PSAM 9

Ninth International Probabilistic Safety Assessment and Management Conference

The Impact of Change in Operational Conditions of a Drifting Rescue Unit on Its Risk Function

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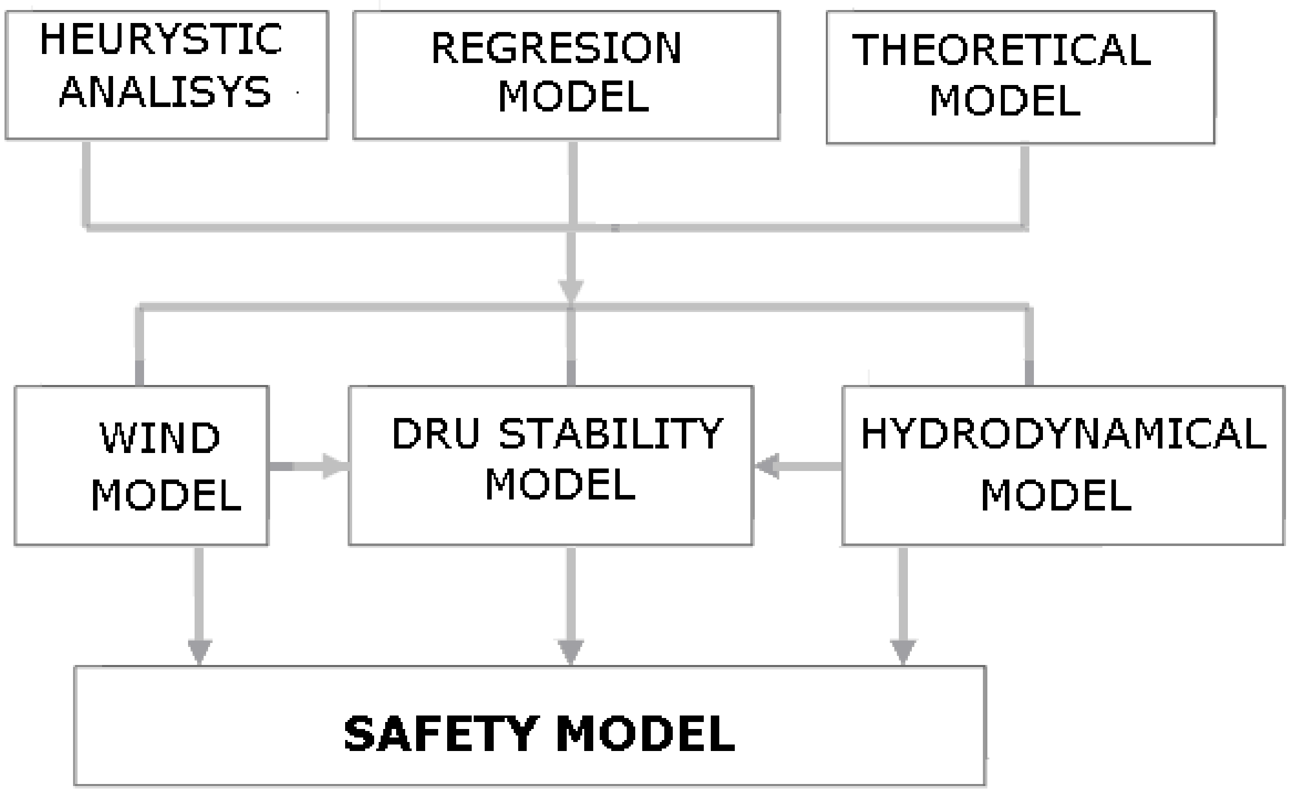
Drifting Rescue Units

DRU capsizing

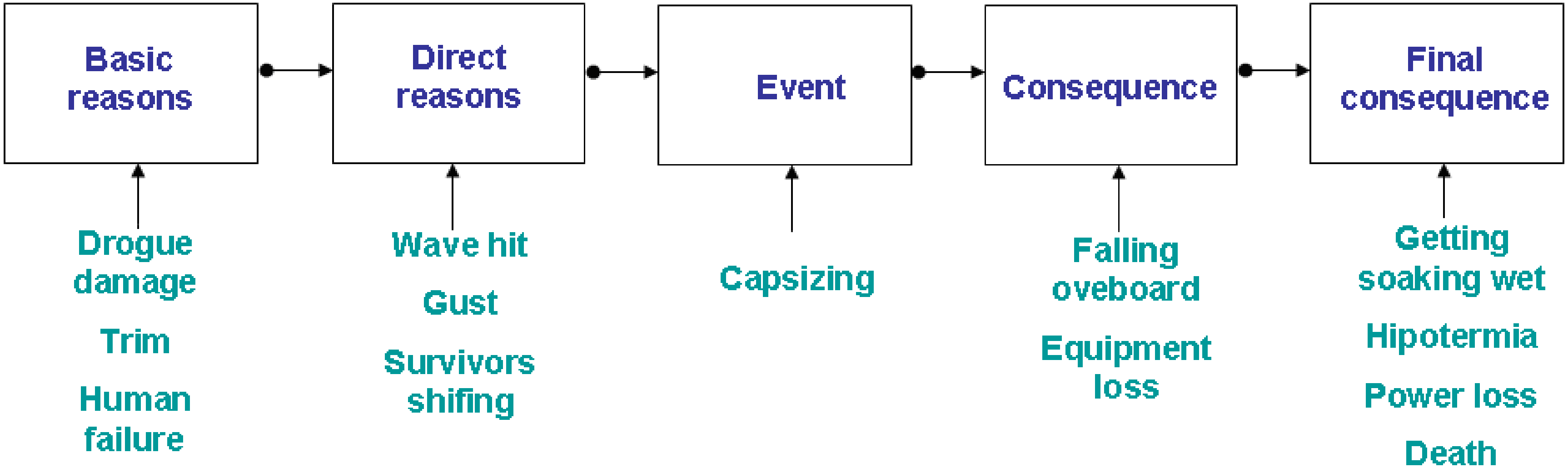
The major sources of stability loss are:

- the momentum change of heeling force due to changes in wind speed (gust risk);
- the change in horizontal position due to the trim and changes of a wave slope (heeling risk);
- distribution of survivors inside, (loading risk);
- the stability losses resulting from the movements on waves, (performance risk).

