JSC/EC5 U.S. Spacesuit Knowledge Capture (KC) Series Synopsis

All KC events will be approved for public using NASA Form 1676.

This synopsis provides information about the Knowledge Capture event below.

Topic: Crew Health/Performance Improvements & Resource Impacts w/Reduced CO2 Levels

Date: September 20, 2012 **Time:** 11:30-12:30 pm **Location:** JSC/B5S/R3102

DAA 1676 Form #: 29308

A PDF of the presentation is also attached to the DAA 1676 and this is a link to all lecture material and video: \\js-ea-fs-03\pd01\EC\Knowledge-Capture\FY12 Knowledge Capture\20120920 James_Cabin C02 Reduction Impacts\For 1676 Review and Public Distribution

*A copy of the video will be provided to NASA Center for AeroSpace Information (CASI) via the Agency's Large File Transfer (LFT), or by DVD using the USPS when the DAA 1676 review is complete.

Assessment of Export Control Applicability:

This Knowledge Capture event has been reviewed by the EC5 Spacesuit Knowledge Capture Manager in collaboration with the author and is assessed to not contain any technical content that is export controlled. It is requested to be publicly released to the JSC Engineering Academy, as well as to CASI for distribution through NTRS or NA&SD (public or non-public) and with video through DVD request or YouTube viewing with download of any presentation material.

Presenter: John James

Synopsis: There have been a cluster of anecdotal reports that ISS crews are experiencing adverse health effects from on orbit exposure to CO2 levels well below the current Spacecraft Maximum Allowable Concentration (SMAC), which is 5.3 mmHg for 180 days of exposure. Developing evidence that this standard should be reduced to protect crew health is not a simple process. Dr. John James' team looked at the reports of headaches by the crew during private medical conferences and matched these with CO2 levels around the time of these reports. They then compared these to CO2 levels when there were no reports of headache. Using benchmark dose modeling, they found that the risk of headache could be predicted in concentration ranges from 2 to 5 mmHg. However, the data are incomplete because there were insufficient data when crews were exposed to concentrations below 2 mmHg. James' team also asked whether neuro-cognitive effects could be identified with CO2 exposure levels and found that these could not be associated with CO2 levels. Finally, they addressed the question of resource use to meet various levels of CO2 control if the SMACs were lowered. They estimated that CO2 restrictions approaching 2 mmHg would require substantial increases in power use and up-mass resources. They are refining their data on CO2 and headaches, and are looking at potential interactions of intracranial pressure and CO2 levels in eliciting ocular effects.

Biography: Dr. John James earned a Ph.D. in pathology from the Graduate School of the University of Maryland School of Medicine in 1981 and has been a board-certified toxicologist since 1986. He came to

JSC in 1989 and serves as the agency chief toxicologist. As such, he is responsible for air quality in human-rated spacecraft. His current research interests include the pulmonary toxicity of lunar dust, the interplay between intracranial pressure and high CO2 levels as they might affect crew health, and methods to discern health effects from exposures to mixtures of compounds.

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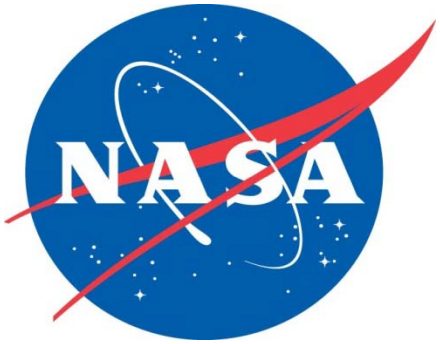


Assessing the Health and Performance Risks of Reduced Carbon Dioxide Exposures and Resource Utilization

