Analysis of the operations of 58 gliders during the last 2 years

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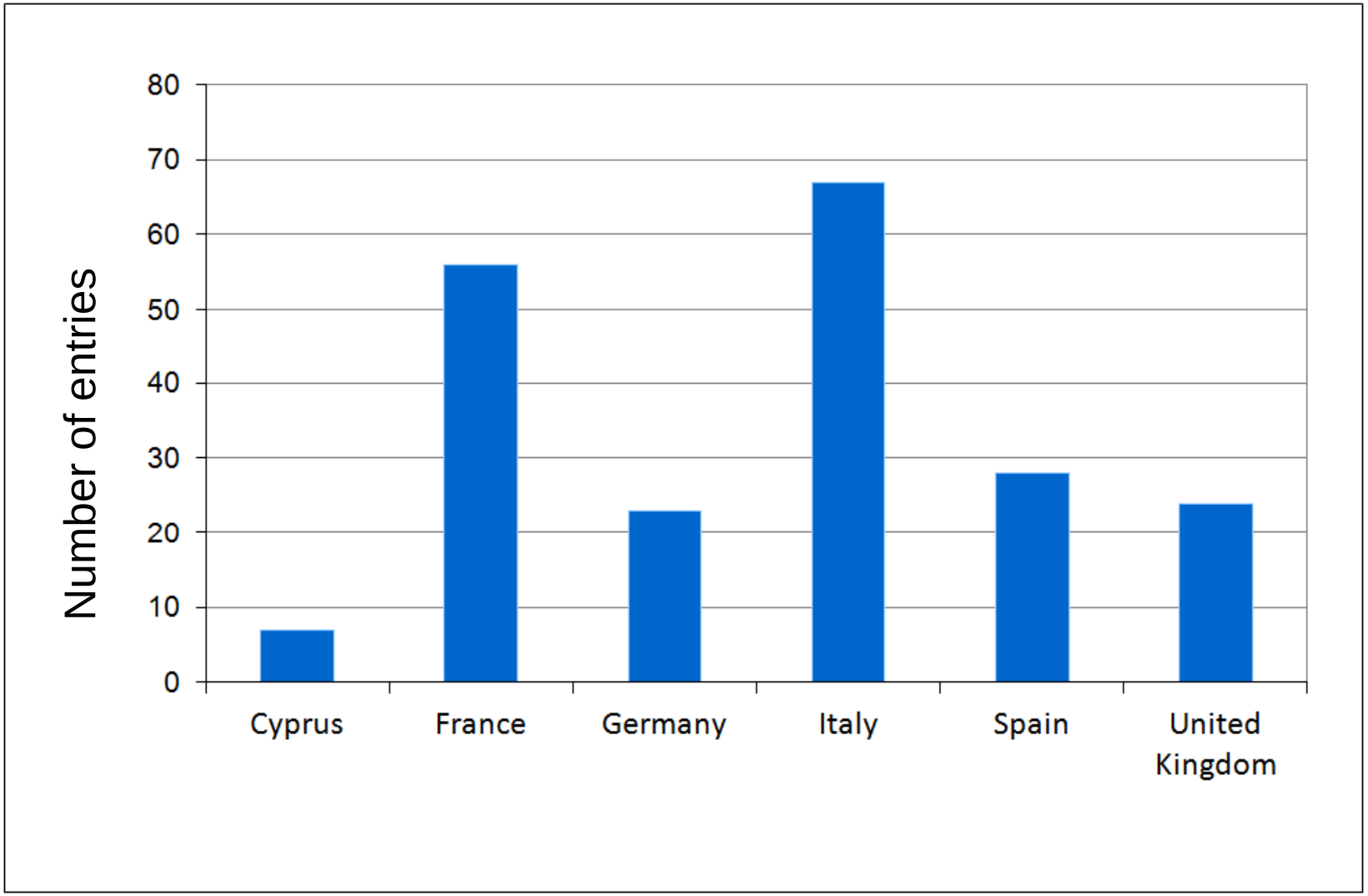
Aim of the Project

- To devise a framework for risk informed decision making in glider operation
- To improve glider coverage for science missions
- To provide a deeper understanding of the factors that effect glider deployment risk
- To inform the glider user community of risk and reliability techniques tailored to glider deployment
- To extend state of the art in risk quantification and modelling techniques

Online Survey

1. Vehicle identifier.
2. Mission number or other mission identifier.
3. Date of the start of the mission.
4. Type of vehicle: SLOCUM G1 (shalow, deep), SLOCUM G2 (shalow, deep), Seaglider 1000m or Spray.
5. Mission type: shelf deployment, shelf-edge deployment or deep-ocean deployment
6. Mission length in days.
7. Mission depth in metres.
8. Answer did the mission end in failure? If yes, specify type of failure.
9. Answer: Did the glider fail initial test?

