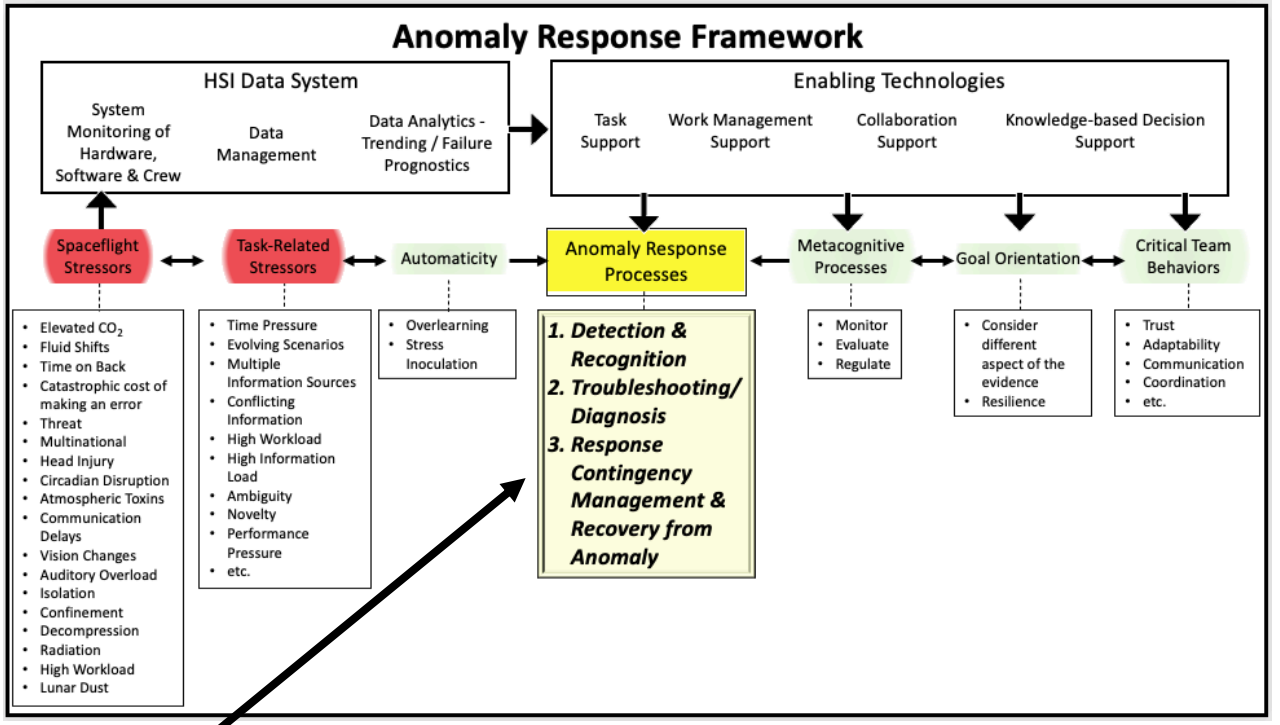
Elevated CO_2 Could Undermine an Exploration Crew's Ability to Independently Respond to Unanticipated, Time- and Safety-Critical Anomalies

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Beard, B. L. (2020). Characterization of how CO_2 Level may Impact Crew Performance Related to the HSIA Risk. NASA TM-20205011433

NASA Human Research Program (HRP)
Human Factors and Behavioral Performance (HFBP) element
Human-System Integration Architecture (HSIA) risk

"Given decreasing real-time ground support for execution of complex operations during future exploration missions, there is a possibility of adverse performance outcomes including that crew are unable to adequately respond to unanticipated critical malfunctions or detect safety critical procedural errors."



Purpose: Characterize how CO_2 Level may Impact Crew Performance Related to the HSIA Risk given the current level of technological advancement to support anomaly resolution

Methods: Trace the relationship between cognitive and motor abilities required for anomaly response with critical mission tasks

Requires knowledge of:

- Anomaly response processes (Woods & Hollnagel, 2006)
- Tasks to be performed by crew on exploration missions (Stuster et al., 2019; Holden et al., 2019)
- Current state of technological maturity (Wu & Vera, 2019) a.k.a. **Technology Challenges**
- CO_2 levels that have negatively impacted performance (published research)

Nine Technology Challenges (TC)

Anomaly Detection & Recognition

1. **Real-time monitoring** of vehicle, environment, team, resources and crew
2. Link agent state with external sources or context (sensor/data fusion)
3. Anomaly or fault detection
4. Quantify and provide system reliability to build user trust

Anomaly Diagnosis/Troubleshooting

5. Provide essential information for diagnosis
6. Provide failure response recommendations with rationales

Response Contingency Management and Recovery

7. Adapt to the dynamics of the task
8. Re-schedule in the case of schedule disruption;
9. Update database to reflect anomaly response processes and lessons learned

TC#1 – Elevated CO_2 Outcomes, Real-Time Monitoring

Publication	Task	CO_2 Concentration (ppm) compared to baseline	Exposure Duration	N
	Rapid Response			
Myhrvold et al. (1996)	Simple reaction time	1000 to 1499, 1500 to 4000	6 hours	548
Myhrvold et al. (1996)	Choice reaction time	1499, 4000	6 hours	548
	Sustained Attention & Information Seeking			
Allen et al. (2016)	Focused activity	1400	8 hours	24
Basner et al. (2017)	PVT accuracy	5050	26.5 hours	6
Kajtár & Herczeg (2012)	Errors found while proofreading	3000, 4000	4 hours	10
Manzey et al. (1998)	Subjective alertness	12500	26 days	4
Manzey et al. (1998)	Unstable tracking	12500	26 days	4
Satish et al. (2012)	Focused activity	2500	2.5 hours	22
Scully et al. (2019)	Focused activity	1200	3 hours	22
	Perception			
Basner et al. (2017)	Line Orientation Discrimination speed	5050	26.5 hours	6
Sun et al. (1996)	Stereoacuity	25000	30 min	3
Yang et al. (1997)	Coherent motion	25000	30 min	3

Graphic containing the studies reporting a significant effect of elevated CO_2 on cognitive or motor performance