John T. James

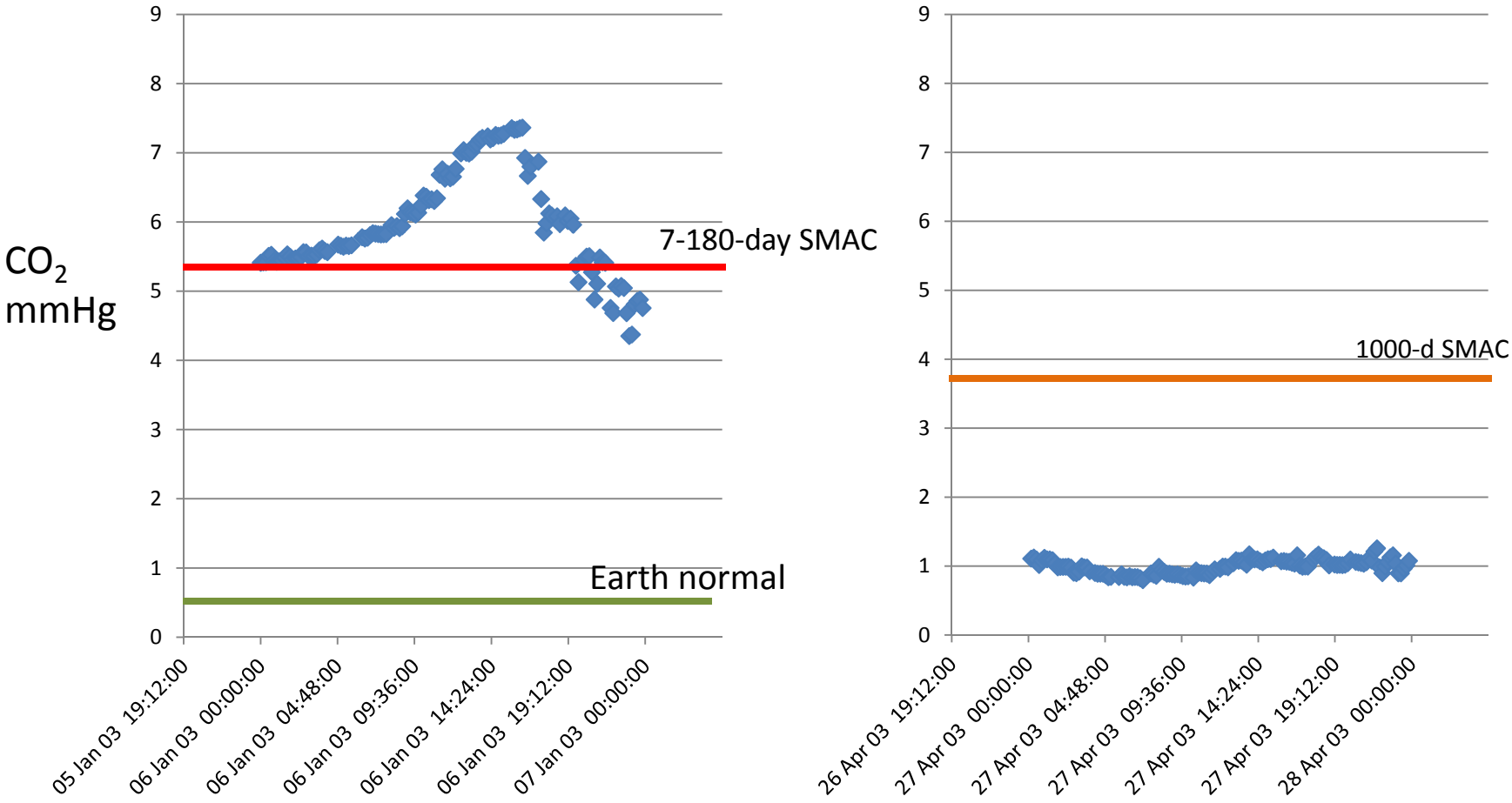
Habitability and Environmental Factors Division

