ALTITUDE DECOMPRESSION SICKNESS (DCS) RISK FACTORS REVISITED

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ALTITUDE DECOMPRESSION SICKNESS RISK ASSESSMENT COMPUTER (ADRAC) MODEL

Currently, ADRAC is the most accurate altitude DCS risk prediction model.

- **Pilmanis AA, Petropoulos LJ, Kannan N, Webb JT. Aviat Space Environ Med 2004; 75(9):749-759.**
- **ADRAC is a statistical model "…based on the loglogistic distribution using three risk factors: pressure in mmHg, preoxygenation time", and an exercise *estimate*.**
- **It uses "…equations which describe bubble characteristics during decompression."**
- **Bubbles, venous gas emboli, are not the best indicators of DCS risk. Too many false negatives and false positives.**

POTENTIAL FOR A BETTER DCS RISK MODEL

This evolving Microsoft Excel-based DCS model uses the same 4 parameters, albeit based on new data and different interpretations.

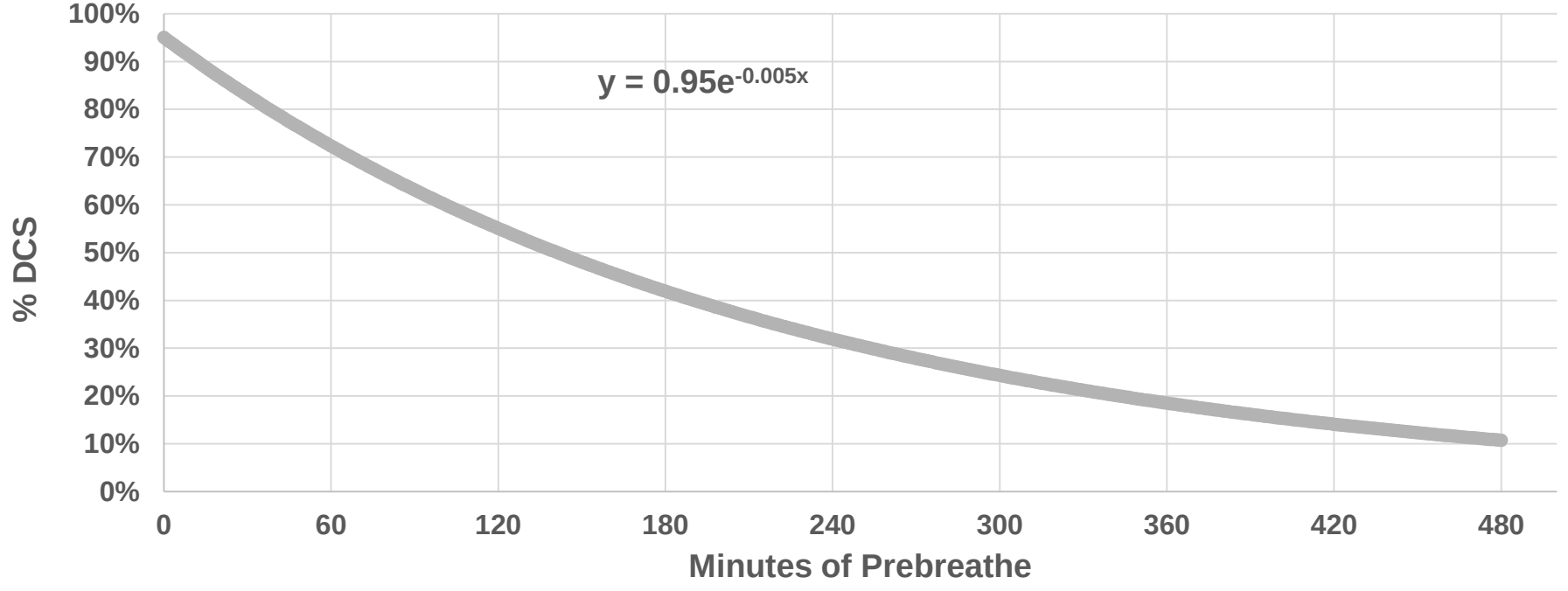
- **Prebreathe time in minutes, breathing 100% O_2 prior to exposure is based on existing, published data.**
- **Tissue Ratio**
  - **Altitude in feet does not have a linear relationship with pressure.**
  - **Tissue ratio more accurately reflects level of supersaturation and its likelihood of forming a gas phase.**
- **Level of activity is the highest 1-min of $\dot{V}O_2$ during each 16-min of testing, ml/kg/min (Webb et al., 2010 & 2016).**
- **Exposure time vs. DCS risk is a sigmoidal curve.**

OTHER PARAMETERS?

