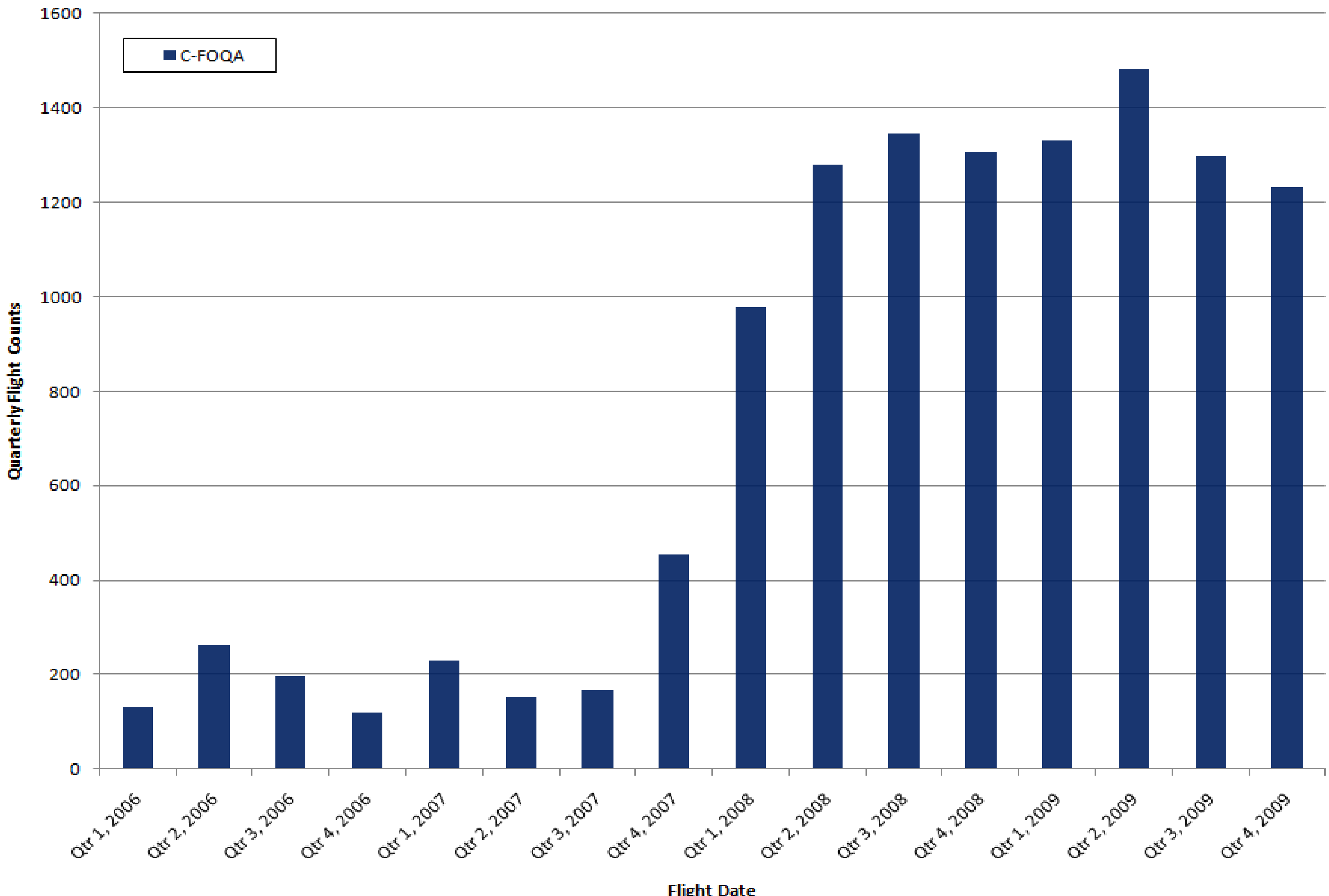
- Bombardier Challenger 300
- Bombardier Challenger 605
- Bombardier Global Express
- Bombardier Global Express XRS
- Dassault Falcon 900EX
- Dassault Falcon 7x
- Embraer ERJ 135
- Gulfstream G450
- Gulfstream G550
- Gulfstream GIV
- Gulfstream GV



Section I: C-FOQA Operational Summary

C-FOQA participants' operational performance and event rates throughout the program focusing on 2009.

Quarterly Flight Counts



***Flight counts only include non-test flights where both the takeoff and landing are recorded in the data.**

Breakdown of Aircraft Limitation Events by Type (2009)

Event Type	Caution Events	Warning Events
EGT Limit Exceedance	0	0
Airspeed Low Relative to Stall Speed	0	0
Stall Warning	0	0
Climb Airspeed Low Relative to Vmca	0	0
VMO (Max Operating Velocity) Limit Exceedance	**1**	0
MMO (Max Operating Mach) Limit Exceedance	**5**	0
Flap/Slat Altitude Limit Exceedance	0	**3**
VFE (Flap Airspeed) Limit Exceedance	**47**	**1**
Slat Airspeed Limit Exceedance	0	0
VLE (Gear-Down Airspeed) Limit Exceedance	0	0
MLE (Gear-Down Mach) Limit Exceedance	0	**1**
VLO (Gear Retraction Airspeed) Limit Exceedance	**1**	0
VLO (Gear Extension Airspeed) Limit Exceedance	**8**	**1**
Takeoff Weight Limit Exceedance	0	0
Vtire (Tire Speed) Limit Exceedance	**1**	0
Upper Maneuv. Load Limit Exceedance (Flaps Up)	0	0
Upper Maneuv. Load Limit Exceedance (Flaps Down)	0	0
Lower Maneuv. Load Limit Exceedance (Flaps Up)	0	0
Lower Maneuv. Load Limit Exceedance (Flaps Down)	0	0
Max Operating Altitude Exceedance	0	0
Takeoff Altitude too High	0	0
Slat Mach Limit Exceedance	0	0
Taxi Weight Limit Exceedance	0	0
Landing Weight Limit Exceedance	0	0
Brake Temperature Limit Exceedance (Takeoff)	0	0
Brake Temperature Limit Exceedance (Taxi In)	0	0
Fuel Temperature Too Low	0	0
Fuel Temperature Too High	0	0

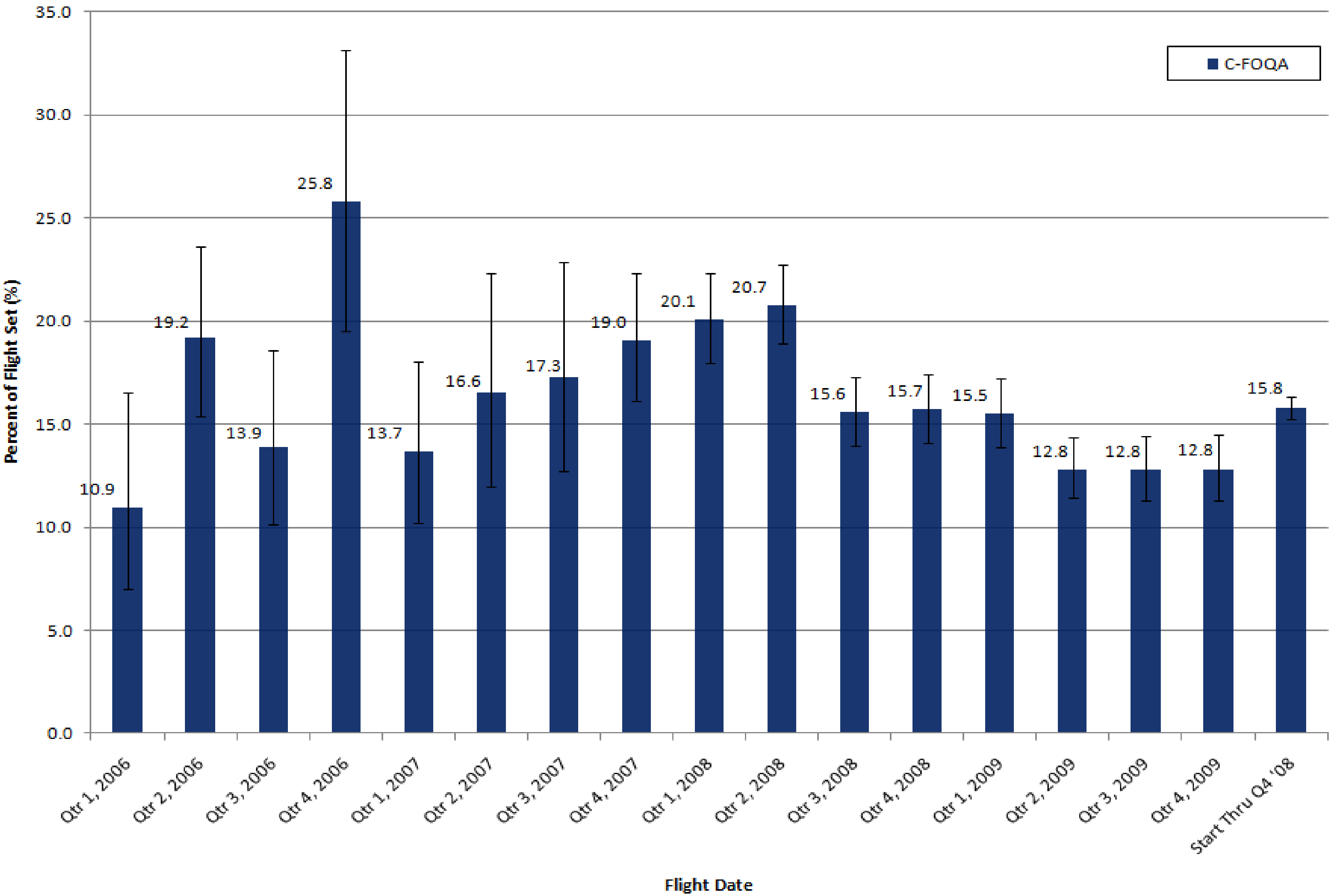
***Refer to operator fleet configuration report for event limits and severities**

Breakdown of Aircraft Maintenance Events by Type (2009)

Event Type	Caution Events	Warning Events
Engine Fire	0	0
Smoke Warning	0	0
Uncommanded Pitch	0	0
Uncommanded Roll	0	**1**
Uncommanded Yaw	0	0
Roll Attitude Disagreement	0	**4**
Pitch Attitude Disagreement	0	0
Thrust Reversers Not Stowed while Airborne	0	0
No Fuel Flow	0	**1**
Low Hydraulic Pressure	0	**1**
Cabin Pressure Warning	0	**1**
Engine Stall or Surge In-Flight	0	**1**
Reverse Thrust while Slow	**23**	0
Hard Landing (vertical speed method)	**4**	0

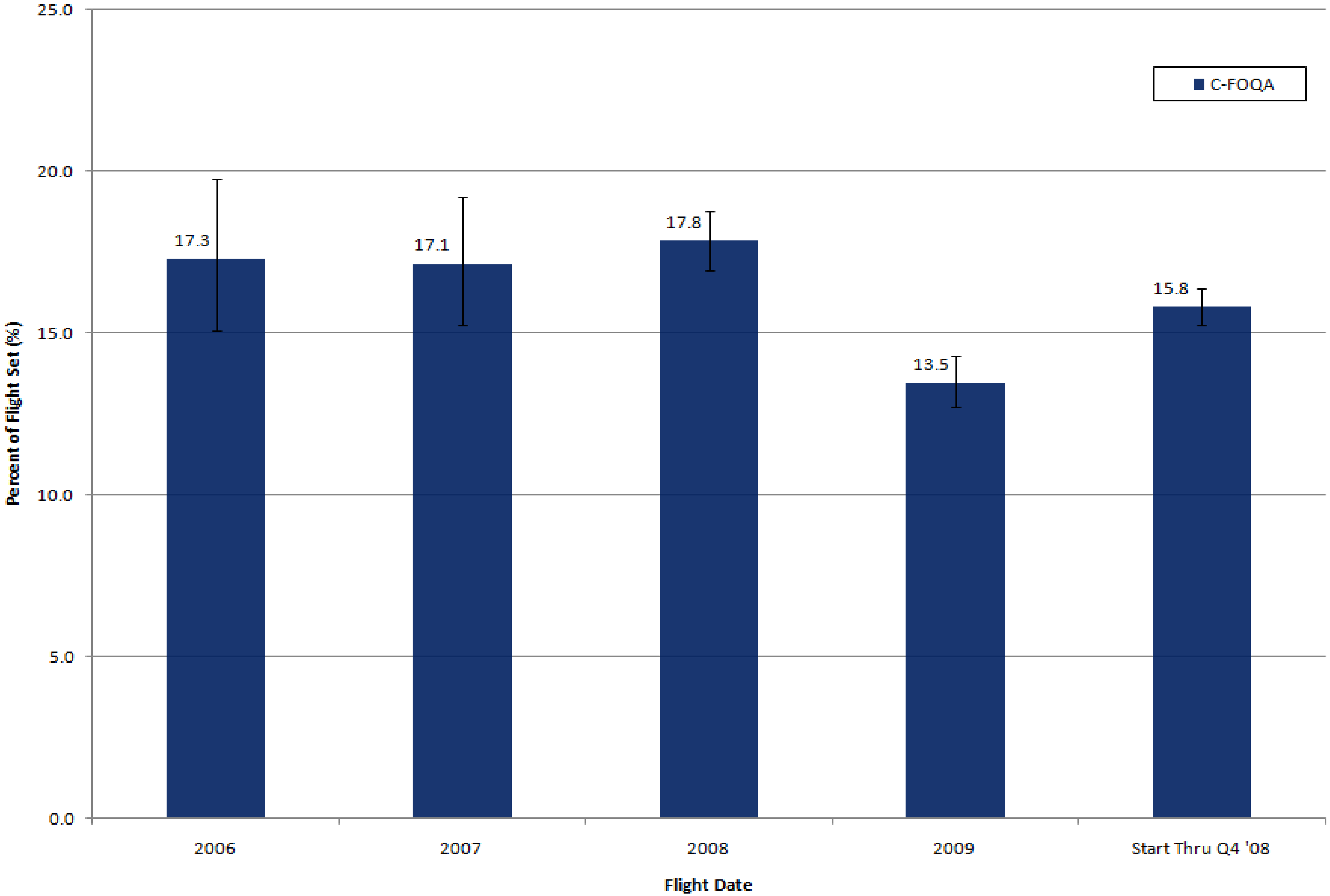
***Refer to operator fleet configuration report for event limits and severities**