DRU safety modeling algorithm



DRU capsizing worse case scenarios



Risk function for capsizing

$$\lambda_{tr}(t) = \sum_{i=1}^{n} \sum_{j=1}^{m} \Pr(S_i) \cdot \Pr(L_j / S_i) \cdot \lambda(t / S_i, L_j)$$

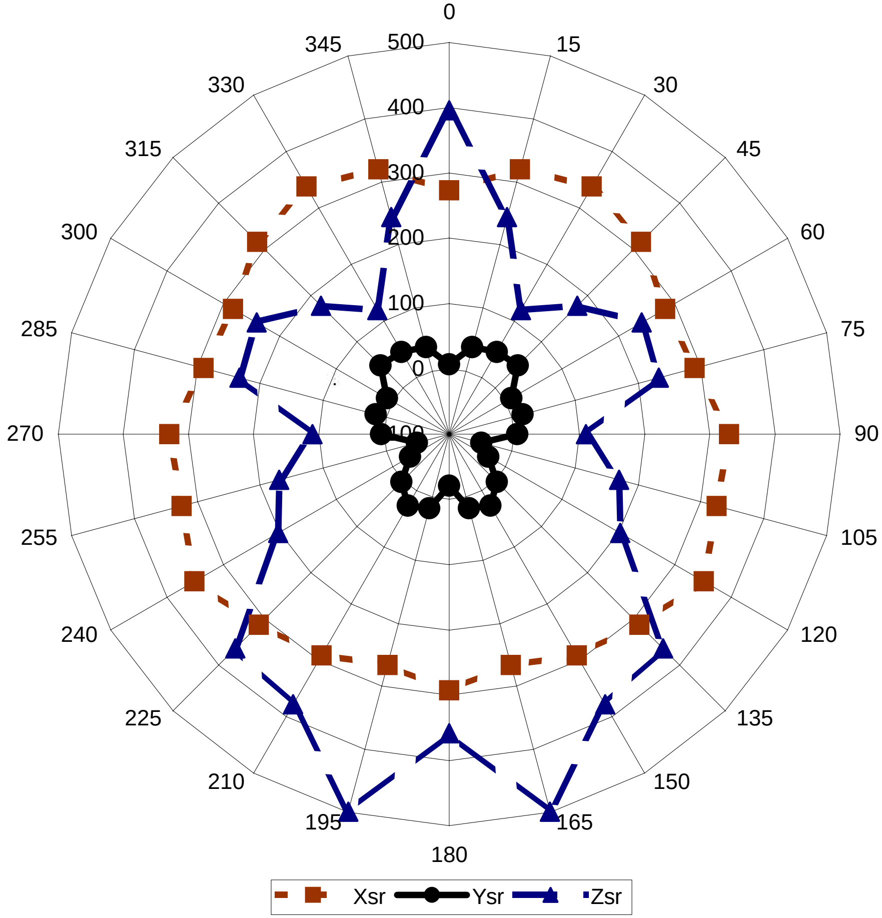
where
$\Pr(S_i)$ – probability of i-scenario occurrence in time period [0,T] with condition S_i,
$\Pr(L_j / S_i)$ – probability of loading condition L_i for i-scenario with condition S_i,
$\lambda(t/S_i,L_j)$ – risk function for i-scenario with condition S_i and loading condition L_i

The safety model

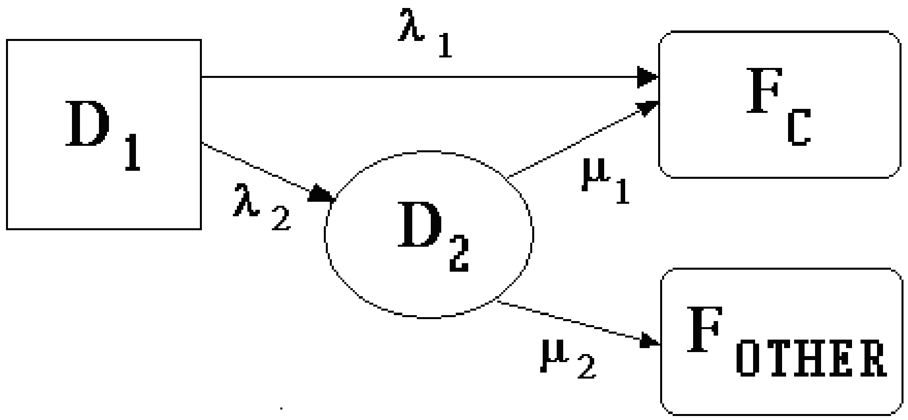
$$P(C) = \sum_i \sum_j \sum_k \sum_w P(C / X_1 = \vec{k}, X_2 = \vec{w}, X_3 = \vec{i} X_4 = \vec{j}) \cdot$$
$$P(X_2 = \vec{w} / X_1 = \vec{k}, X_3 = \vec{i} X_4 = \vec{j}) \cdot P(X_1 = \vec{k}, X_3 = \vec{i} X_4 = \vec{j})$$

where
X_1 – vector of DRU parameters, (shape, dimensions, weight);
X_2 – vector of DRU loading parameters, (number of survivors, survivors deployment);
X_3 – vector of sea wave parameters, (high, slope, period);
X_4 – vector of wind parameters, (speed, direction, gust, fluctuation).
sums are taken for all possible values of vectors X_2, X_3, X_4.

Spatial distribution of wind forces



DRU safety states changing



where
- D_1 safe state,
- D_2 transitory state,
- F_C capsizing,
- F_{other} other failure.

DRU safety states changing

$$P'_{D_1}(t) = -(\lambda_1 + \lambda_2)P_{D_1}(t)$$

$$P'_{F_C}(t) = P_{D_1}(t)\cdot\lambda_1 + P_{D_2}(t)\cdot\mu_1$$

$$P'_{D_2}(t) = P_{D_1}(t)\cdot\lambda_2 - P_{D_2}(t)\cdot(\mu_1 + \mu_2)$$

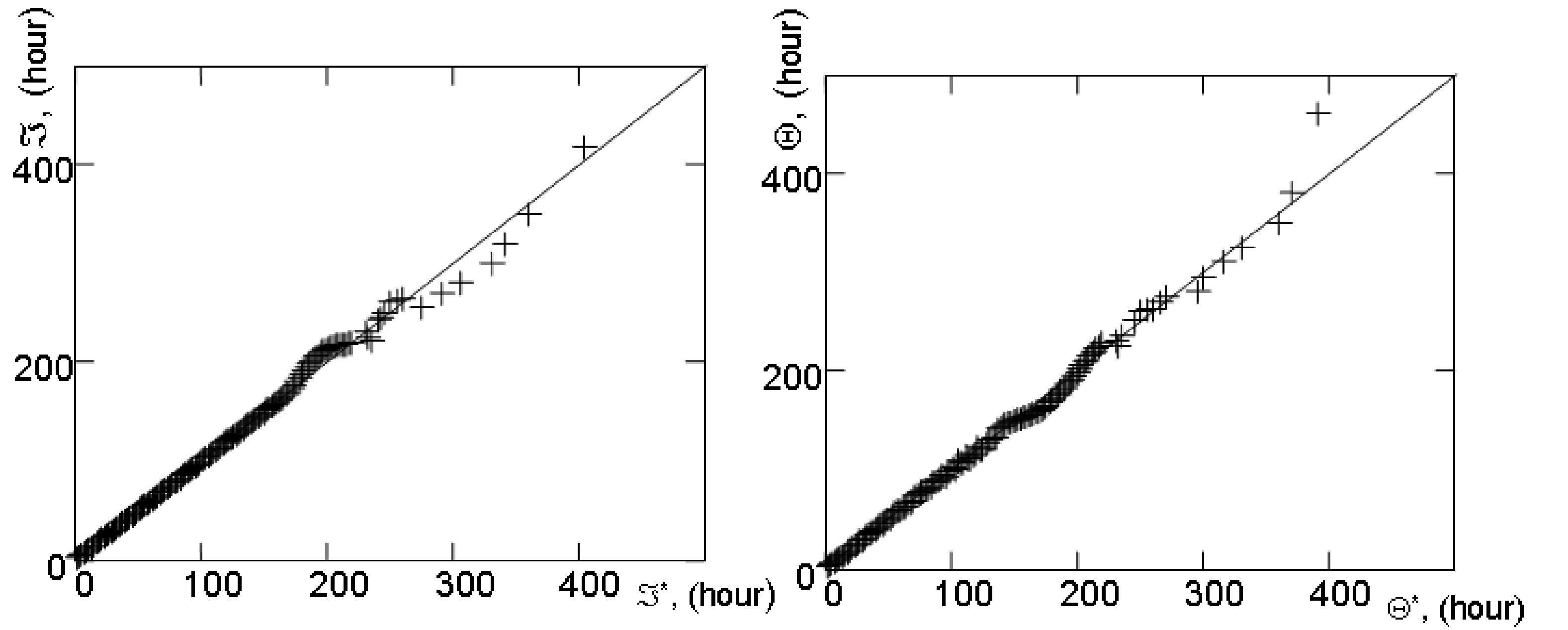
$$P'_{F_{OTHER}}(t) = P_{D_2}(t)\cdot\mu_2$$

Parameters μ_1, μ_2, λ_1, λ_2 are strongly correlated with sea wave and wind parameters.

