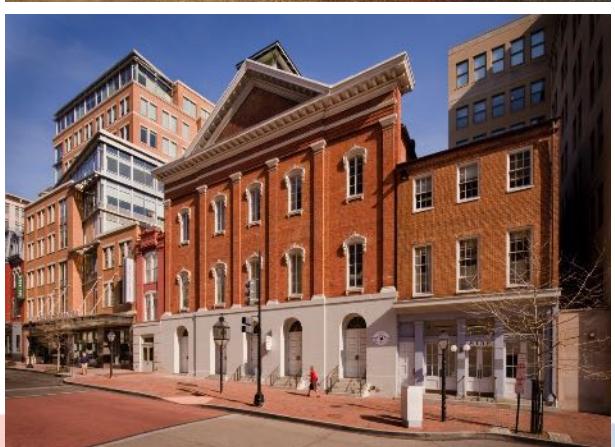
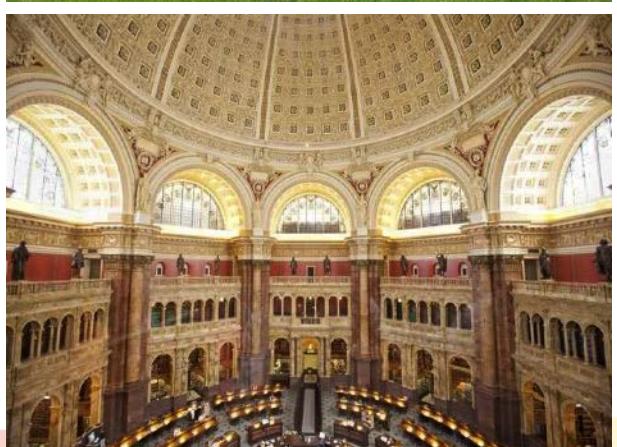


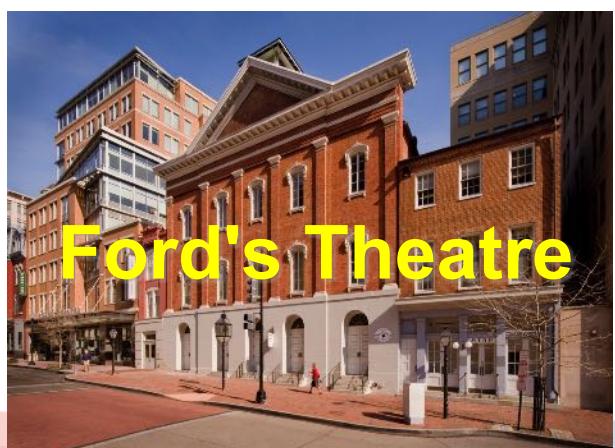
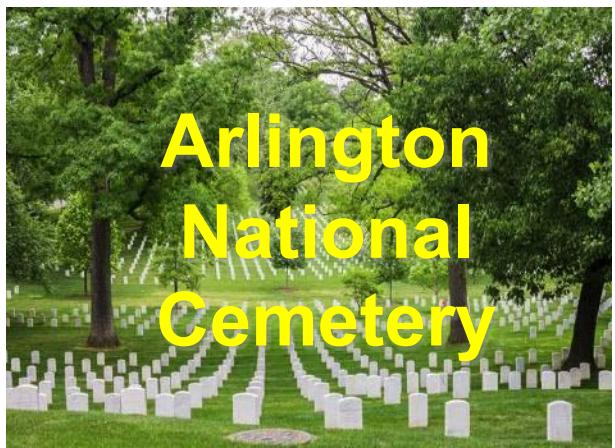
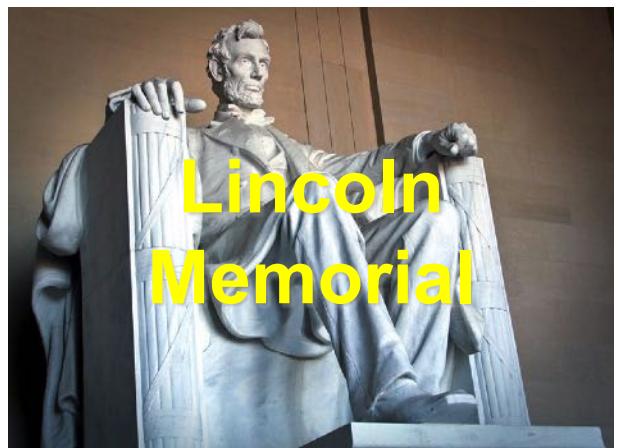