Quarterly Flight Operations Event Rates



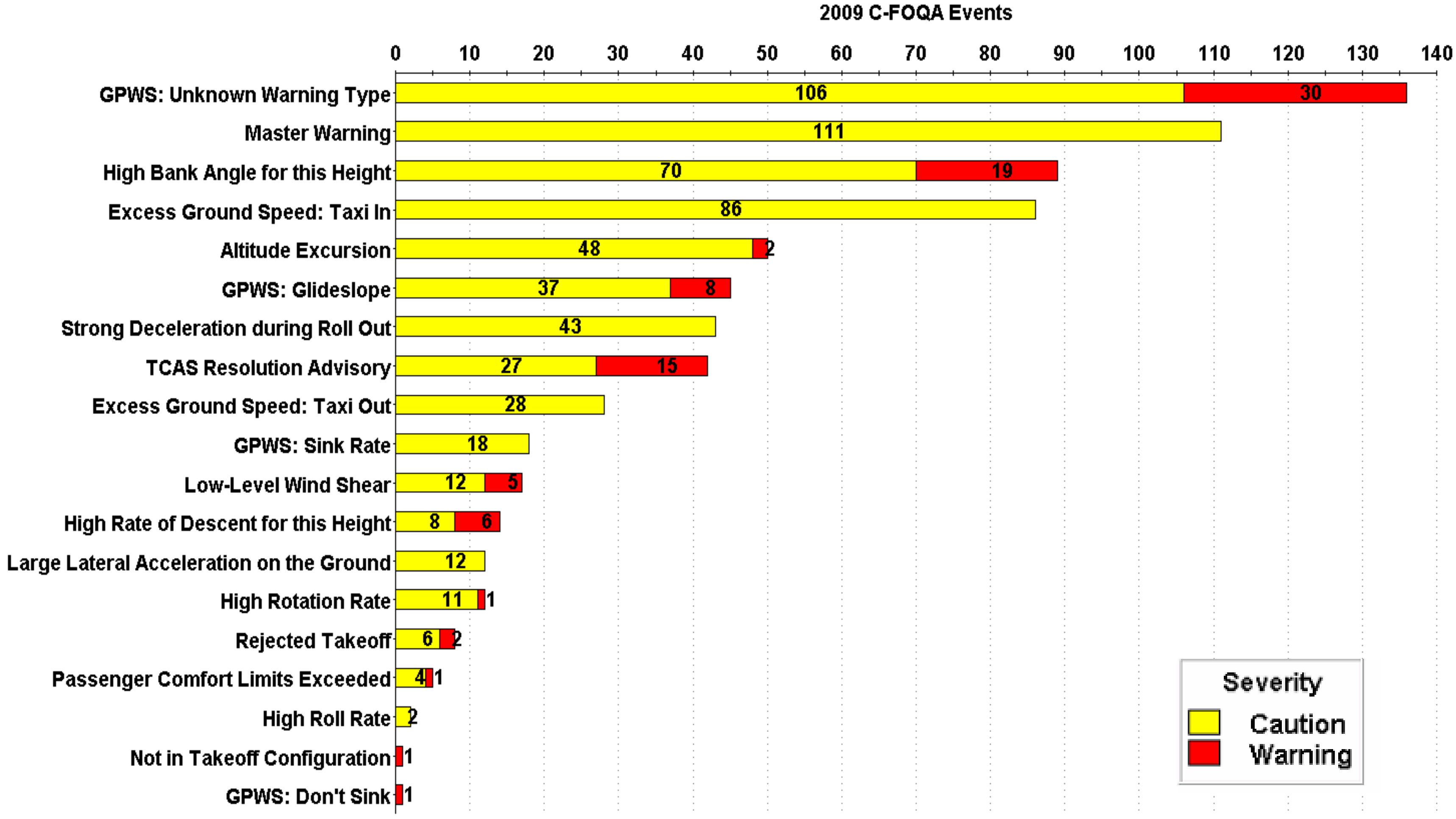
***Error Bars Calculated with 90% confidence interval**

Annual Flight Operations Event Rates



*Error Bars Calculated with 90% confidence interval

Breakdown of Flight Operations Events by Type (2009)



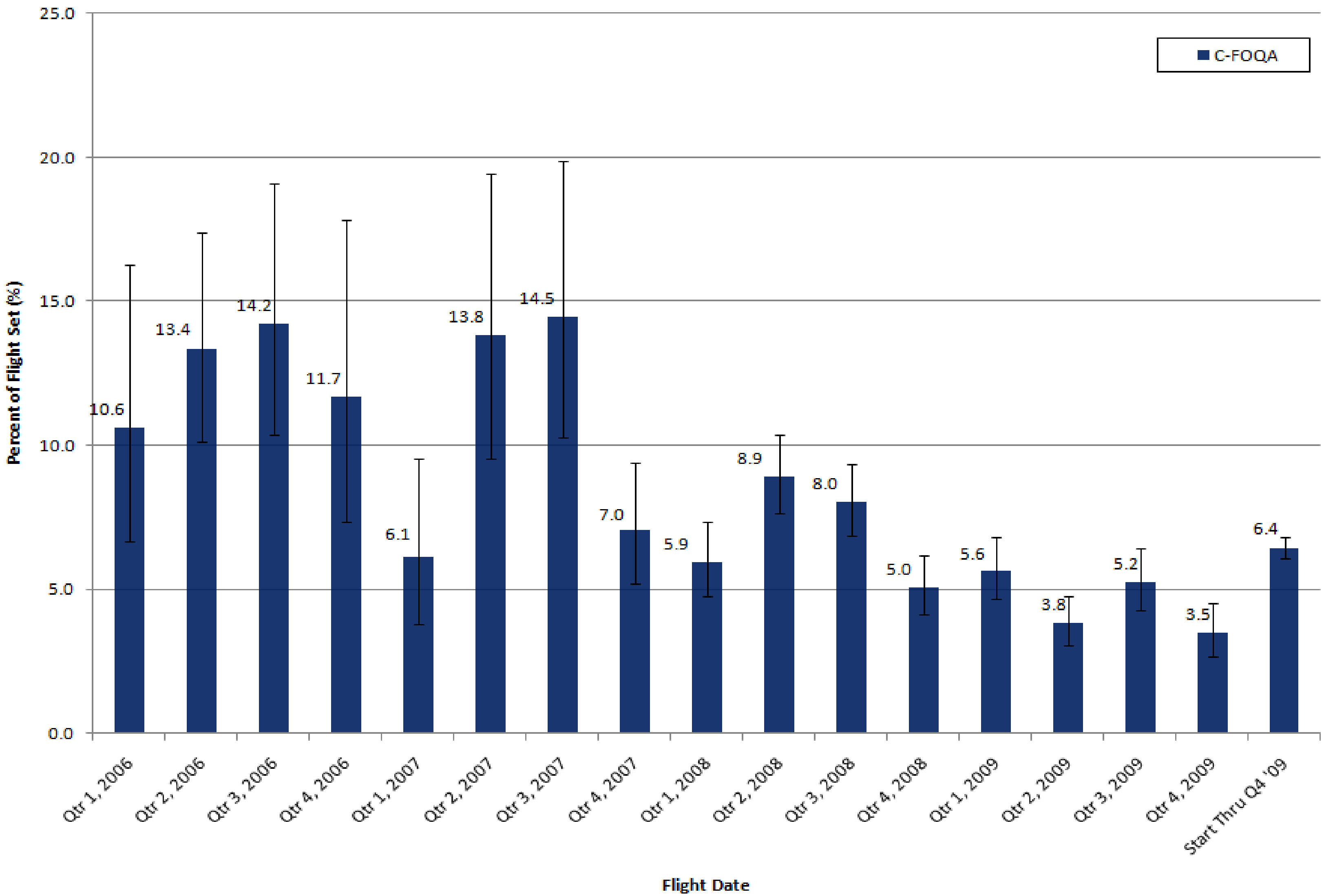
*Refer to operator fleet configuration report for event limits and severities

Section II: C-FOQA Approach Stability

C-FOQA participants' approach performance from the combined data-set.

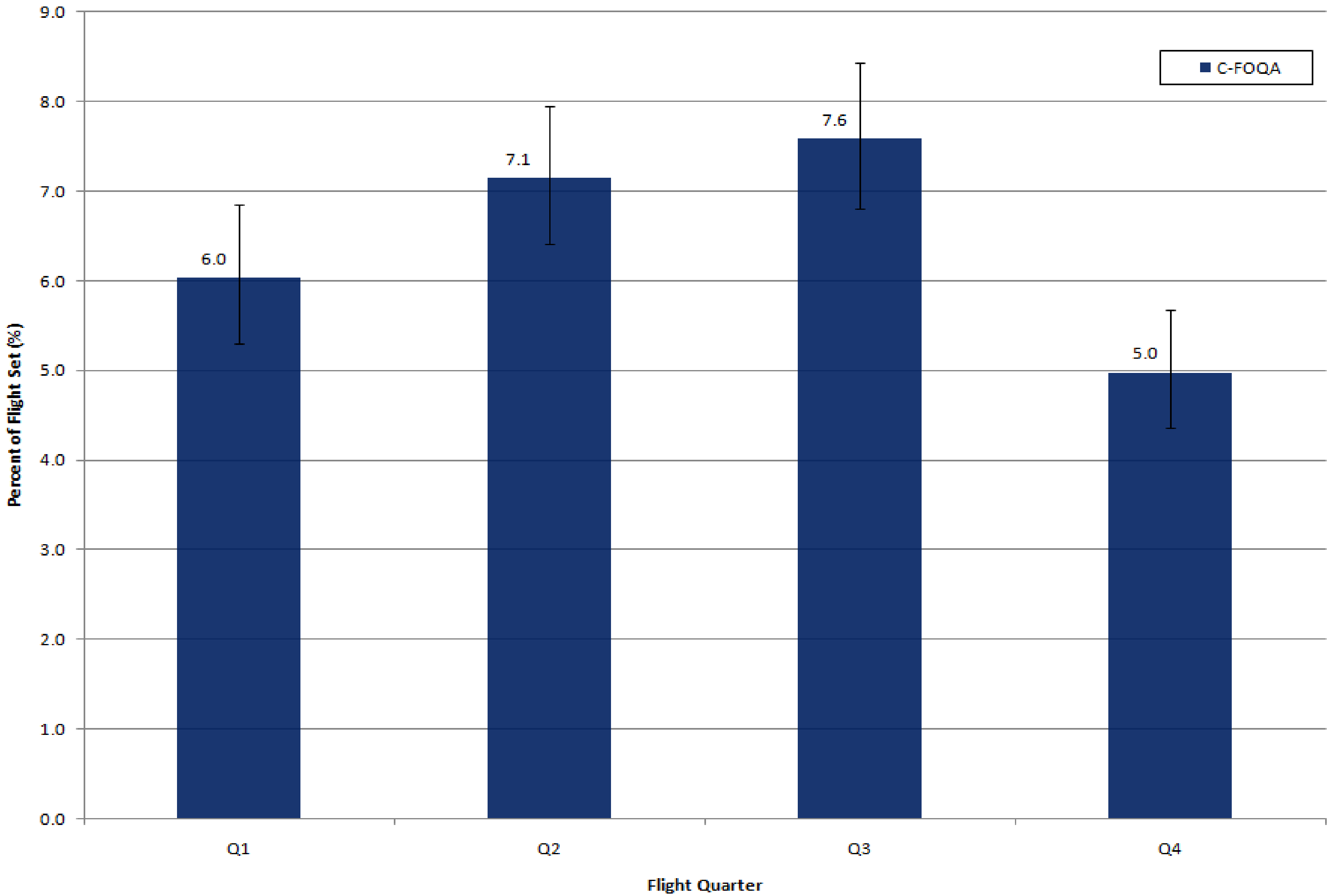
The C-FOQA Standard Event Limits (SEL), established by the Flight Safety Foundation, are used for group analysis and can be found in the Appendix.