- **Rate of ascent? No; Pilmanis et al. (2003)**
- **Gender? No; Webb et al. (2003)**
- **Weight?, Age?, BMI?, Menstrual Cycle?, Maximal Aerobic capacity?, Yes; Webb et al. (2003; 2005)**
- **Worth including in a model? No; not enough effect compared to the big 4**

EFFECT OF PREBREATHE TIME VS. DCS RISK

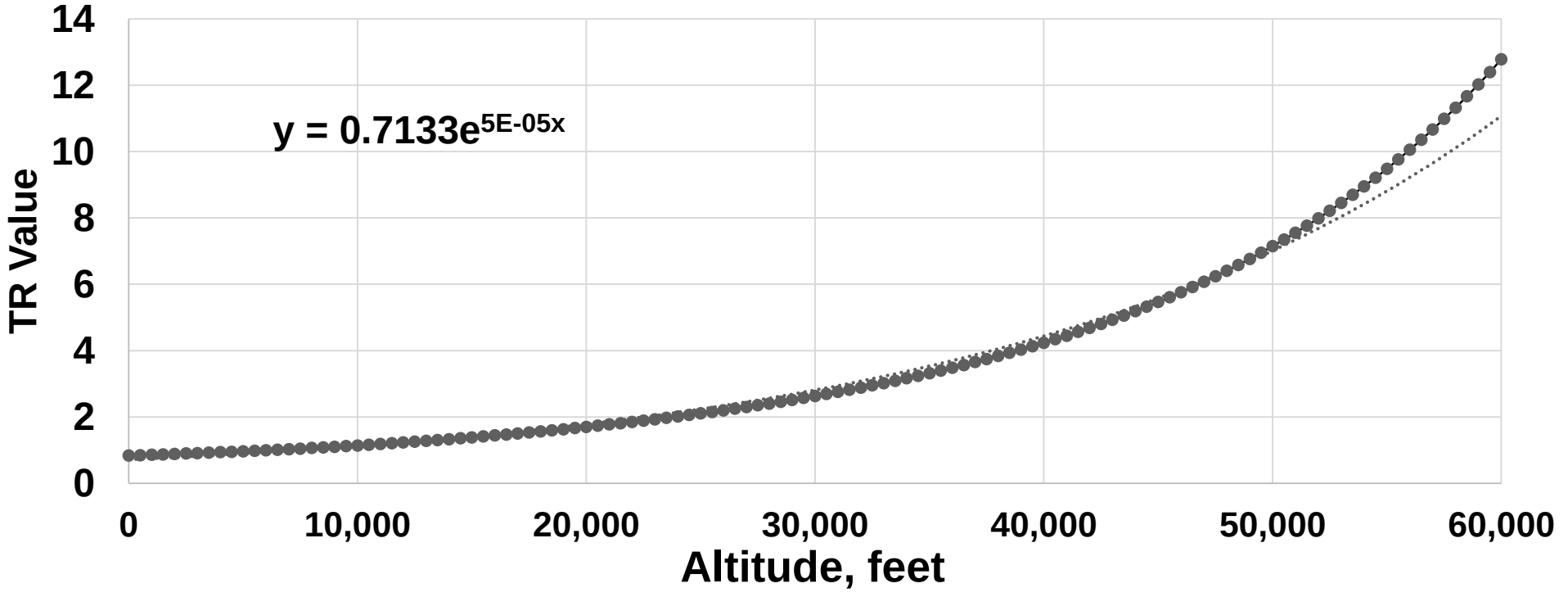
- **A plot of prebreathe times vs. incidence of DCS (30,000 ft, 4-h exposure) yielded a close approximation of an exponential curve.**
- **The trendline equation was used for this model.**



Webb JT, Pilmanis AA. Preoxygenation time versus decompression sickness incidence. SAFE J. 1999; 29:75-8.