Participating countries



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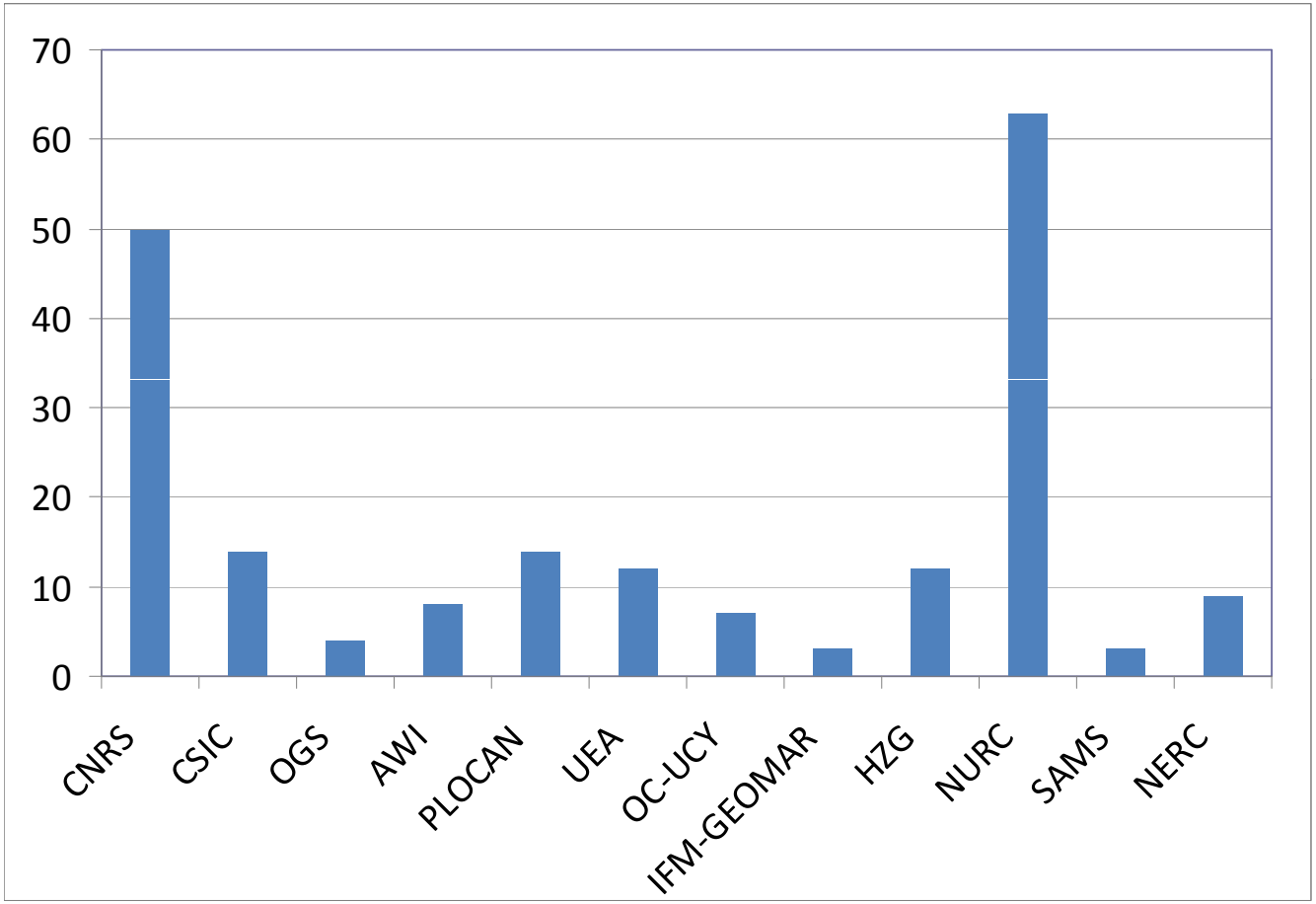
Participating Centres



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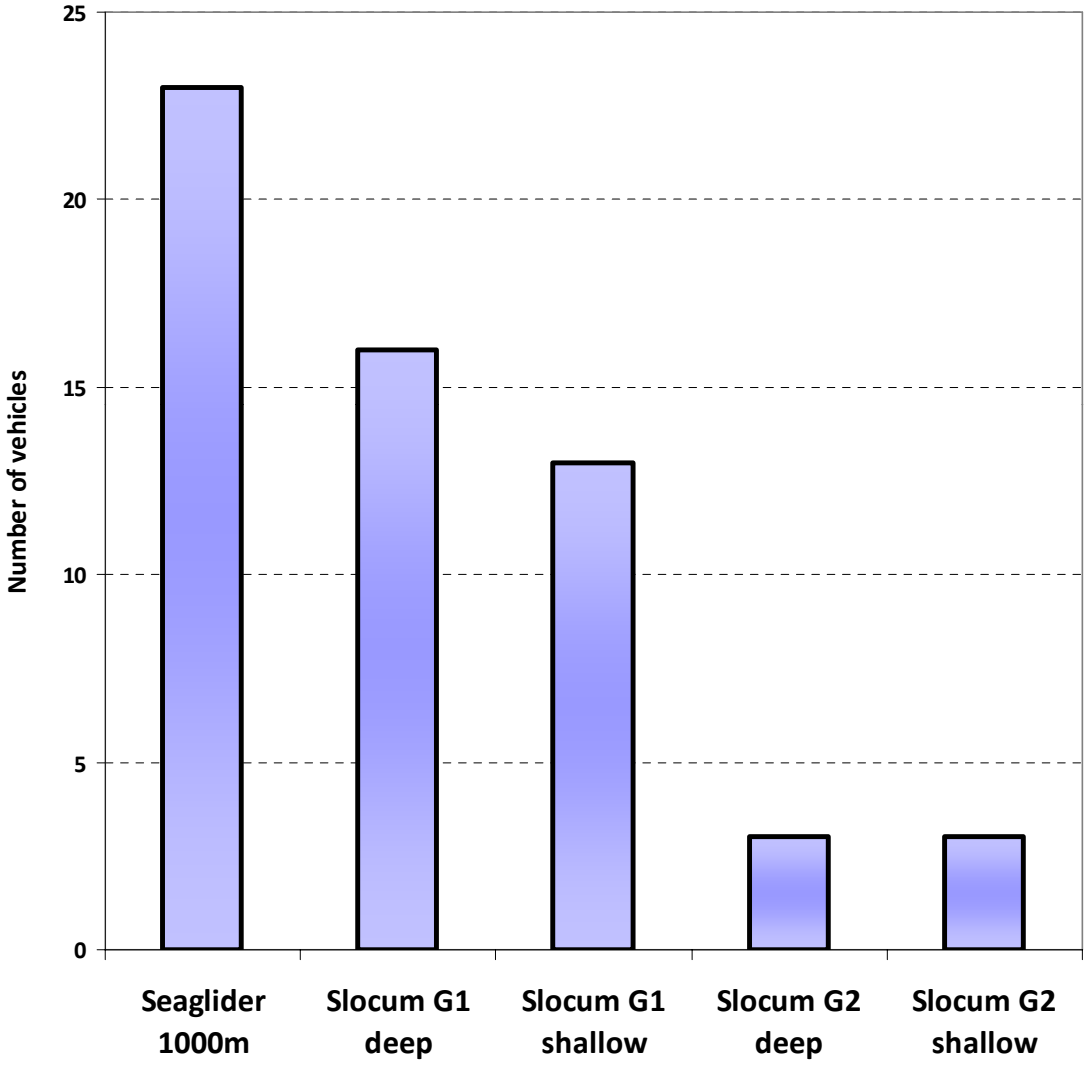
Glider types



