

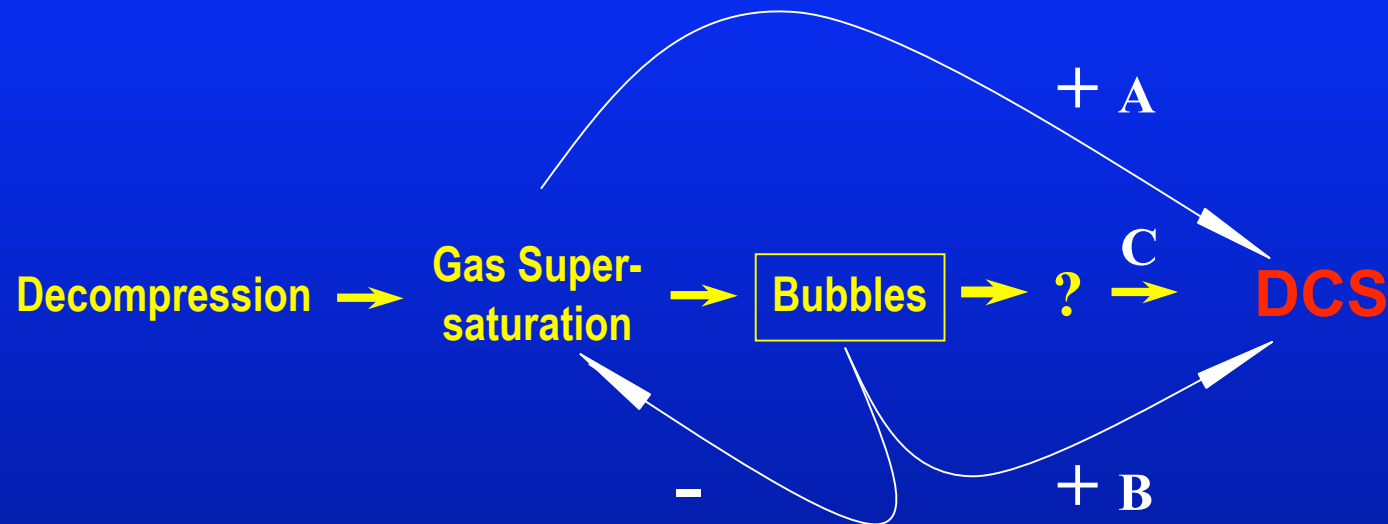
Empirical Evaluation of the Efficacy of Deep Stops in Air Decompression Dives

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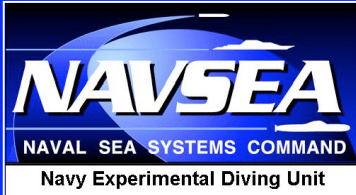
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The Paradigm



- A) $P_{DCS} = f(\text{inert gas burden})$
- B) $P_{DCS} = f(\text{bubble volume})$
- C) $P_{DCS} = f(\text{bubble-induced processes})$