Quarterly Unstable Approach Event Rates



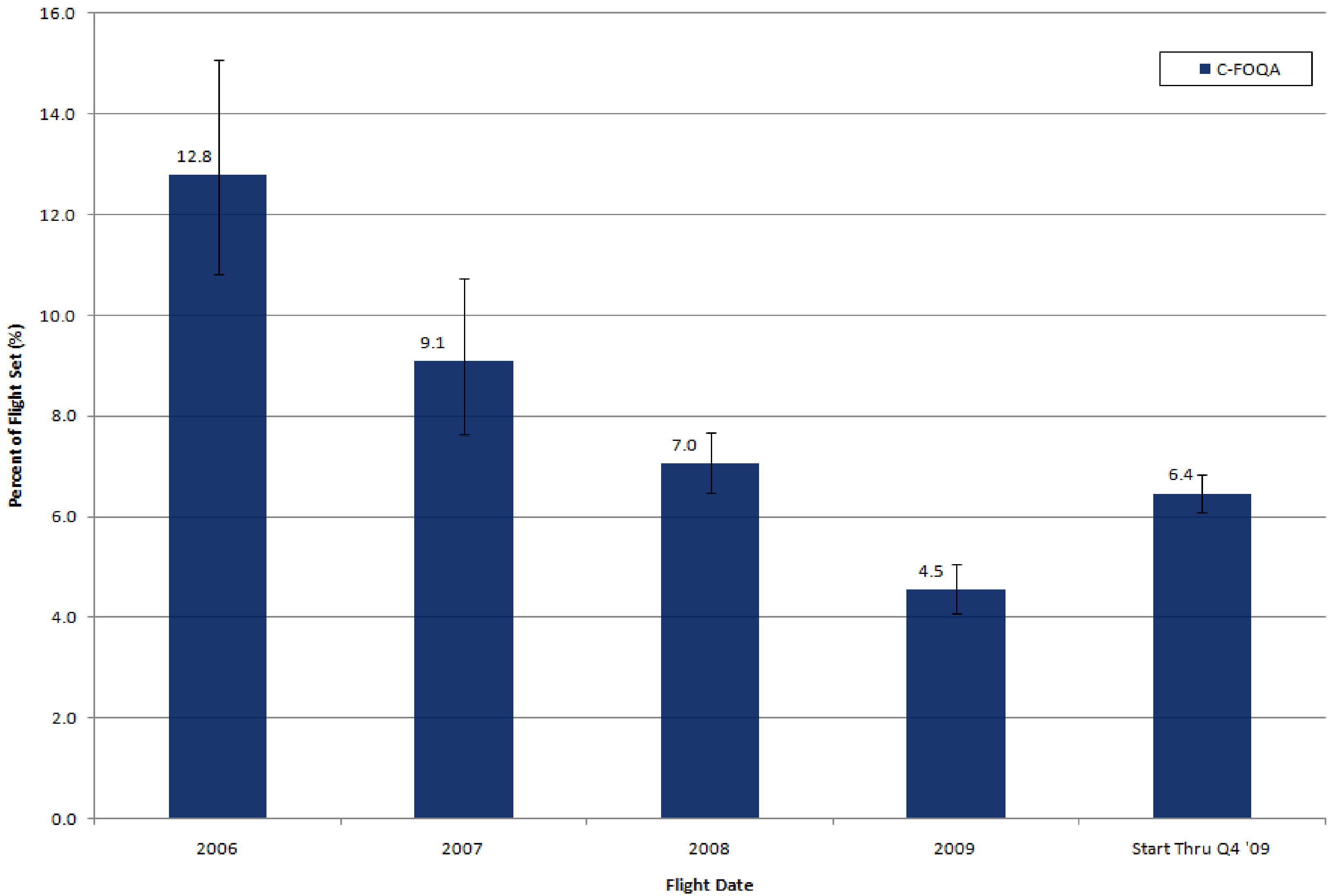
***Error Bars Calculated with 90% confidence interval**

Seasonal Unstable Approach Event Rates (All Years Combined)



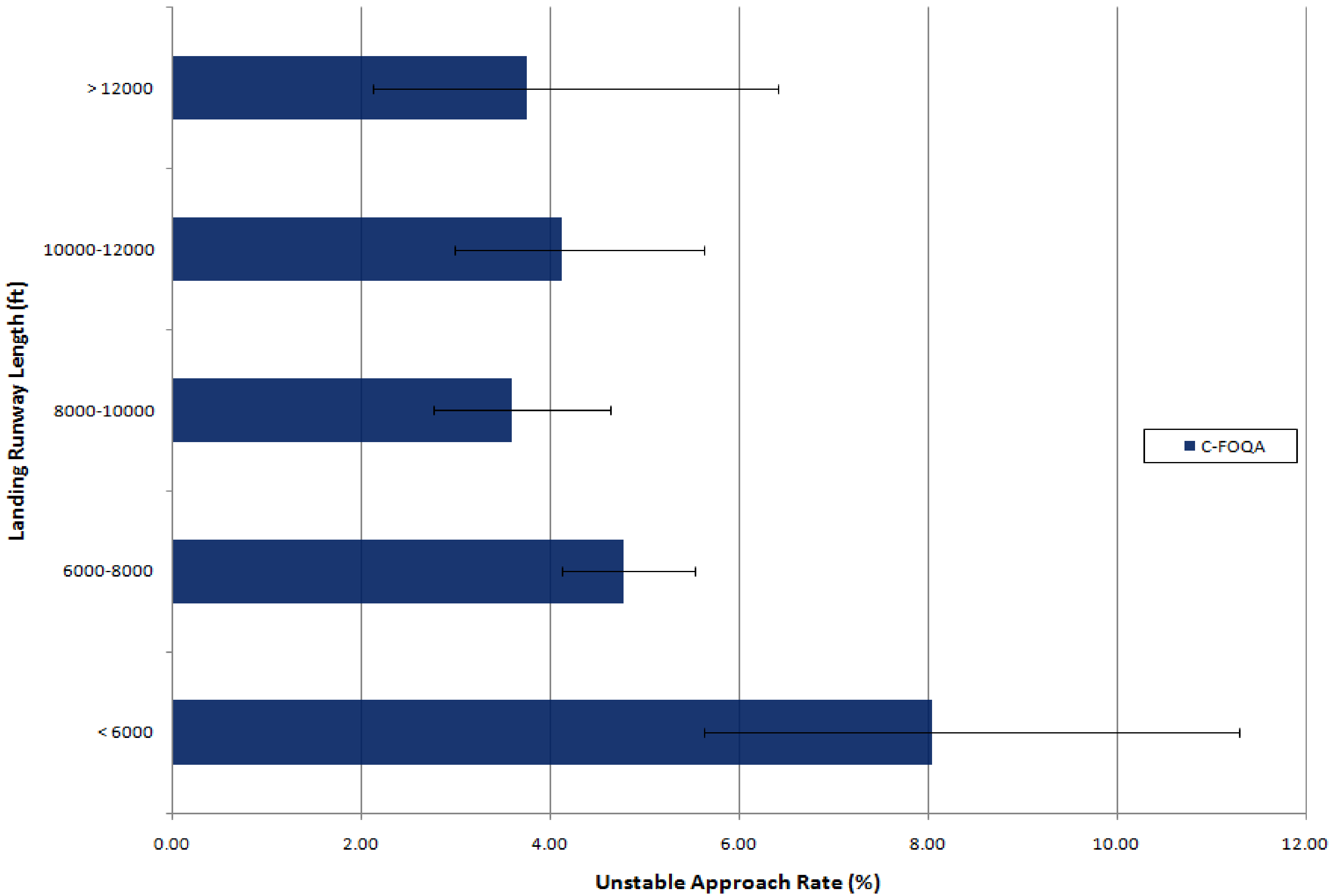
*Error Bars Calculated with 90% confidence interval

Annual Unstable Approach Event Rates



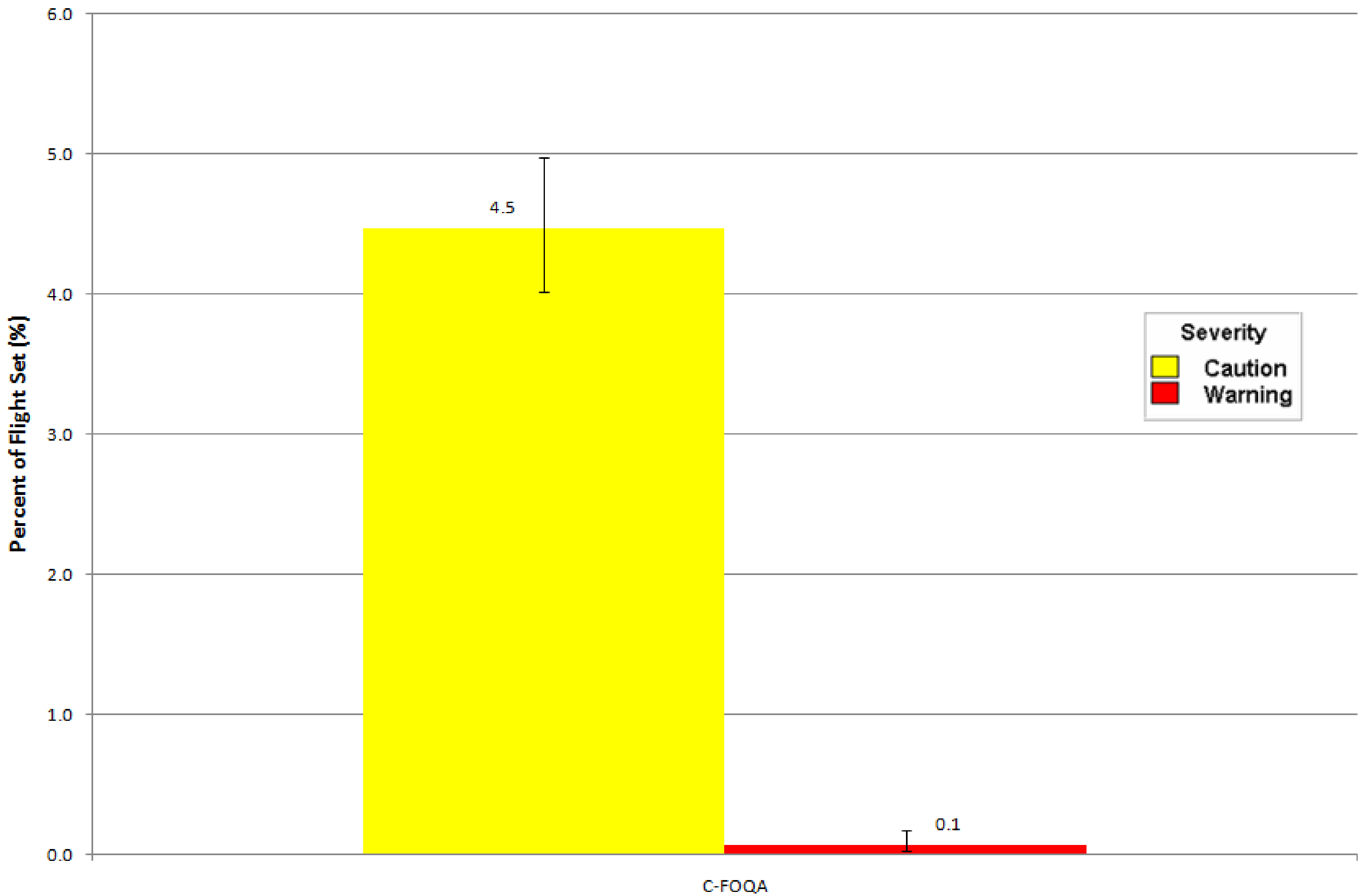
***Error Bars Calculated with 90% confidence interval**

Unstable Approach Rates by Runway Length (2009)