The probability of DRU capsizing is a function of hydro meteorological parameters.

Markov Switching Model

Storms and weather windows



Empirical distribution of storm duration F(ℑ)

Empirical distribution of weather window duration F(Θ)

Quantile bi-plot of exponential distribution of storm duration and weather window duration for the Baltic Sea

Markov Switching Model

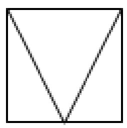
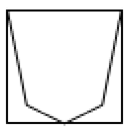
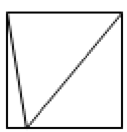
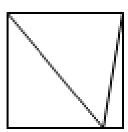
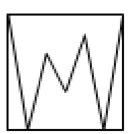
Storms and weather windows

Storm category	I	II	III	IV	V
I	0.5	0.1	0.1	0.2	0.1
II	0.3	0.1	0.2	0.2	0.2
III	0.6	0.2	0.1	0.1	---
IV	0.3	0.2	0.2	0.3	---
V	0.2	0.3	0.2	0.4	---

Probability matrix of transformation of one storm category into another

Markov Switching Model

Classification of weather windows

Type	Shape	*Description*	*Threshold*					
			1h	***2h***	***3h***	***1h***	***2h***	***3h***
			Number of weather windows			**%**		
I		Smooth decrease and then increase of storm activity	31	22	16	14.9	22.2	47.1
II		Wind waves in the "window" are much weaker than the selected threshold value *h*	67	17	14	32.2	17.2	41.2
III		Gradual increase of storm activity or result of passage of a chain of storms with different tracks	39	14	*	18.8	14.1	*
IV		Strong residual wave field that is decaying after storm passage	49	16	*	23.6	16.2	*
V		Wave heights close to the threshold value *h*	22	30	4	10.5	30.3	11.7

Markov Switching Model

Model description

$$Y(t) = \{X(t) \times b_k, S(t) = k; k = 0,1,\ldots,5\}$$

where

- b_k is the vector of model (1) parameters,
- S (t) is the state variable which changes through time.

Markov Switching Model

Model description

The transition matrix for the Markov chain S(t) of storm types is determined by tables 1 where

$$\boldsymbol{p_{ji} = P\,(S_{t+1} = j \mid S_t = i)}$$

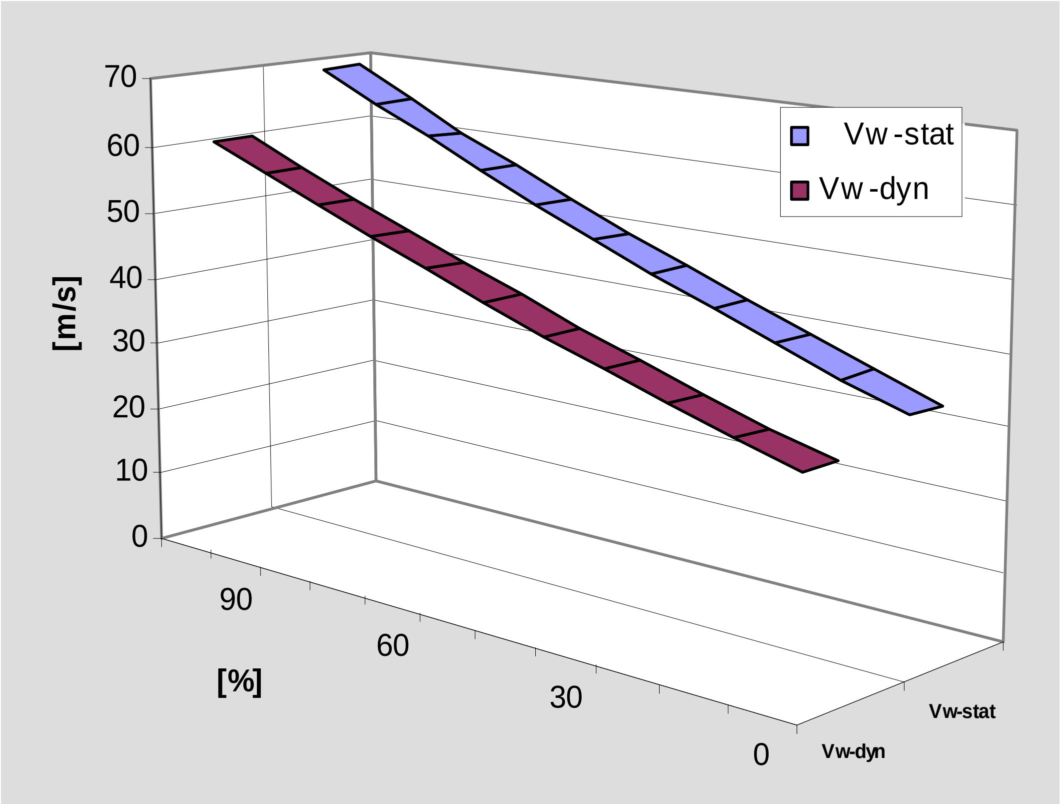
Conclusion

The most often used collective rescue systems, in all weather conditions, is the drifting rescue unit.

Problems of drifting rescue units safety occurring during the operation have not been solved yet.

Conclusion

The two principle features that affect stability are *static* and *dynamic* forces. Stability is the resistance of a raft to forces that tend to induce heeling. *Static* forces are caused by placement of weight within the hull. Flooding a raft makes it susceptible to static forces, which may adversely affect stability. *Dynamic* forces are caused by actions outside the hull such as wind and waves. Strong gusts of wind or heavy seas, may build up a dangerous sea tending to capsize a raft.



Conclusion

The application of simulation involves specific steps in order for the simulation analysis to be successful.

Regardless of the type of problem and the objective of the study, the process by which the simulation is performed remains similar.

Conclusion

At first the type of DRU and a region should be determined.

Then the information about storm and weather windows classification for chosen region has to be collected and/or existing data should be gathered.

