Required accuracy on measurement of speed, fuel consumption and power for 1% accuracy of estimation on performance

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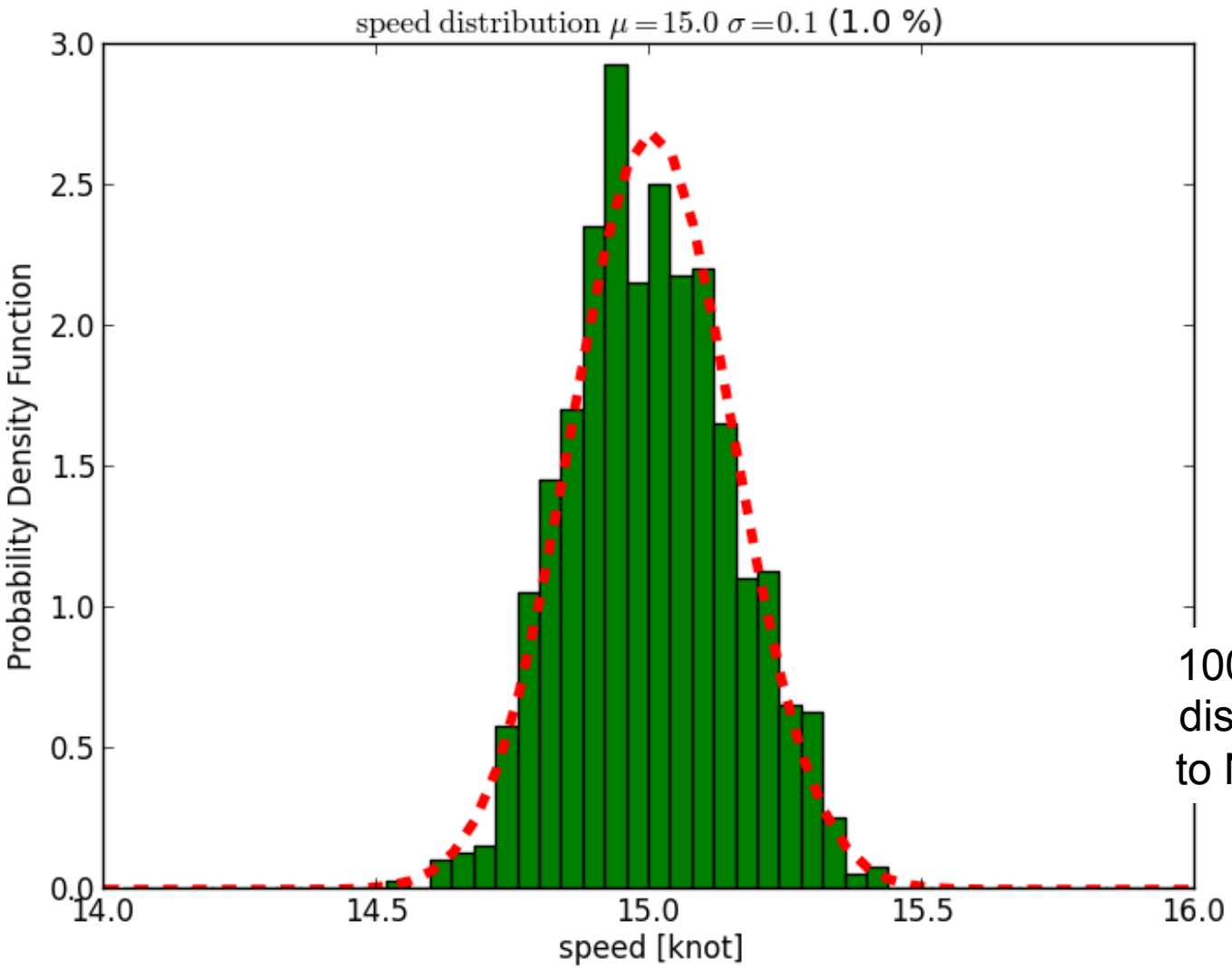
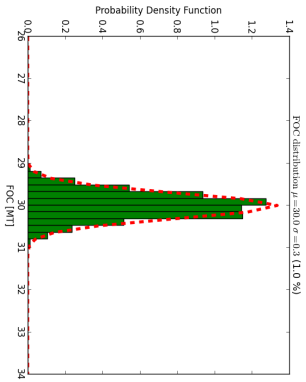
an emerge of 1% accuracy of measurement