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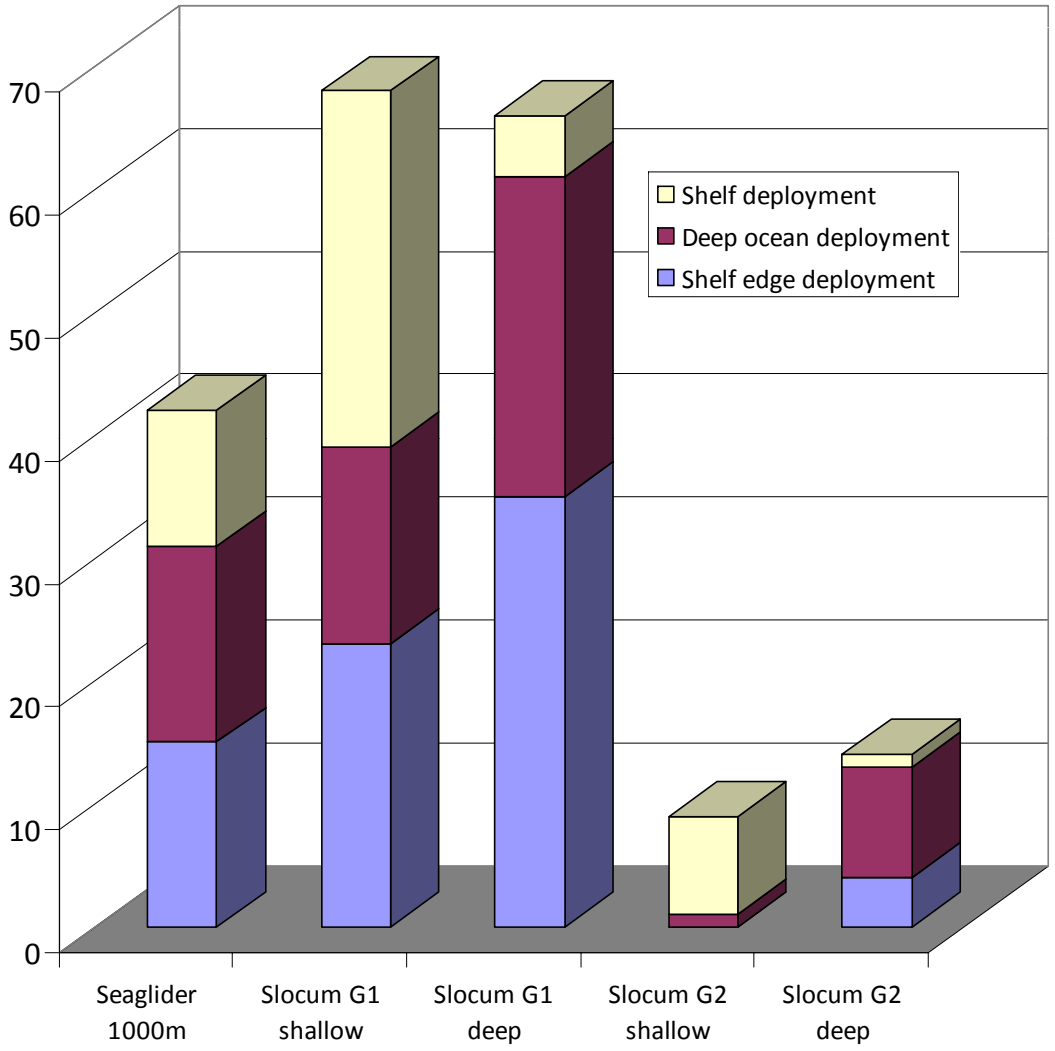
Operating Environments



Vehicle	Median mission endurance [days]
Seaglider 1000m	64
Slocum G1 shallow	8
Slocum G1 deep	19
Slocum G2 shallow	18
Slocum G2 deep	12

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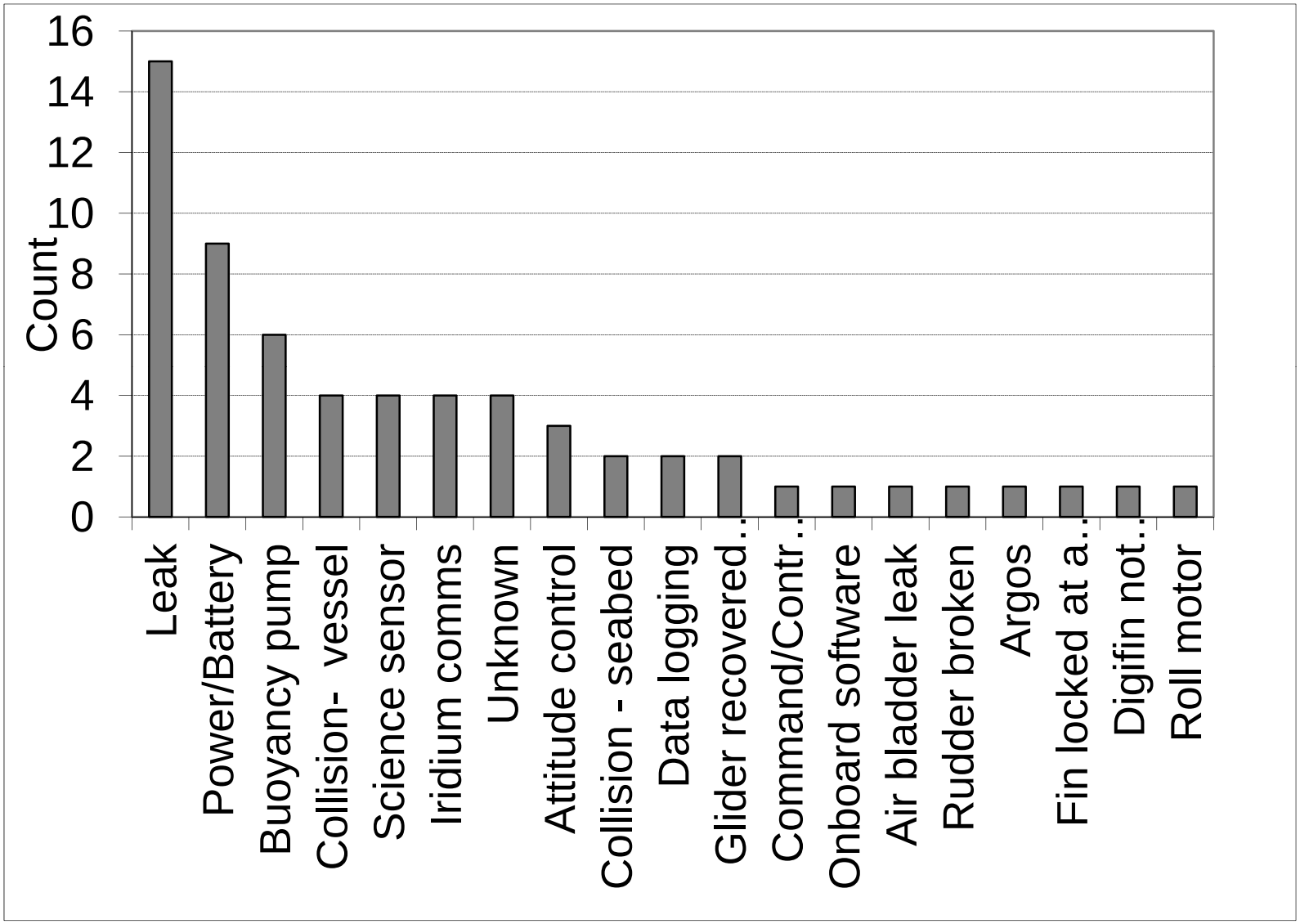
Failure data