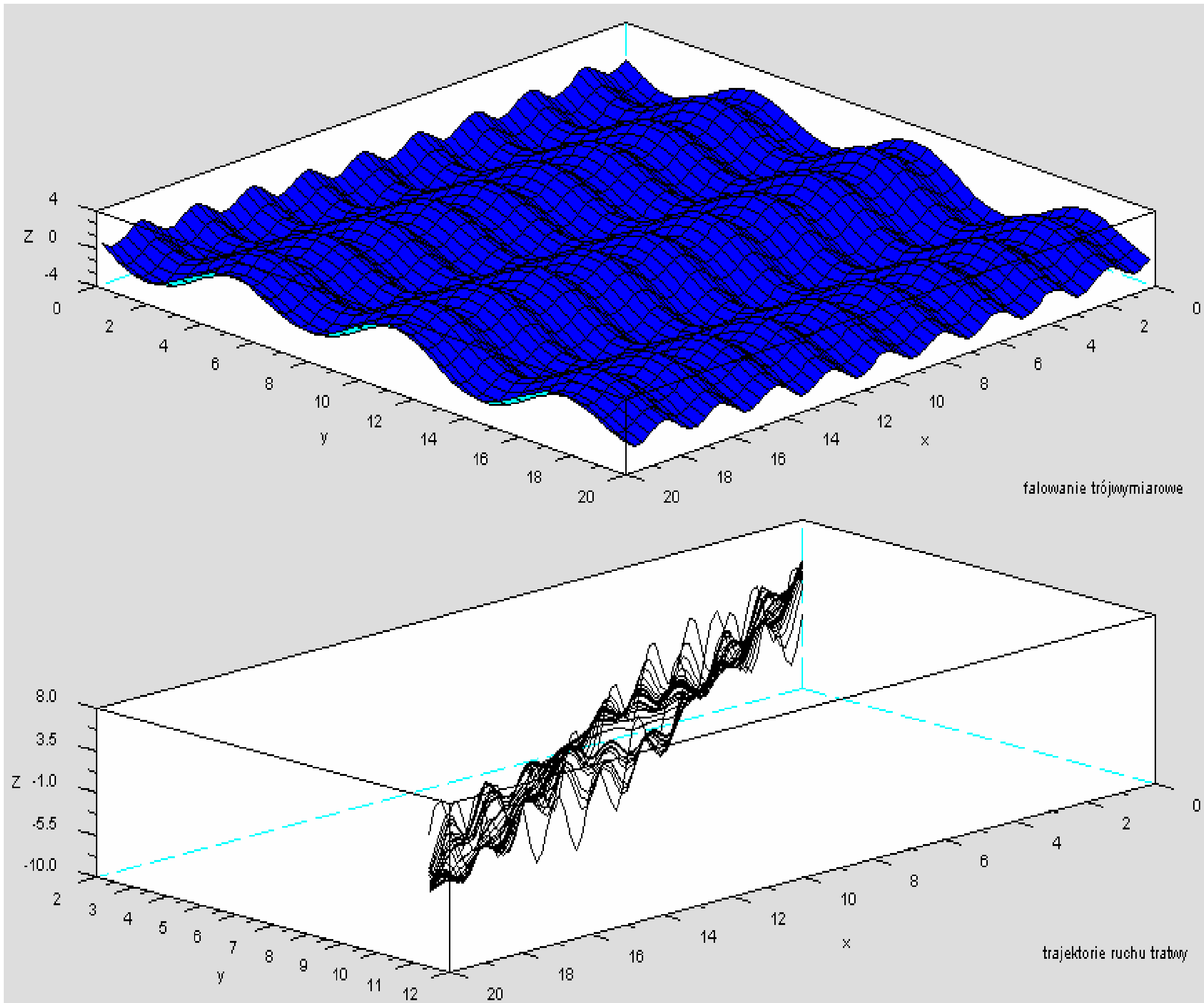
The parameters of theoretical distributions of storm and weather windows duration must be estimated.

After that once can start the experimentation which involves executing the simulation runs and statistically analyzing results to approximate the safety of DRU.

Conclusion

The methods presented in this paper suggest that it seems reasonable to use the Markov switching model in computer simulation for estimation the DRU safety factor.

The investigation focusing on the presented methods should be continued for other more complex models related to the multi-state DRU systems (free falling life boat) in variable operation processes.



Z
4
0
-4
y
x
falowanie trójwymiarowe
Z
8.0
3.5
-1.0
-5.5
-10.0
y
x
trajektorie ruchu tratwy

DRIFTING RESCUE UNITS SAFETY MEASURES - SIMULATION APPROACH

IMPROOVING SAFETY OF LIFE RAFTS

RESEARCHES:
- TOWING TANK
- WIND TUNNEL
- SEA

MODEL:
- ENVIRONMENT
- MASS DISTRIBUTION
- SHAPE
- DROGUE

SIMULATION

SAFETY ASSESSMENT OF EXISTING LIFE RAFTS

PROBABILITY OF ACCIDENT

SAFETY CRITERIA FOR LIFE RAFTS

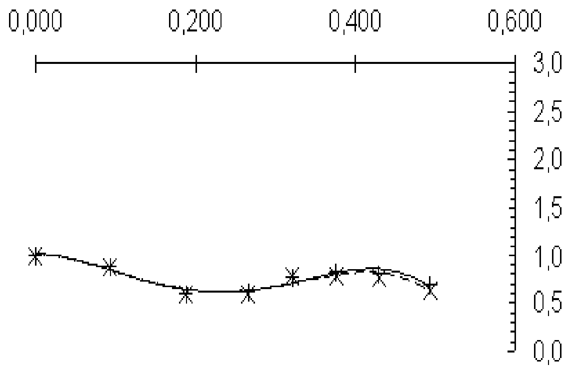
NEW CONCEPTS OF LIFE RAFTS

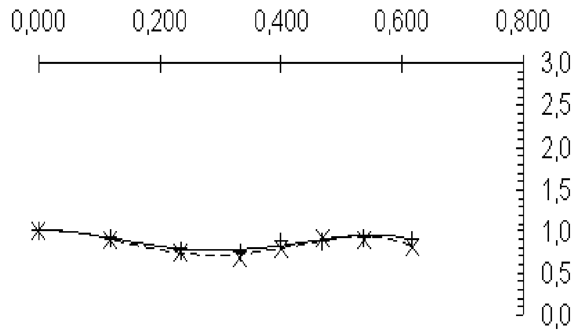
Examination of wind pressure and water resistance forces