20 September 2012

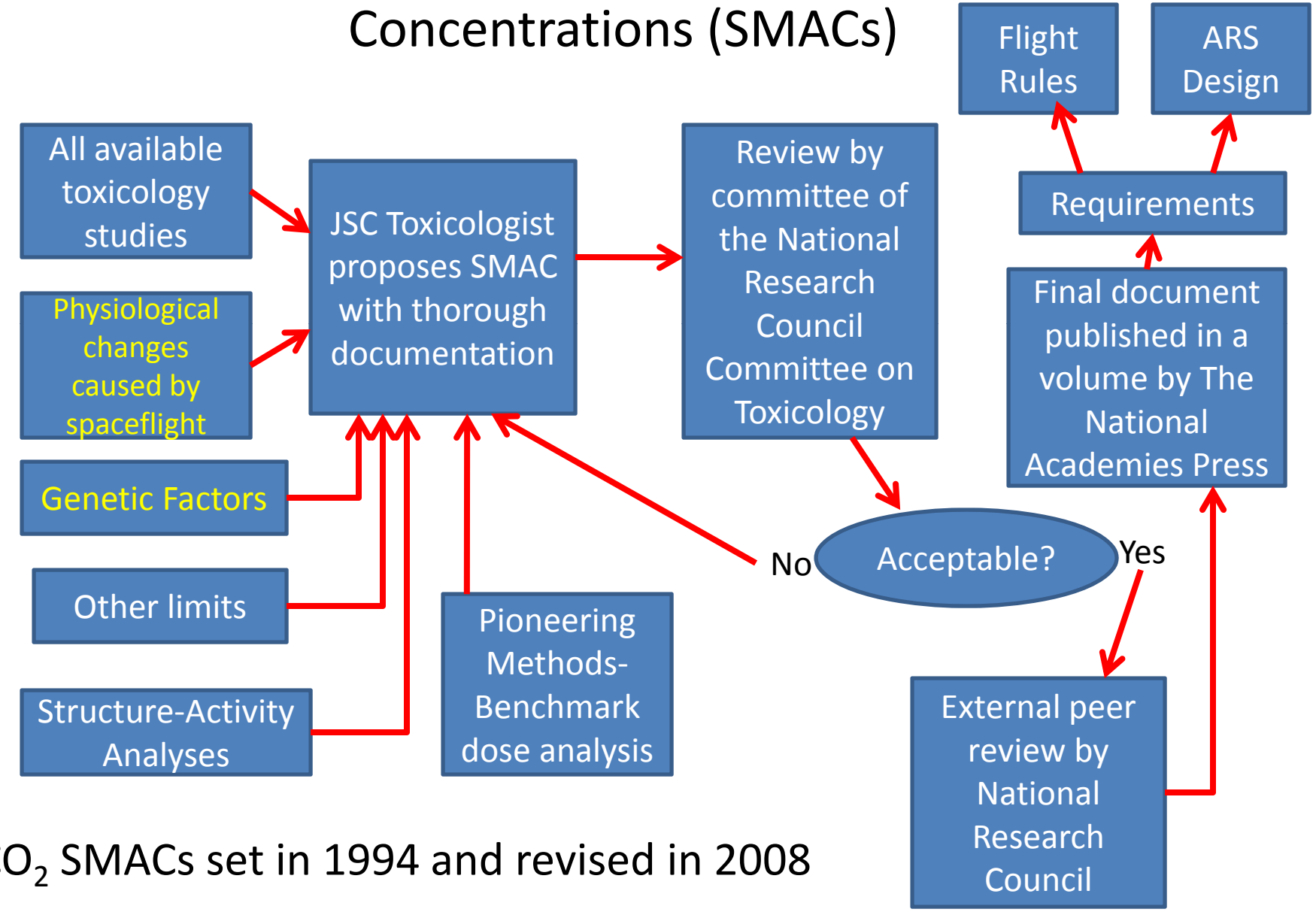
Pathway

- Risk: Exposures to CO_2 during spaceflight
- Risk Management: Spacecraft Maximum Allowable Concentrations(SMAC)
- Reality: Current ISS status with CO_2
- Revision: Initial attempts to associate elevated CO_2 with ***acute*** adverse effects
- Revision: Attempts to associate sustained and elevated CO_2 levels with ***lasting*** adverse effects
- Selection: Thoughts on genetic differences
- Transition to Operations: flight rules
- Looking ahead: near-term and for exploration

Risk: 24-hr Exposures to CO_2 During Spaceflight from MCA Data



Risk Management: Spacecraft Maximum Allowable Concentrations (SMACs)

