NAVSEA TA 10-12

Decompression Algorithm Development and Implementation

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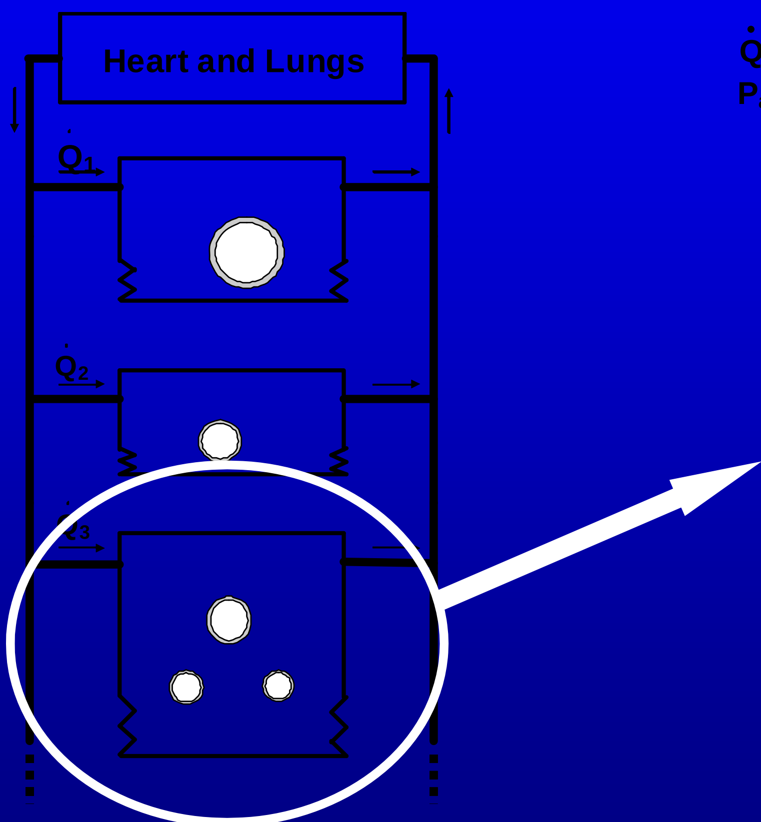
Project Overview

- Objectives
  - Develop decompression algorithm(s) that
    - are applicable to diving, altitude, and flying-after-diving problems
    - allow adjustment of the balance between time spent decompressing and the risk of decompression sickness (DCS)
    - account for the influences of exercise and thermal stresses
- Approach
  - Probabilistic gas and bubble dynamics models
  - Track gas exchange and bubble evolution in hypothetical gas exchange compartments through successive stages of a given profile
  - DCS risk expressed as function of prevailing bubble profusion (number density) and size

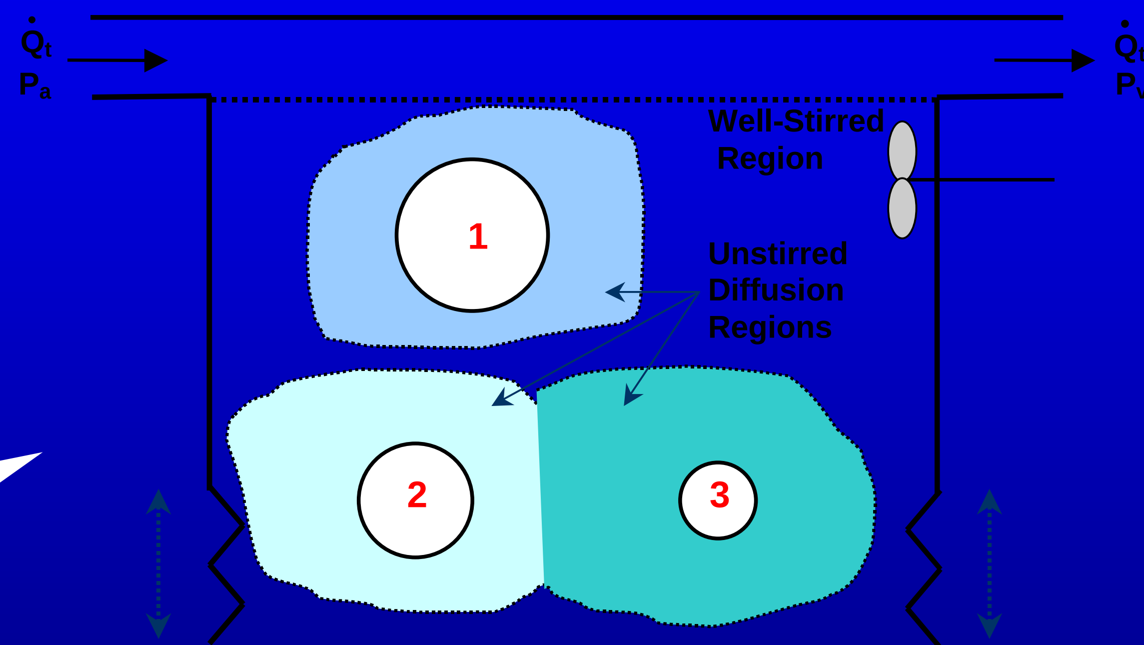
Gas and Bubble Dynamics Models Schematic