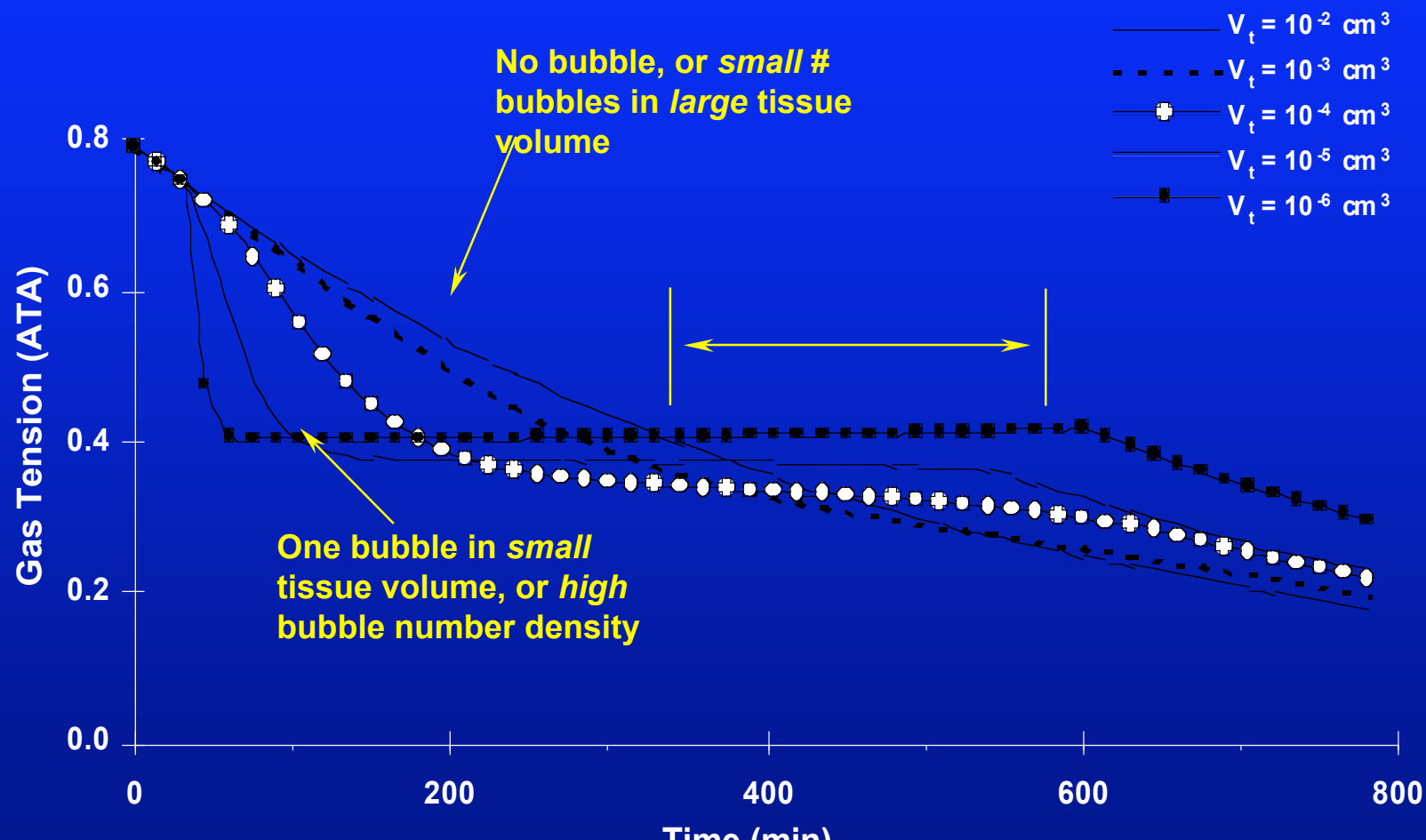
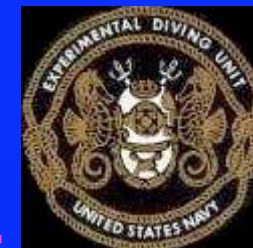


The Problem

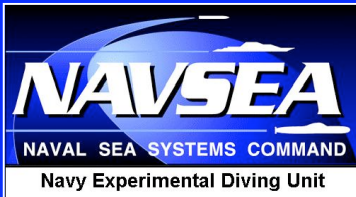


- Bubble formation slows kinetics of gas elimination
 - Consequence: Longer decompressions than if bubbles do not form
- Prevention of bubble formation during decompression must therefore:
 - Allow shorter decompressions at the same DCS risk
 - Reduce DCS risk for decompressions of the same length

Effects of Bubble Formation and Growth on Gas Elimination



From: Srinivasan RS, Gerth WA, Powell MR. Mathematical models of diffusion-limited gas bubble dynamics in tissue. Journal of Applied Physiology, 86(2): 732-741, 1999.

