Investigating Hypoxia

711 HPW / HPIF

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Investigating Hypoxia

First…

- I have no financial relationships to disclose.
- This presentation contains the opinion of the author and does not the reflect the view of the U.S. Air Force or Department of Defense.

Investigating Hypoxia

- **Hypoxia**
  - **Definition:** An inadequate supply of oxygen to the tissues.
  - 4 Types of Tissue Hypoxia by primary mechanism
    - Hypoxic (Altitude)
    - Anemic/Hypemic (Transport)
    - Ischemic (Stagnant)
    - Histotoxic (Toxins)

Investigating Hypoxia

Symptoms/Signs of Hypoxia

- **Symptoms**
  - Air Hunger
  - Lightheadedness
  - Visual Deficits
  - Headache
  - Tingling/Numbness
  - Hot/Cold Flashes
  - Disorientation/Dizzy
  - Nausea
  - Euphoria
  - Fatigue

- **Signs**
  - Cyanosis
  - Hyperventilation
  - Loss of Coordination
  - Mental Confusion
  - Lack of Responsiveness
  - Impairment of Judgement/Decision Making

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Cognitive and Performance Effects

Stages and Effects of Hypoxia Exposure				
	Indifferent	**Compensatory**	**Disturbance**	**Critical**
Altitude	0-10,000 ft	10,000-15,000 ft	15,000-20,000 ft	20,000-30,000 ft
SPO2	98 - 90%	90 - 80%	80 - 70%	70 - 60%
Effects	Decrease in night vision	Drowsiness Poor Judgement Impaired Coordination Impaired Efficiency	Impaired Flight Control Impaired Handwriting Impaired Speech Decreased Coordination Impaired Vision Decreased Pain Sensation Impaired Intellectual Function Decreased Memory Impaired Judgement	Circulatory Failure CNS Failure Convulsions Cardiovascular Collapse Death

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Time of Useful Consciousness
(Effective Performance Time, EPT)

Altitude in Flight level	Altitude in feet	Time of Useful Consciousness/EPT
FL 150	15,000	30 min or more
FL 180	18,000	20 to 30 min
FL 220	22,000	5 to 10 min
FL 250	25,000	3 to 5 min
FL 280	28,000	2.5 to 3 mins
FL 300	30,000	1 to 2 mins
FL 350	35,000	30 sec to 60 sec
FL 400	40,000	15 to 20 sec
FL 430	43,000	9 to 12 sec
FL 500 and above	50,000	6 to 9 sec

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Variability of Response:

Research evidence and anecdotal experiences provide support to significant baseline and daily variation in individual tolerance to acute hypoxia exposures.

- **Factors**
- Rate of Exposure
- Acclimatization
- Aerobic Fitness
- Vascularization
- Red Blood Cell count
- Meds/Supplements
- Smoking
- Hydration
- Temperature

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Investigating Hypoxia
Challenges and Lessons Learned

Challenges

- **Pilot as the sensor for system failures/hypoxia**
  - Fly to fail design of oxygen equipment
  - Requires pilot/aircrew recognition, correction, reporting
  - Symptoms of altitude hypoxia similar to other conditions
    - Hyperventilation, toxic exposures, dehydration, fatigue
  - Hypoxia can be very insidious with slow cabin decompression
  - Fast/High cabin decompression degrades recognition time
  - Time of useful consciousness can vary daily based on physiological state and combination of contributing factors

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Investigating Hypoxia
Challenges and Lessons Learned

Challenges

- If symptom-free post-flight, pilot may be released or short-term DNIF'd without tests (blood, lungs, etc)
- Don't measure pilot physiological state pre-flight
  - What factors could enhance/emulate hypoxia?
- Don't measure pilot physiological state in-flight
  - Unable to match to aircraft system state for cause/effect
- Can be large base-to-base variation in hypoxia event response and investigation process
- Some a/c components must be removed to test