Whole Body:



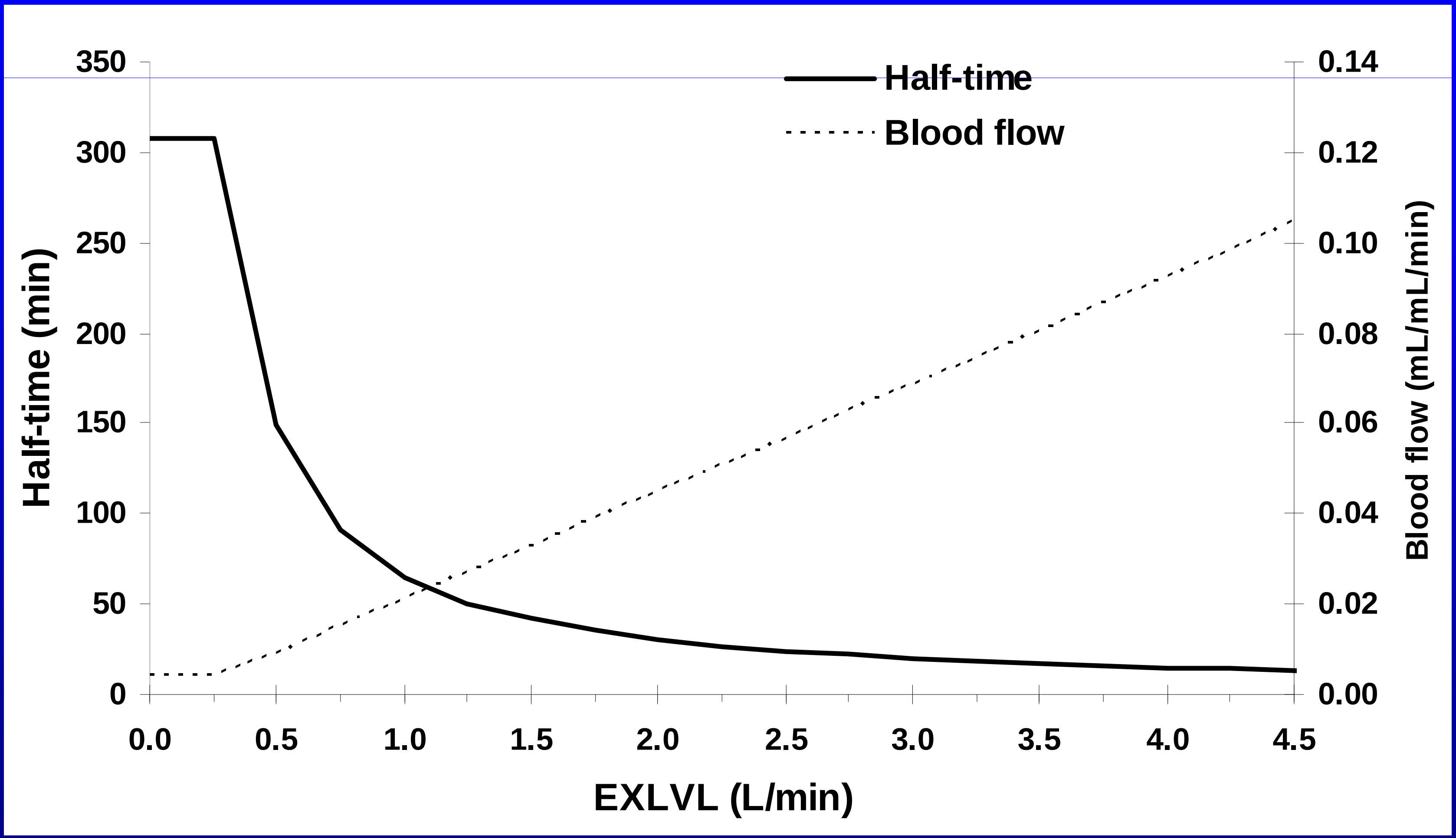
n parallel-perfused compartments

Compartment Detail:



Diffusion region around each bubble is unstirred and heterogeneously perfused with zero gas flux at the outer boundary (light dotted line)

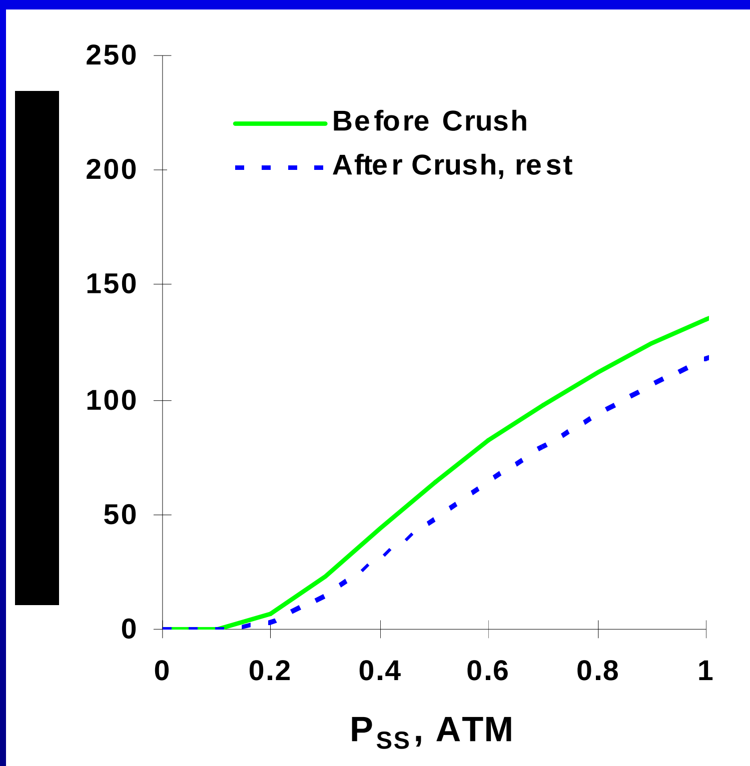
Modeled Exercise Effect on Gas Exchange



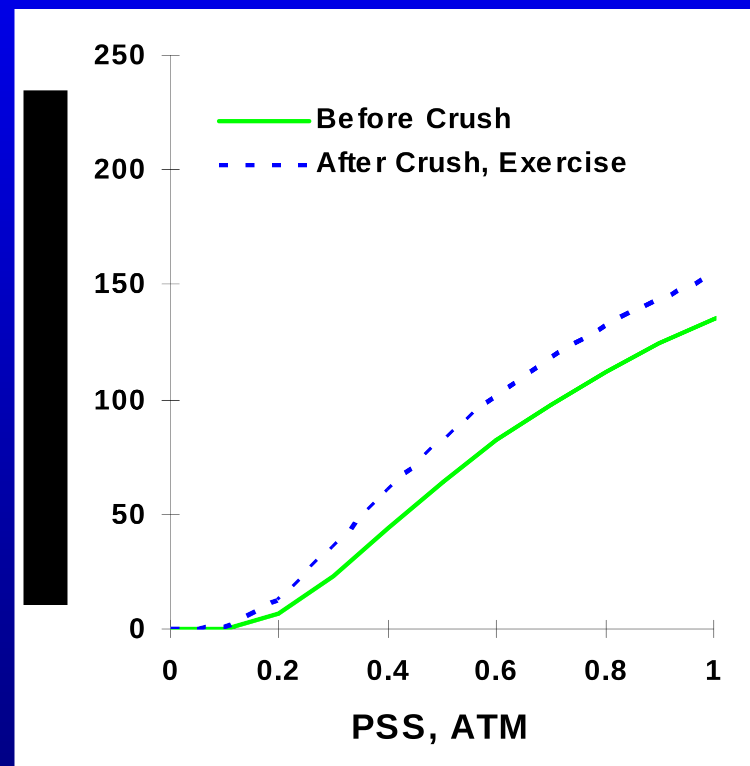
Blood-tissue O_2 exchange includes consideration of physiologic Hb-O_2 binding and metabolic O_2 consumption.

Modeled Exercise Effect on Bubble Nucleation

Both the distribution of nuclei and the number of nuclei recruited at given gas-supersaturations are affected by exercise.