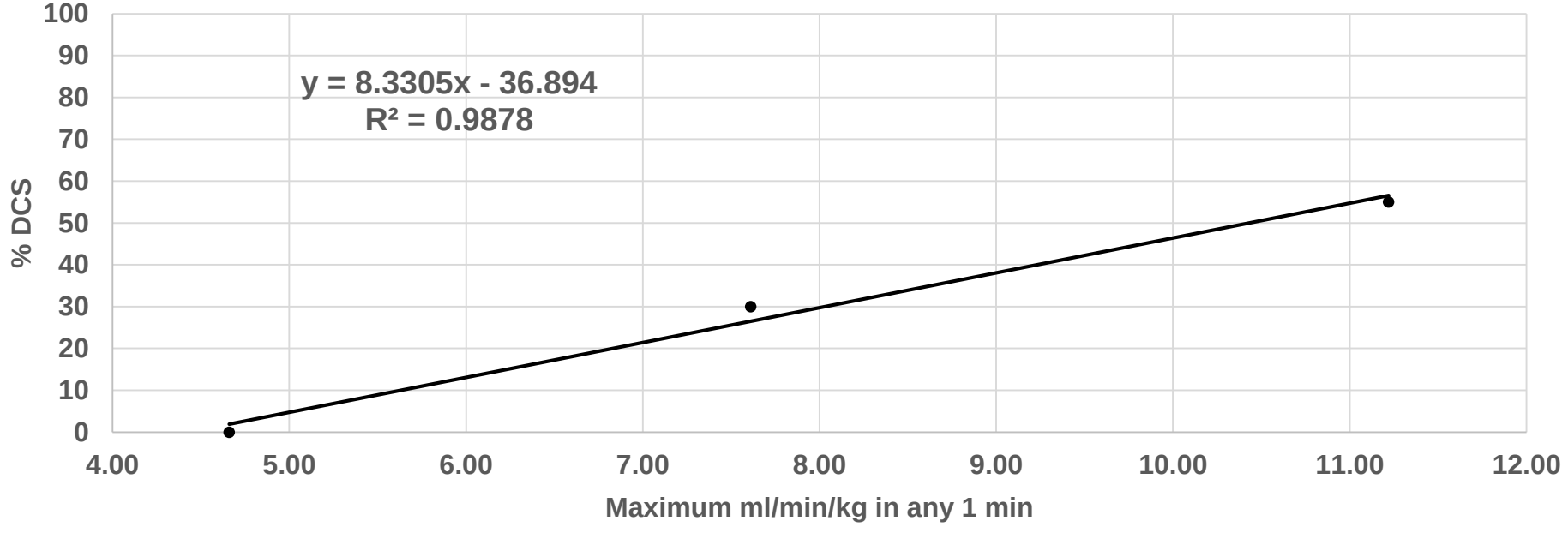
EFFECT OF ALTITUDE VS. DCS RISK

- **Exposure altitude in feet and pressure at altitude are not linear, hence use of this exponential curve's trendline equation for this model. Tissue Ratio is 593 mm Hg/mmHg at Exposure Altitude. Assisted by Andrew Abercromby, NASA JSC, EVA Physiology Laboratory**



LEVEL OF ACTIVITY VS. DCS RISK

- **ADRAC used only 3 levels of activity as inputs.**
- **Additional experiments showed a straight line relationship between level of activity and DCS risk, allowing more sensitivity and accuracy [0 prebreathe, 22,500 ft, 4 h].**



Webb JT, Krock LP, Gernhardt ML. Oxygen consumption during exposure as a risk factor for altitude decompression sickness. Aviat Space Environ Med 2010; 81(11):987-92.

Webb JT, Morgan TR, Sarsfield SD. Altitude decompression sickness risk and physical activity during exposure. Aerosp Med Hum Perform. 2016; 87(6):516-520.

EXPOSURE TIME VS. DCS RISK

- **The ADRAC line becomes linear and continues to increase after a short initial lag.**
- **Exponential increase DCS incidence versus exposure time is a sigmoidal curve, leveling after exponential increase:**