28th Annual **INCOSE**
international symposium

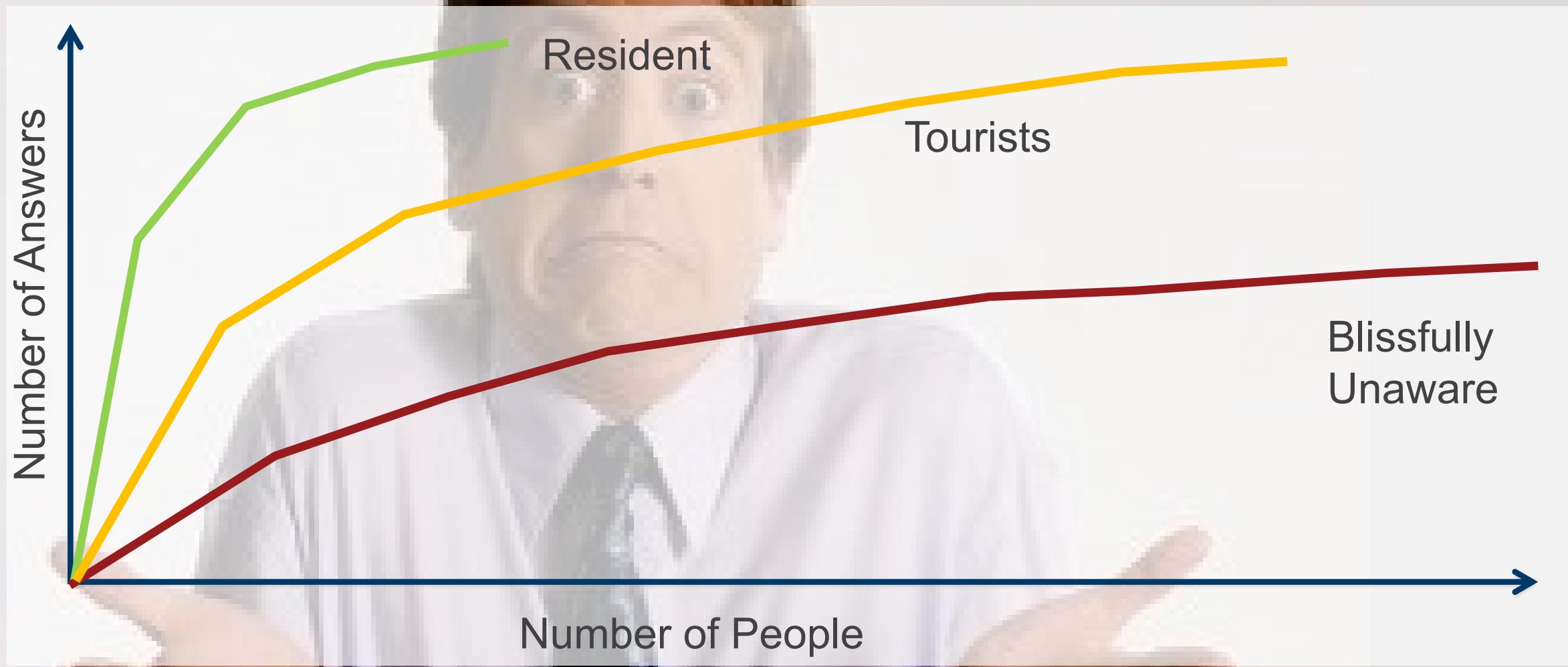
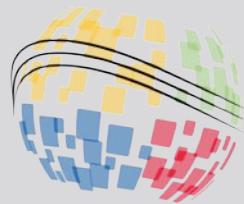
Washington, DC, USA
July 7 - 12, 2018

How Many Systems Engineers Does it Take to Change a Light Bulb?





How Many Systems Engineers?