1 ata crush



1 ata crush,
exercise @ 1 L-O_2/min

DCS Risk Function

$$h(t) = \sum_{i}^{n_c} g_i \left[\frac{(V_{b,i} - Vr0_i) \cdot (N_{b,i})^{B_{N,i}}}{V_{t,i}} \right]$$

$n_c \equiv$ number of compartments (tissues)

$g_i \equiv$ compartmental gain

$V_{b,i} \equiv$ prevailing compartmental bubble volume

$Vr0_i \equiv$ compartmental nucleonic bubble volume

$V_{t,i} \equiv$ compartment volume

$N_{b,i} \equiv$ prevailing number of bubbles in compartment

$B_{N,i} \equiv$ compartmental bubble number power factor

Provides means to balance effects of exercise on compartmental perfusion (which tend to *decrease* DCS risk after decompression) with those on bubble recruitment/nucleation (which tend to *increase* DCS risk after decompression).

Model Parameterization

- Model parameter values found by maximizing the likelihood of model-estimated DCS incidences for a large body of compiled laboratory data for flight profiles and their DCS outcomes
- Calibration data:

Source	# Man-Exposures	# DCS	# DCS Marginals	DCS Incidence (%)
USAF	1194	401	0	33.6
NASA				
Conkin DCS Database	549	84	0	15.3
PRP Phases I-IV	178	19	3	10.8
Totals	1921	504	3	26.3

