PHYSIOLOGICAL MONITORING OF AIRCREW FOR PREDICTION AND DETECTION OF PERFORMANCE IMPAIRMENT

John Crowley MD MPH
Science Program Director
US Army Aeromedical Research Laboratory

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U.S. Army Aeromedical Research Laboratory

USAARL HISTORICAL CONTRIBUTIONS

ISO Jolt Standard

Cockpit Air Bags

Crash Neck Injury

CG vertical distance

Severe injury risk

Accepted neck injury risk

Head-supported weight

Crash Helmet Standards

Night Vision Goggles

Crash Survival

Aircrew Heat Stress

Communication Ear Plugs
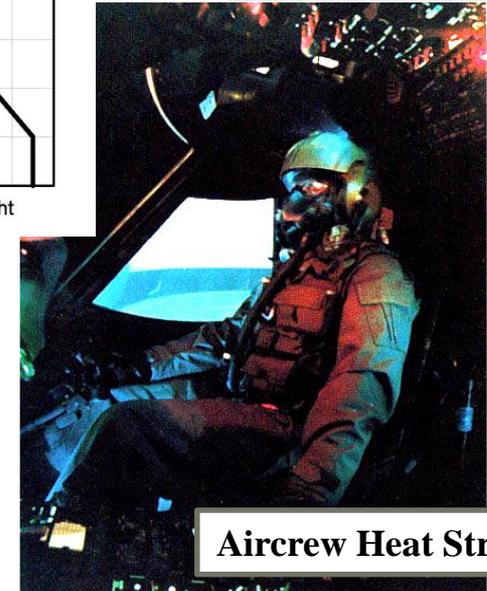
Aerospace
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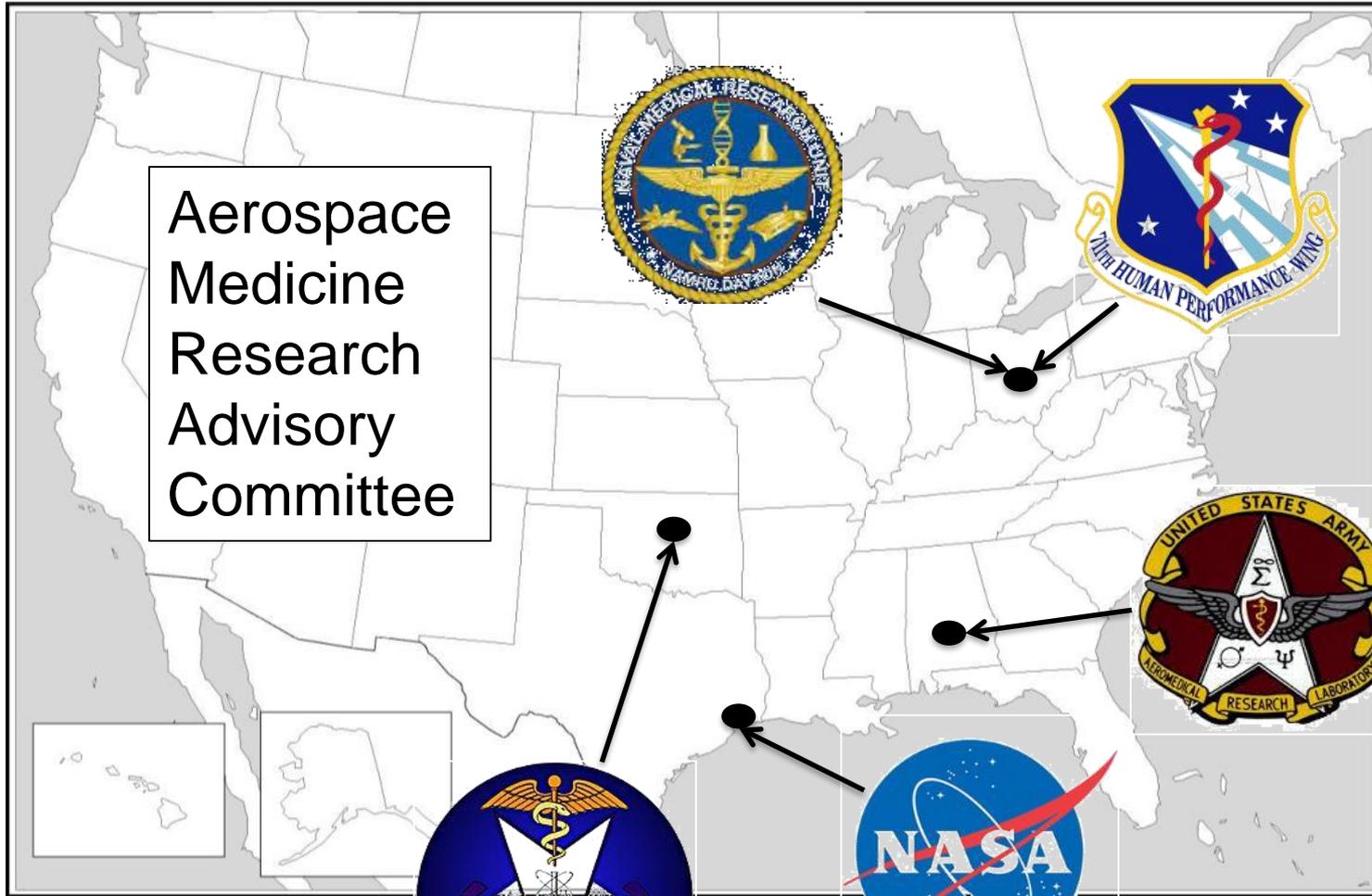
Now Back To:

PHYSIOLOGICAL MONITORING OF AIRCREW FOR PREDICTION AND DETECTION OF PERFORMANCE IMPAIRMENT

Unclassified

WHERE DID THAT IDEA COME FROM?

- Wearables – hot topic

Unclassified

EXPLOSION IN TECH AND INTEREST

GLOBAL WEARABLE TECHNOLOGY MARKET

BY DEVICES

■ 2016   ■ 2022

Categories: Fitness & Wellness Devices, Smart Watches, Smart Glasses (VR and AR), Smart Clothing, Others

FITNESS AND WELLNESS DEVICES was the highest revenue generating segment and is estimated grow at a CAGR of 15.6% from 2016 to 2022

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WHERE DID THAT IDEA COME FROM?

- Wearables – hot topic

- Human monitoring
  - Disease Diagnosis
  - Disease Monitoring
  - Physical Fitness
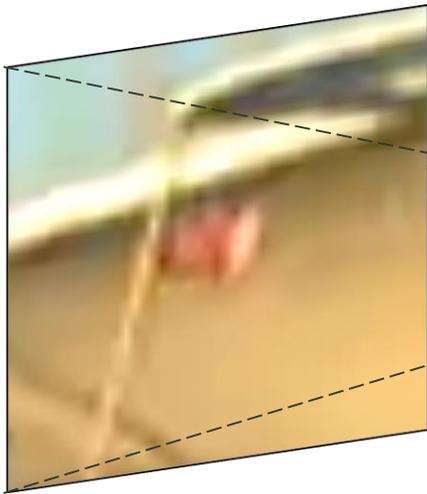 - Personal Health Monitoring
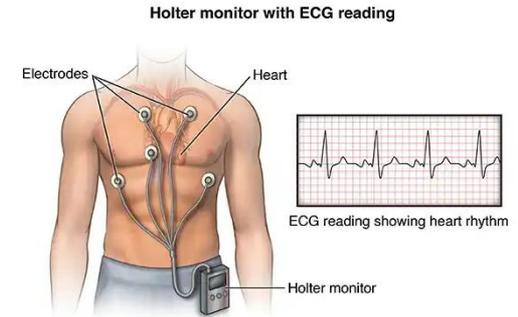
Continuous Glucose Monitoring

MONITORING THE AIRCRAFT VS MONITORING THE HUMAN -- TO ASSESS PILOT PERFORMANCE…

- Human monitoring the aircraft (since the beginning)

"yaw string" or streamer?

sound

EXAMPLE: AUTOMATIC GROUND COLLISION AVOIDANCE SYSTEM (AUTO GCAS)

- Human monitoring the aircraft (since the beginning of aviation)

- Aircraft monitoring the aircraft
  - Relevant to this discussion (example)
    - Aircraft is watching for human failure

Terrain mapping, geolocation and automation are used to detect and avoid potential ground collisions.