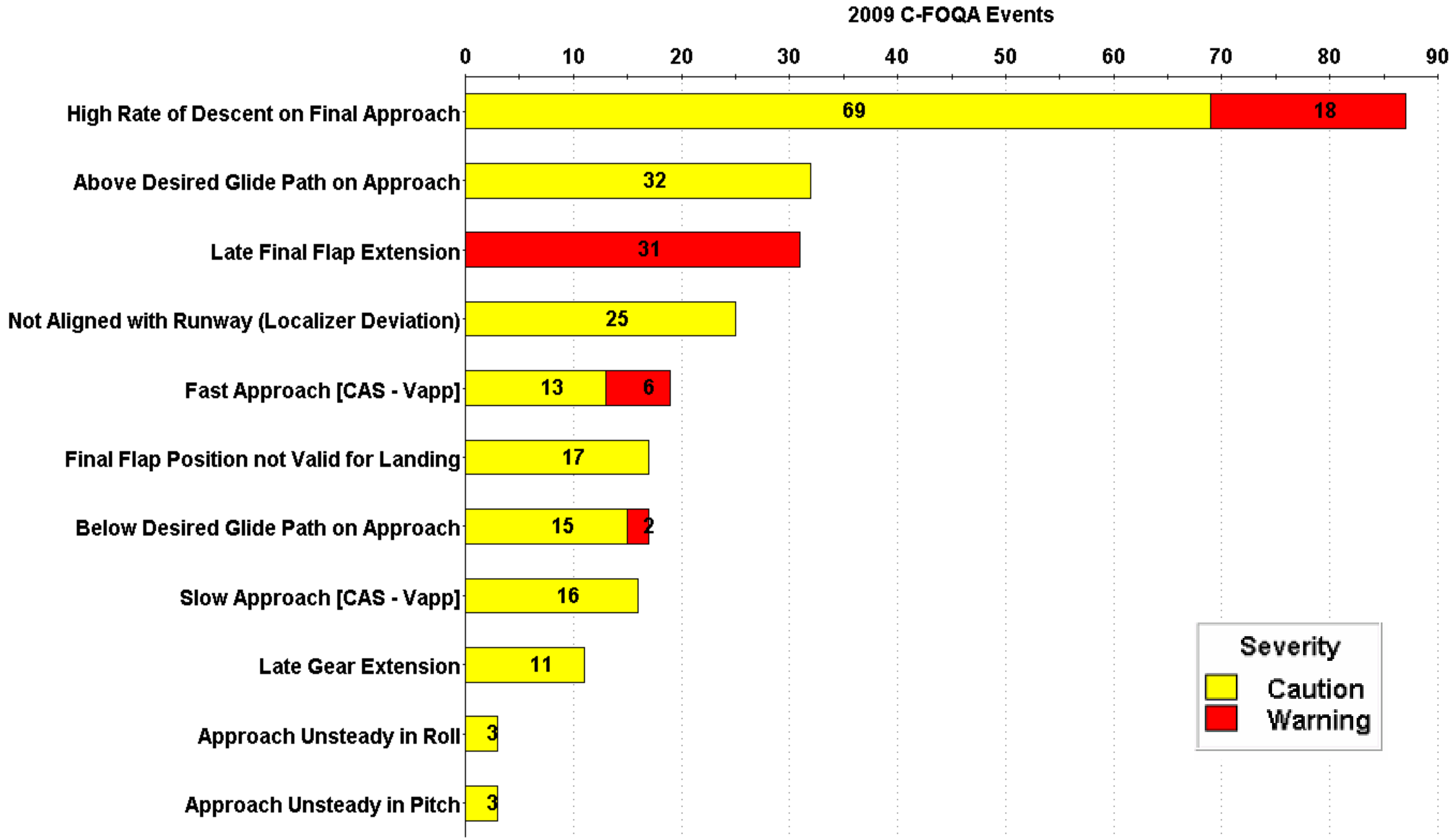
*Error Bars Calculated with 90% confidence interval

Unstable Approach Event Rates and Severity (2009)



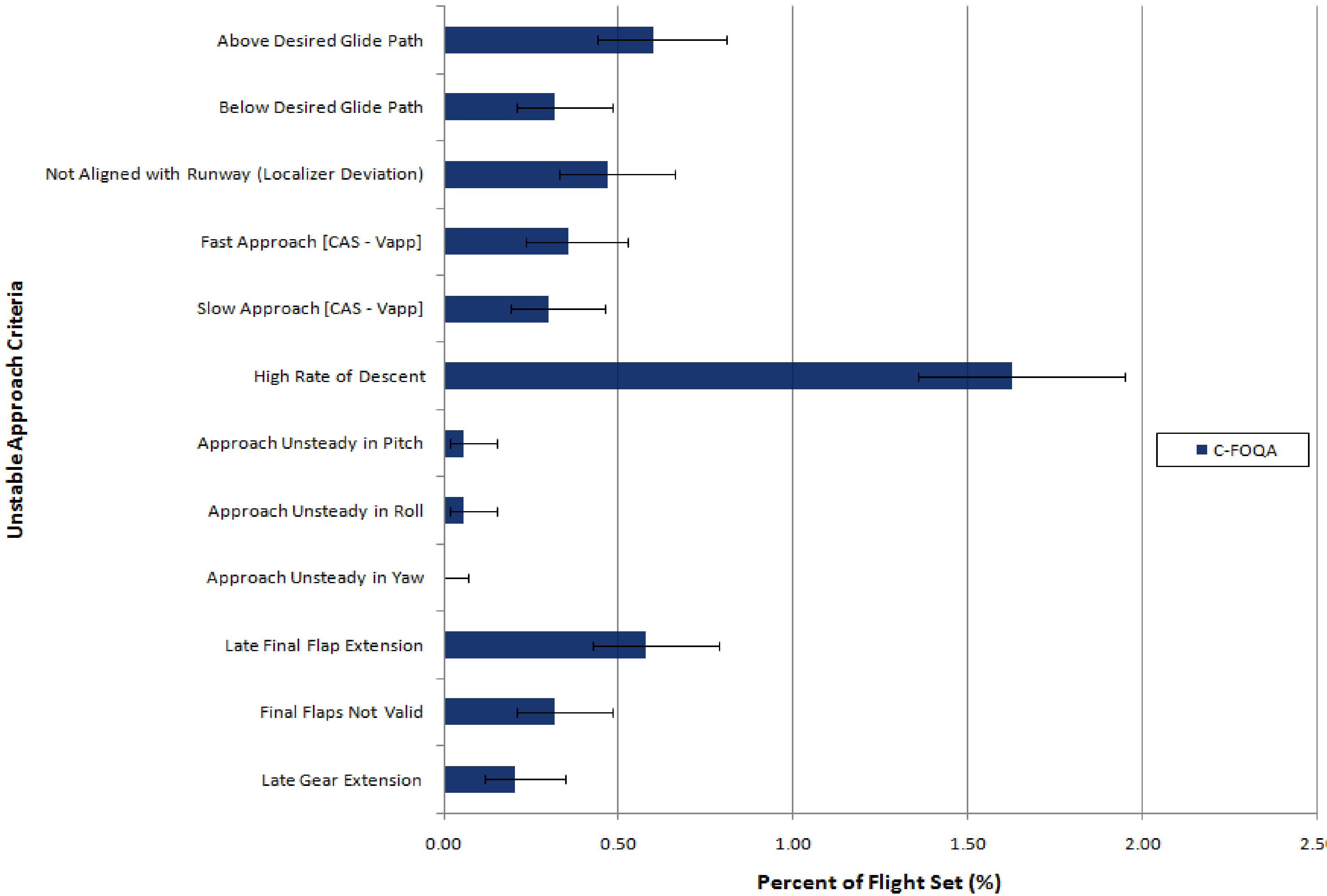
***Error Bars Calculated with 90% confidence interval**

Breakdown of Unstable Approach Events by Cause (2009)



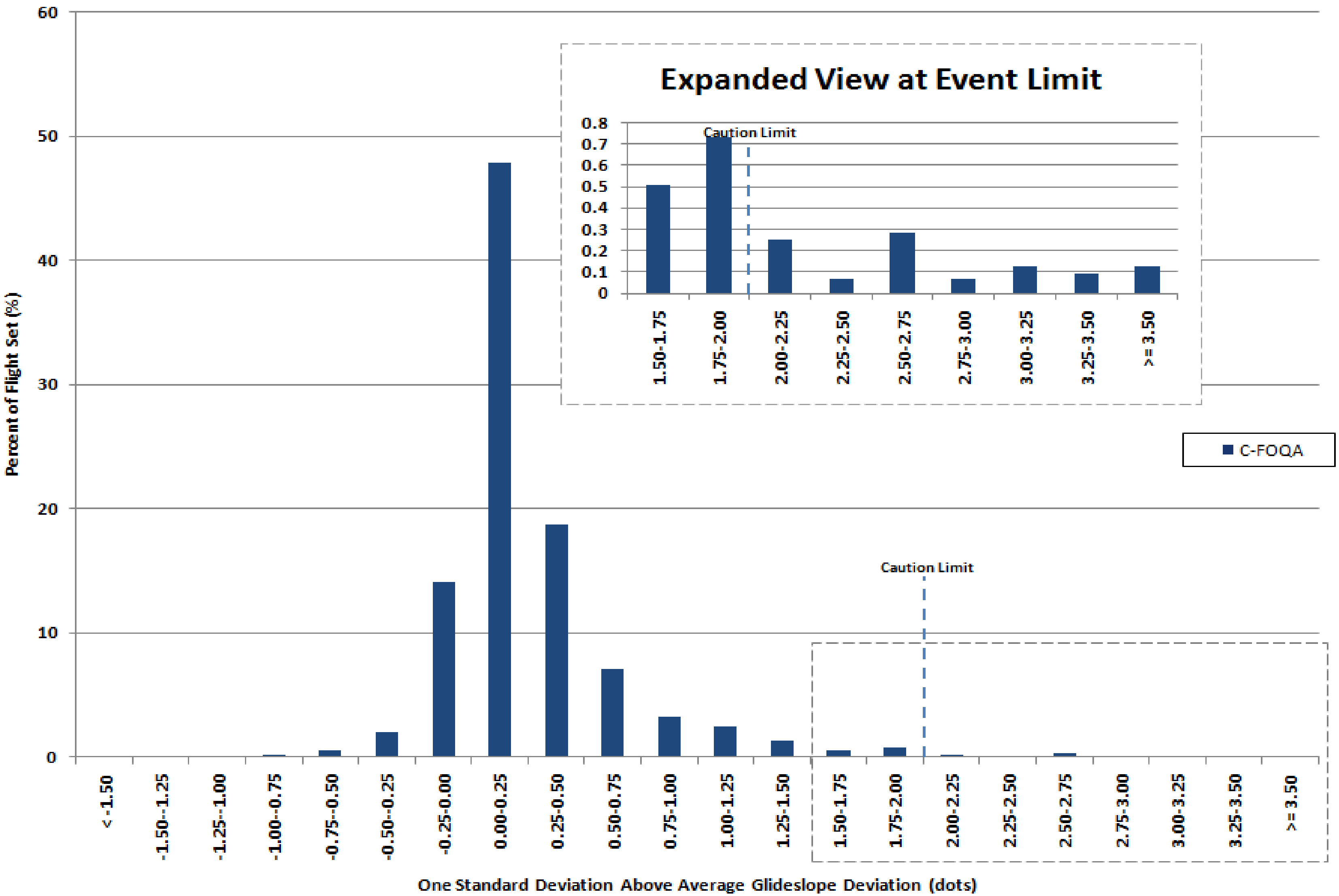
*Refer to operator fleet configuration report for event limits and severities

Unstable Approach Rates by Cause (2009)