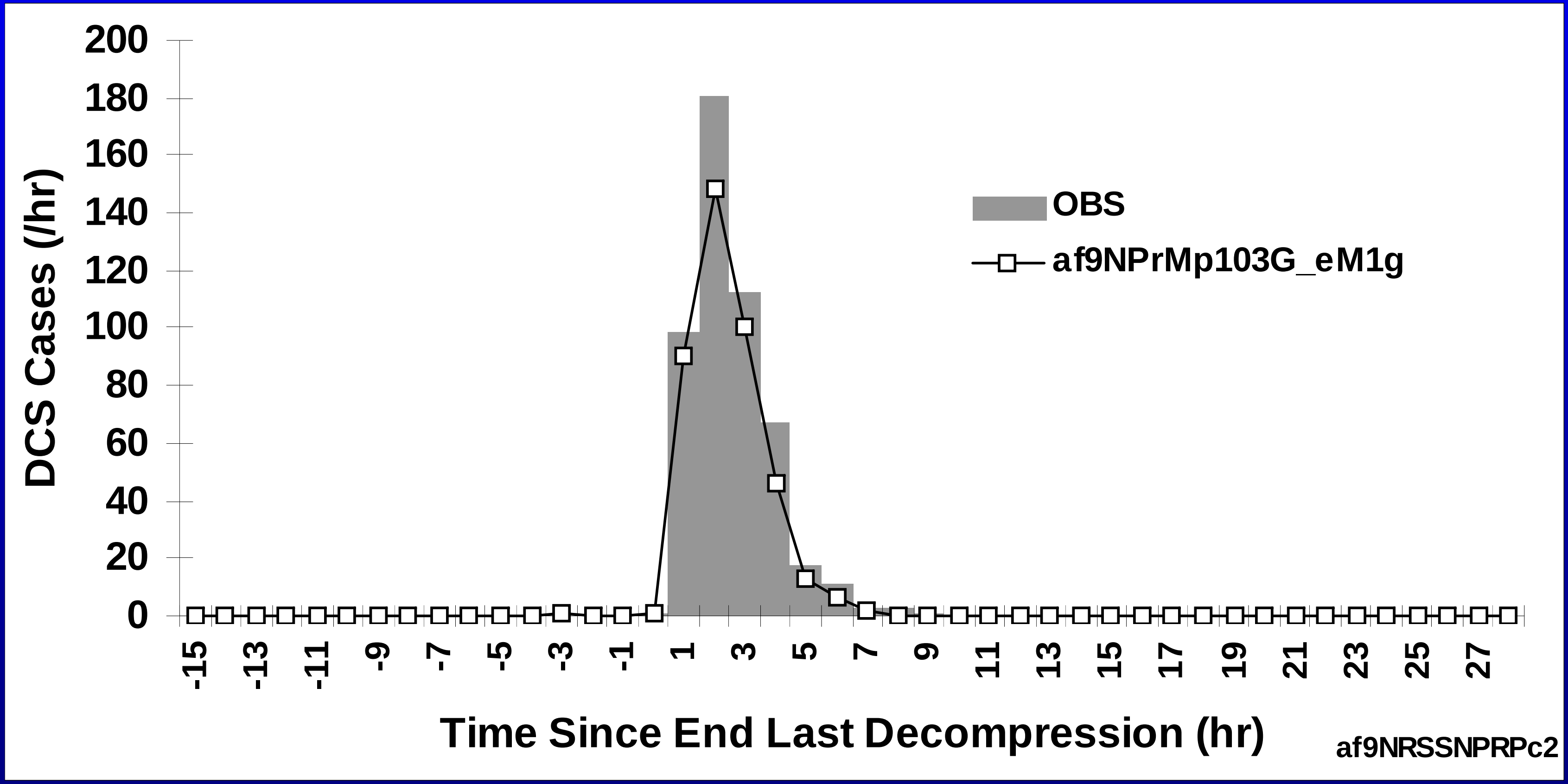
Likelihood Maximization Results

MODEL	Log Likelihood
Fitted	**-2.508×10^3**
Perfect	-0.975
I-O Null	-1.106×10^3
Survival Null	**-3.790×10^3**

c-index = 0.5976

Tissue	Gas	Half-time (min)	Bbbl r_{min} (cm)
1	O_2	307.6	1.12×10^{-5}
	N_2	307.6	

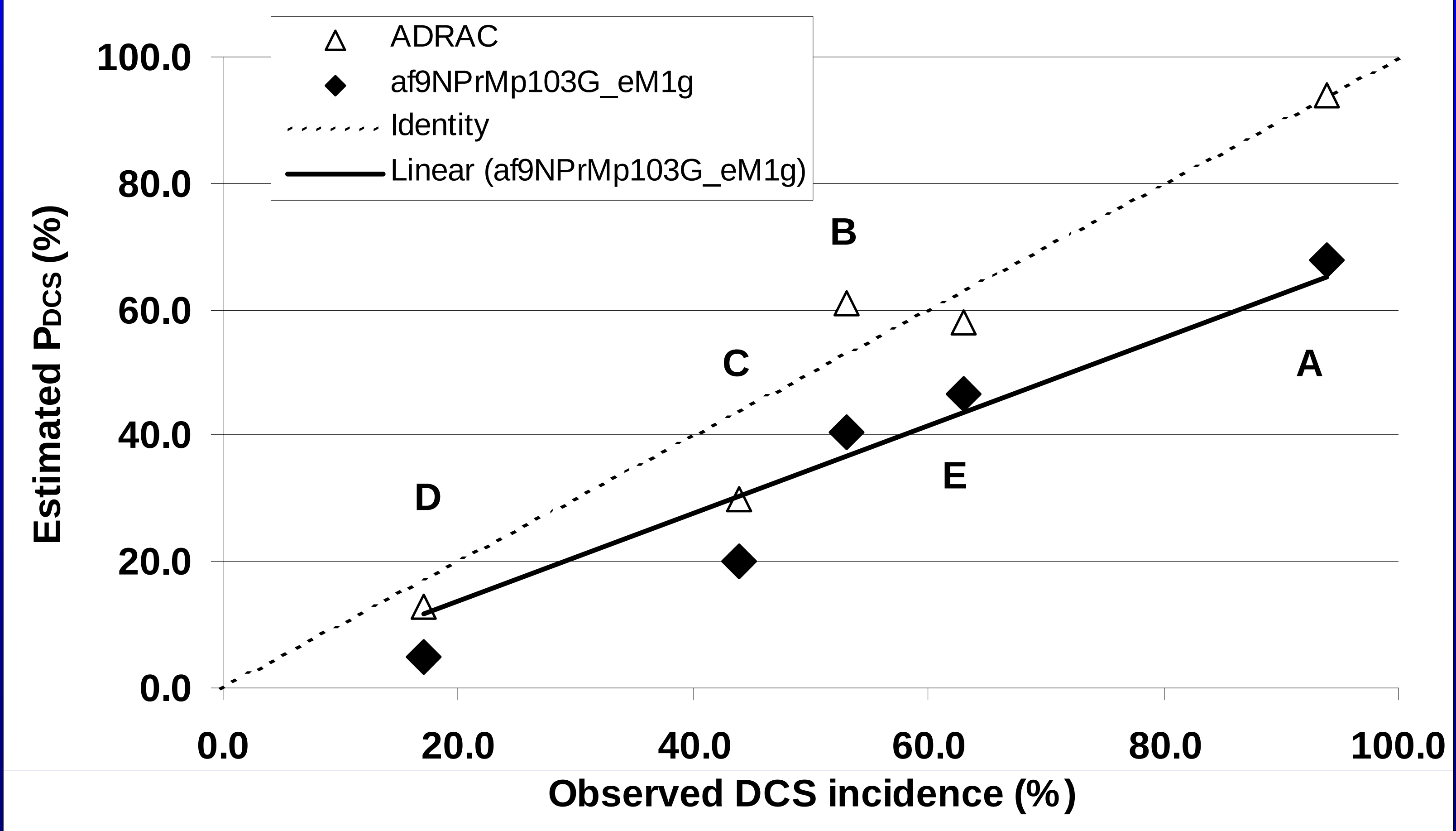
Observed and Estimated Occurrence Density Functions