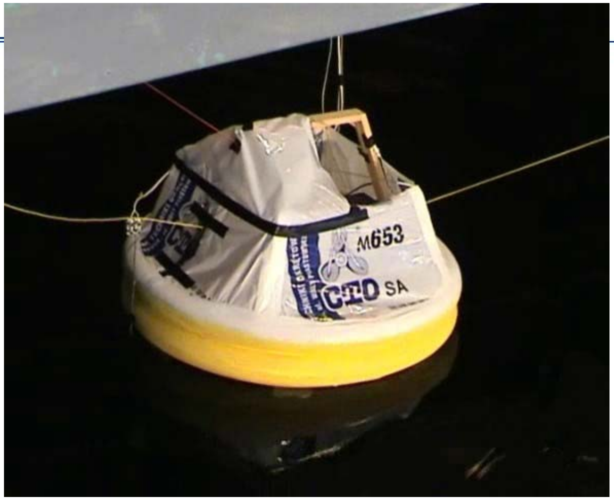
Research at sea

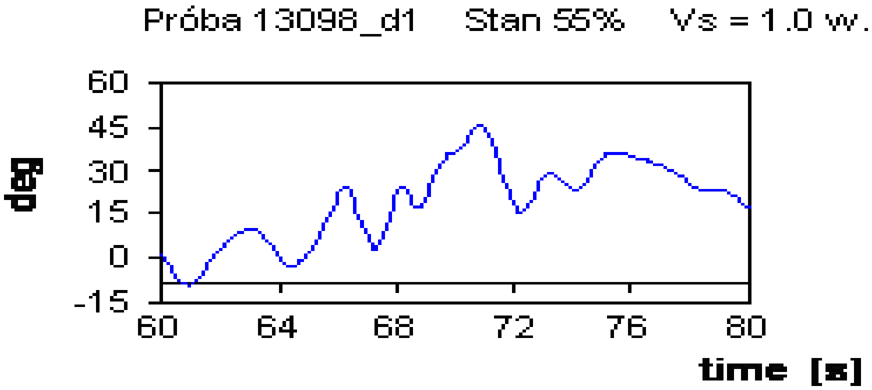
FORCE CAUSING DEFORMATION

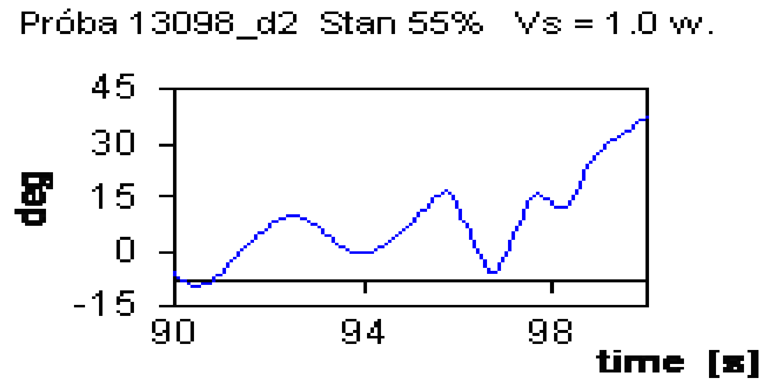
TOWING TANK RESEARCHES



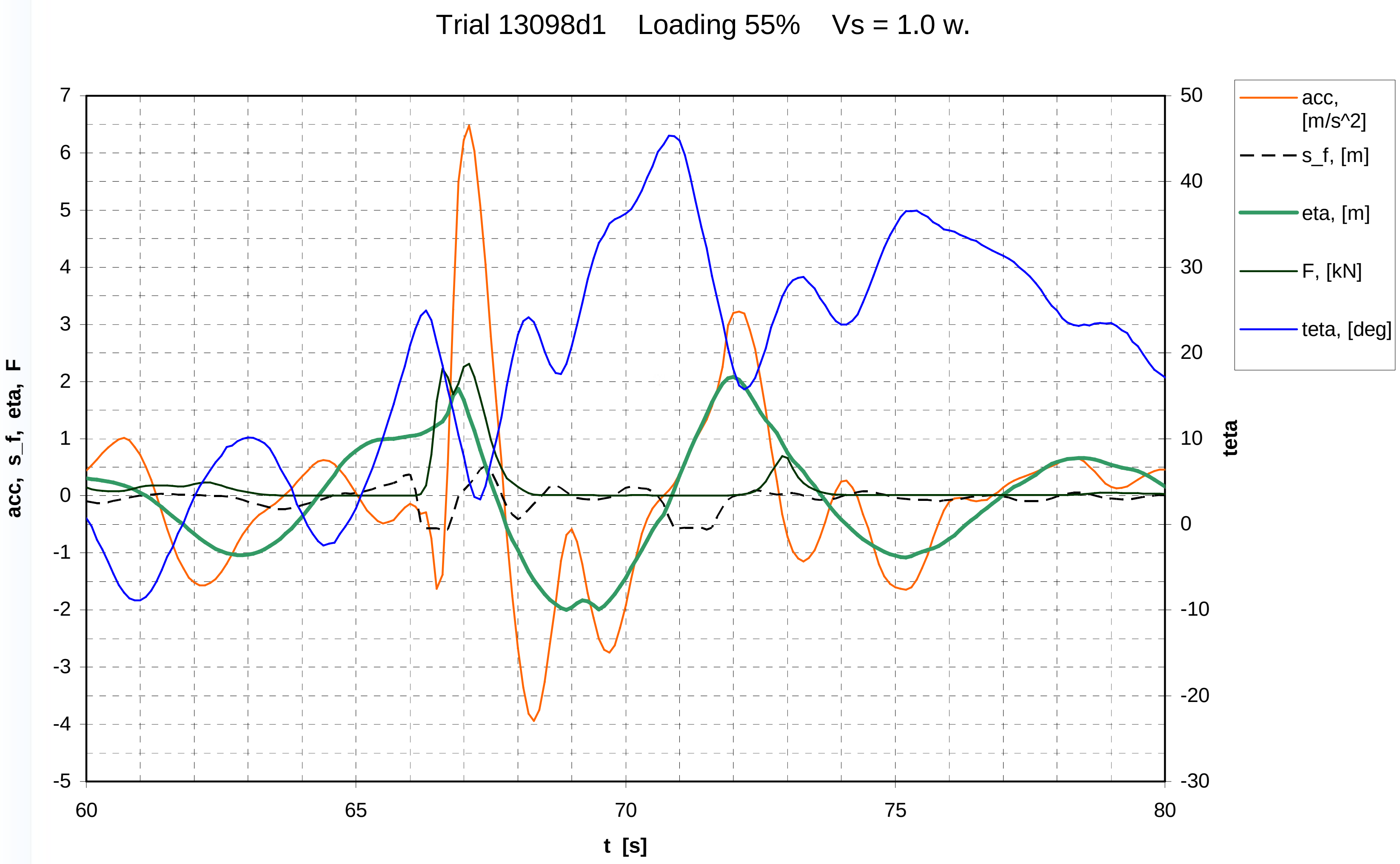








TESTS RESULTS



Simulation modeling provides an effective and powerful approach for capturing and analyzing the life raft system.

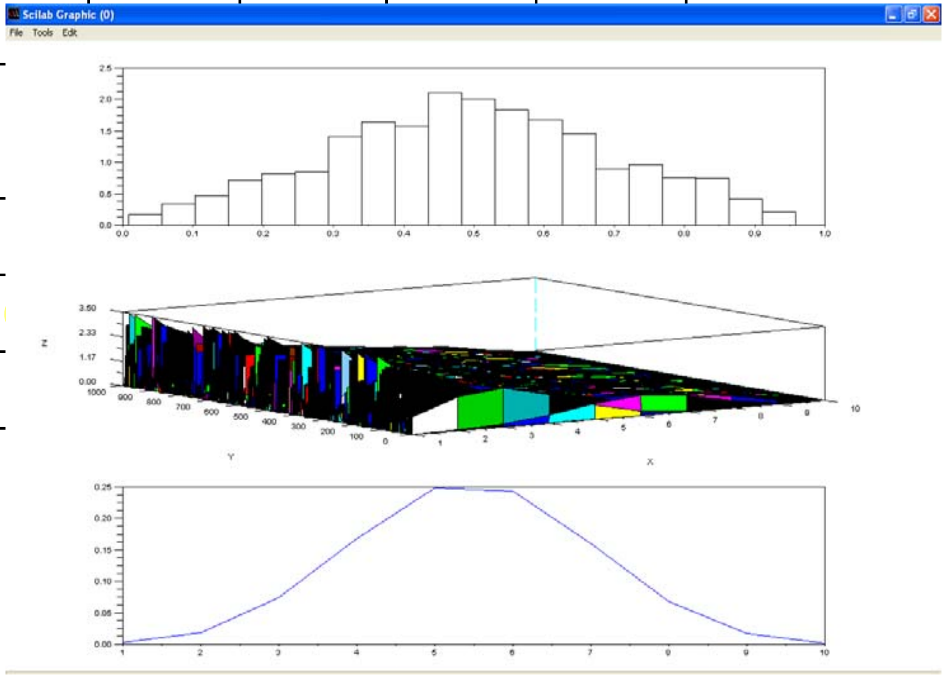
The safety analysis can be based on computer generated data derived from simulation.