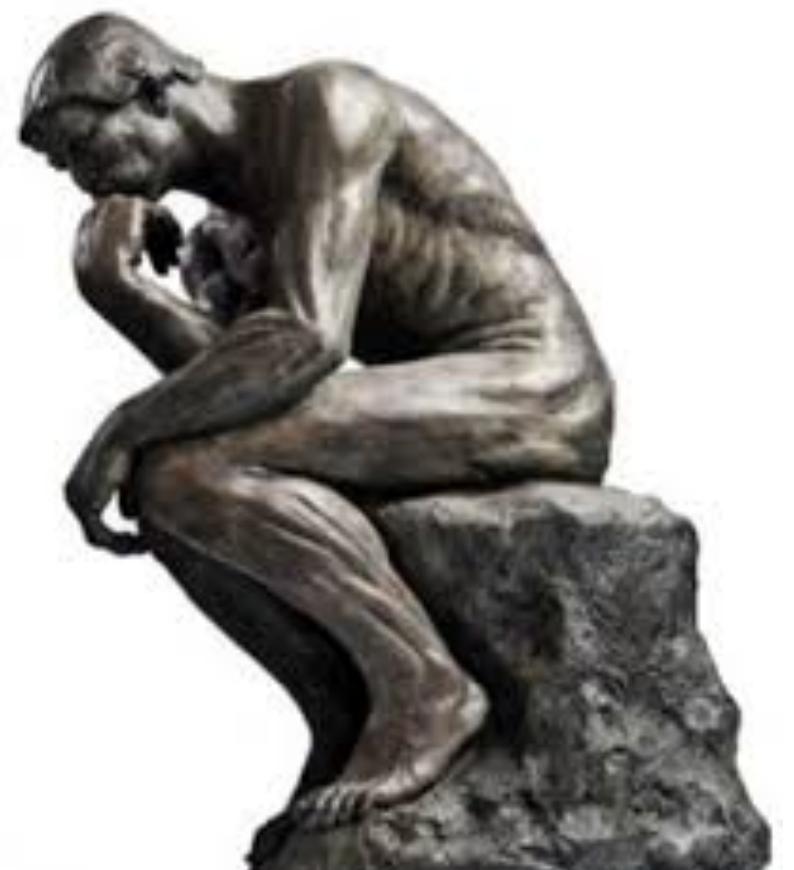




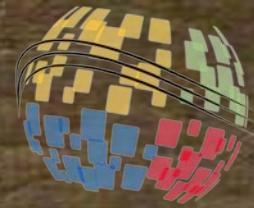
Do you use Judgement?

- Decision Making
- Brain storming
- Risk identification and classification
- Project planning and defining schedules
- Independent review
- Benefits estimation
- Concept exploration and definition
- Problem Solving
- Requirements capture & definition
- Design and development
- Verification & Validation
- Systems Engineering

* Any activity or role that is dependent on capability and experience



Sir Francis Galton (1822 – 1911) was an English Victorian statistician



A painting of a large ox standing in a field, facing left. A man in 19th-century clothing stands to the right, holding a long staff or stick. The background shows a landscape with trees and a cloudy sky.

At a 1906 country fair in Plymouth, 800 people participated in a contest to estimate the weight of an Ox. The median guess, was accurate within 1% of the true weight.



Wisdom Of Crowds works when there is:

- **Diversity of opinion.** People have a range of different opinions.
- **Independence:** People's opinions aren't determined by the opinions of others.
- **Aggregation:** Some mechanism exists for combining the results – we use Median.