	Seaglider 1000m	Slocum G1 shallow	Slocum G1 Deep	Slocum G2 shallow	Slocum G2 deep
Total endurance[days]	2514	772	1461	188	550
Number of Aborts due to failures	19	13	23	3	5
Abort rate (per day)	0.00756	0.0168	0.0157	0.0159	0.00909
Number of losses	7	2	1	0	0

Failure Modes



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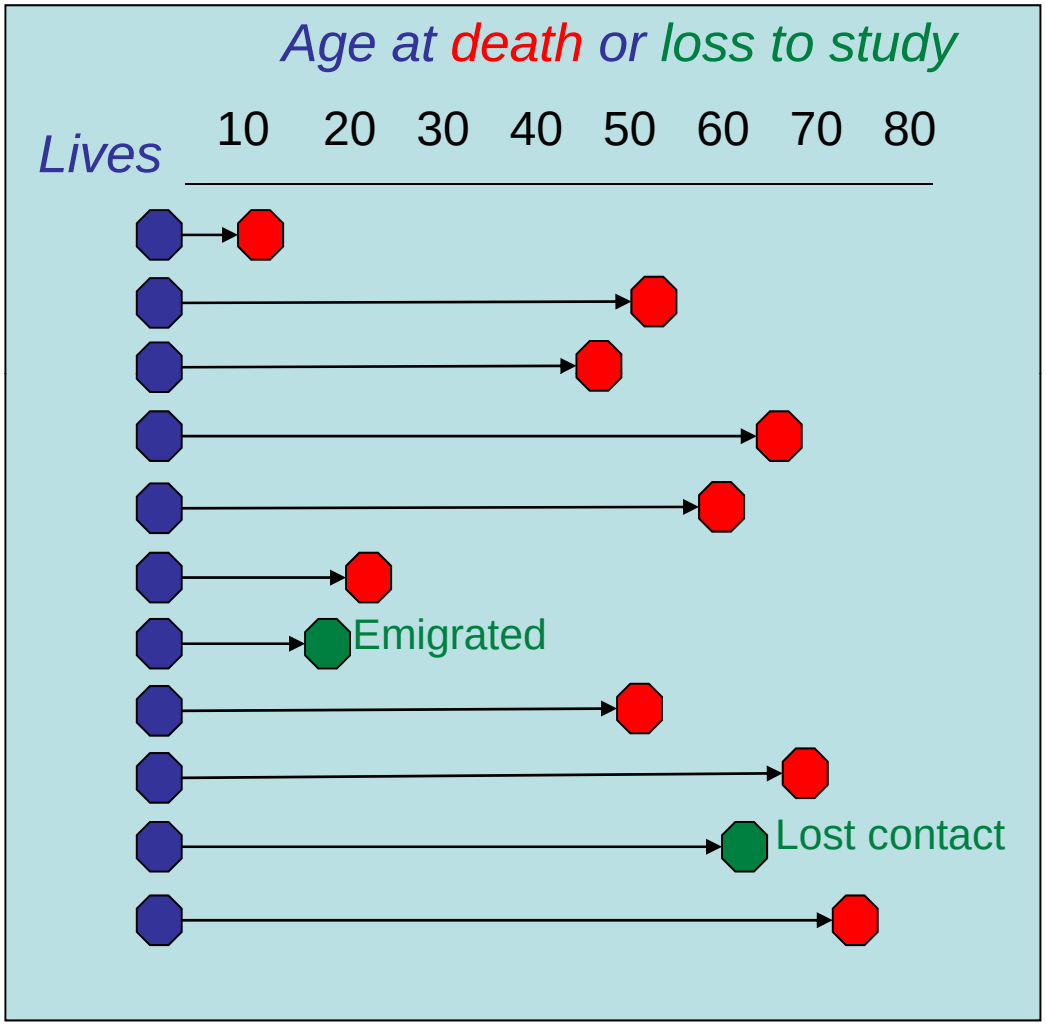
Lifetime Analysis: People - Kaplan Meier estimator



The loss-to-study subjects are 'censored'. They are included in each interval up to their last recorded age, but not counted as deaths.

The Kaplan Meier non-parametric estimator:

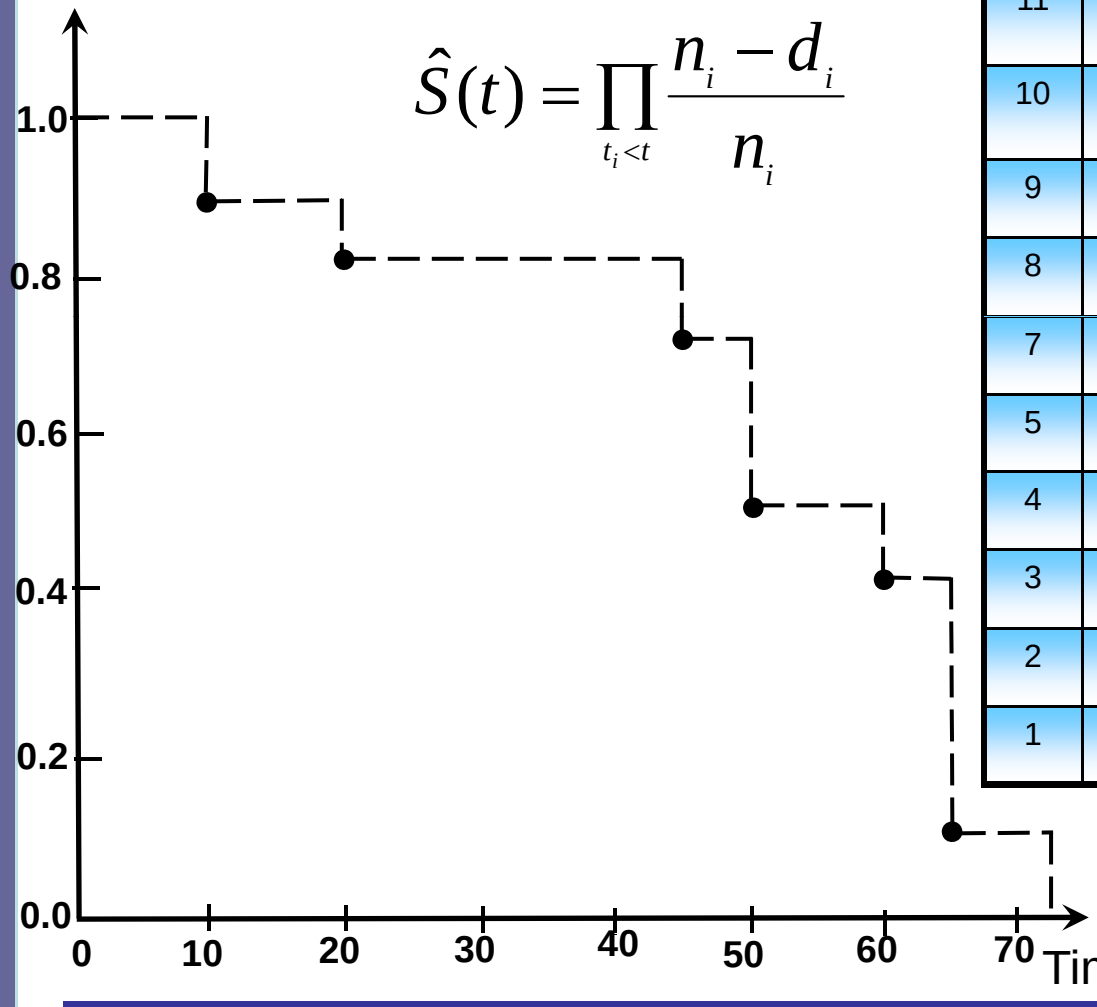
$$\hat{S}(t) = \prod_{t_i < t} \frac{n_i - d_i}{n_i}$$

n_i is the number of lives at risk, and d_i the number of deaths in each interval.

Lifetime Analysis: Kaplan Meier estimator

Probability of survival

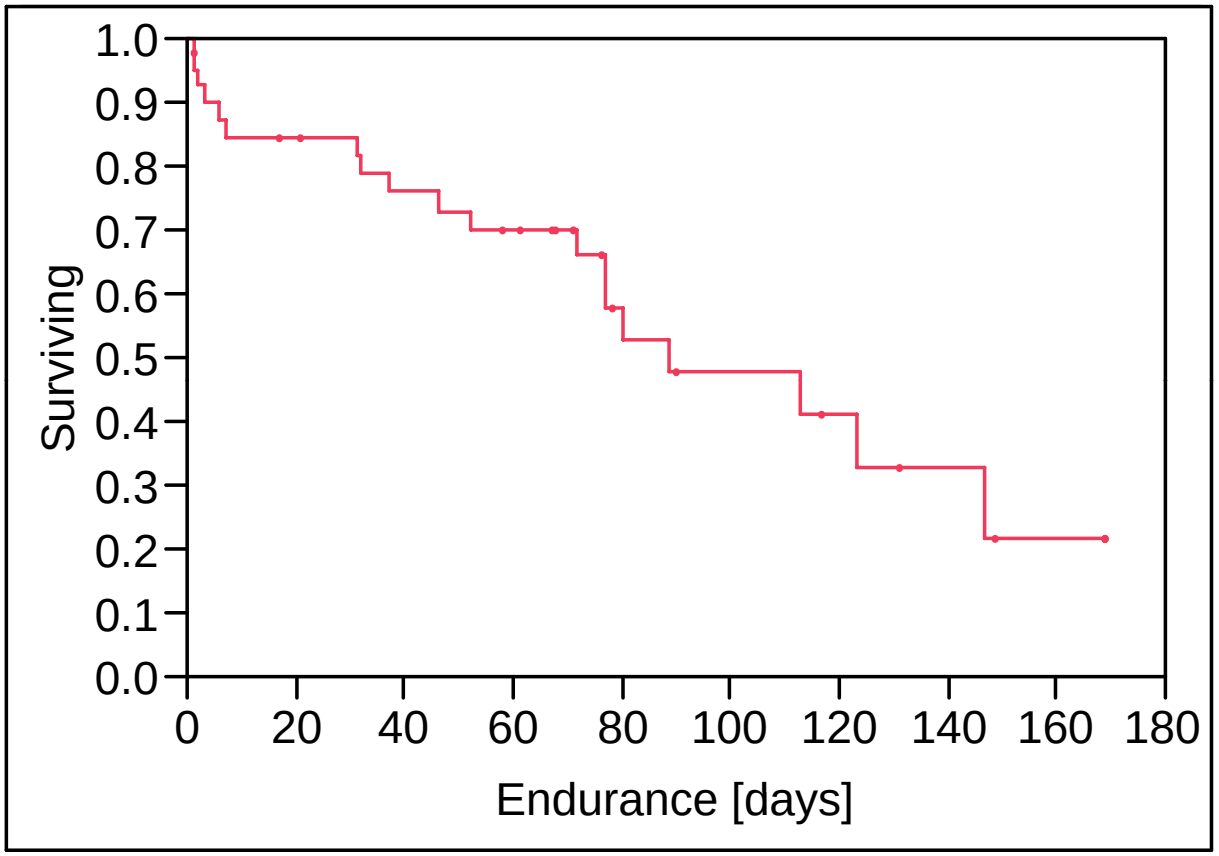
$$\hat{S}(t) = \prod_{t_i < t} \frac{n_i - d_i}{n_i}$$



n_i	Time t_i	d_i	C_i	$(n_i-d_i)/n_i$	$\hat{S}(t)$
11	0	0	0	1	1
11	10	1	0	(11-1)/11 = 0.909	0.91
10	17	0	1	(10-0)/10 = 1	0.91
9	20	1	0	(9-1)/9 = 0.88	0.81
8	45	1	0	(8-1)/8 = 0.71	0.71
7	50	2	0	(7-2)/7 = 0.50	0.50
5	60	1	0	(5-1)/5 = 0.8	0.40
4	61	0	1	(4-0)/4 = 1	0.40
3	65	1	0	(3-1)/3 = 0.67	0.27
2	67	1	0	(2-1)/2 = 0.5	0.13
1	72	1	0	(1-1)/1 = 0	0