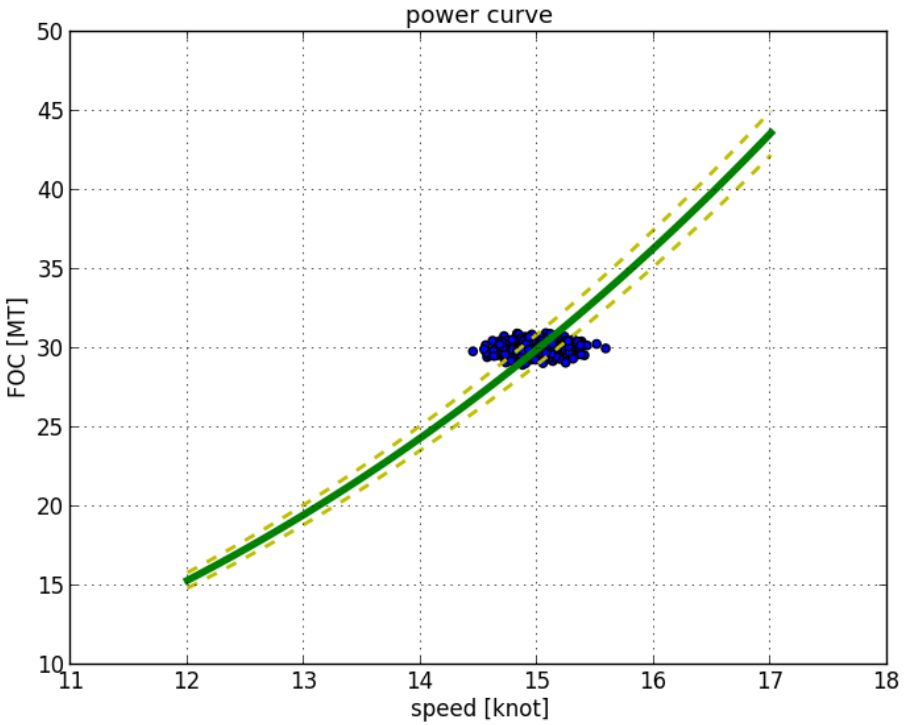
- For example, for measurement of speed of 15.0 knot, measurement results may scatter as figure below.



1000 random number distribution according to Normal Distribution

What happens under 1% accuracy of measurement in both speed and fuel consumption?

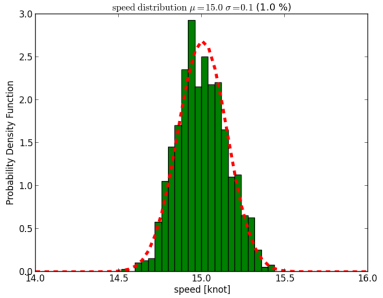




Total accuracy
will be 3.2 %.