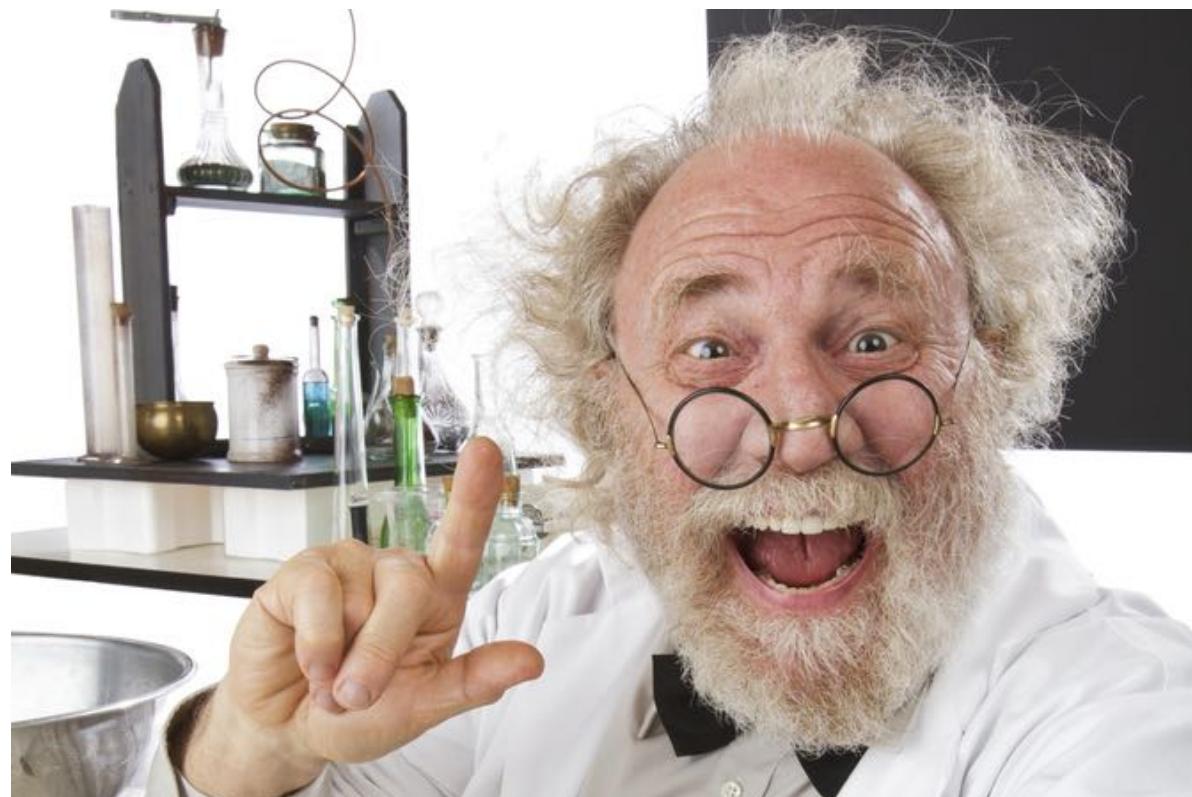




The Experiment

80 questions prepared that people could answer. We received 3760 guesses.

For each guess we wanted the person's **Confidence** in their own guess in the range 0 (no confidence) to 100 (certainty)





How many people live in the United Kingdom?

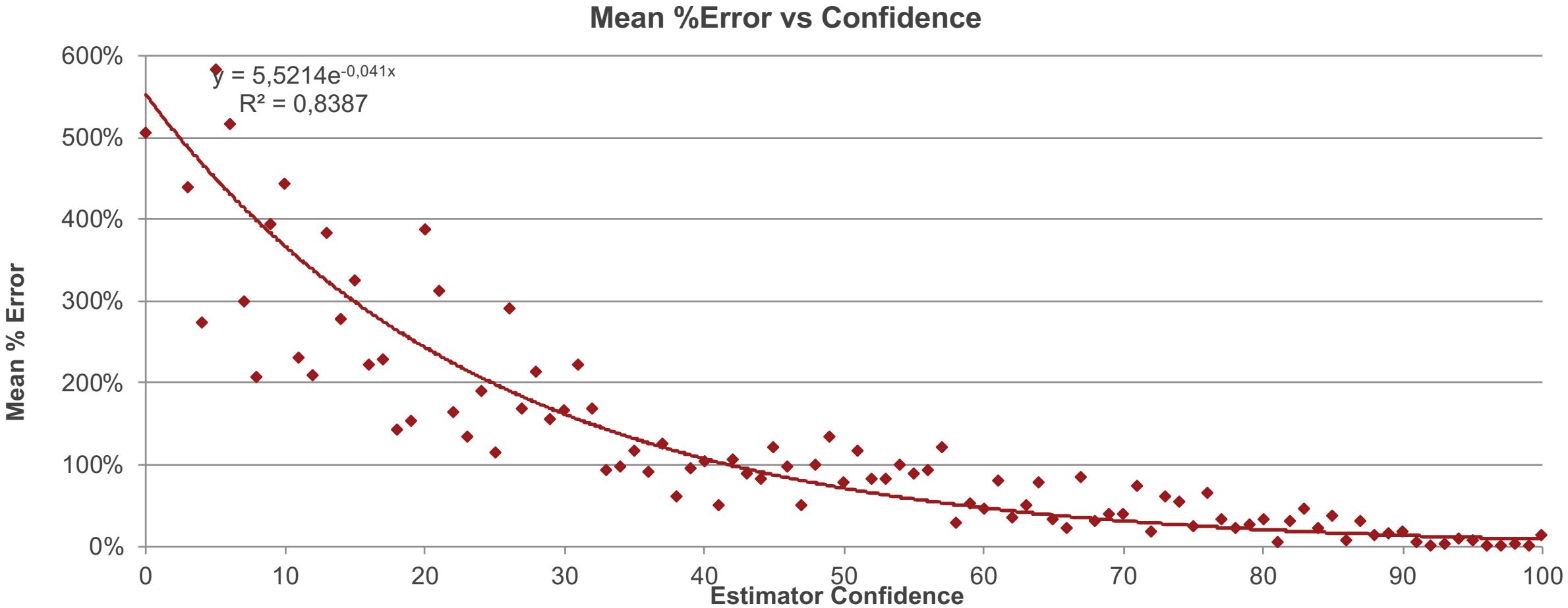
Actual answer 65 million

Median = 65 million (268 guesses with an average confidence = 68%)

Individual guesses between 7 million and 5 billion!