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Investigating Hypoxia
Challenges and Lessons Learned

Challenges

- Inexplicable hypoxia
  - No cabin pressure loss and cabin below 10K’
  - A/C & Oxygen system passes post-event inspections
  - Cannot identify a mechanical culprit
  - But…pilot/aircrew recovered on emergency oxygen and is symptom-free post-flight

Investigating Hypoxia
Challenges and Lessons Learned

The Investigation: Human-Machine System Lessons

- **Human**
  - Keep pilots informed of investigation efforts/results if there's a system-wide issue
  - Have a standardized investigation response to hypoxia
  - Ensure mx investigation and human tests are considered together
  - Use a "Golden Hour" approach to physical exam/tests
  - New/Upgrade Oxygen Systems Acquisitions
    - What do you want to know if there's an event/mishap?
    - Is there meaningful flight data/tech data of interoperability of components and system/sensor behavior effects on human?

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Investigating Hypoxia
Challenges and Lessons Learned

The Investigation: Human-Machine System Lessons

- **Machine**
  - Fully capable/available testing equipment for preventive maintenance
  - In-aircraft testing/adequate system simulation of mishap suspect components
    - Include in-line/associated systems that may not be suspect
  - Tracking of components after repair/replacement
  - High-Level OPR for all fleet life support systems data
  - New/upgrade systems acquisition
    - What do you want to know if there's an event/mishap?
    - Is there meaningful flight data/tech data of interoperability of components and system/sensor behavior?

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Investigating Hypoxia
Mitigation and Prevention

Pilot monitoring considerations:

- Wearable sensor technology is evolving
  - Non-invasive Band-Aid size flexible sensors
  - Integration into pilot flight equipment/aircraft flight data
- Aircraft integration
  - Tie to aircraft system state flight data recorder
  - Pilot and aircraft interfaces can be expensive
  - Automated/adaptive technology still developing
- What to measure: SPO2, blood lactate, exhaled biomarkers
  - What are the alert settings for the pilot
- Pilot in-flight decision aid or data for aeromedical disposition or both?

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Investigating Hypoxia
Mitigation and Prevention

Hypoxia Recognition and Recovery Training

- **4 Notional Considerations**
  - Fidelity
  - Concurrency
  - Frequency
  - Mode

Investigating Hypoxia
Mitigation and Prevention

Hypoxia Recognition and Recovery Training

- **Fidelity**
  - Replicate hypoxia effects (signs/symptoms)
  - Replicate flight environment/tasks
  - Replicate emergency procedures
- **Concurrency**
  - Aircraft Oxygen Systems Interface/Behavior
  - Aircraft ICAWS
  - Aircraft mission systems

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Mitigation and Prevention

Hypoxia Recognition and Recovery Training

- **Frequency**
  - Symptom and EP memory longevity
  - Upgrades/changes to oxygen system components
- **Mode**
  - Hypobaric mask off
  - Normobaric mask-on mixture
  - Normobaric mask-off mixture
  - Hypobaric mask-on mixture
  - Scenario-based

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Mitigation and Prevention

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Oxygen System Knowledge & Discipline

- **Pilots need to know:**
  - How their Oxygen system works within the aircraft architecture and flight performance
  - Fault-tree for Oxygen system failure
  - What function/failure means for physiological performance
  - Real-time system performance
  - Emergency procedures

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Investigating Hypoxia
Challenges and Lessons Learned

- **Conclusions**
  - **Mishap investigation will be challenging any time the pilot is the sensor for system failure**
  - **Current/emerging technologies may offer solutions**
    - Ease the burden on the pilot for recognition and recovery
    - Provide a decision aid to the pilot ***before*** hypoxia affects performance
    - Optimize human-system integration
    - Enables investigator to tie aircraft system state to pilot system state if a mishap occurs
  - **Whether pilot remains the sensor for hypoxia or not, training/simulation on oxygen systems is vital**

Questions?