1000 simulations by
Monte Carlo method

Average 30 ton
of fuel at accuracy
σ 1%



Average 15 knot
Of speed at accuracy
σ 1%

Total accuracy under various accuracy of measurement of speed and fuel consumption

1000 simulations by Monte Carlo method

Accuracy at measurement of speed

accuracy at measurement of fuel consumption	0.1%	0.2%	0.3%	0.4%	0.5%	0.6%	0.7%	0.8%	0.9%	1.0%
0.1%	0.32	0.61	0.91	1.20	1.50	1.80	2.10	2.40	2.70	3.00
0.2%	0.36	0.63	0.92	1.22	1.51	1.81	2.11	2.41	2.71	3.01
0.3%	0.42	0.67	0.95	1.24	1.53	1.82	2.12	2.42	2.72	3.01
0.4%	0.50	0.72	**0.99**	1.26	1.55	1.84	2.14	2.43	2.73	3.02
0.5%	0.58	0.78	1.03	1.30	1.58	1.87	2.16	2.45	2.75	3.04
0.6%	0.67	0.85	1.08	1.34	1.61	1.89	2.18	2.47	2.76	3.06
0.7%	0.76	0.92	1.14	1.39	1.66	1.93	2.21	2.50	2.79	3.08
0.8%	0.85	**1.00**	1.20	1.44	1.70	1.97	2.25	2.53	2.82	3.10
0.9%	**0.95**	1.08	1.27	1.50	1.75	2.01	2.28	2.56	2.85	3.13
1.0%	1.04	1.17	1.35	1.56	1.80	2.06	2.33	2.60	2.88	3.16

Accuracy of estimation

Blue 1.0% or less

Yellow 1.0% ～2.0%

Orange 2.0% ～3.0%

Red more than 3.0%

In order to obtain total 1% accuracy for estimation of performance, it is necessary to have 0.3% accuracy on measurement of speed and 0.4% accuracy on measurement of fuel consumption.

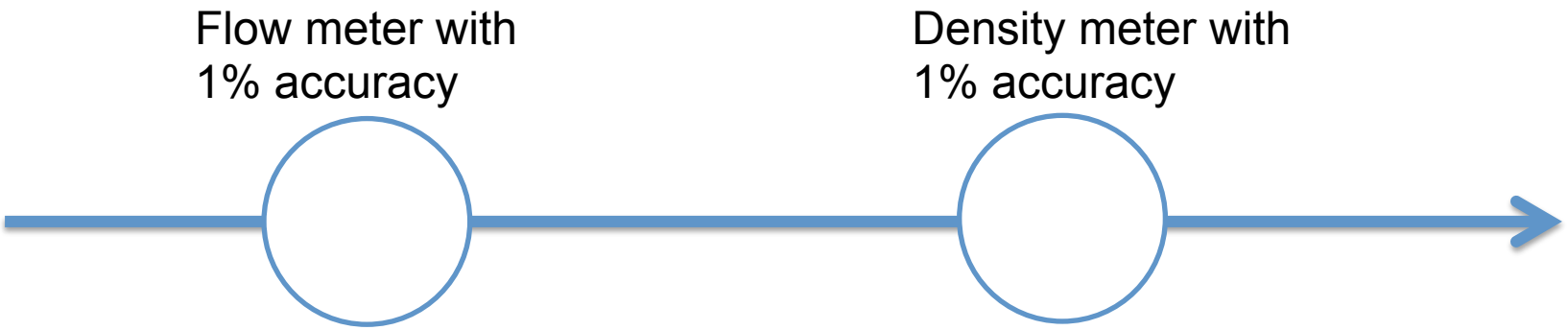
Error of speed measurement is usually greater than error of fuel measurement. Therefore, error of speed measurement influences greatly.

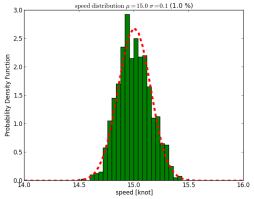
Fuel consumption Y is function of X^3, then

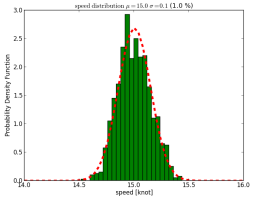
$Y = aX^3$, $(Y+ \Delta Y) / Y - 1 = (X + \Delta X)^3 / X^3 \fallingdotseq 3 \Delta X / X$,

Therefore, error of X acts three times bigger than error of Y.