Pilmanis, et al., 2004

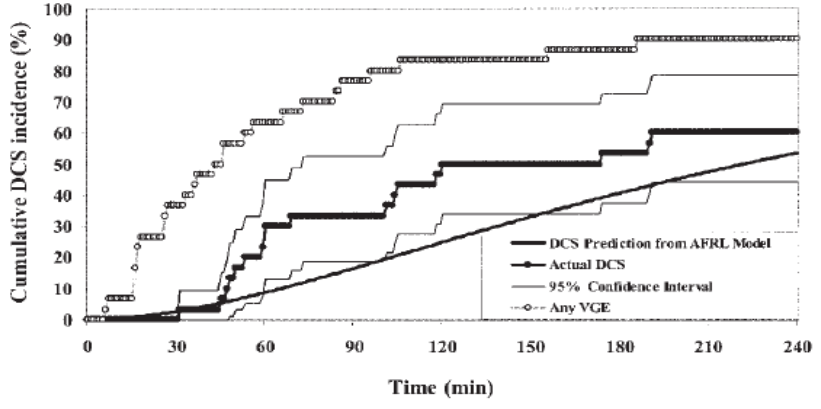
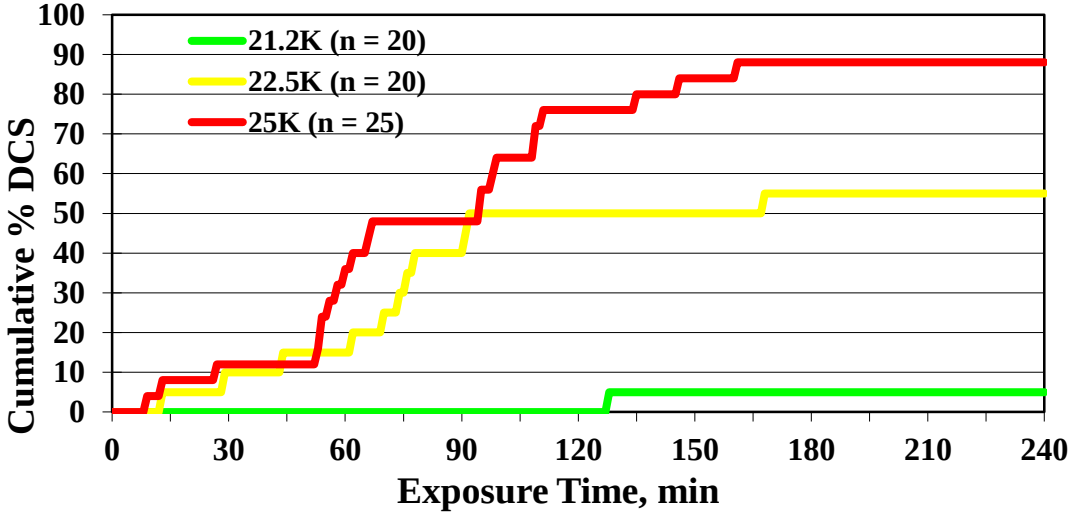


Fig. 2. Cumulative DCS and any VGE vs. exposure time for Profile B (25,000 ft); predicted vs. actual % DCS incidence and 95% confidence intervals.