Model Performance/Validation

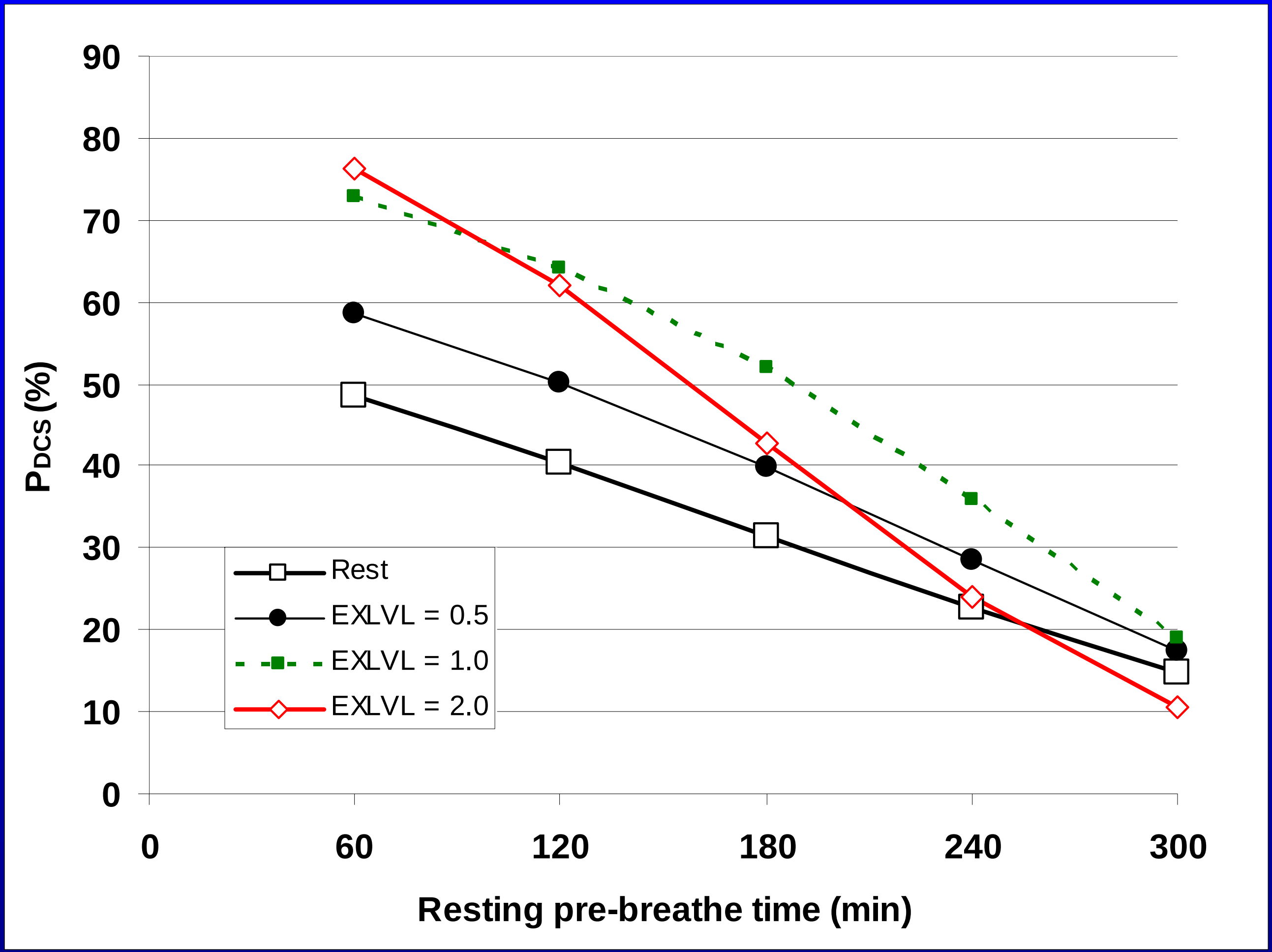
Validation profiles*:

- A) 90GLPB, NIFPB, 35,000/180-Moderate exercise
- B) 30GLPB, NIFPB, 25,000/240-Heavy exercise
- C) 15GLPB, NIFPB, 22,500/240-Heavy exercise
- D) 0GLPB, NIFPB, 18,000/360-Heavy exercise
- E) 75GLPB, NIFPB, 30,000/240-Rest



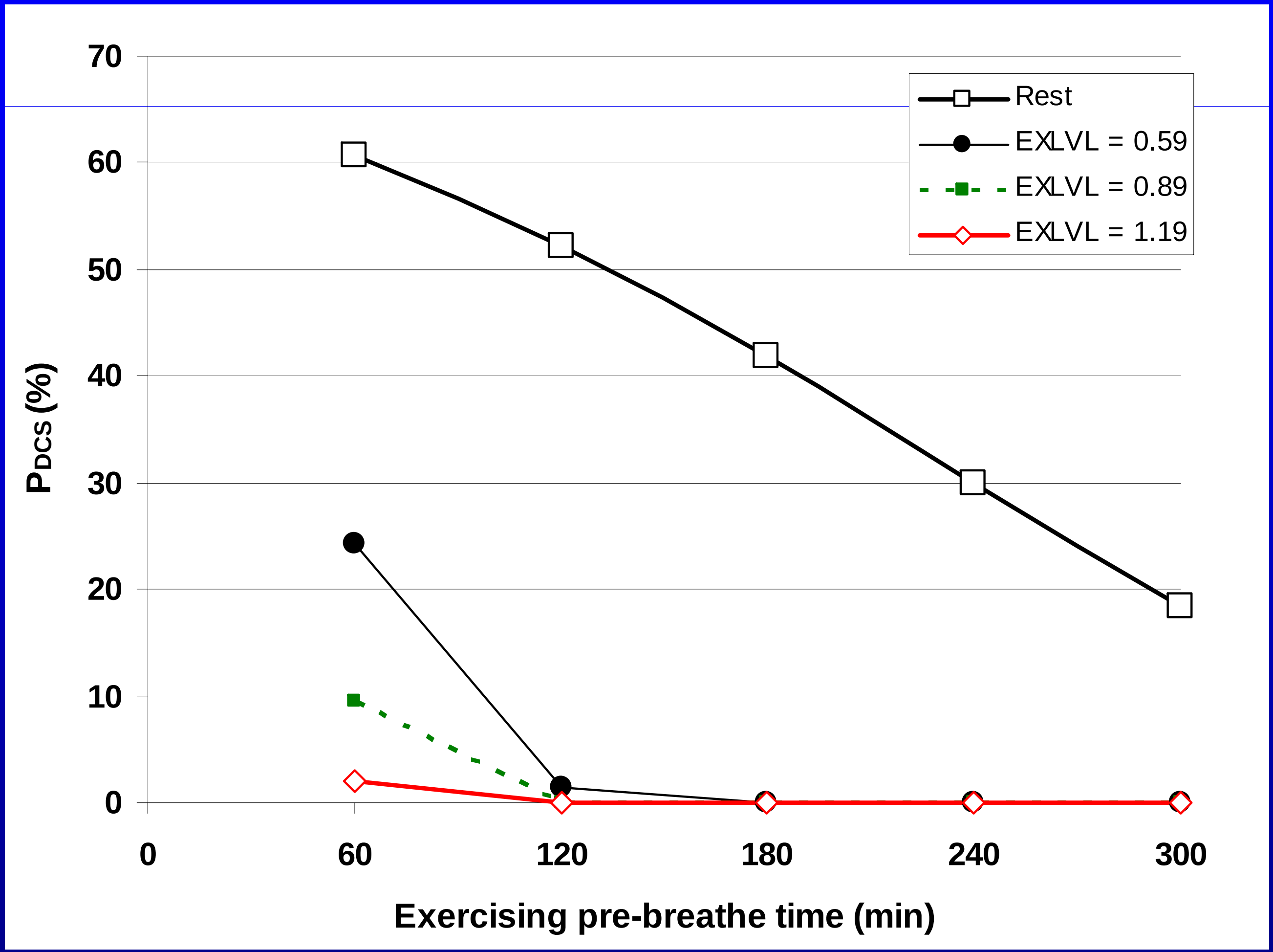
* Pilmanis AA, Petropoulos LJ, Kannan N, Webb JT. Decompression sickness risk model: Development and validation by 150 prospective hypobaric exposures. Aviat Space Environ Med 2004; 75:749-59.