THE SAFETY MODEL

Safety model description and input

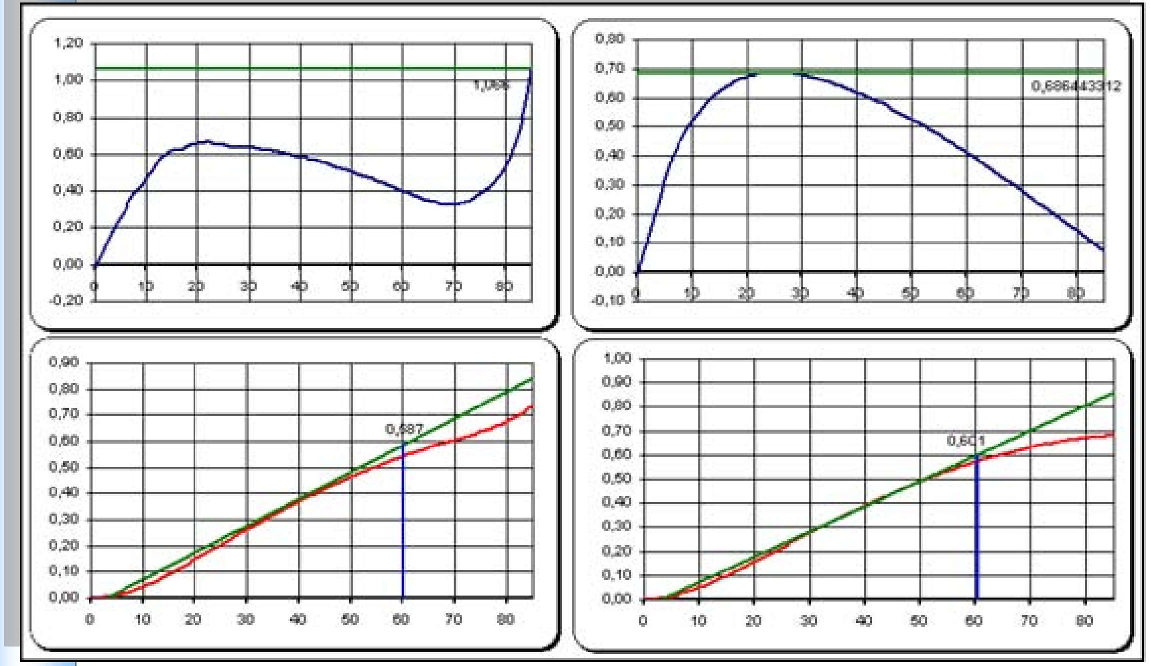
Wave--param.		Wind--param.		Life raft--param.		Drogue--param.		Line	
H	1,5	V	20	M	855	N	25		
L	25			RB					
				Num. surv.					
				X_2					
				V_2					
D t	0,05			typ					

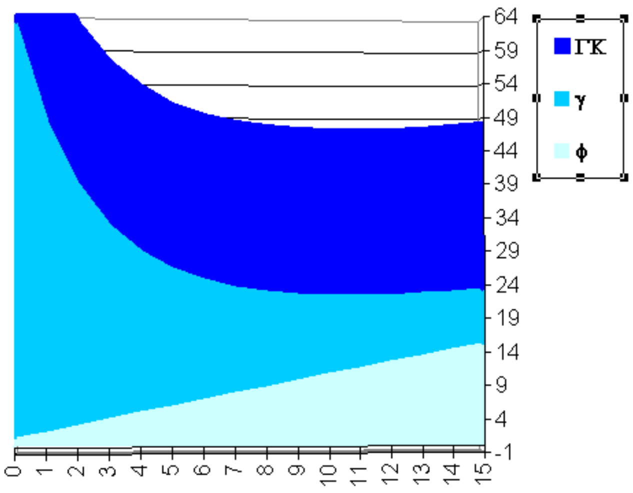
The input parameters table



THE SAFETY MODEL

At the second module life raft stability parameters for static and dynamic cases are count using the finish element method

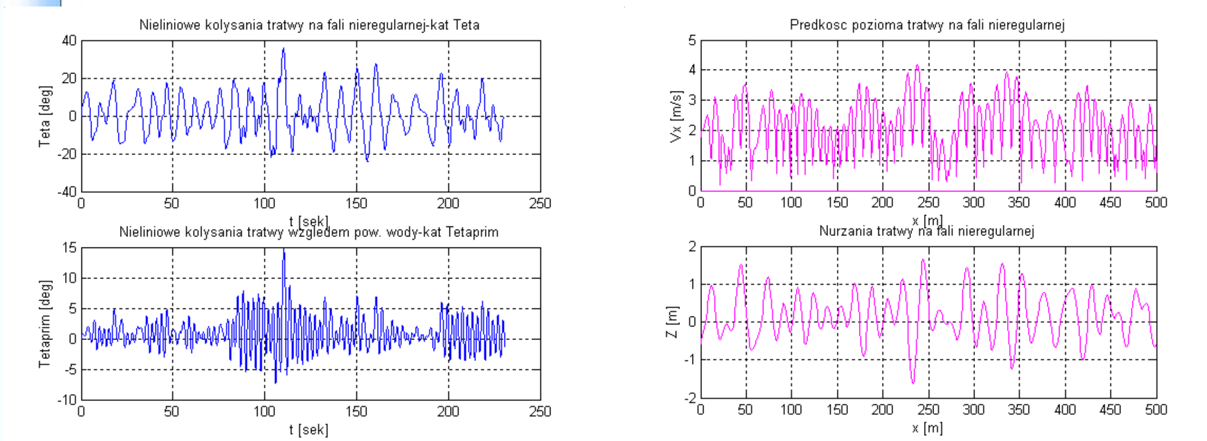


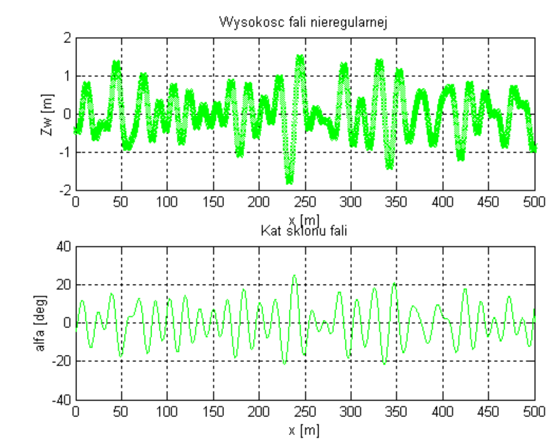


Critical angles (Φ-bottom above water, γ- life raft board in water) and vertical position of gravity’s center G

THE SAFETY MODEL

The third module is used to estimate the probability distribution of the life raft heeling, rolling, acceleration, and pitching parameters according to wave and wind characteristic