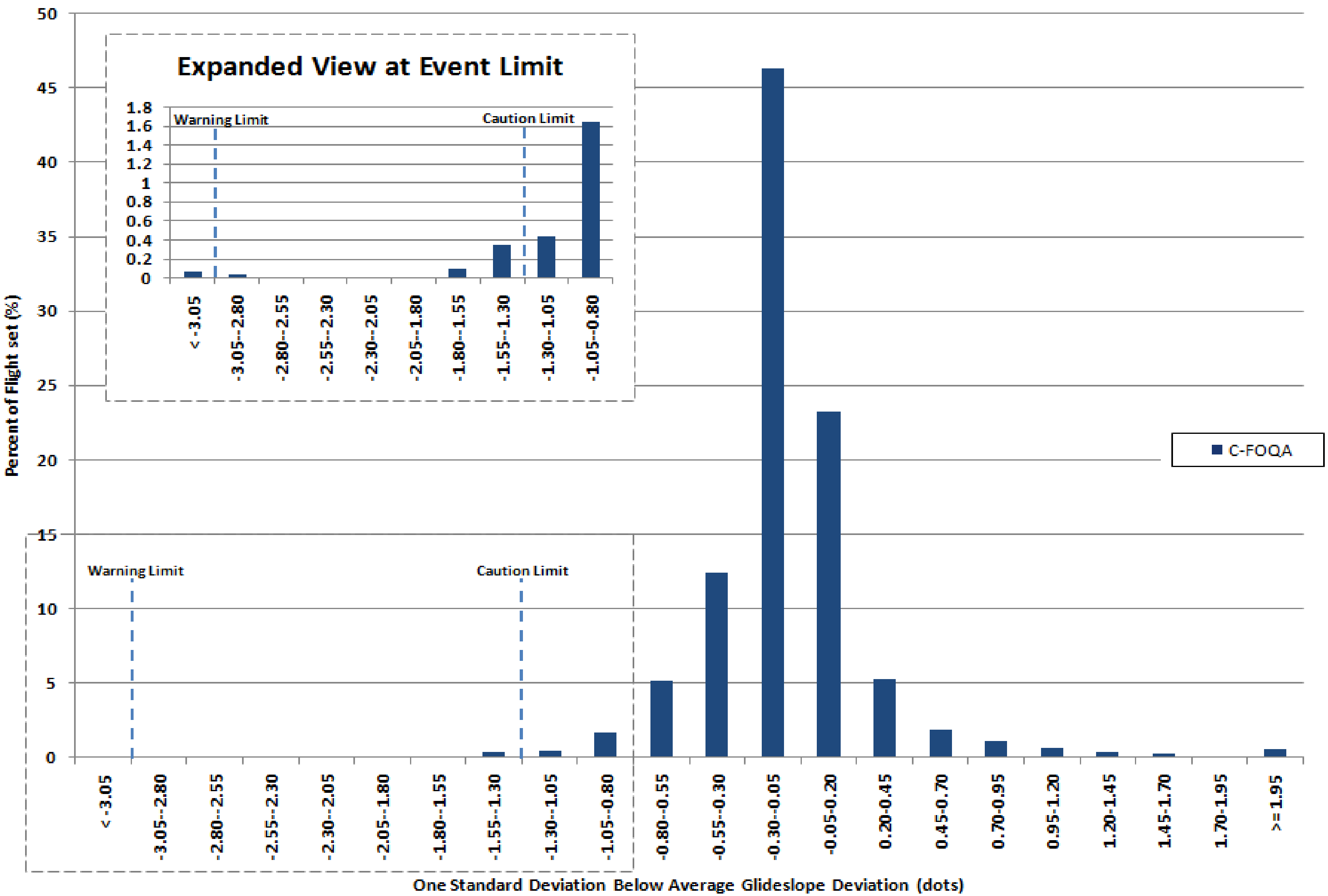


***Error Bars Calculated with 90% confidence interval**

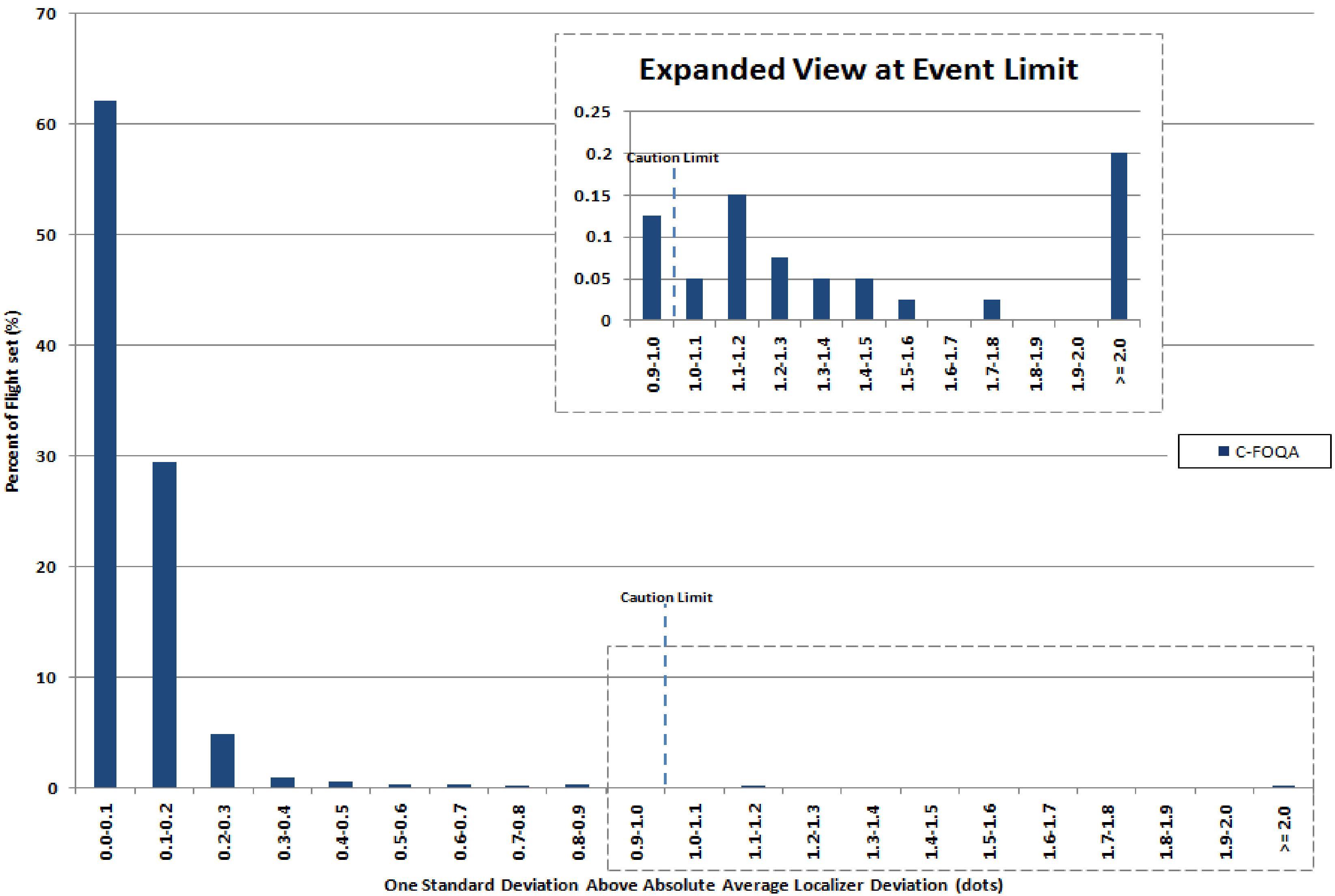
Above Desired Glide Path Distribution (2009)



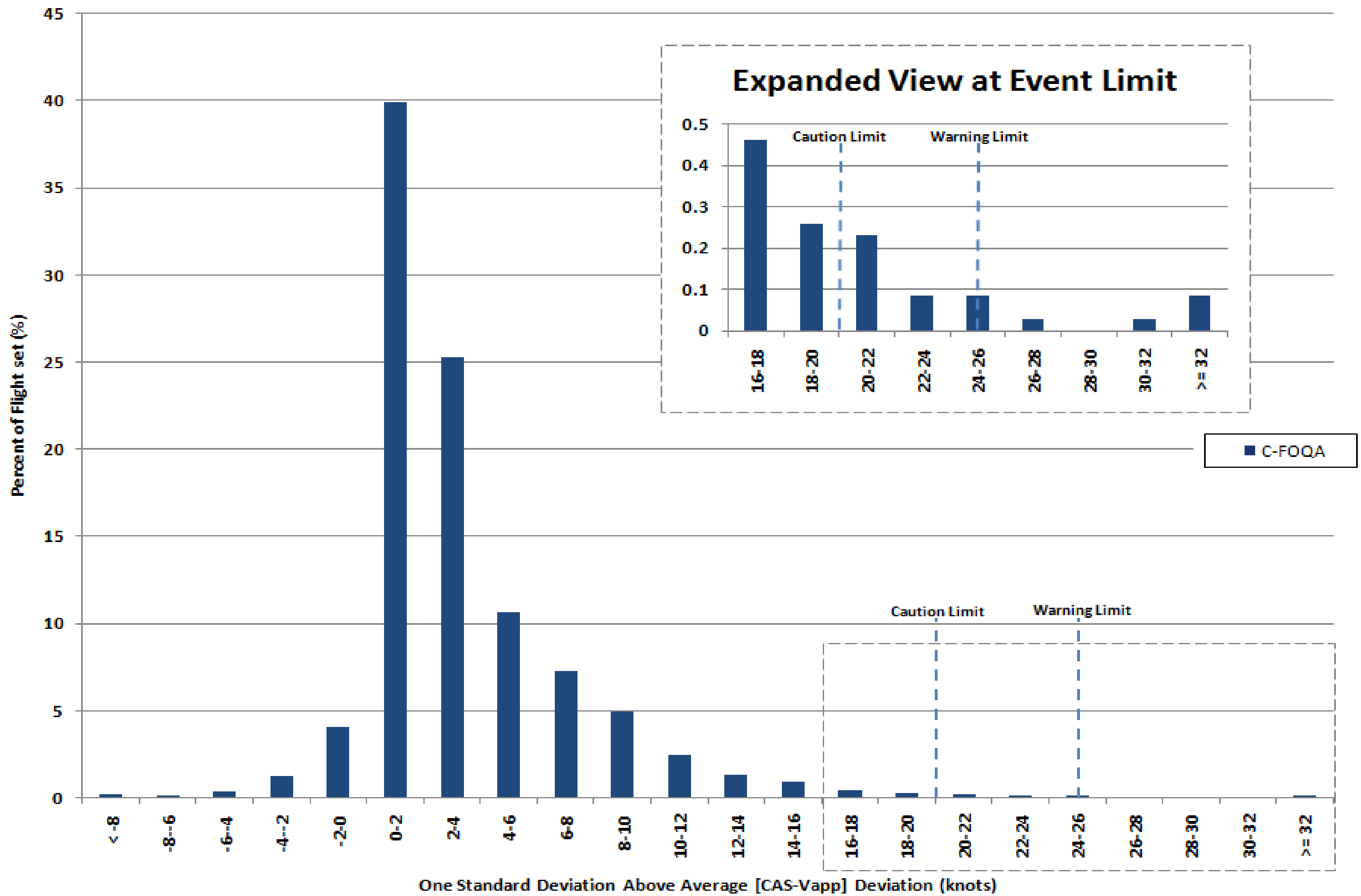
Below Desired Glide Path Distribution (2009)



Not Aligned with Runway Distribution (2009)



Fast Approach [CAS-Vapp] Distribution (2009)