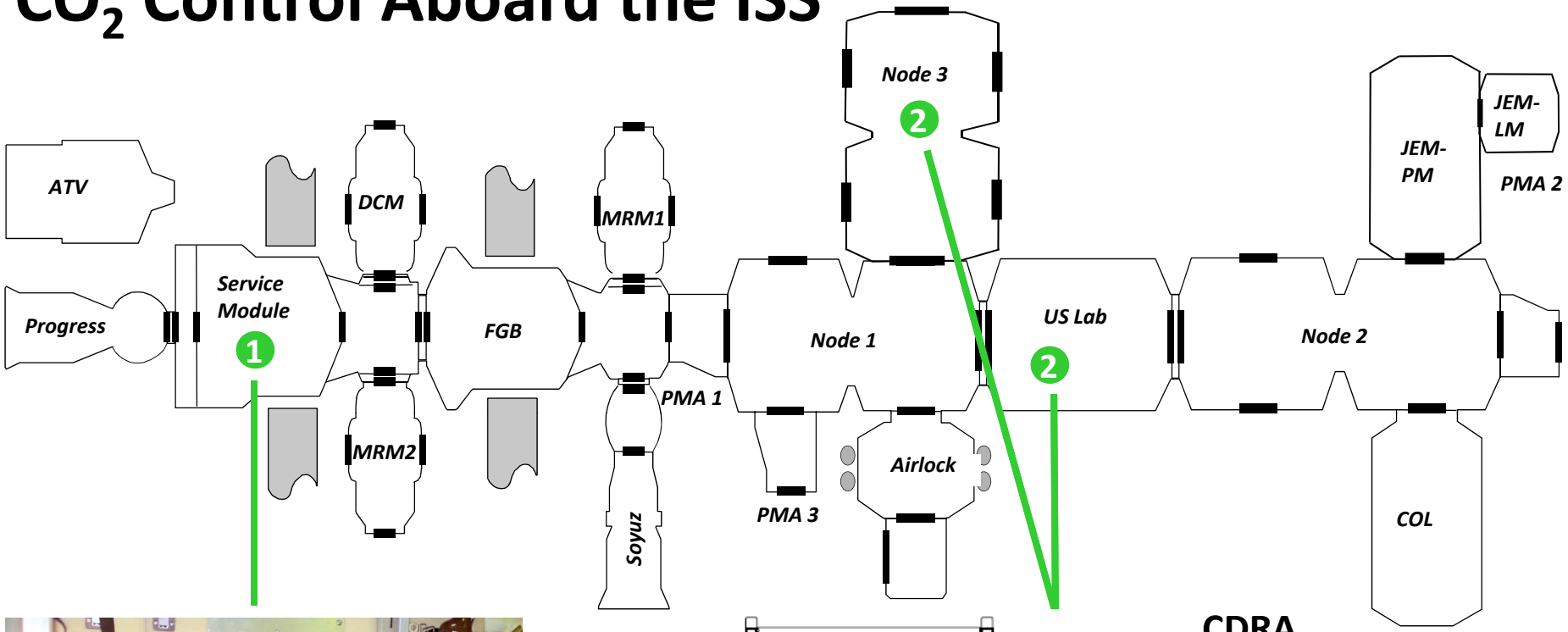


CO_2 SMACs set in 1994 and revised in 2008

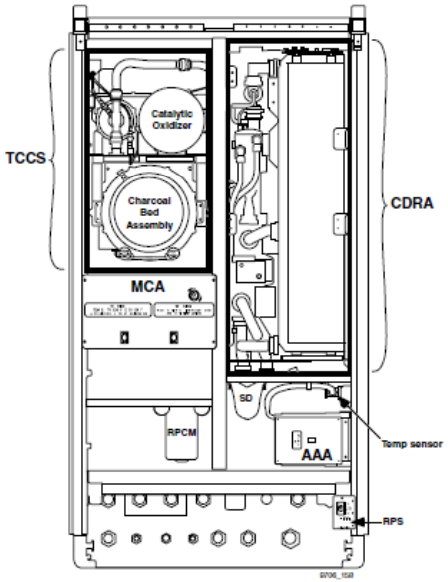
Selected Exposure Limits for CO_2

Source (year set)	Time	Limit (%)
US Navy in NRC (2007)	90 d	0.5
NRC (2007) EEGL	1 h	2.5
EEGL	24 h	2.5
CEGL	90 d	0.8
NIOSH (2004)-REL	Working lifetime	0.5
OSHA-PEL	Working lifetime	0.5
NIOSH (2004)-IDLH	brief	4.0
ACGIH (2004)-TLV	Working lifetime	0.5
ACGIH (2004)-STEL	15 min	3.0
SMAC (2008)	1 h	2.0
SMAC (1996)	24 h	1.3
SMACs (1996)	7-180d	0.7
SMAC (2008)	1000 d	0.5