Lifetime table

Probability of Mission Ending in Failure



Risk profile for the Seaglider 1000m

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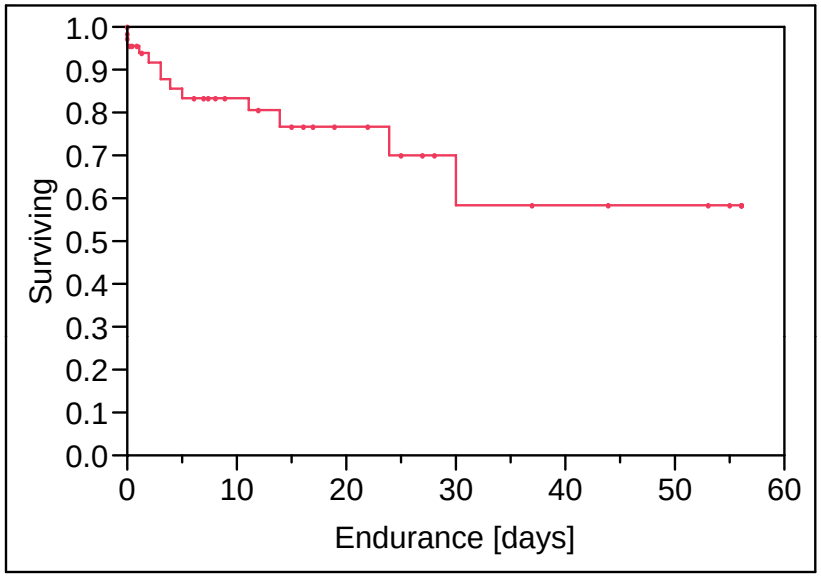
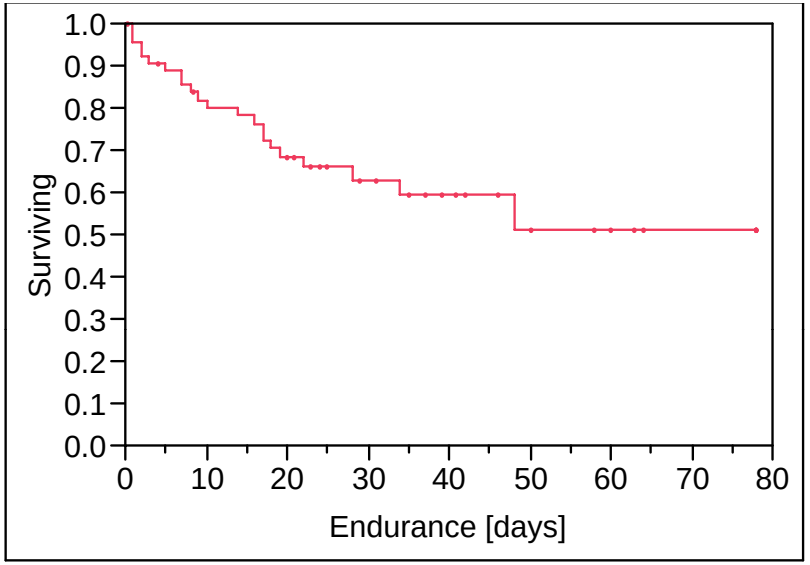
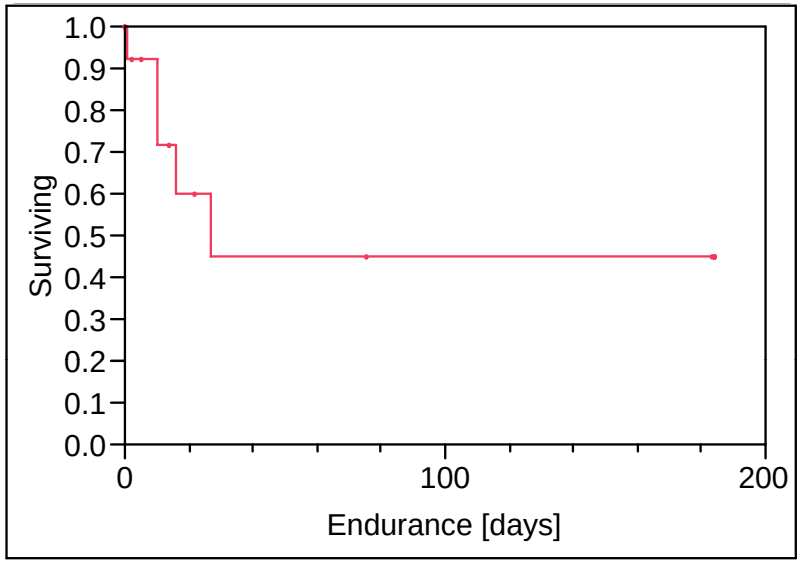
Probability of Mission Ending in Failure – Slocum G1

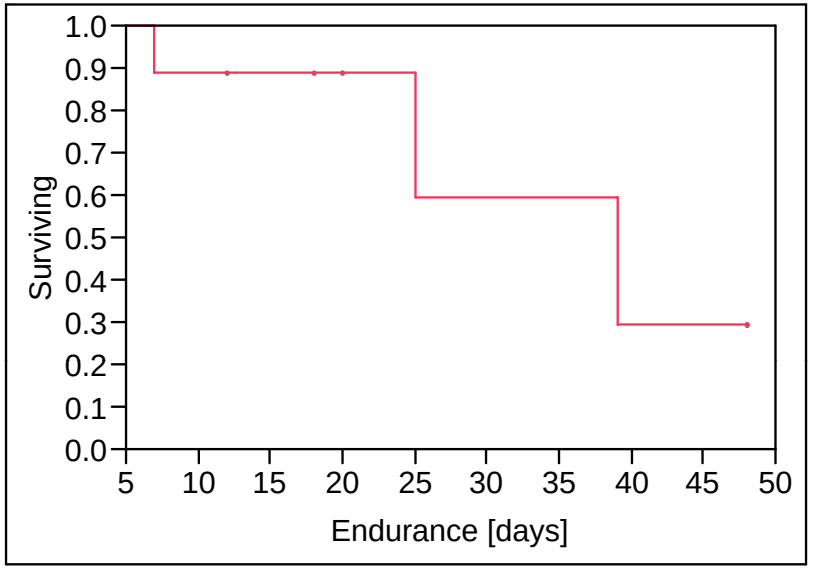




Risk profile for the Slocum G1 Shallow glider on the left, Slocum G1 Deep on the right.