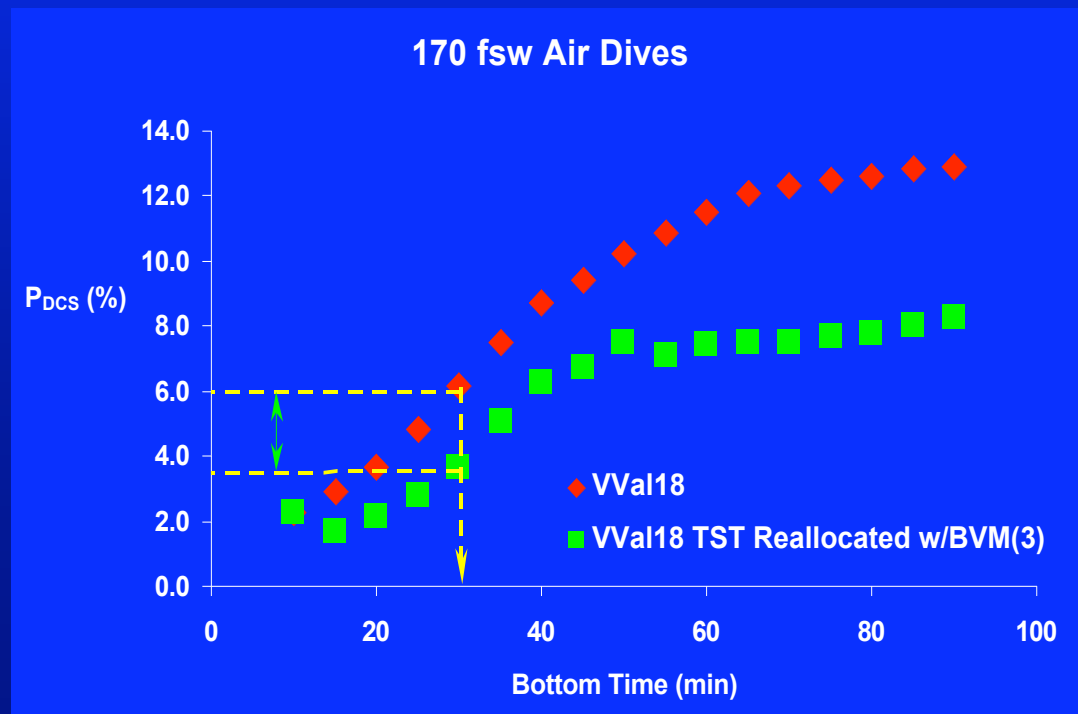


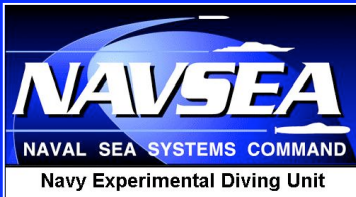
Experimental Design: Schedule Selection



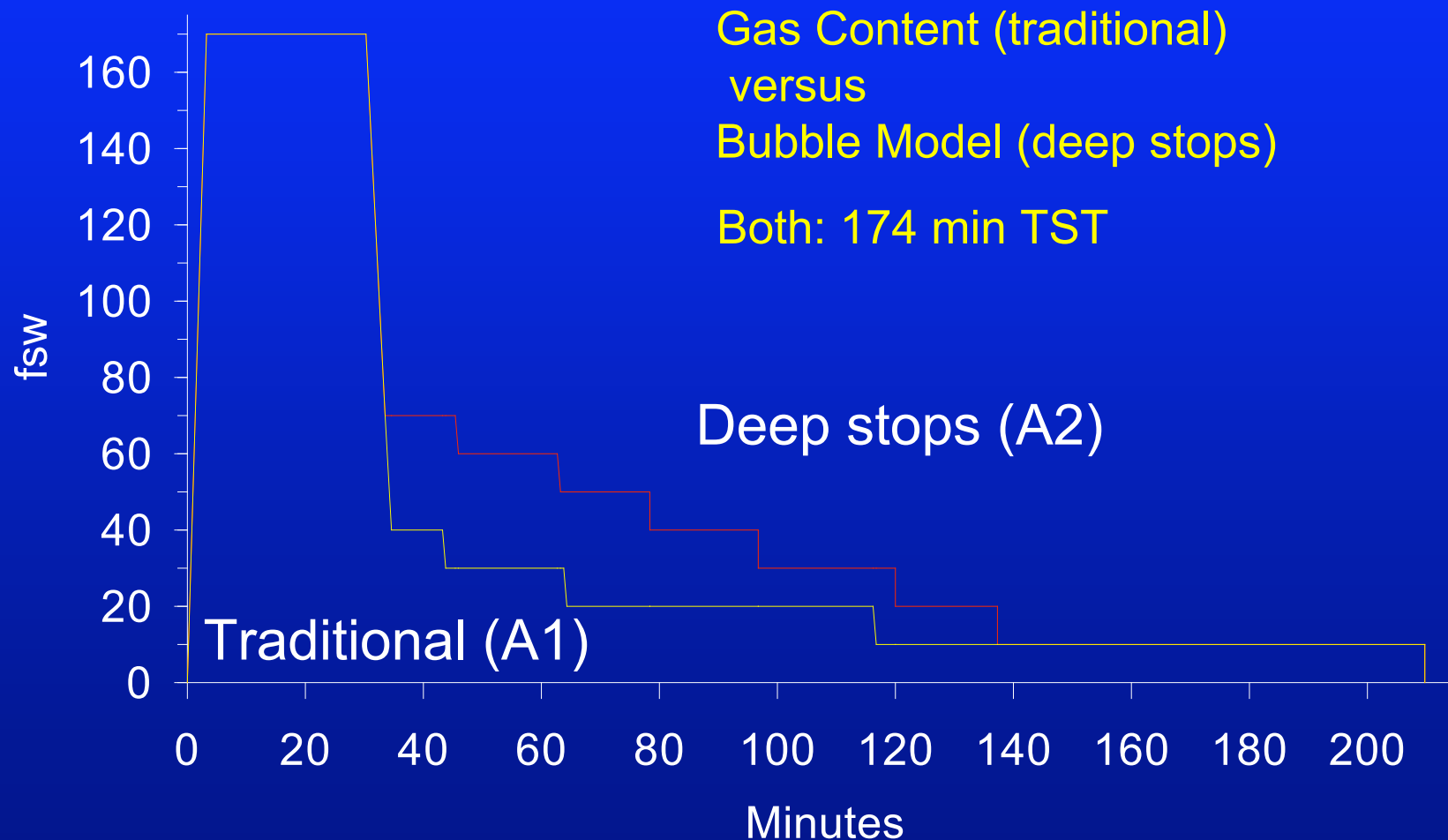
- **A1: “Traditional” schedule prescribed by algorithm that controls compartmental gas contents; i.e., VVal-18 Thalmann Algorithm**
- **A2: Traditional TST reallocated among stops to obtain minimum DCS risk with an algorithm that controls bubble formation; i.e., BVM(3)**
- **Both schedules must have discernibly different and testable DCS risks**