What happens on calculation of fuel consumption under 1% accuracy of measurement of fuel flow rate and fuel density?







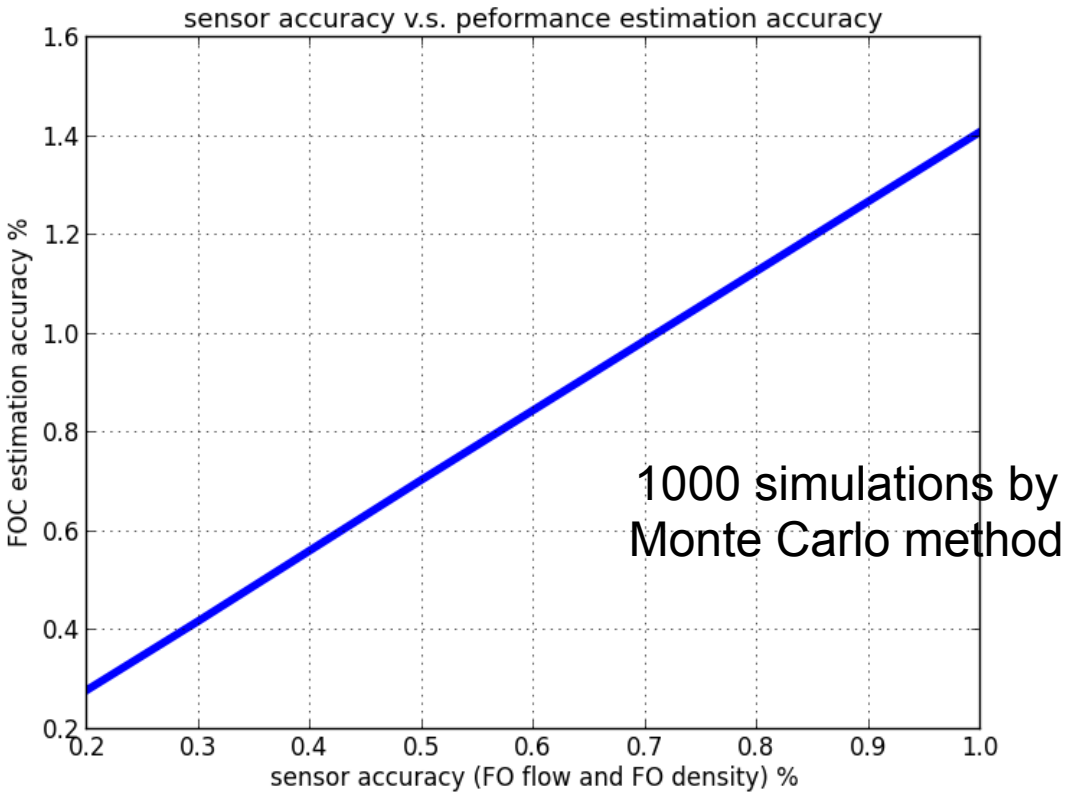
1000 simulations by Monte Carlo method

Fuel consumption = flow rate x density

1% accuracy of fuel flow rate and density measurement results in 1.4% accuracy of fuel consumption calculation.

What happens on calculation of fuel consumption under various accuracy of measurement of fuel flow rate and fuel density?

Accuracy		
Fuel flow	density	Fuel consumption
1.0%	1.0%	1.41 %
0.7 %	0.7 %	0.99 %
0.5 %	0.5 %	0.71 %
0.2 %	0.2 %	0.28 %



In order to obtain 0.4% accuracy of calculation of fuel consumption, it is necessary to measure fuel flow rate and fuel density in 0.2% accuracy.

Conclusion

- Goal: 1% accuracy on estimation of performance
- Necessary accuracy of each measurement requires as follow:

sensor	Required accuracy
Doppler log	0.3 %
Power meter or fuel consumption	0.4 %
Fuel flow meter	0.2 %
Fuel density meter	0.2 %