There is a correlation between %Error & Confidence





70% of people under estimate



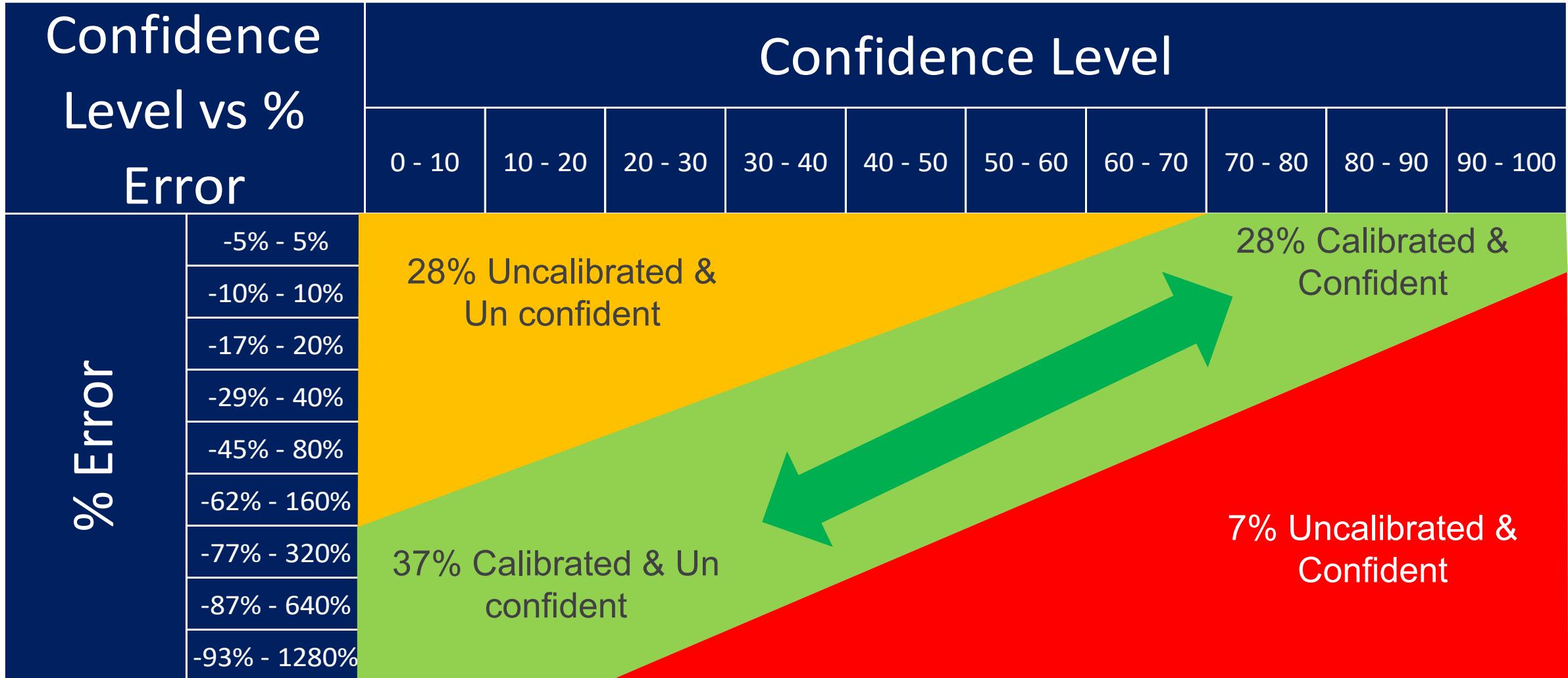


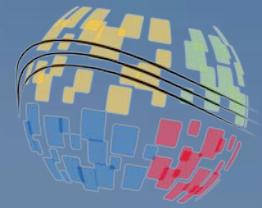
Calibration

Confidence Level vs % Error		Confidence Level									
		0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 100
% Error	-5% - 5%	20	19	31	27	41	59	54	93	86	116
	-10% - 10%	27	27	24	36	40	53	42	51	45	38
	-17% - 20%	49	30	39	40	48	67	39	37	18	11
	-29% - 40%	77	72	55	68	74	69	51	40	15	3
	-45% - 80%	114	88	56	59	70	70	32	24	7	4
	-62% - 160%	124	95	74	77	62	52	21	19	4	2
	-77% - 320%	140	93	70	39	35	44	17	15	6	2
	-87% - 640%	117	51	41	25	13	16	3	3	3	1
	-93% - 1280%	65	37	11	10	6	5	2	3	2	0



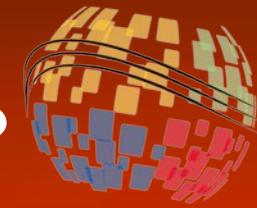
Calibration





Accuracy =
Confidence × Calibration

In meters, how tall is the tallest pyramid of Giza (Egypt)?