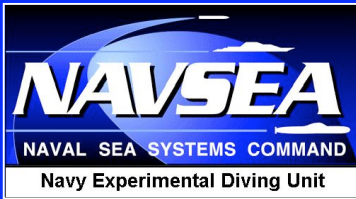
- **BVM(3) reallocation has greatest impact at long bottom times where DCS risks are excessively high**
- **The two schedules for a 170 fsw (52 msw)/30 min dive, with 174 min TST, are testable at 6.0 and 3.8% risk**





Test Dive Profiles: 170 fsw/ 30 Min Air Dives

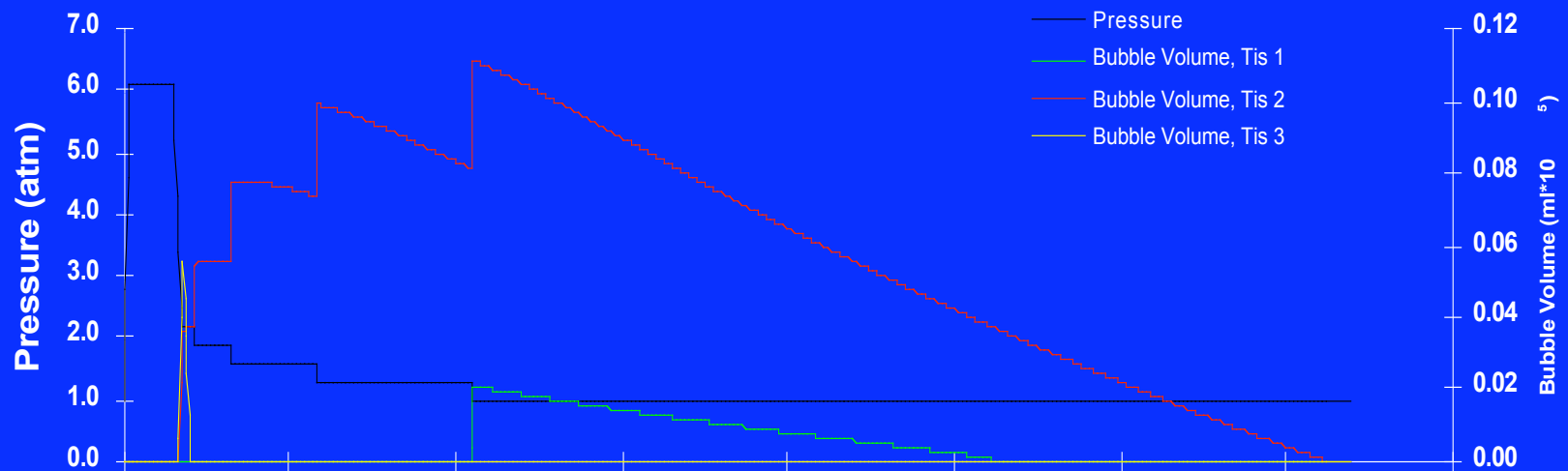




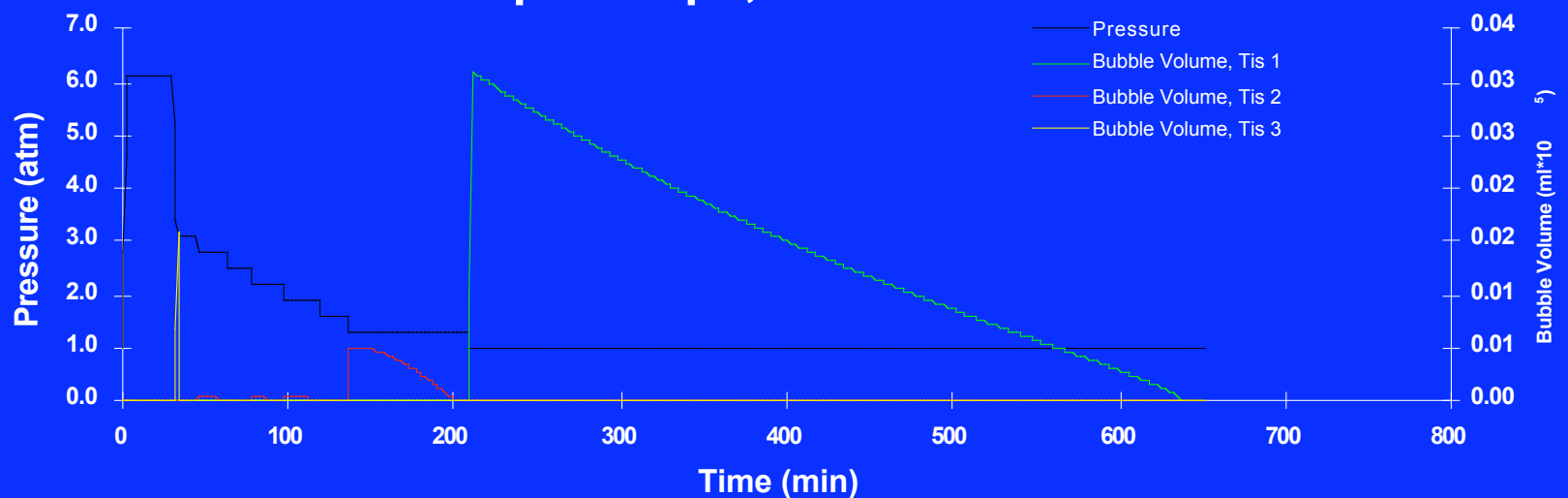
Decompression Schedules and Corresponding Bubble Volume Profiles in 170 fsw /30 min Test Dives

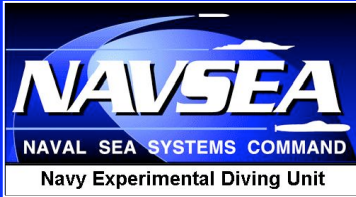


VVal-18
(A1)



Reallocated: More time at deeper stops, limited bubble evolution
(A2)