Model Performance/Predictions



- Resting oxygen prebreathes
- 4-hour exposures at 30,320 ft altitude (4.3 psia) w/ exercise at indicated levels (EXLVL= whole-body $\dot{V}_{O_2}$, L-O_2/min)

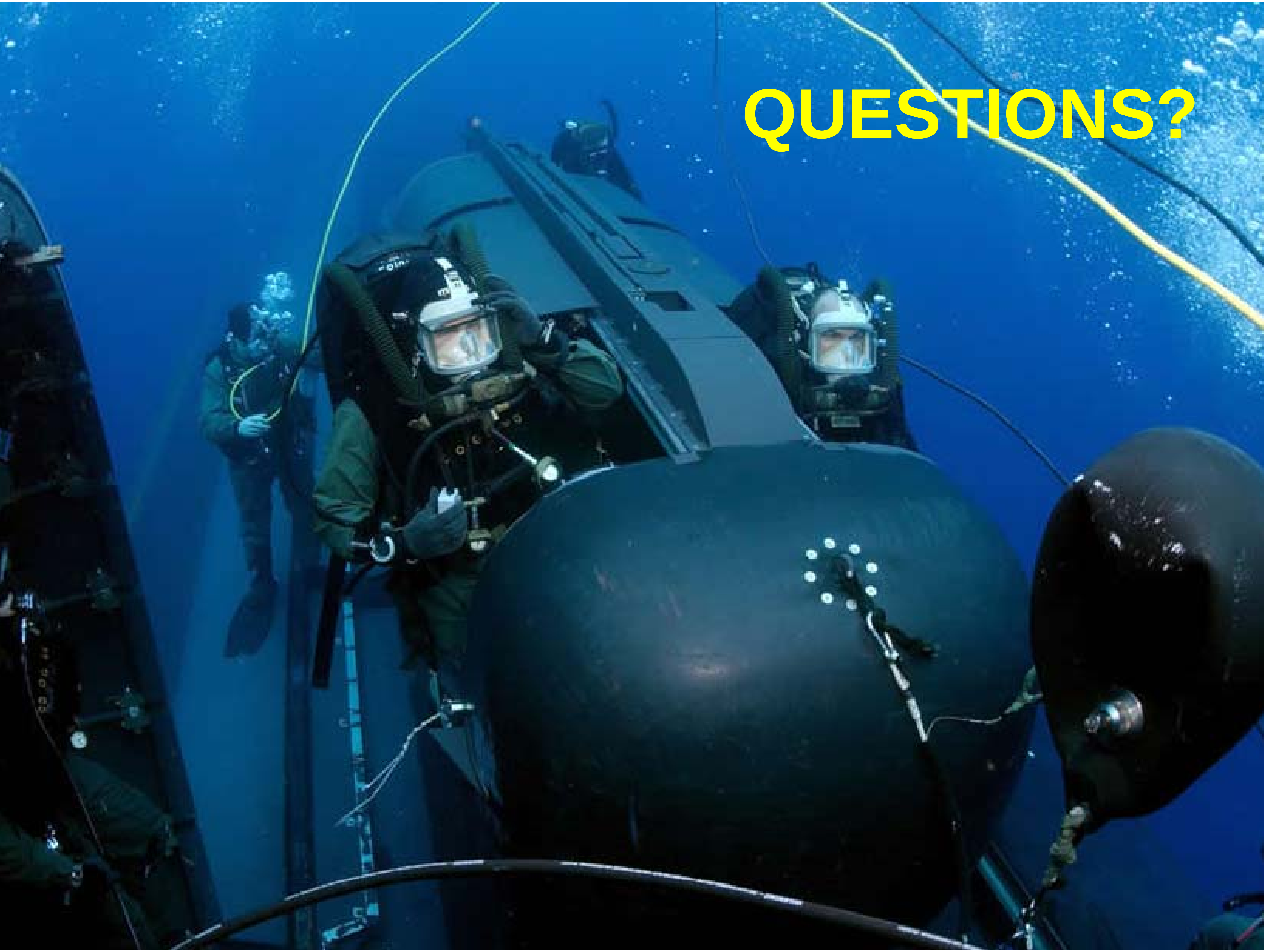
Model Performance/Predictions



- Oxygen prebreathes of various duration w/ exercise at indicated levels
- 4-hour exposures at 30,320 ft altitude (4.3 psia) w/ exercise at EXLVL= 0.55 (= whole-body $\dot{V}_{O_2}$, L-O_2/min).

Conclusions

- The optimized model captures essential features of known effects of exercise on DCS risk in altitude exposures
- Model structure will form the basis for a comprehensive model for diving and flying-after-diving problems.


QUESTIONS?