Actual Answer is 139m

Median = 140 (61 responses with an average confidence of 49%)

Guesses between 7m and 20,000m

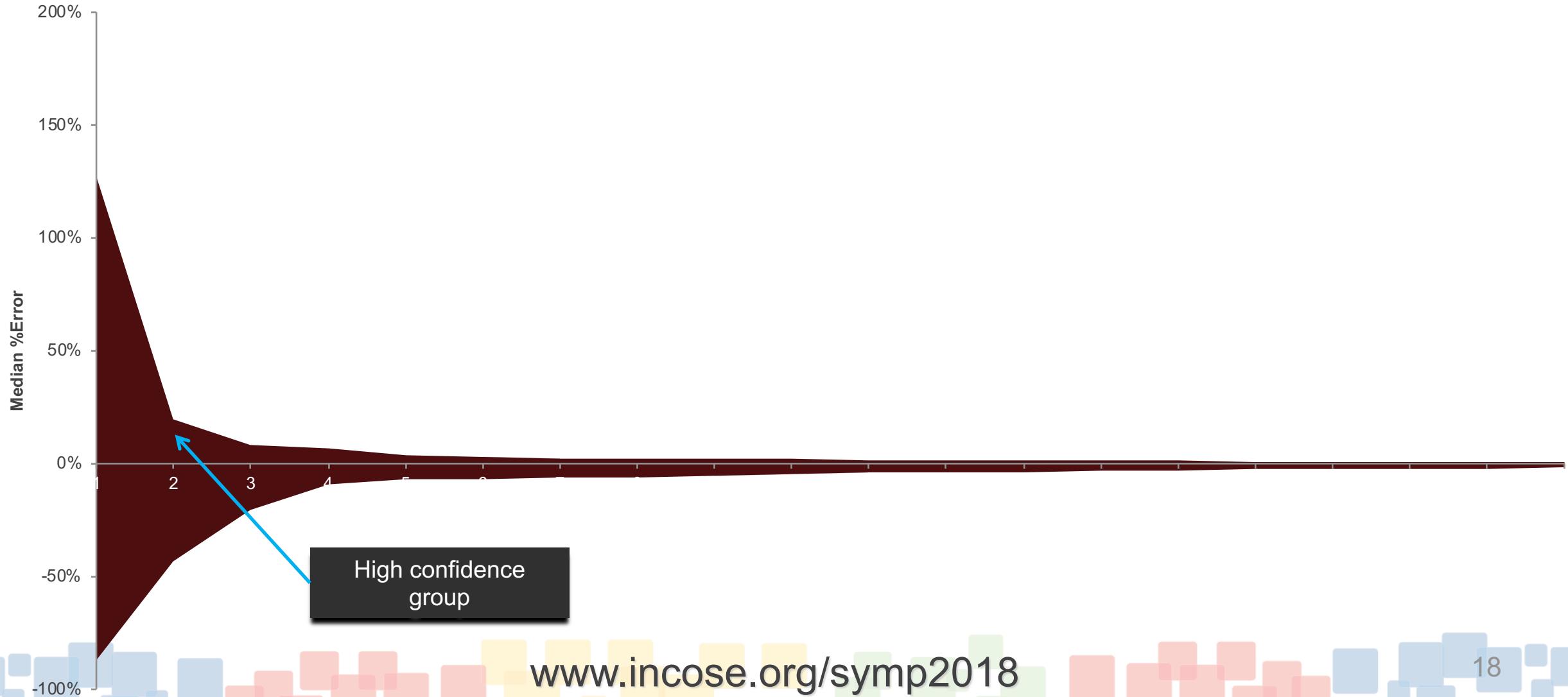


The first person
into space was
an Egyptian!