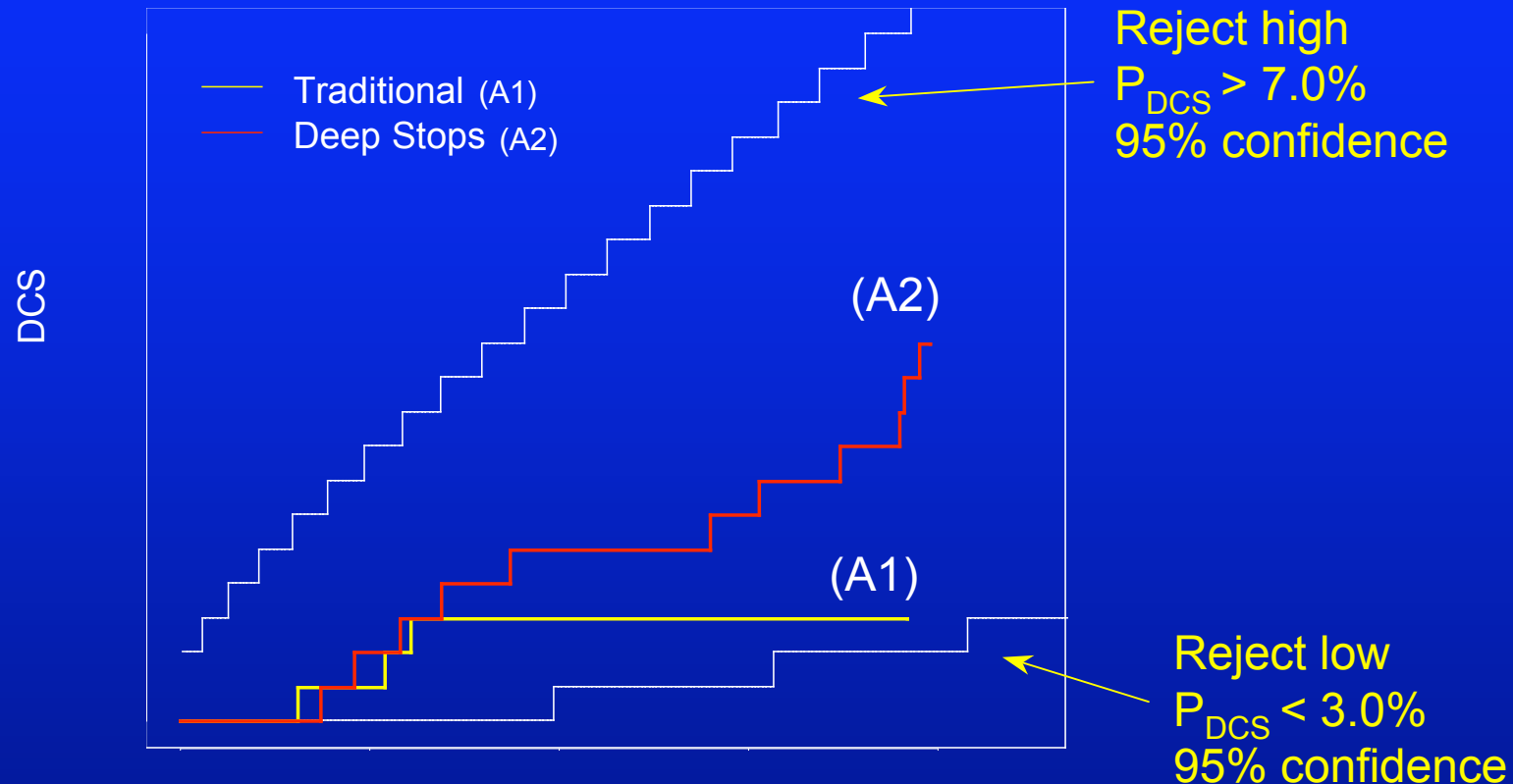


Test Dive Conditions



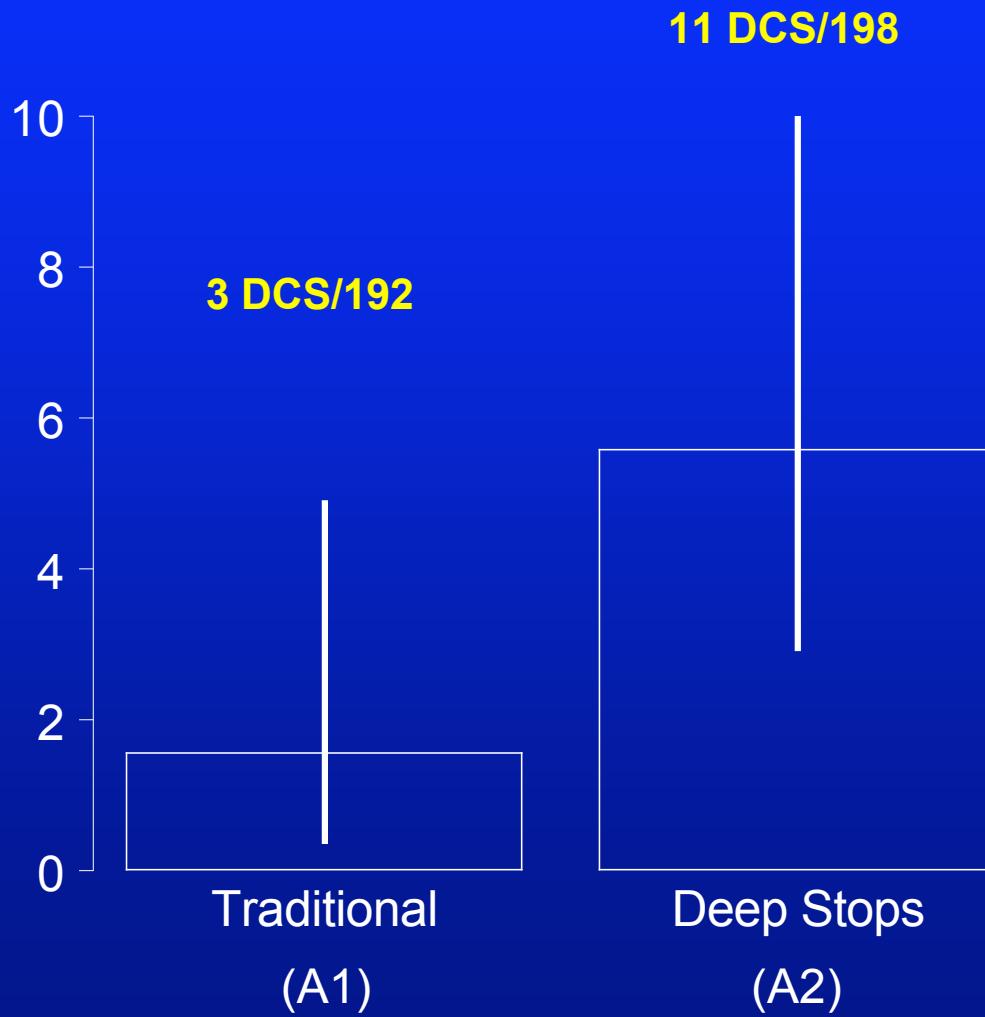
- Descent rate = 60 fsw/min (18 msw/min)
- Ascent rate = 30 fsw/min (9 msw/min),
- Divers wore swimsuits and t-shirts, breathed surface-supplied air via full face masks, and were immersed in 86 °F (30 °C) water in the NEDU Ocean Simulation Facility wet pot throughout each dive.
 - Equivalent to 60 - 65 °C cold conditions for wet suited divers, no suit compression artifact: See Doolette, *et al.*, These Proceedings
- Divers performed 115 watt cycle ergometer work at 170 fsw until 1 minute before leaving bottom, then rested during subsequent decompression.
- Divers were monitored for venous gas emboli (VGE) with trans-thoracic cardiac 2-D echo imaging (Siemens Medical Solutions® Acuson Cypress Portable Colorflow Ultrasound System) at 30 minutes and 2 hours postdive.
- 375 man-dives on each schedule planned within an accept-reject sequential trial envelope