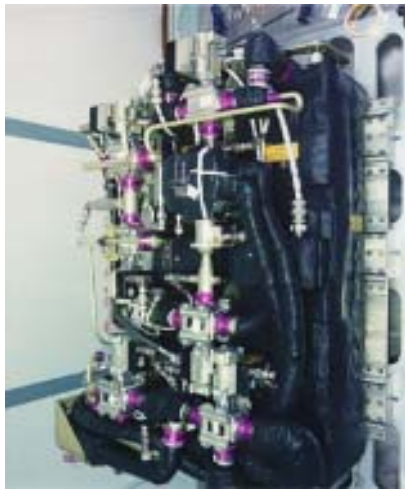
CO_2 Control Aboard the ISS



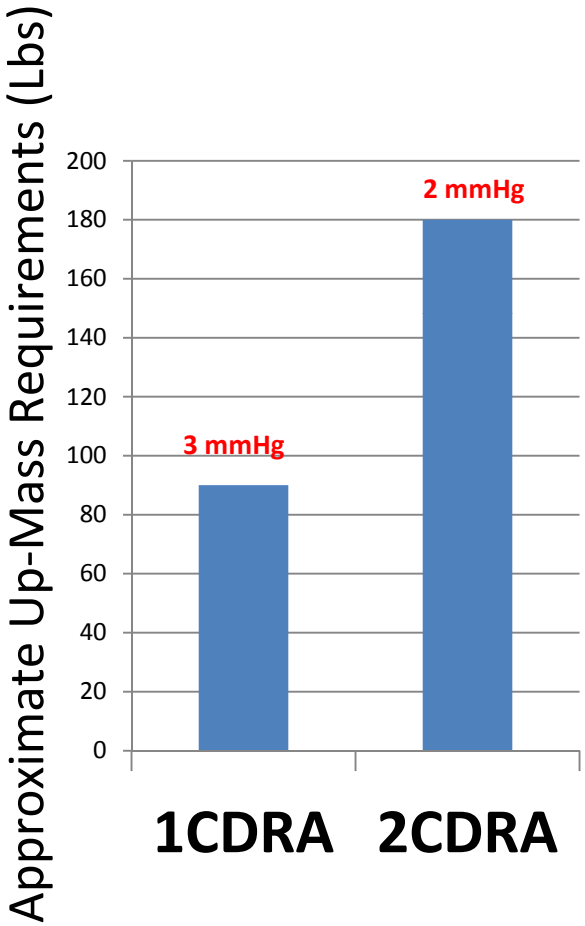
Vozdukh

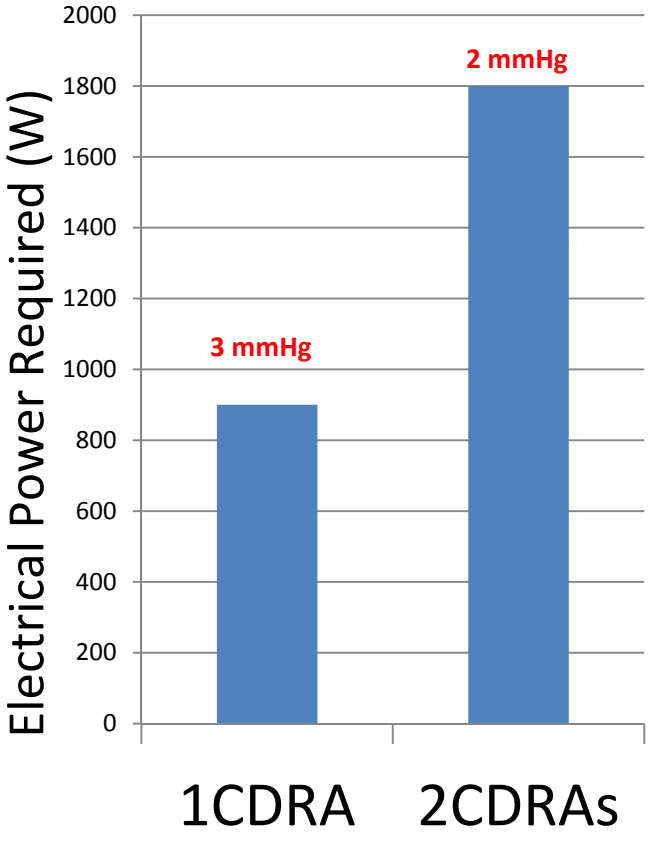


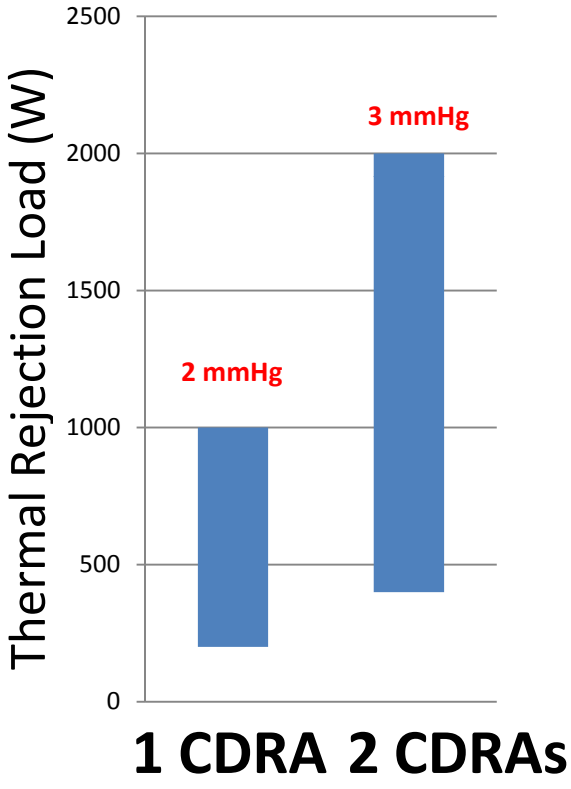
CDRA



Reality: Current ISS status with CO_2: 6 Crewmembers &Vozdukh Operating







Revision: Attempts to Associate Elevated CO_2 Levels with Acute Adverse Effects

- Behavioral Effects-WinSCAT
  - Mathematical Processing
  - Continuous Performance Task
  - Code Substitution Delayed Recognition
  - Match to Sample
  - Looked at total score, sub-scores, and changes in these
  - Compared to CO_2 averages and peak levels 1 and 7 days before
- Headaches
  - 12 Identified from private medical conferences in ~10 years
  - Searching call-down records
- Visual disturbances

Revision: Attempts to Associate Elevated CO_2 with Lasting Adverse Effects

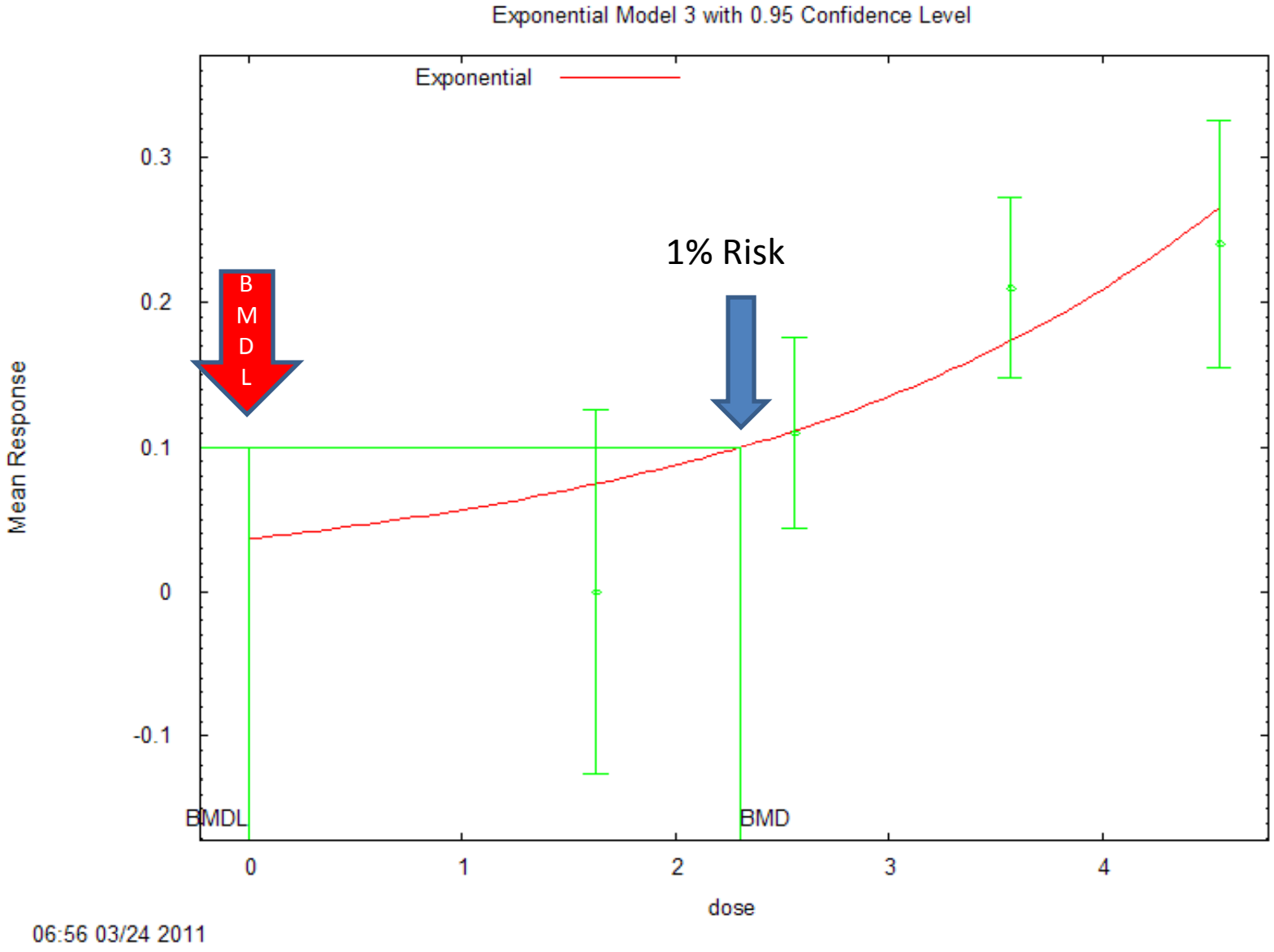
- **Visual changes are common during prolonged missions (48% complained of near-vision difficulty)**
- **Lasting visual changes have been reported in a few crewmembers after flight**