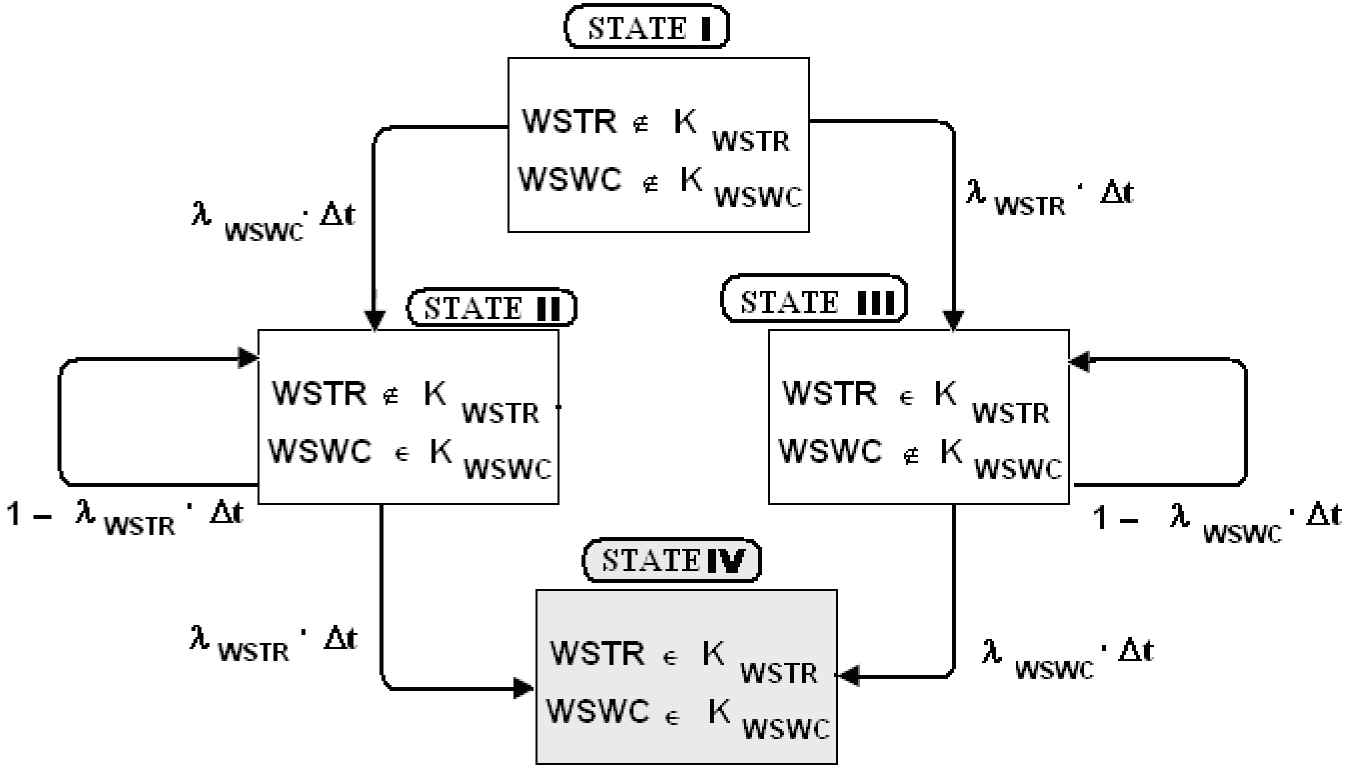


The life raft motion parameters (heeling, rolling, acceleration, pitching) – example for 10-life raft.

Characteristic parameters for random generated wave

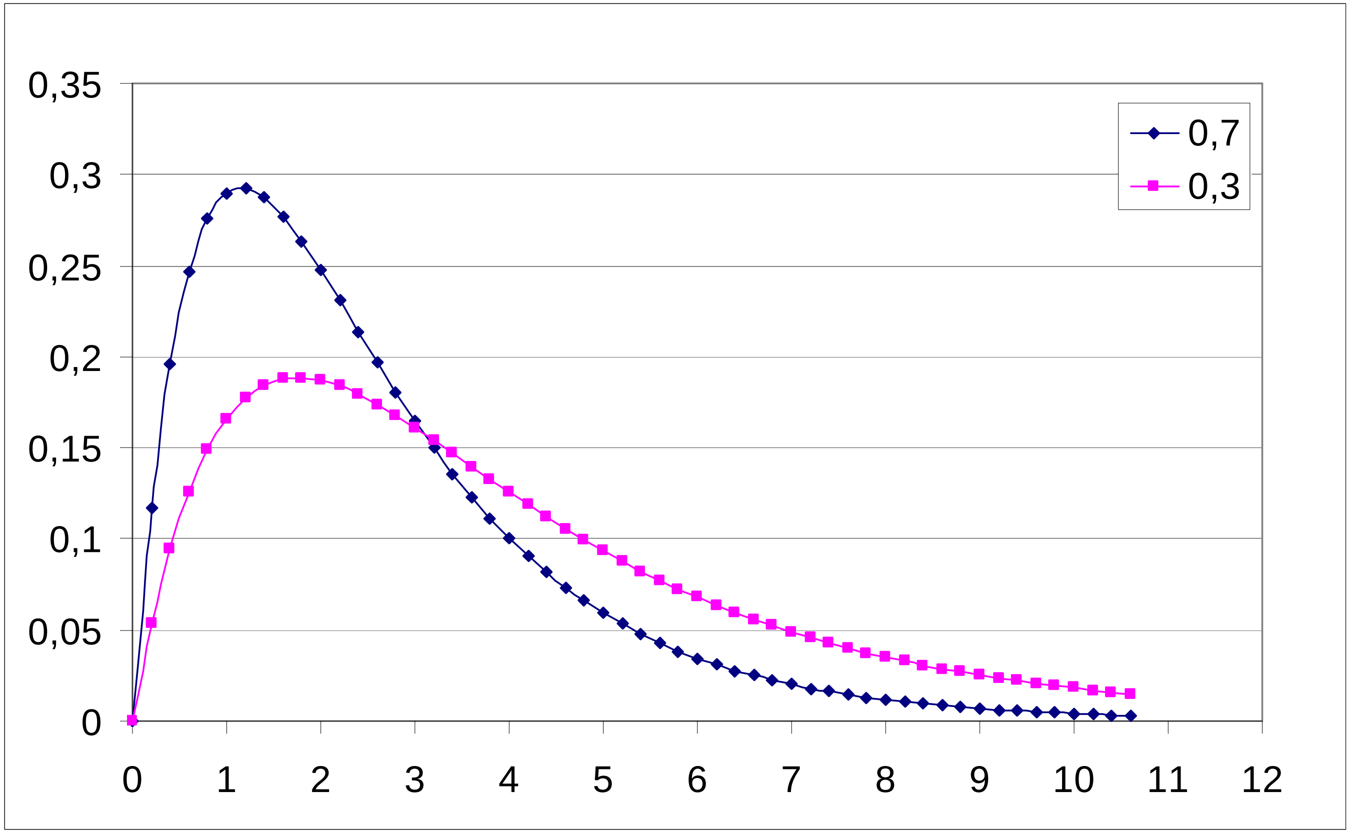
THE SAFETY MODEL

The fourth module is used to estimate the probability of occurrence of the life raft failure