Sequential Trial Envelope and Results



Man-diving stopped within sequential trial envelope at midpoint
interim analysis: P_{DCS} (Deep Stops) $>$ P_{DCS} (traditional)

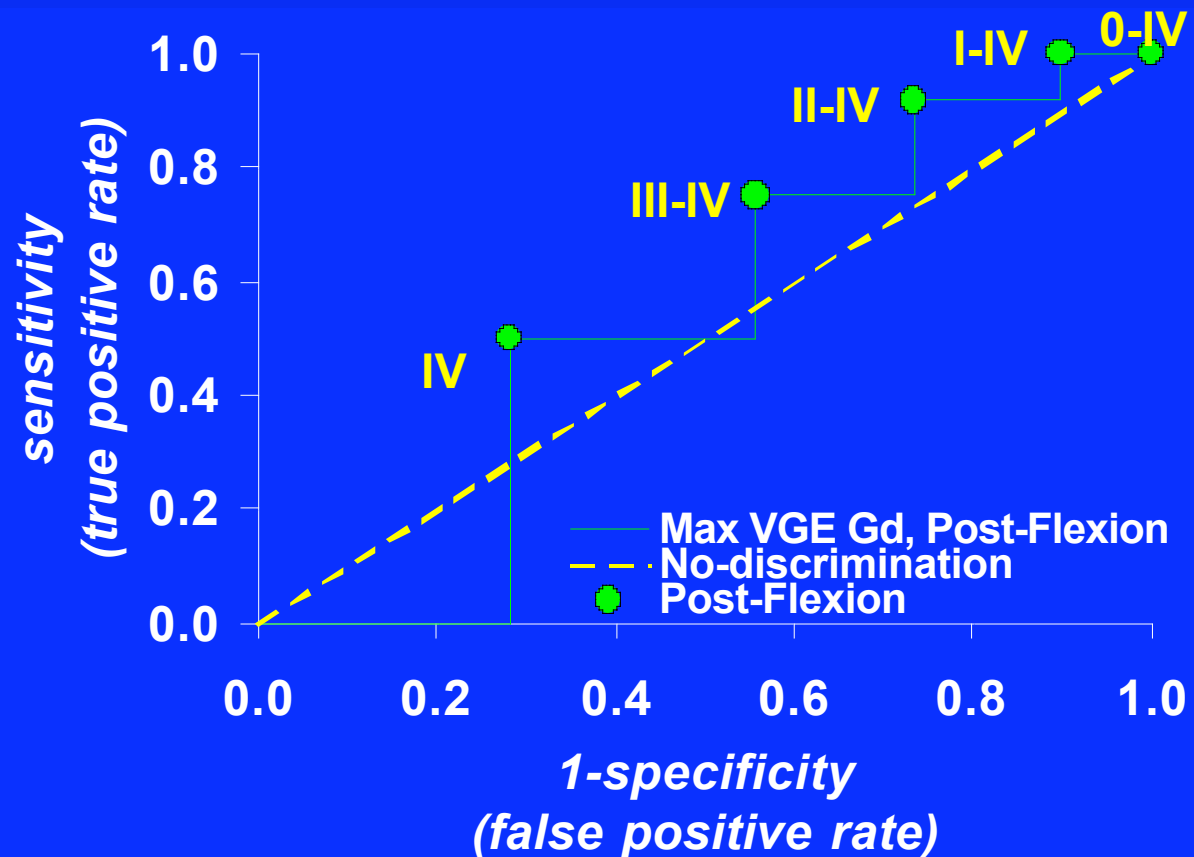
Results: DCS



- A1 vs. A2 (two-sided Fisher)
 - $P = 0.053$
- A1 < A2 (one-sided Fisher)
 - $P = 0.030$