Mader TH, et al. Optic disc edema, globe flattening, choroidal folds, and hyperoptic shifts observed in astronauts after long durtion space flight. Ophthalmology 2011; 118:2058-2069

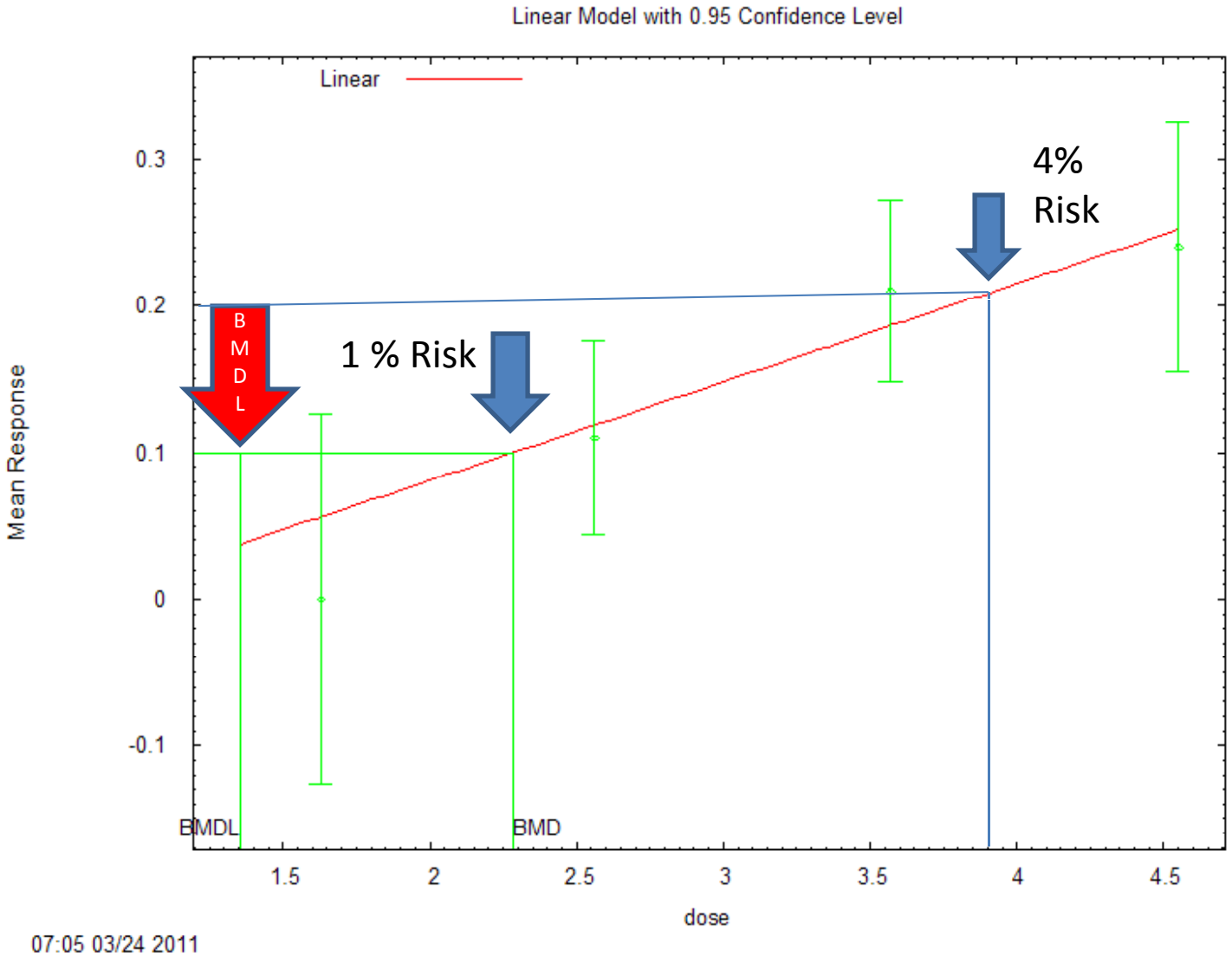
Data Sorting: Headaches vs. Incidence in CO_2 Bands

- Raw incidence in four bands (% of PMCs)
  - <2 mmHg
  - 2-3 mmHg
  - 3-4 mmHg
  - >4 mmHg
- Use arcsine of square root of the decimal % to apply benchmark dose analysis
- Calculated average CO_2 level in each band
- Tried 5 benchmark dose models (3 ‘worked’)