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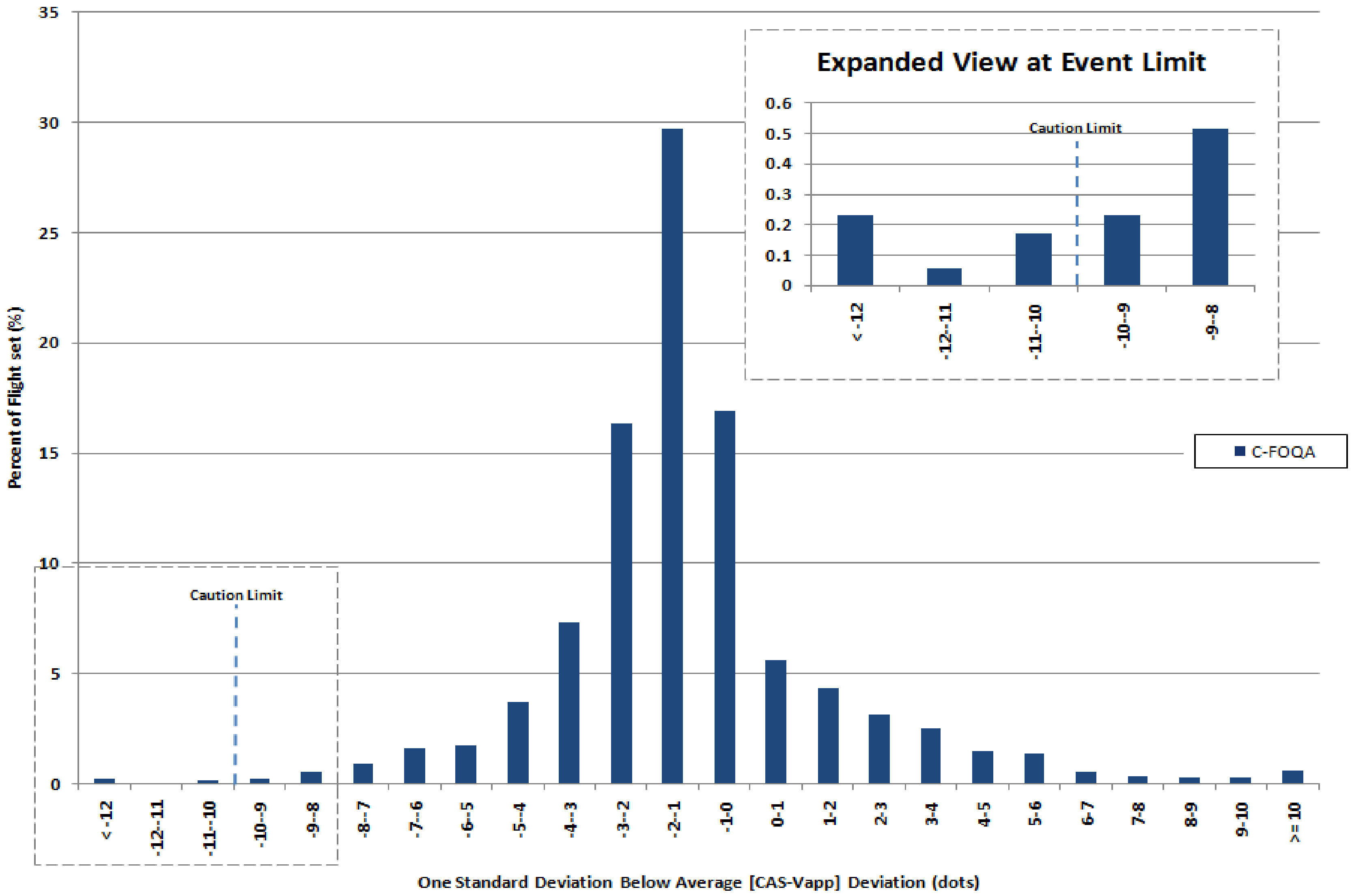
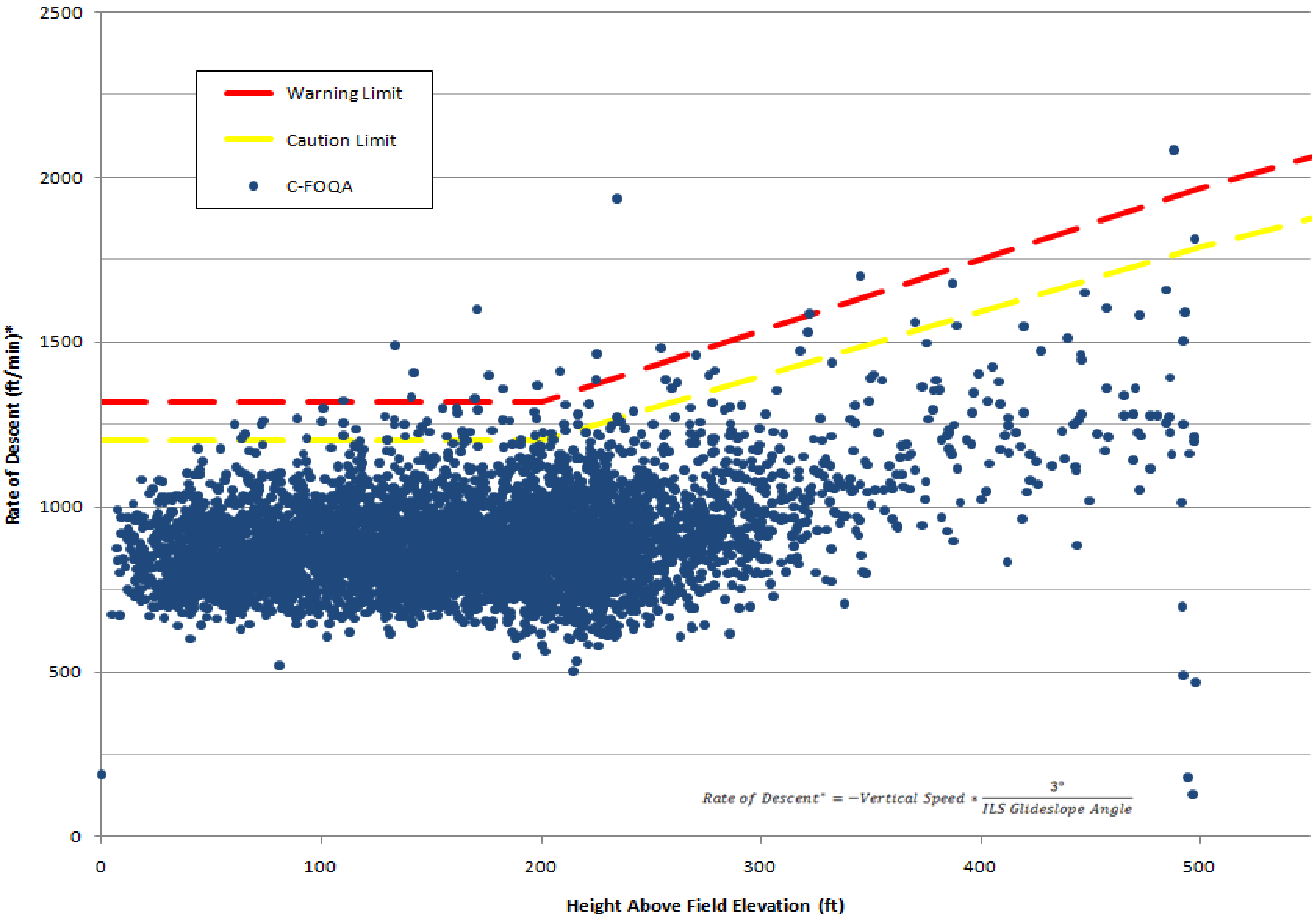
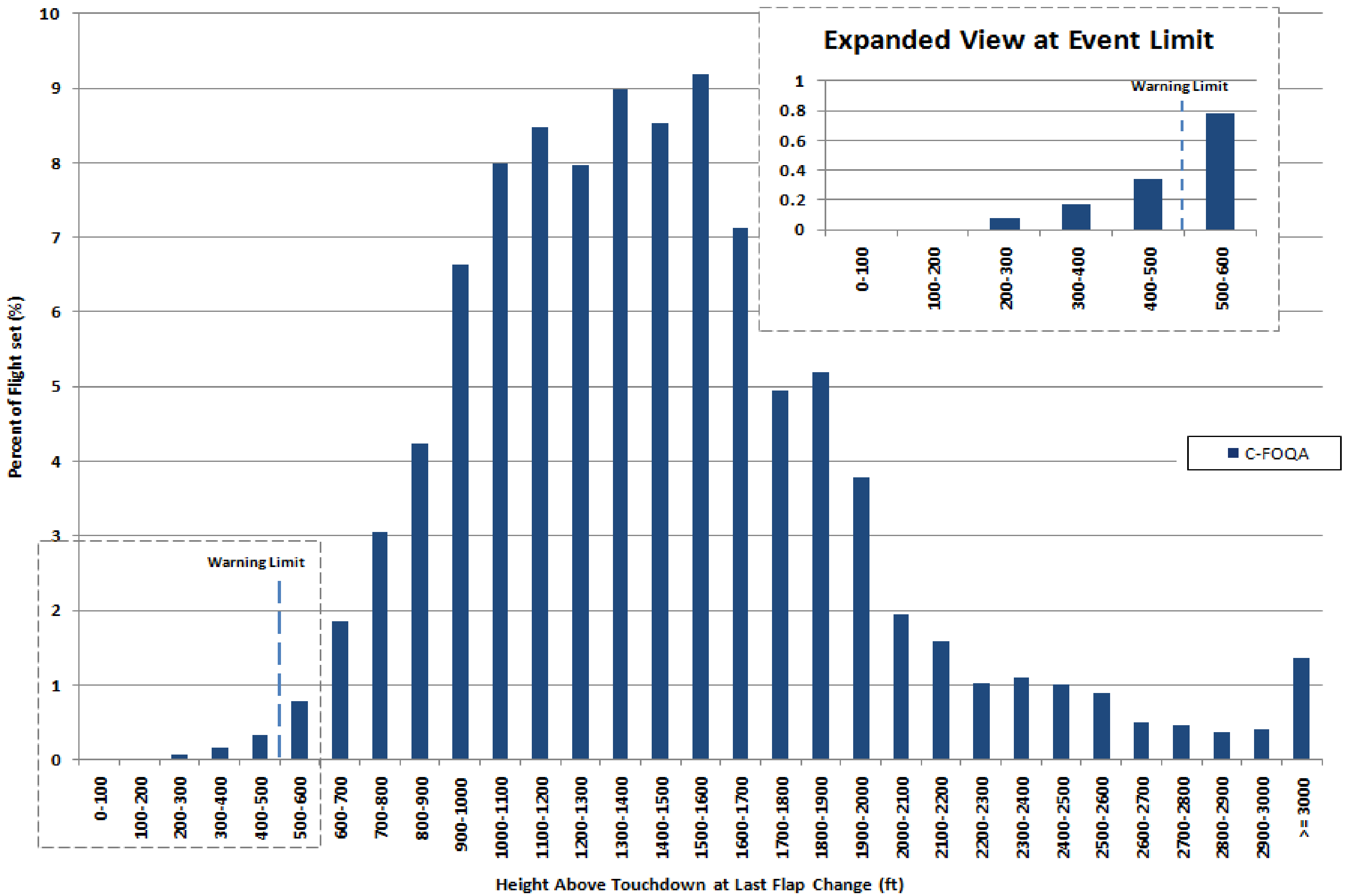
Slow Approach [CAS-Vapp] Distribution (2009)



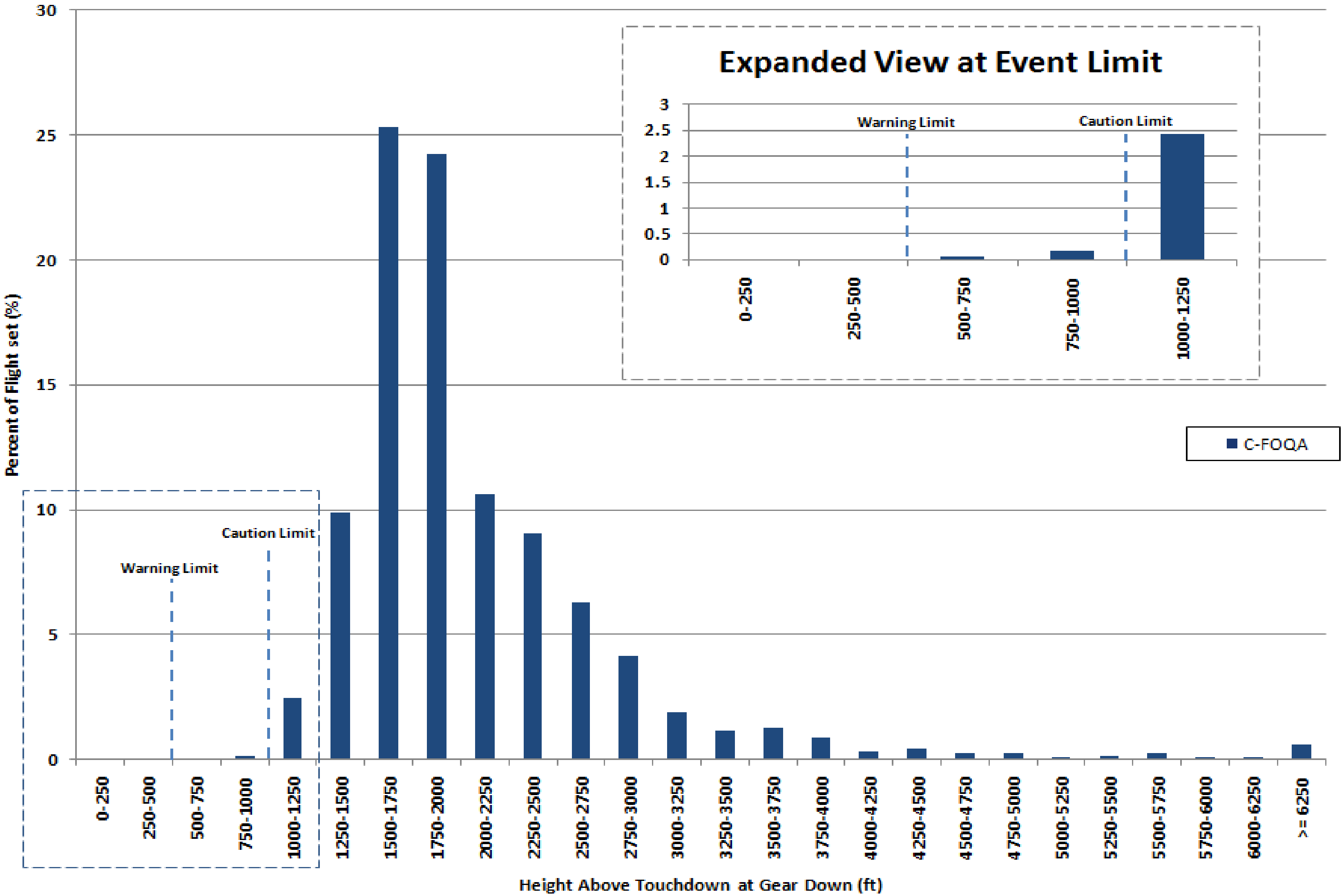
High Rate of Descent Distribution (2009)



Late Flap Extension Distribution (2009)