Results: VGE and DCS

Receiver-Operator Characteristic (ROC) Curve

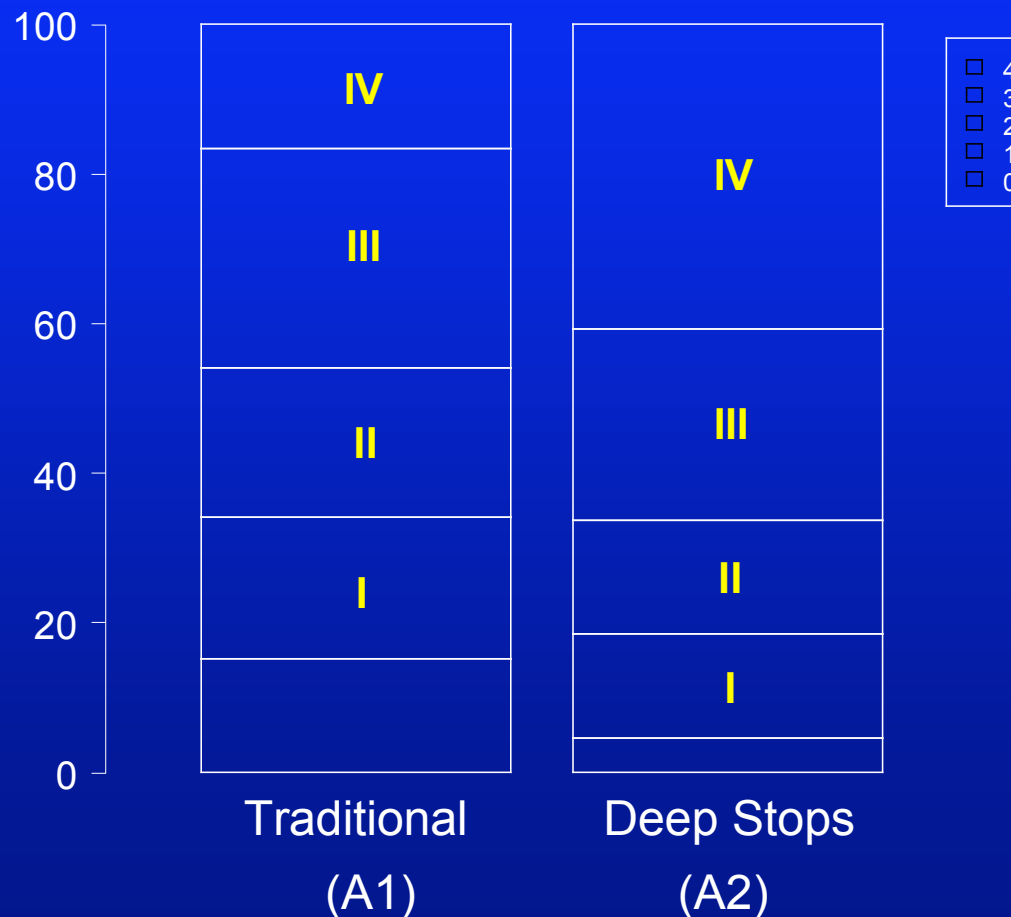


Area Under Curve (AUC) = 0.68

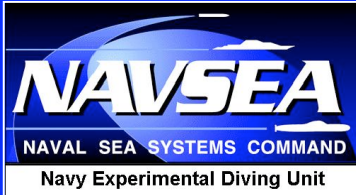
Results: VGE As Measure of Decompression Stress



Maximum VGE Grade (Modified Spencer) of all examinations



VGE Gd higher after A2 than after A1; $P < 0.0001$, Wilcoxon rank sum test

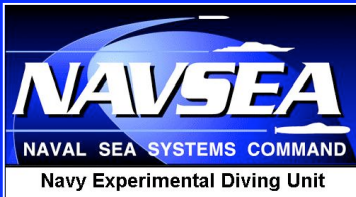


Conclusions



Deep stops didn't work here. Both DCS and VGE were higher after the deep stops schedule than after the traditional schedule

Slower gas elimination or continued gas uptake offset benefits of reduced bubble growth at deep stops



ACKNOWLEDGEMENTS



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Questions ?



NEED U DEEP STOPS PROTOCOL



-OR-