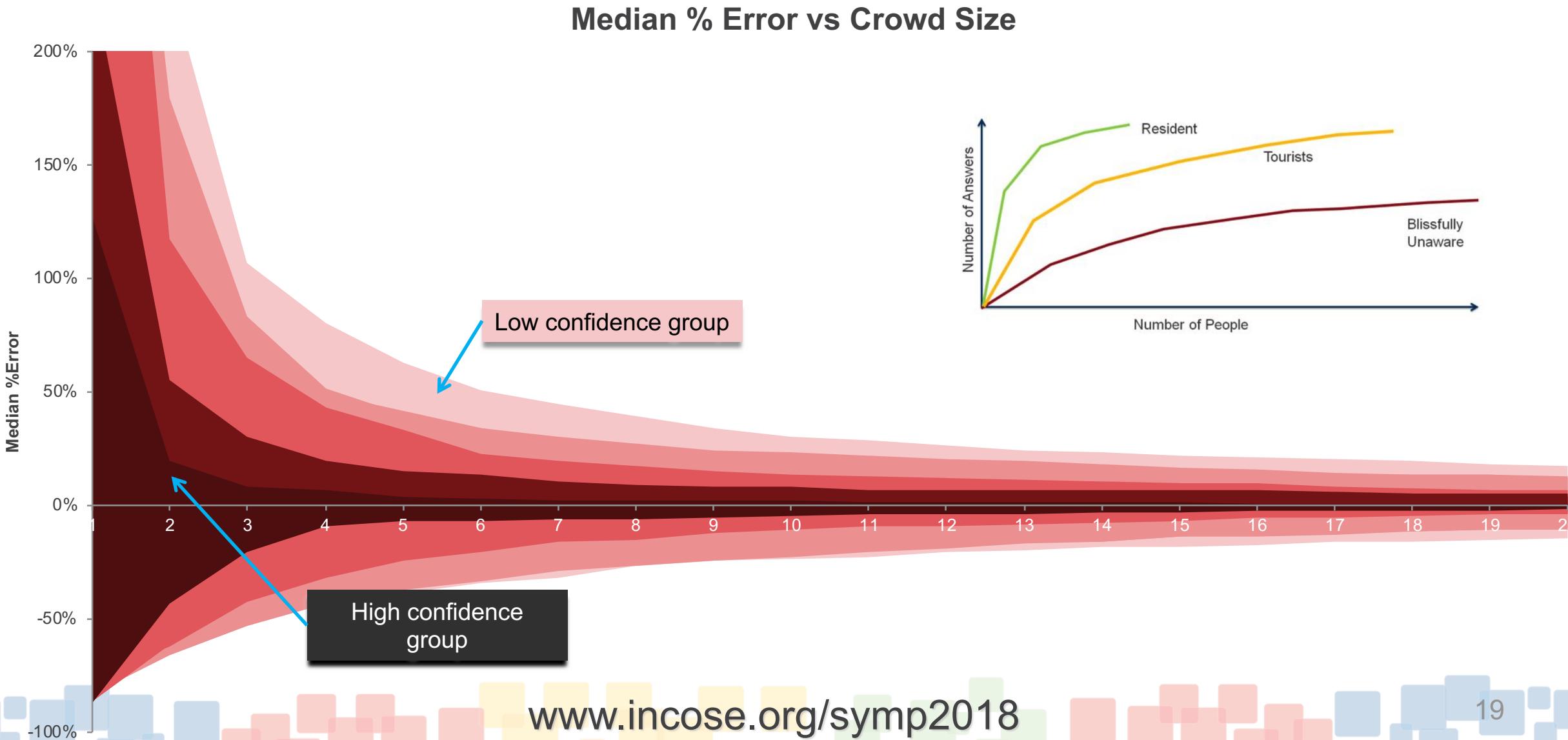
Accuracy improves with crowd size

Median % Error vs Crowd Size





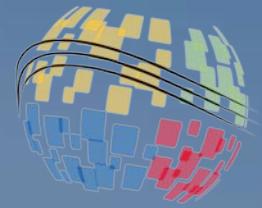
Accuracy improves with crowd size



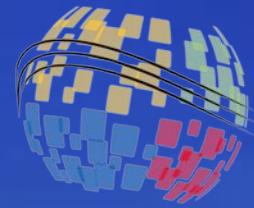


Crowd size as a function of confidence & desired ERL

Estimator Confidence Level	Median	Required Estimate Precision / ERL								
		-93% - 1280%	-87% - 640%	-77% - 320%	-62% - 160%	-45% - 80%	-29% - 40%	-17% - 20%	-9% - 10%	-5% - 5%
	100	1	1	1	1	2	3	4	5	5
	90 - 100	1	1	1	2	3	3	4	5	12
	80 - 90	1	1	2	3	5	5	7	11	41
	70 - 80	1	2	2	4	6	10	17	40	185
	60 - 70	1	2	2	4	8	16	41	117	x
	50 - 60	1	2	3	6	14	30	101	x	x
	40 - 50	1	2	2	6	16	44	x	x	x
	30 - 40	2	2	6	12	39	162	x	x	x
	20 - 30	2	4	8	21	115	x	x	x	x
	10 - 20	3	6	12	47	x	x	x	x	x
	0 - 10	4	8	22	168	x	x	x	x	x



Accuracy =
Confidence × Calibration
× Crowd Size



In meters, how tall is the Eiffel Tower in Paris?

Actual height = 324 m

Median = 332 m (117 guesses average confidence
= 56% = -6% / +7%)

Individual guesses between 35m and 50,000m!