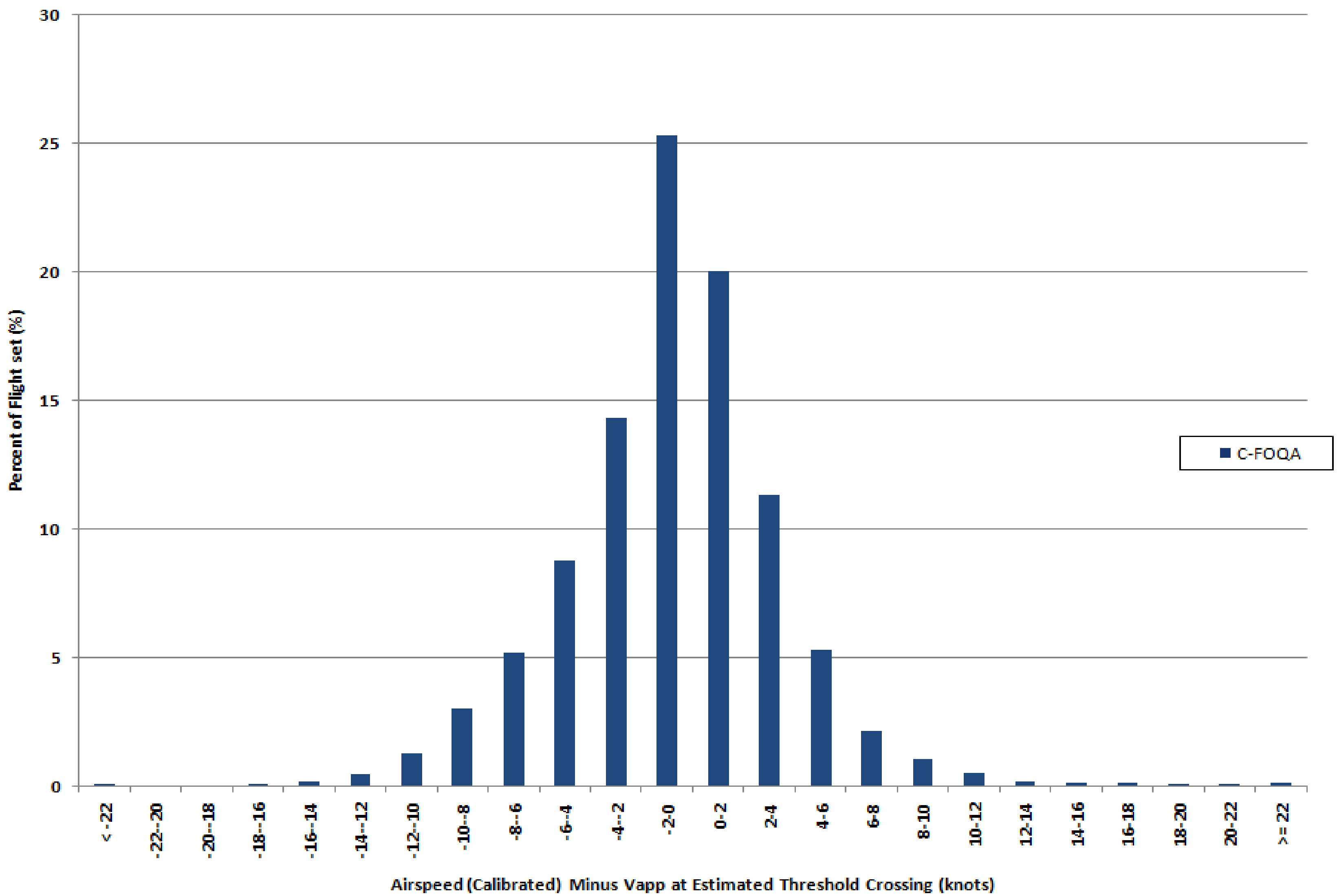
Late Gear Extension Distribution (2009)



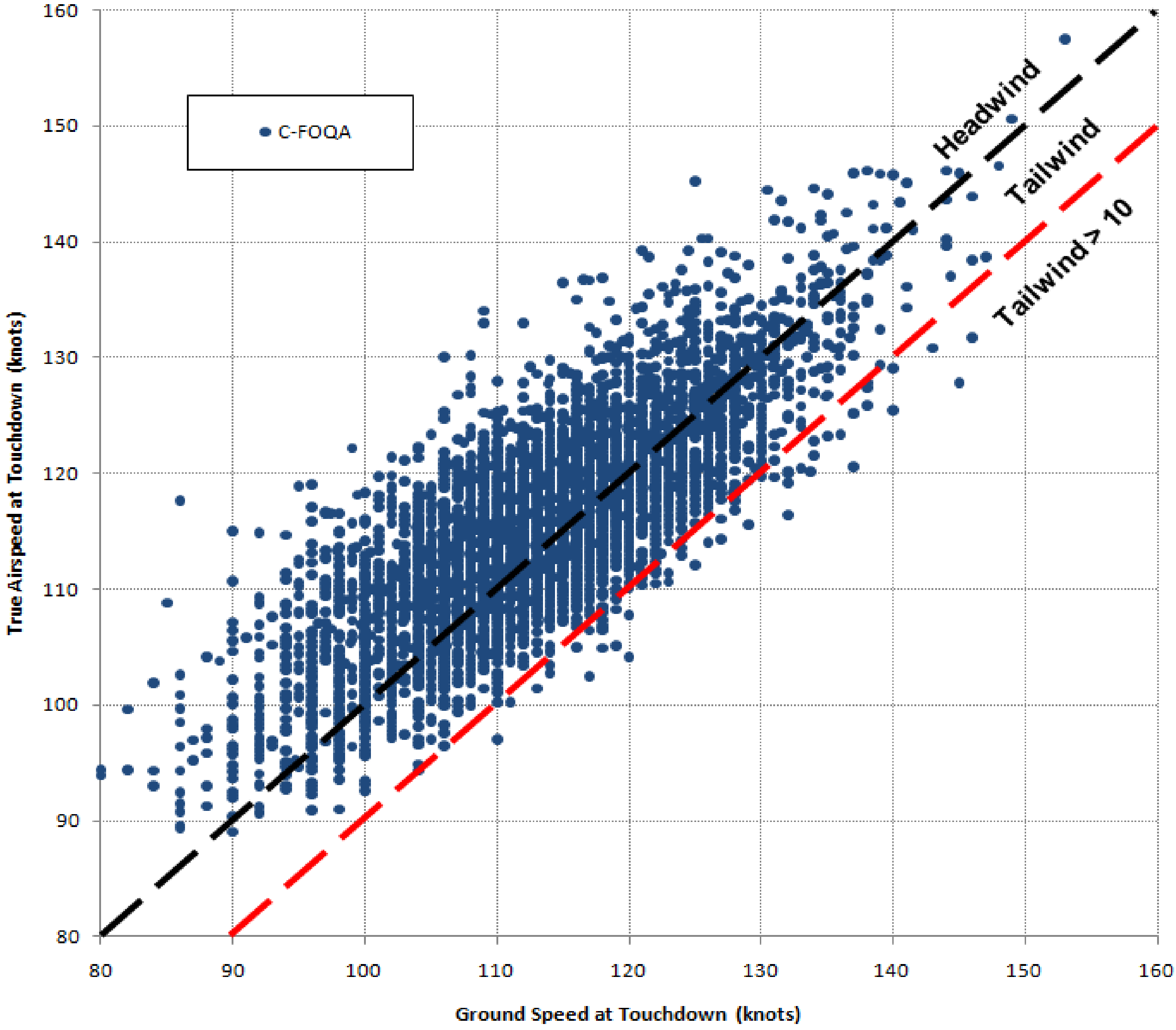
Section III: C-FOQA Landing Performance

C-FOQA participants' landing performance from the combined data-set.

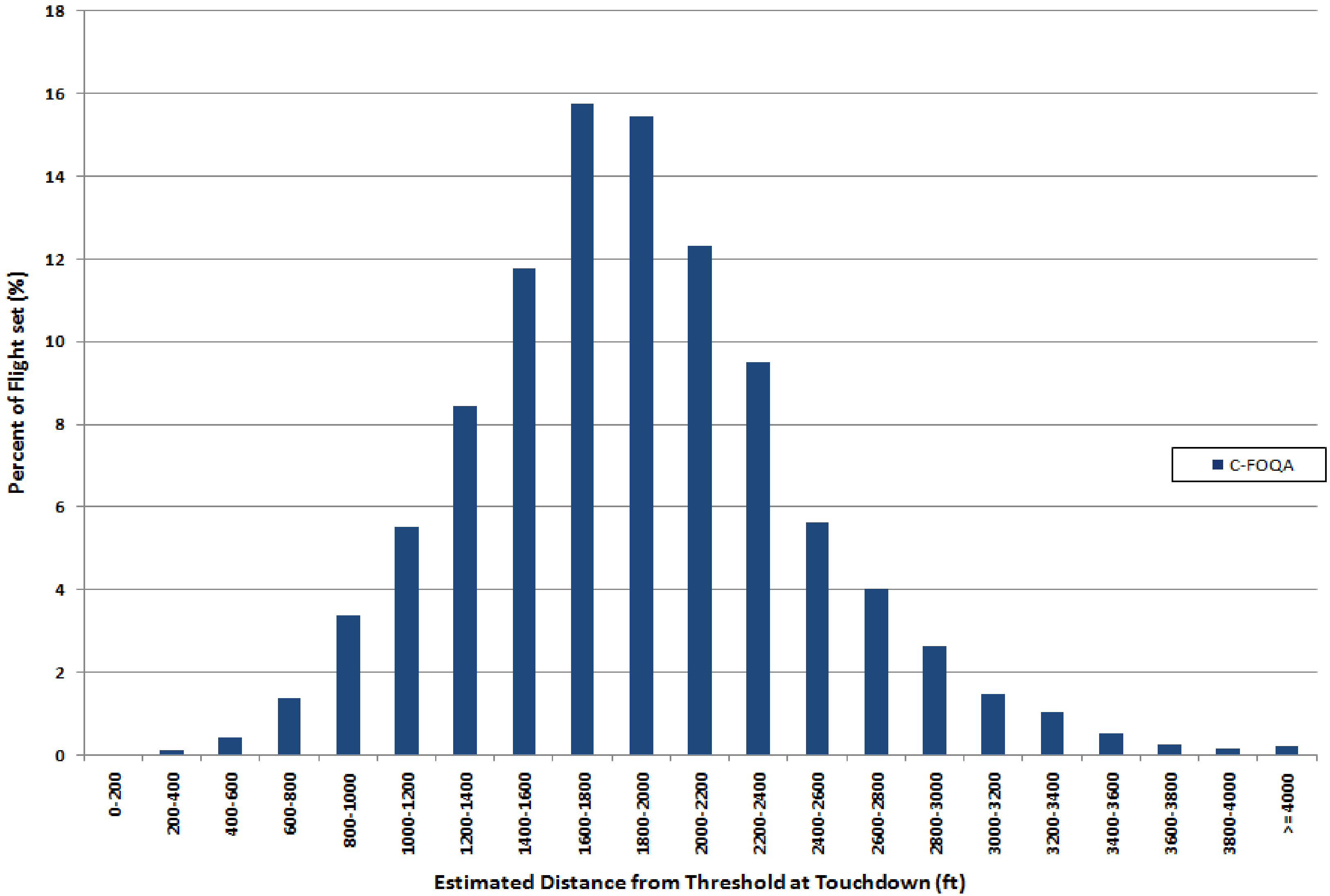
Distribution of (Airspeed – Vapp) at Threshold (2009)