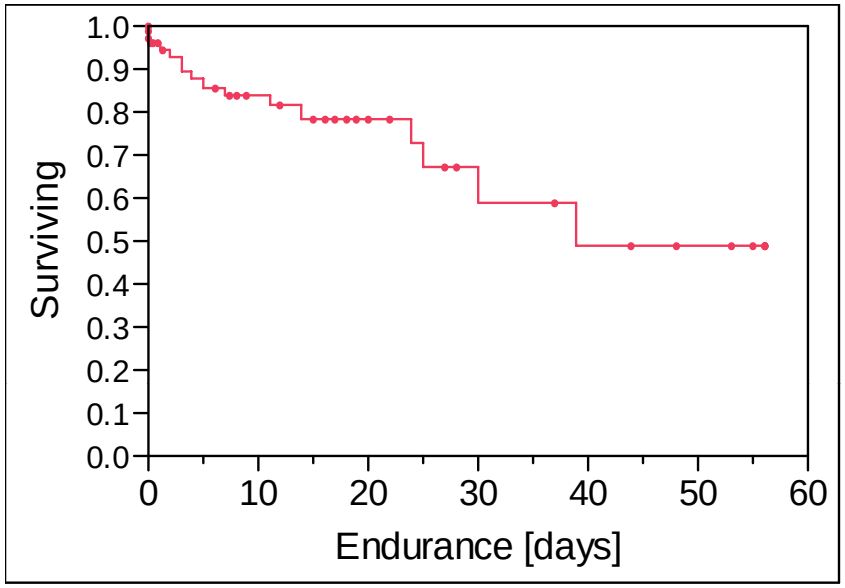
Probability of Mission Ending in Failure – Slocum G1

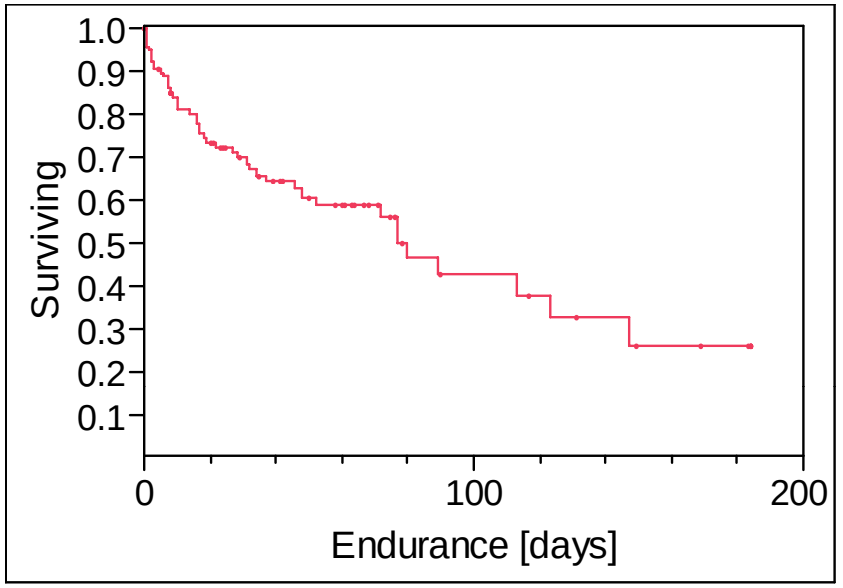




Risk profile for the Slocum G2 Shallow glider on the left, Slocum G1 Deep on the right.

Survival for deep and shallow gliders





Survival for Shallow and deep gliders

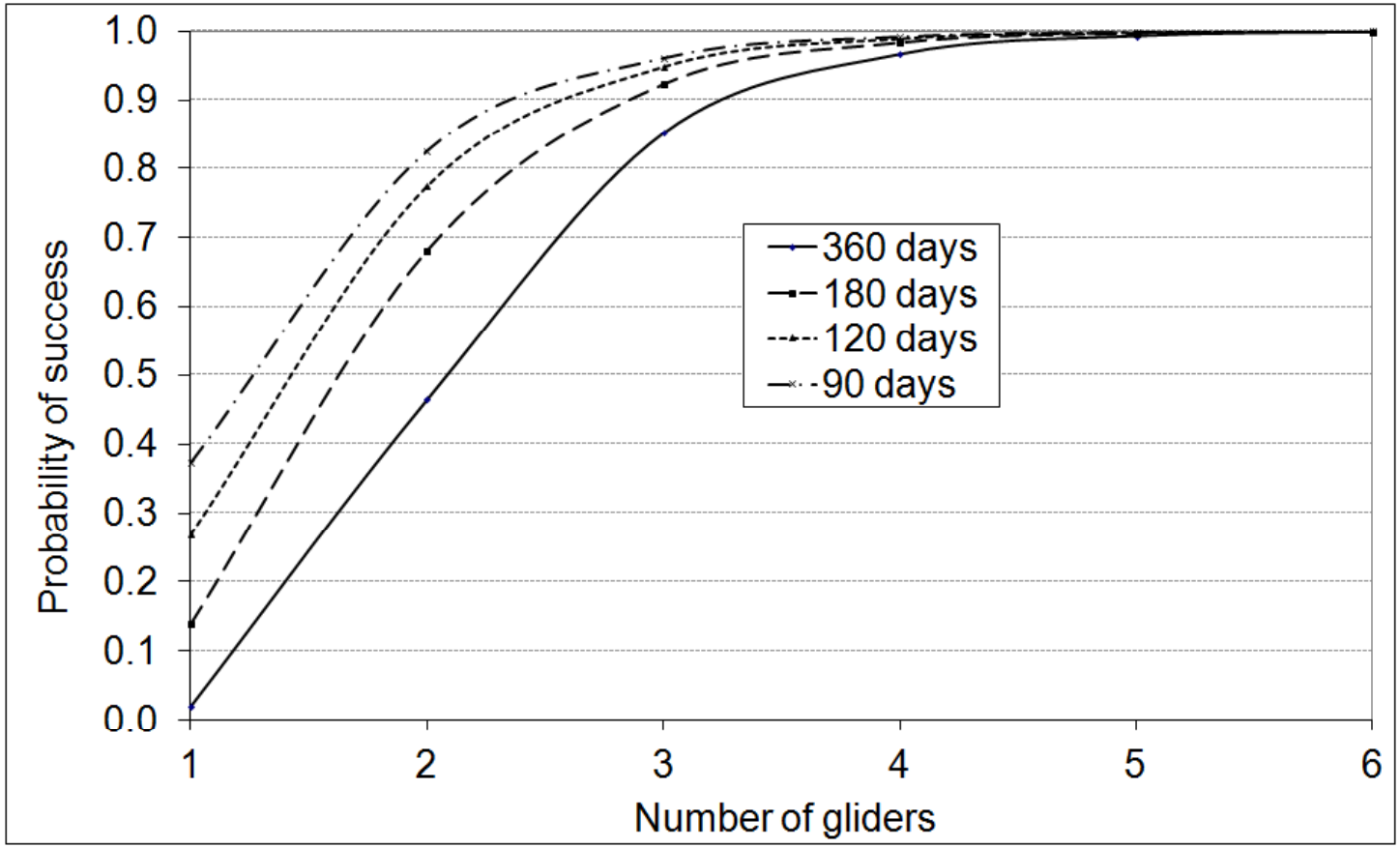
	Shallow glider	Deep glider
MTBF (days)	60	104
Failure rate	0.0167	0.00960