THE SAFETY MODEL

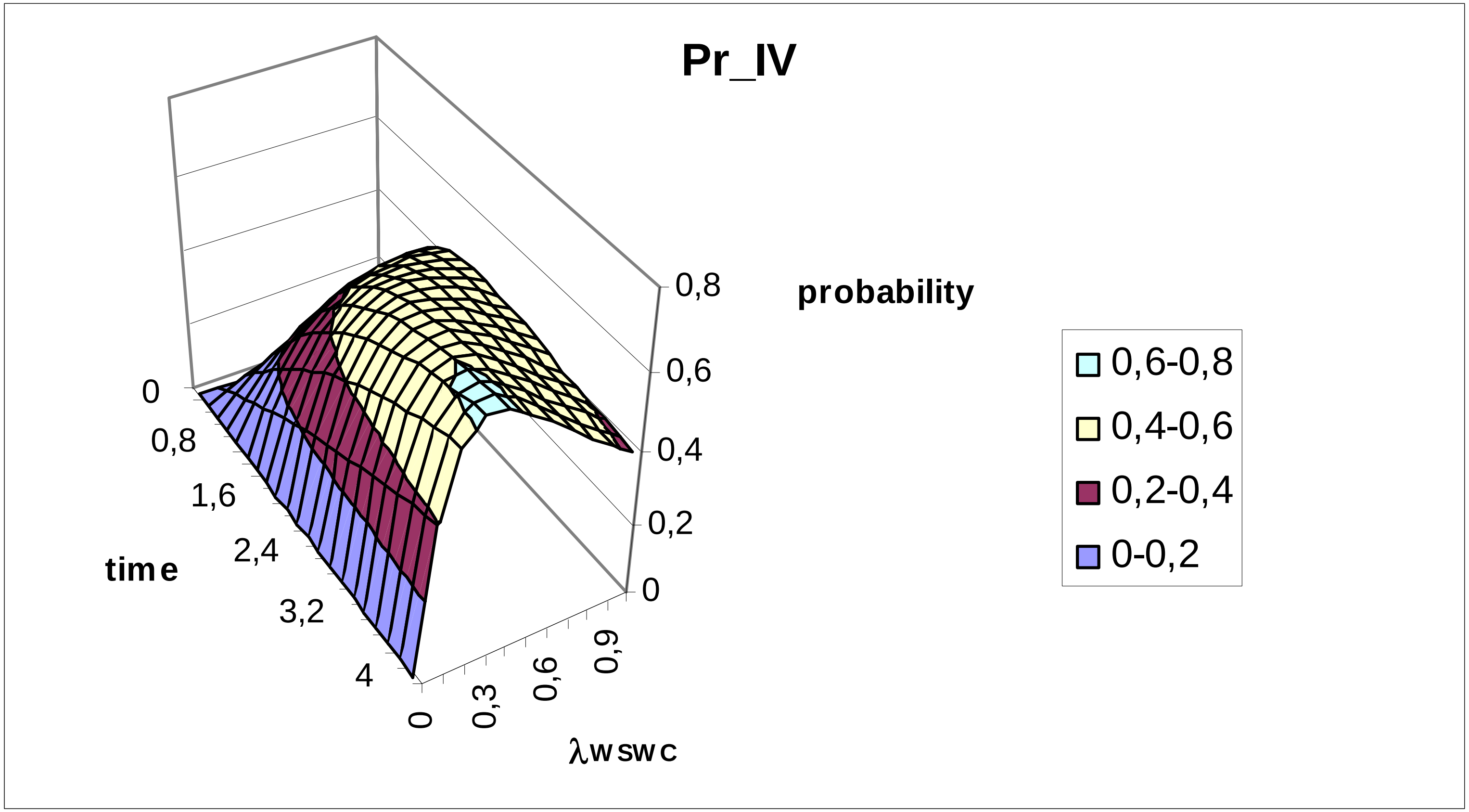
The probability of occurrence of the life raft failure



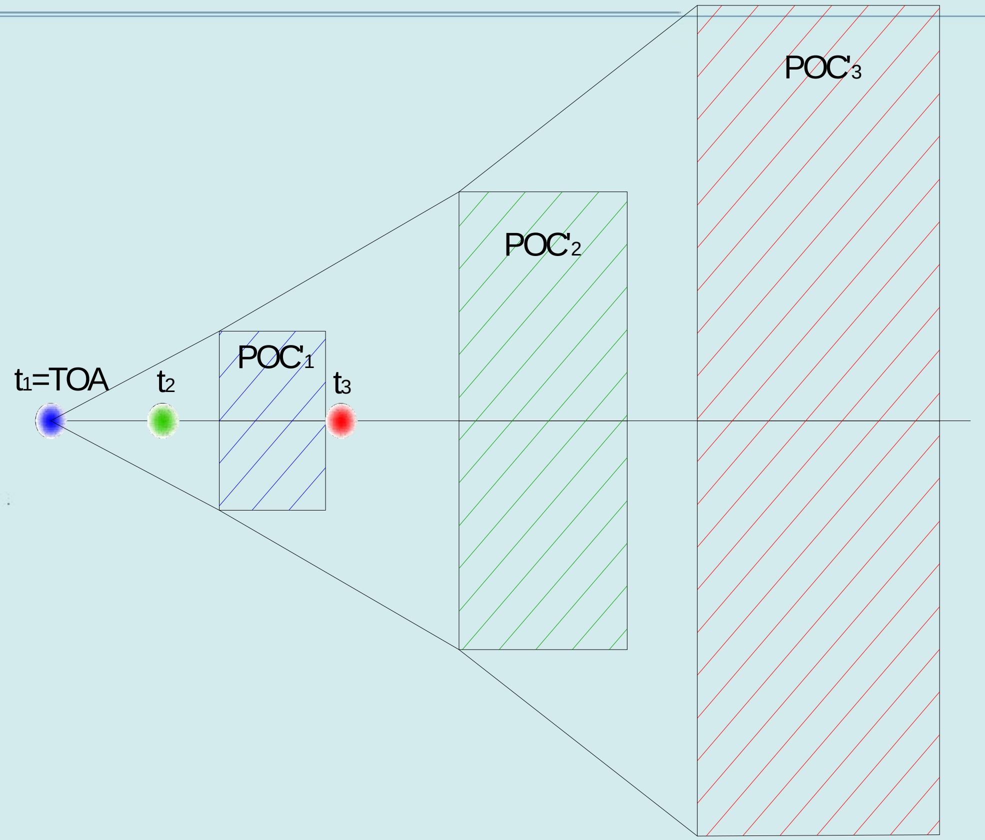
Liferaft with drogue – 0,3; Liferaft without drogue – 0,7

THE SAFETY MODEL

The probability of occurrence of the life raft failure



Modified probability of containment



$$POC'_i = POC \cdot p_A(t)$$

$p_A(t)$ – probability of life raft failure

Fields of applying

ESTIMATING OF PROBABILITY OF LIFE RAFT FAILURE ALOW TO STATE THE EVALUATION SYSTEM FOR THE EXISTING LIFE RAFTS

ESTIMATING OF PROBABILITY OF LIFE RAFT FAILURE ALOW TO PREPARE PRECISELY OPTIMISED SEARCH PLAN

ESTIMATING OF PROBABILITY OF LIFE RAFT FAILURE ALOW TO STATE THE EVALUATION SYSTEM FOR THE FUTURE SAFER CONCEPTS

THE SAFETY MODEL

The probability of occurrence of the life raft failure