**Whilst having dinner at the top of the
Eifel tower I was in space!**



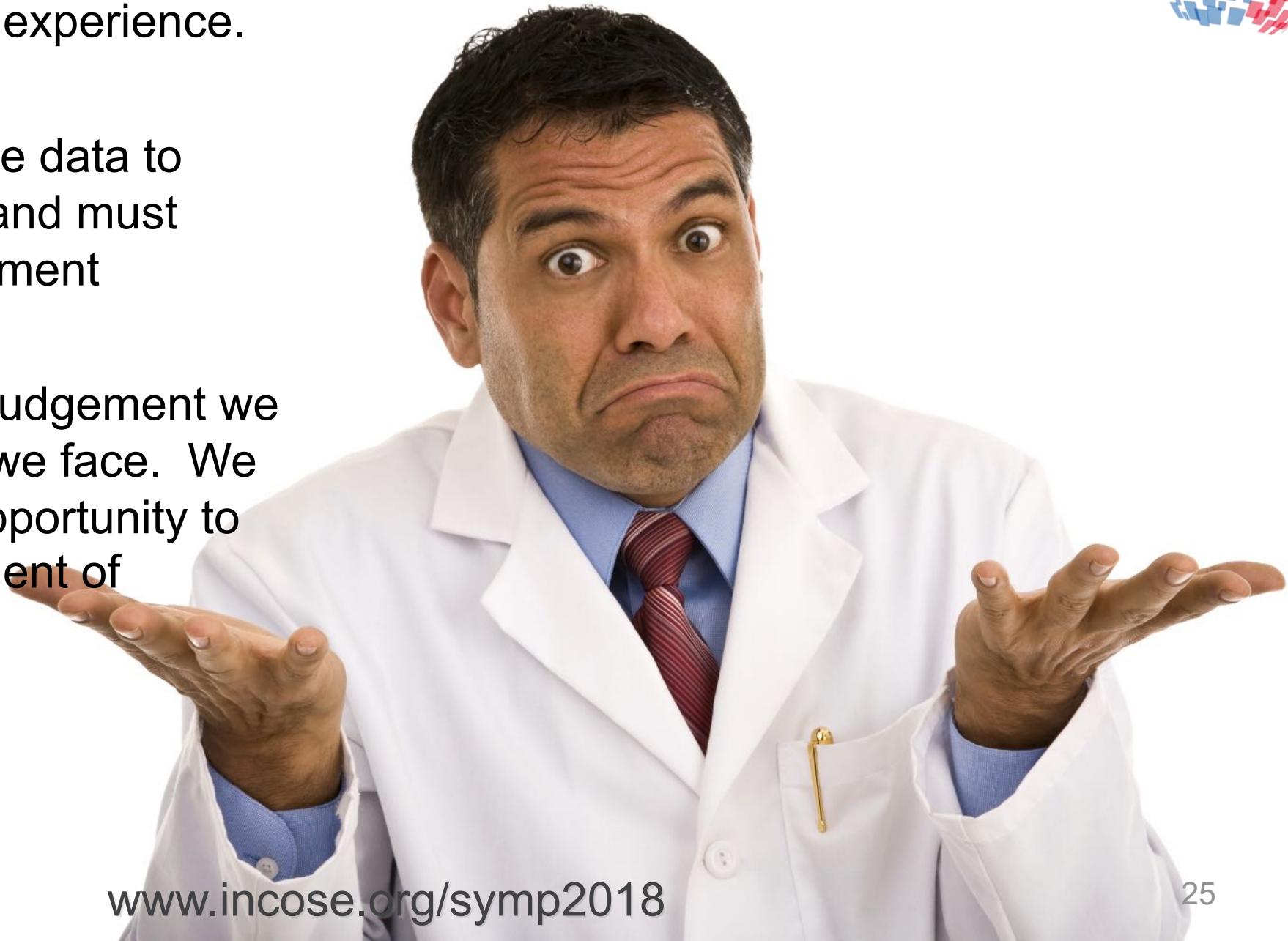
72% of people under estimated the +/- range

		Crowd Size									
		2	3	4	5	6	7	8	9	10	
Estimator Confidence Level	100	55%	72%	83%	89%	93%	96%	98%	99%	100%	
	90 - 100	52%	72%	84%	91%	94%	97%	98%	99%	100%	
	80 - 90	48%	70%	82%	89%	93%	96%	97%	98%	99%	
	70 - 80	46%	69%	81%	89%	93%	96%	97%	98%	99%	
	60 - 70	45%	68%	80%	88%	92%	95%	97%	98%	99%	
	50 - 60	45%	67%	80%	87%	92%	95%	96%	98%	99%	
	40 - 50	44%	66%	80%	87%	91%	95%	96%	97%	98%	
	30 - 40	43%	64%	76%	84%	89%	92%	94%	96%	97%	
	20 - 30	39%	59%	71%	80%	85%	89%	92%	94%	96%	
	10 - 20	37%	55%	67%	76%	81%	85%	89%	91%	94%	
	0 - 10	35%	52%	64%	74%	79%	84%	87%	91%	93%	

Many aspects of Systems Engineering
rely on judgement and experience.

Many of us will not have data to
support our decisions and must
therefore rely on judgement

If we are going to use judgement we
should know the risks we face. We
should also take the opportunity to
improve on the judgement of
individuals



How long is the Nile?

Actual distance 6,854 km (4,179miles)

Median = 4278miles (167 guesses and average confidence of 33% = -16% / +19%)

Guesses between 7km and 670,000 km

According to one person, the Nile looped the earth over 17 times!



Any questions?

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