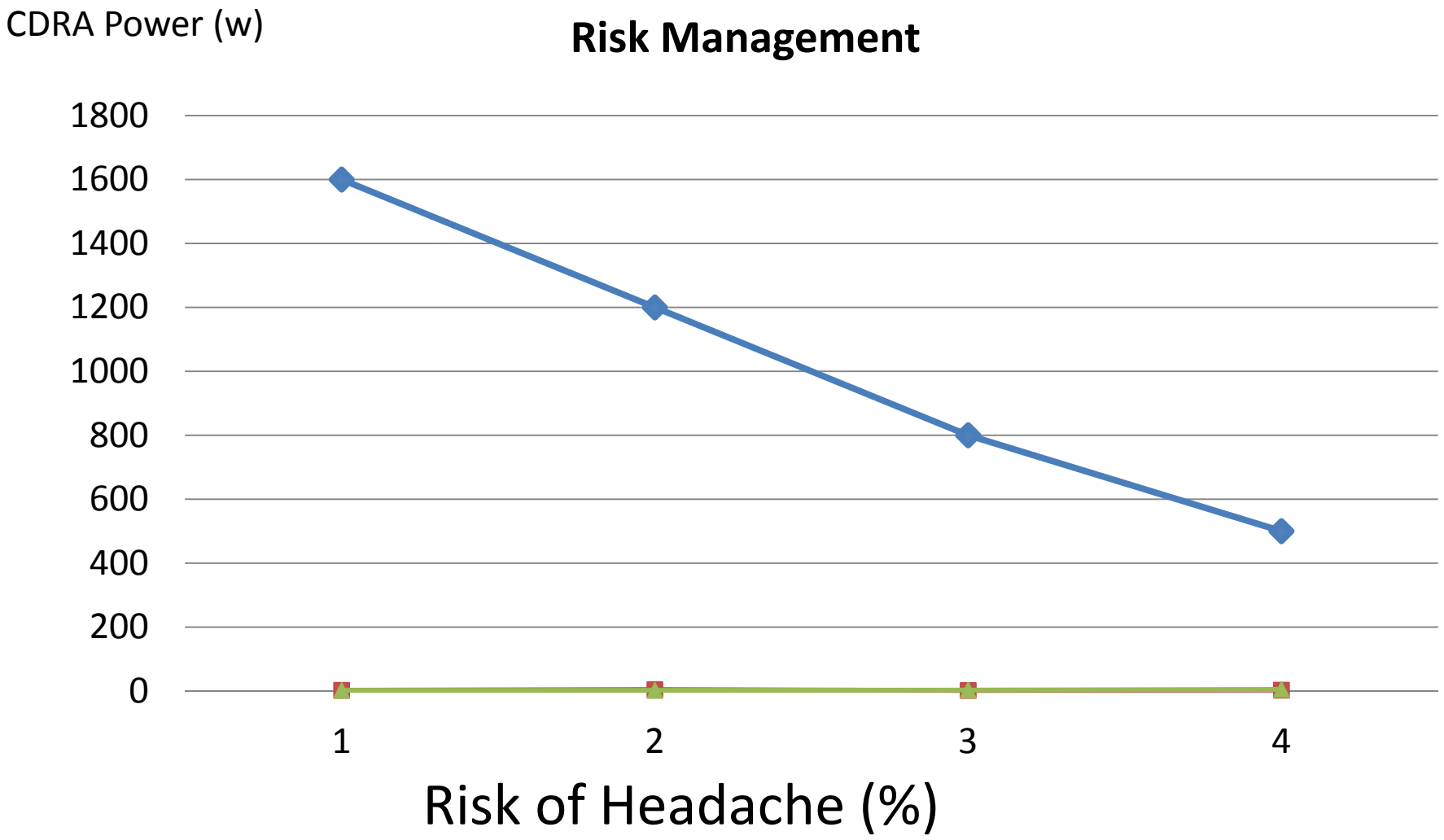
Headache Risk & 24-hr Average CO_2



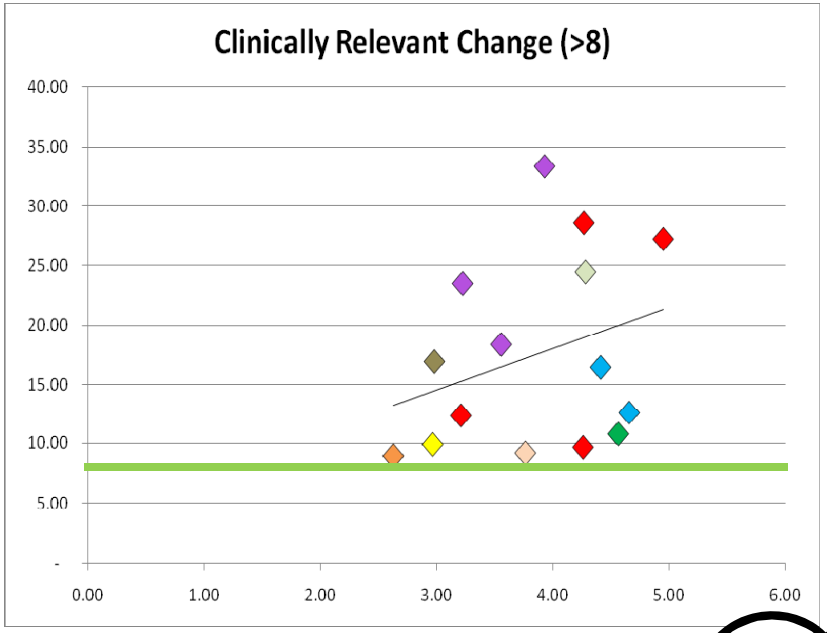
Headache Risk & 24-hr Average CO_2



CDRA Power Consumed vs. Risk of PMC-Reported Headache - Estimate

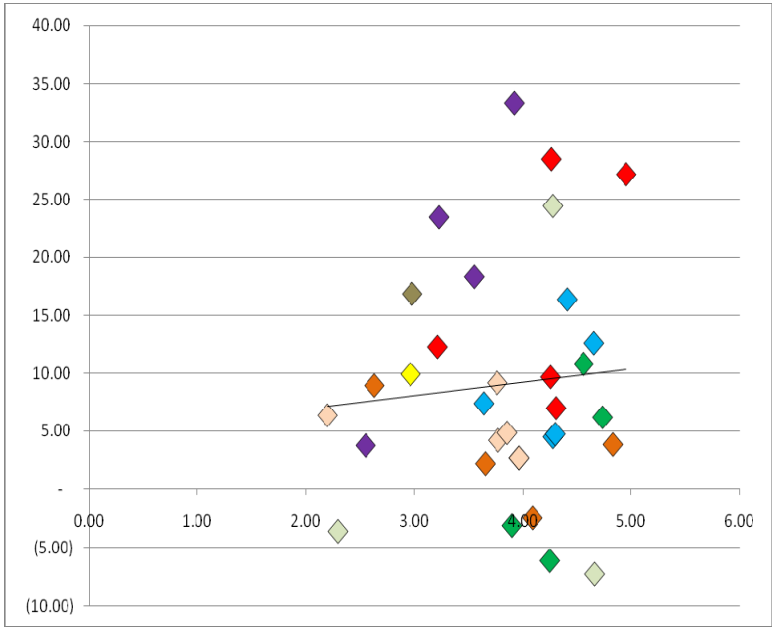


Δ Continuous Performance Task

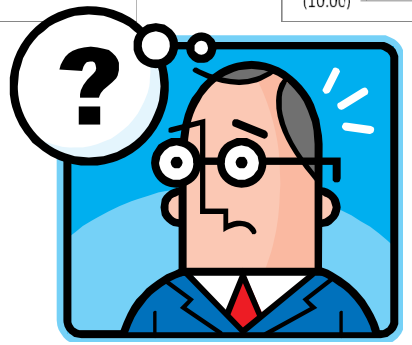


CO_2 mmHg

Δ CPT



CO_2 mmHg



Selection: Semi-Random Thoughts on Genetic Differences

- **Pigs appear to have widely variable response to stunning doses of CO_2**
- **Humans with panic disorder (PD) respond differently to high levels of CO_2 based on subtype**
  - **Respiratory vs. non-respiratory PD patients**
  - **PD runs in families**
  - **Do high CO_2 levels (>5%) have any relevance to possible genetic differences in the general population?**

Transition to Operations: Flight Rules

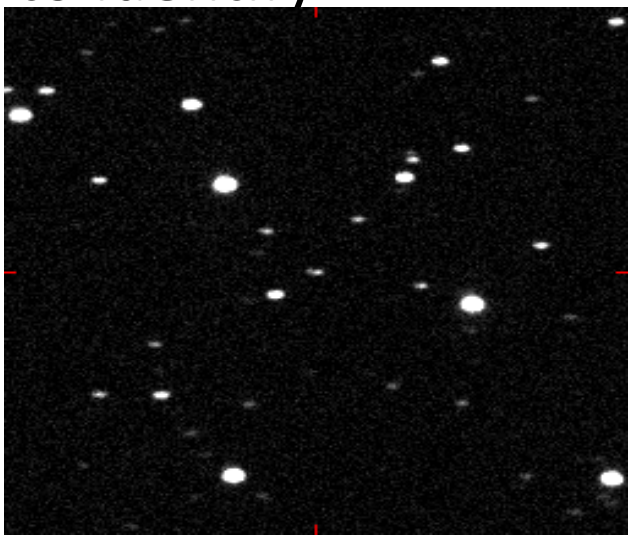
- Current flight rule requires more drastic action as CO_2 levels rise
- In practical terms we try to operate with CO_2 below 4 mmHg
- Management also depends on any symptoms presumed to be associated with CO_2 exposure
- Hardware failures, local pockets, and large crew size can pose a challenge to managing CO_2 to 3 mmHg or less

Looking Ahead-Near Term

- Acquiring more data from PMCs and SMOT notes
- Does CO_2 play a role in recently-recognized ocular effects?
- Can animal models inform us of the interaction of fluid shifts and elevated CO_2 exposure in causing ocular effects?
- Would more sophisticated behavioral studies of astronauts on orbit reveal an association between deficits and elevated CO_2?

Observations & Recommendations

- Aboard ISS we may be faced with some hard choices between management of crew health risks and practical CO_2 management.
- Explore differences in response to CO_2 levels in the range from 2 to 8 mmHg using ground-based model (bed rest?) ➔ identify genetic differences.
- Perform blind challenges aboard the ISS to determine changes in susceptibility on orbit in the range from 2 to 8 mmHg. Use highly sensitive tests to identify significant effects.
- We must have a clear grip on CO_2 issues before we launch human exploration missions.



Acknowledgments

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