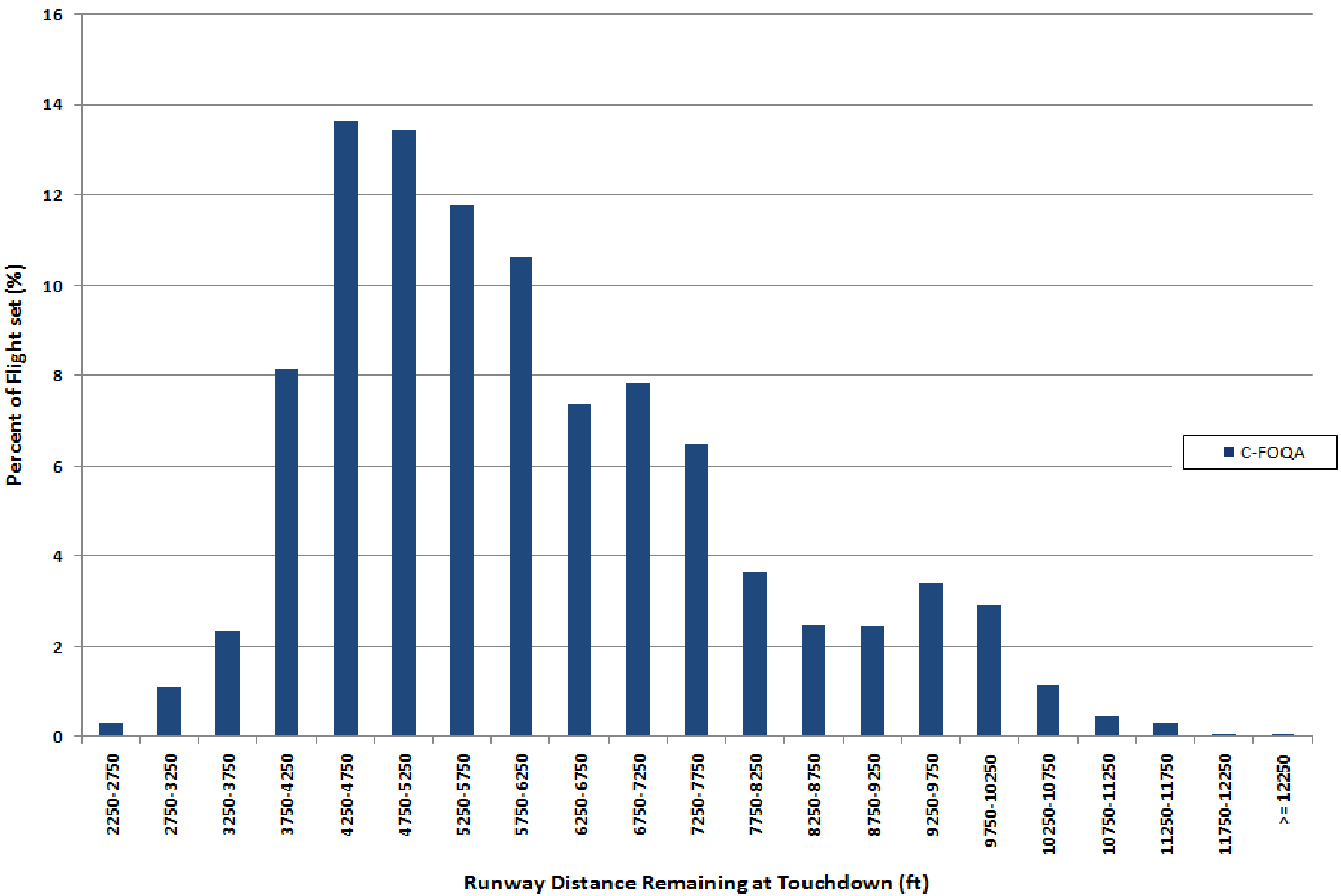
Groundspeed vs. Airspeed at Touchdown (2009)



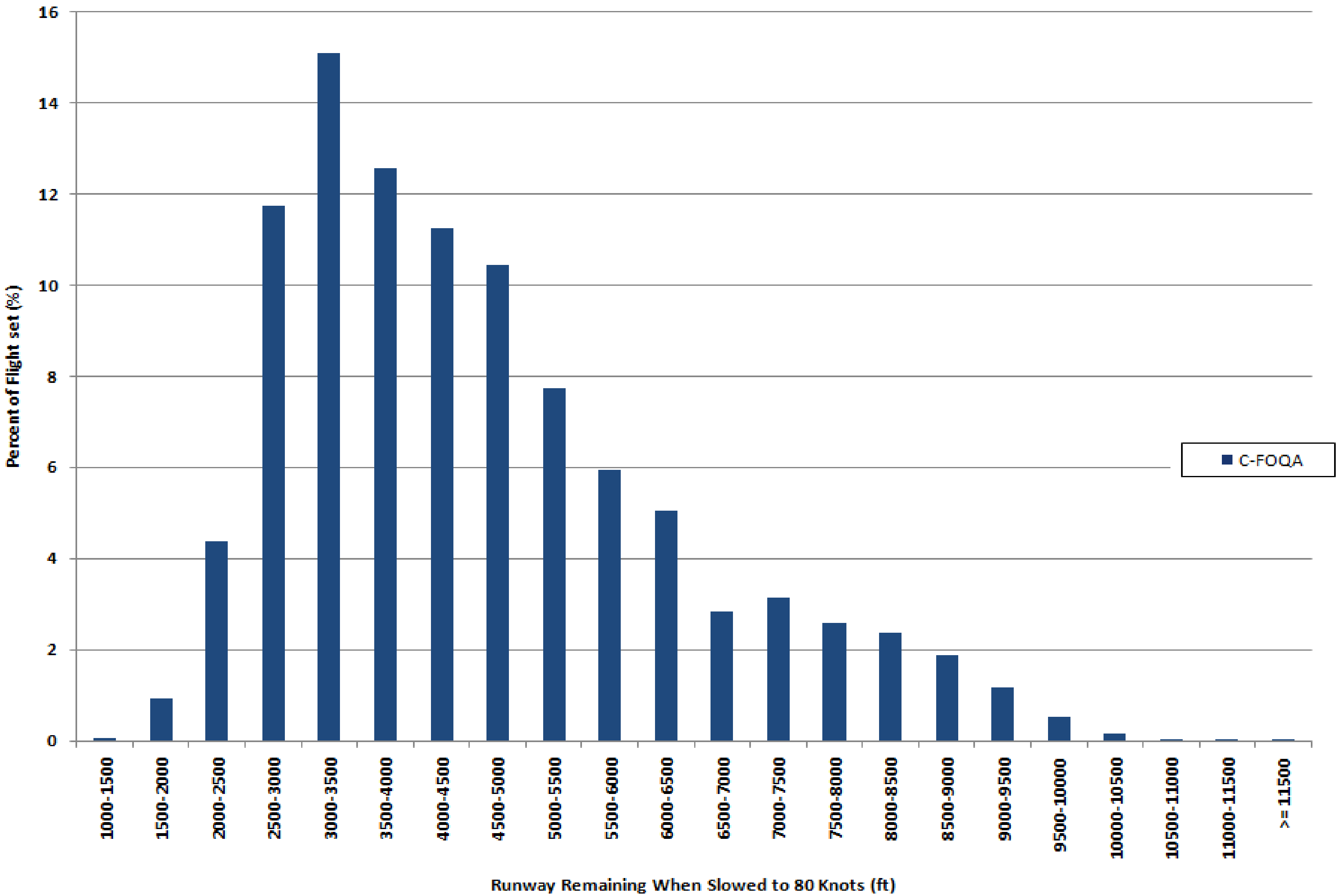
Distribution of Distance from Threshold at Touchdown (2009)



Distribution of Runway Distance Remaining at Touchdown (2009)



Runway Remaining When Slowed to 80 Knots (2009)



Appendix

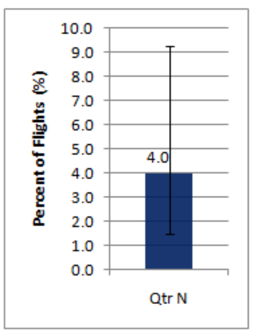
Rate Error Bars Explained

Rate Error Bars (Wilson Confidence Intervals)

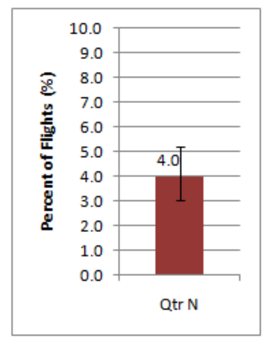
When event rates are calculated we are computing binomial proportion confidence intervals along with the raw proportions. This allows us to confirm whether or not a trend is relevant. Event rates can be thought of as a binomial population in most cases (either the flight does or does not have an event). Unfortunately, this will not work if more than one event per flight is expected.

Imagine there is a bag of 1,000 marbles with 10% red and 90% percent blue. If one were to draw only two marbles out of the bag and then use the results to make an estimation of the bag's true population, then it stands to reason that some estimations will better reflect reality than others. For example, there is an 18% chance of drawing one red and one blue. It would, however, be incorrect to say that the true population in the bag is 50/50 red and blue despite the results of the draw. This small sample sized introduced a sampling bias that should be noted. One way to illustrate this sampling bias when presenting the estimate of the true population is with error bars.

The same goes for estimating populations of flights and this report will use Rate Error Bars (calculated with the Wilson Confidence Interval) to indicate instances of possible sampling bias. The two examples below will help to explain how to interpret these Rate Error Bars.



For this example, there are 4 events in 100 flights (4.0%), however, due to the large sample bias, we can only say with 90% confidence that the 'true' rate is between 1.5% and 9.3%.



For this example, there are 40 events in 1000 flights (still 4.0%), however, because the sample population has been dramatically increased, we can say with 90% confidence that the 'true' rate is between 3.1% and 5.2%.

It is expected the Rate Error Bars will decrease over time as the C-FOQA program matures and the sample size increases.

The calculation for determining the location of the error bars is below:

$$\frac{(E \pm 0.5) + \frac{Z^2}{2} \pm Z\sqrt{\frac{(E \pm 0.5)}{N} * \left(N - (E \pm 0.5)\right) + \frac{Z^2}{4}}}{N + Z^2}$$

where 'E' is the number of Events, 'N' is the reference flights, and 'Z' is the score. For all C-FOQA calculations 90% confidence is used, resulting in a score of 1.645.

Unstable Approach Events
C-FOQA Standard Event Limits

Unstable Approach Events	Phase of Flight	Measurement Criteria		C-FOQA SEL		units
Runway Alignment				**Caution**	**Warning**	**-**
1) Above Desired Glide Path	500 ft HAT - 200 ft AGL	One Standard Deviation above Average Glideslope	>	2	-	dots
2) Below Desired Glide Path	500 ft HAT - 200 ft AGL	One Standard Deviation below Average Glideslope	<	-1.3	-3	dots
3) Not Aligned with Runway (Localizer)	500 ft HAT - TD	One Standard Deviation outside Average Localizer	>	1	-	dots
Airspeed						
4) Fast Approach (Airspeed vs. Vapp)	500 ft HAT - 50 ft AGL	One Standard Deviation above Avg (Airspeed - Vapp)	>	20	25	knots
7) Slow Approach (Airspeed vs. Vapp)	500 ft HAT - 50 ft AGL	One Standard Deviation below Avg (Airspeed - Vapp)	<	-10	-	knots
Rate of Descent (ROD)						
9) High Rate of Descent	500 ft HAT - TD	ROD ÷ ROD Limit*	>	0	10	%
Configuration						
11) Final Flap Change is Late	Descent & Approach	HAT at Last Flap Change	<	-	500	feet
12) Final Flaps Not Valid for Landing	Descent & Approach	Final Flap Setting	<	Landing Flaps	-	degrees
13) Gear Extension is Late	Descent & Approach	HAT at Gear Extension	<	1000	500	feet
Aircraft Body Rates						
14) Unsteady in Pitch	500 ft HAT - 100 ft AGL	Standard Deviation of Pitch Rate	>	1.5	-	deg/sec
15) Unsteady in Roll	500 ft HAT - 50 ft AGL	Standard Deviation of Roll Rate	>	4	-	deg/sec
16) Unsteady in Yaw	500 ft HAT - 100 ft AGL	Standard Deviation of Yaw Rate	>	3	-	deg/sec

*Rate of Descent Limit Changes with Altitude and Glide Path Angle and has a Lower Limit of 1200 ft/min

Comparisons Against the Mean vs. the Mean ± One Standard Deviation

In event-based testing, two kinds of errors are possible:

1) Missed Detection: An event is not triggered and the event actually occurred.
2) False Positive Alarms: An event is triggered and the event actually did not occur.

The design of an event hypothesis trigger represents a trade-off between Missed Detections and False Positive Alarms. Event triggers are often defined by looking at a set of measurement samples accumulated during an interval of interest and requiring a function of these samples to exceed an established limit. Since individual samples can be prone to data error, it is beneficial to evaluate multiple samples in order to minimize False Positive Alarms. Specifically, when it is determined that a sufficient number of valid recorded samples exceed an established limit, then an event can be reliably triggered.

•50% Exceedance Method: Comparisons Against the Mean

A common approach is to compare the MEAN, μ, of a measured distribution against a fixed limit. In this case, an event would be triggered when 50% of the samples exceed the limit. With a significantly large sample set, requiring an event to have 50% of its samples exceeding the limit can significantly reduce False Positive rates due to random or periodic data error. However, a drawback of this approach is that when 49% of the samples (or less) exceed the limit, then an event will not be generated. For this reason, usage of the MEAN as an event hypothesis trigger can lead to events which are prone to Missed Detections.

•16% Exceedance Method: Comparisons Against the Mean ± 1 Std Dev (μ ± 1σ)

Another approach is to design an event which would trigger when more than 16% of the total recorded samples exceed the established limit. It has been determined that this approach is less prone to Missed Detections and yet still requires a sufficient number of samples exceeding the limit that False Positive rates are low. Assuming that the sampled data set has Gaussian properties, the usage of the MEAN + 1 STD DEV (for upper limit events) and the MEAN - 1 STD DEV (for lower limit events) can be used to identify the limiting value separating the outlying 15.8% from the rest of the samples. For this reason, defining event triggers based on the MEAN ± 1 STD DEV is referred to as the 16% Exceedance Method.