Webb & Pilmanis, 1999

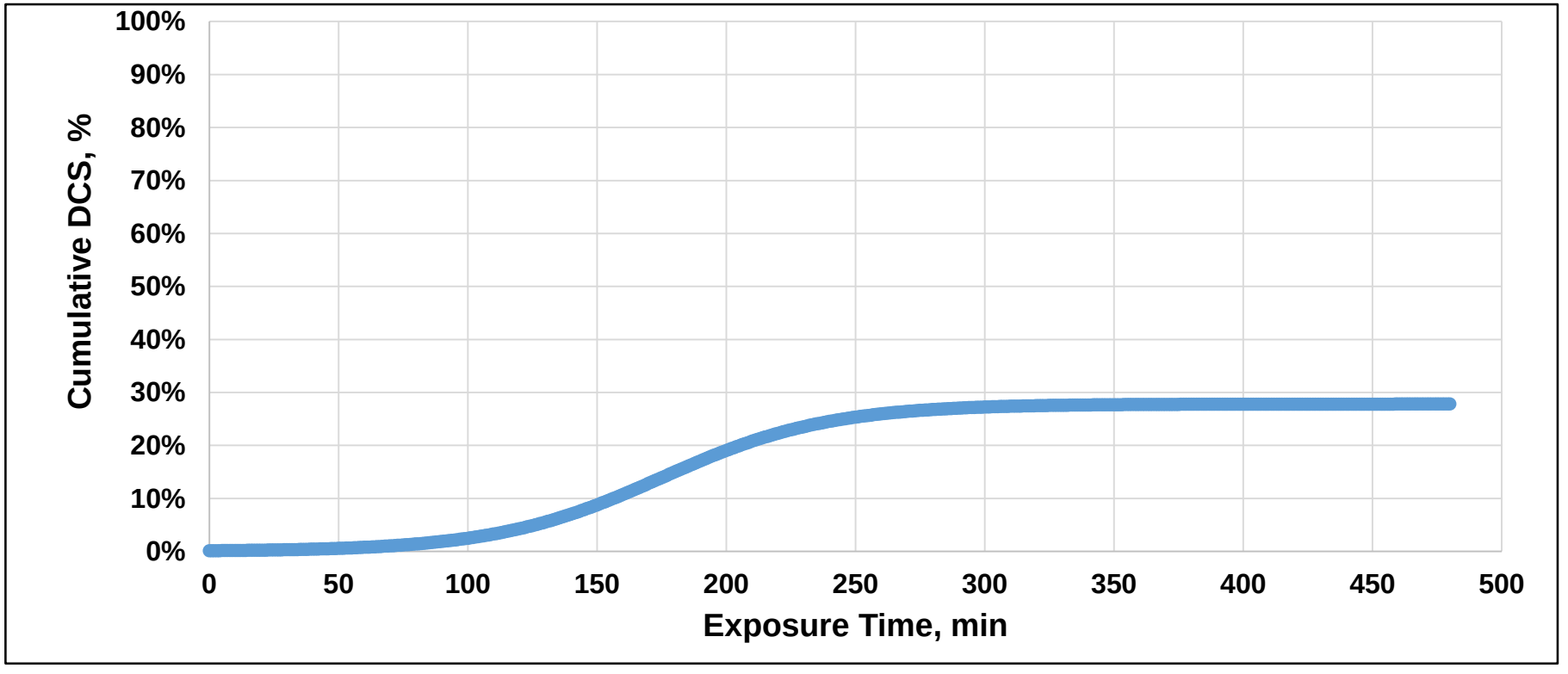


SIGMOIDAL CURVE OF DCS RISK

- **Part of the effort during development of this model is oriented at production of a true sigmoidal curve of DCS risk versus exposure duration based on the other three primary factors discussed earlier.**
- **Despite good predictive value using individual factors, successfully integrating those factors with exposure time has not yet been achieved.**
- **Sigmoidal Curve Eq.: 1/(1+EXP(-0.155*(A2/6-35)))**

SIGMOIDAL CURVE BASIS

PARAMETER	ENTER VALUE
100% O_2 prebreathe, min (0-480)	0
Altitude, ft (12,000-60,000' in 500-ft increments)	22500
Highest O_2 Consumption in any min, ml/kg/min (4.5-13)	7.6
Exposure time (10-480 min) vs. %DCS Risk Figure below	Check Figure Below



SUMMARY

- **The improved DCS risk factors have been developed and checked against existing data.**
- **Further research is needed, and is continuing toward the goal of achieving a usable integration.**

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DCS PROTOCOLS CONDUCTED AT BROOKS AFB/CITY-BASE; "BROOKS"

- **Database Covers Research from 1983-2015**
  - **26 protocols**
    - **120 altitude profiles**
      - **Prebreathe: 0-240 minutes**
      - **Altitudes: 9,000 feet to 40,000 feet**
      - **Duration: 30 min to 480 min**
      - **Level of activity: Seated Rest to Heavy Cycle Ergometry**
      - **Rate of Ascent: 1000 fpm - 80,000 fpm (0-40,000 feet in 30 sec)**
  - **Subject-Exposures**
    - **2356 Male (3.9 times the number of Female subjects)**
    - **610 Female (20.6%)**
    - **Age: 18.9 – 51.8**
    - **2966 subject-exposures where DCS was a possible outcome**
  - **>48 peer-reviewed publications; almost all in ASEM/AMHP**

CHAMBER “C” AT BROOKS

ADRAC RISK FACTORS

- **4-parameter ADRAC model inputs**
  - **Prebreathe time - 0-240 minutes**
  - **Altitude - 11,500 – 35,000 feet**
  - **Exercise/activity - Rest, Mild, Heavy**
    - **Rest = mean of about 5% of estimated peak O_2 consumption**
    - **Mild = mean of 8–20% of estimated peak O_2 consumption**
    - **Heavy = over 20% of estimated peak O_2 consumption**
  - **Duration at Altitude – 30-240 minutes**
- **ADRAC is still the most accurate, validated, altitude DCS model and is in current use by the USAF**