Coverage Estimation

$$Psurv = P_N(N,1) = (1 - P_N(N,1))^M = (1 - p(t)^N)^M$$

N	number vehicles
M	number of missions
Psurv	probability of survival
p(t)	probability of loss for endurance t

Ocean Coverage - Shallow gliders



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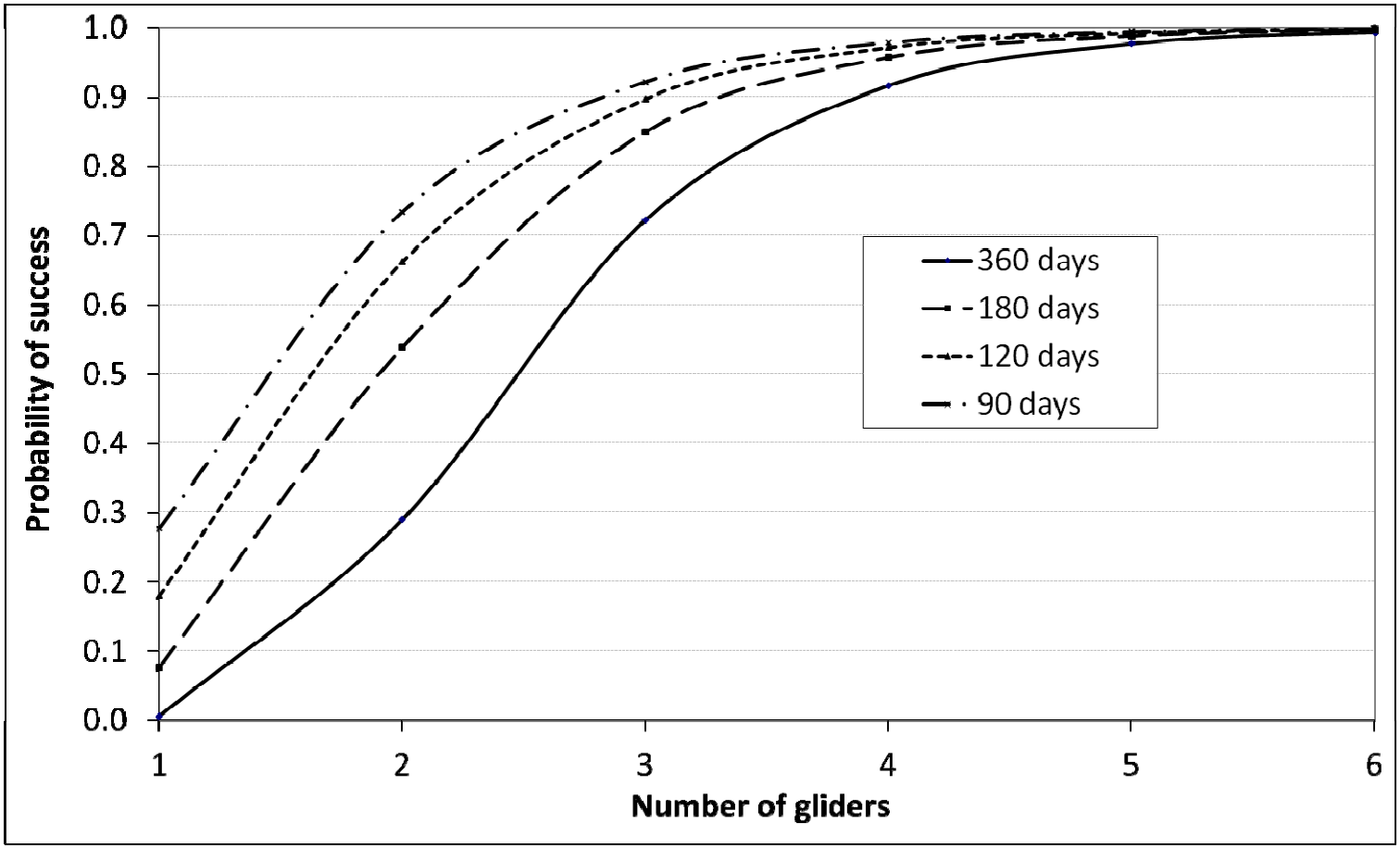
Ocean coverage – Deep gliders



Conclusions

- A risk informed mission planning will not only reduce operational costs but it will also increase our confidence that mission requirements will be met
- A formal approach for quantifying the coverage that can be achieved with a fleet of gliders has been presented.
- There is room for undersea glider reliability growth
- Interaction with manufactures will hopefully see undersea gliders achieving the same level of reliability growth as that observed for APEX floats