1 Program detects imminent ground impact and prompts pilot to take action.

2 If pilot is unresponsive, Auto-GCAS assumes temporary control to divert the aircraft out of harm's way.

3 Once on a safe trajectory and the pilot is responsive, the system returns control to the pilot.

LOCKHEED-MARTIN SLIDE

F-35 + AutoGCAS = Increased Survivability

Collier Trophy Awarded in 2018

8 F-16 Pilots Saved

Integrated on the F-35 — 7 Years Ahead of Schedule

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AIRCRAFT DATA PLUS HUMAN DATA

- Auto-GCAS does not use any data directly from pilot

- Concept for Future Aviation Safety:
    - Combine system data with pilot data
    - Expand range of detected states
    - Take safety of manned aviation to next level

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LOTS OF RESEARCH OVER MANY YEARS

Proceedings of the Human Factors and Ergonomics Society Annual Meeting

Real-Time Assessment of Operator State in Air Traffic Controllers Using Ocular Metrics

Jonny Kuo, Michael G. Lenné, Rama Myers, more...

First Published September 28, 2017 · Research Article

https://doi.org/10.1177/1541931213601547

Abstract

Thesis **PDF Available**

Tools and methods for Human-Autonomy Teaming: Contributions to operator state monitoring and system adaptation

October 2021
Thesis for: HDR

Authors:

International Conference on Augmented Cognition

AC 2014: Foundations of Augmented Cognition. Advancing Human Performance and Decision-Making throug Adaptive Systems pp 26-34 | Cite as

Untangling Operator Monitoring Approaches When Designing Intelligent Adaptive Systems for Operational Environments

Authors   Authors and affiliations

Ming Hou, Cali M. Fidopiastis

Real-Time Monitoring of Cognitive Workload of Airline Pilots in a Flight Simulator with fNIR Optical Brain Imaging Technology

July 2016
DOI:10.1007/978-3-319-39955-3_14
Conference: International Conference on Augmented Cognition

Authors:

Monitoring Metabolic Status: Predicting Decrements in Physiological and Cognitive Performance.

Show details

Contents ☑   Hardcopy Version at National Academies Press
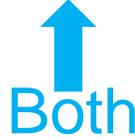
Search this book

5   Strategies for Monitoring Cognitive Performance

How eye tracking will take aviation to new heights

Includes Everything: Physio, Psych, Cog, even Acft…

PHYSIOLOGICAL MONITORING OF AIRCREW FOR PREDICTION AND DETECTION OF PERFORMANCE IMPAIRMENT

Both

Most aspects of 'performance'

Ans: The Scope is Broad

"PHYSIOLOGICAL EVENTS" VS "COGNITIVE" DECREMENTS

- Military FW issue mainly

- Cognitive performance is cross-platform

- All are legitimate concerns for civil aviation

Can Real Time Pilot Monitoring Help Reduce Unexplained Physiological Events?

By Woodrow Bellamy III | December 18, 2020
Send Feedback | @WBellamyIIIAC

Air Force Research Lab, Ball Aerospace, hypoxia, Unexplained Physiological Events (UPEs)

Target Candidates With Ease

GET STARTED >

Avionics INTERNATIONAL

An F-35B pilot connects an air hose to her flight suit at Marine Corps Air Station Beaufort. (U.S. Marine Corps:

16

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ANOTHER APPLICATION: AEROMEDICAL STANDARDS / WAIVERS

- In addition to physiology and cognitive monitoring, health-related parameters can be monitored

- Could be useful for healthy aircrew (but issues exist)
- Could allow 'grounded' aircrew to fly
  - Operator State Monitoring system is backup/safety net for selected diagnoses that otherwise would be disqualifying

- Examples
  - Blood glucose (diabetes)
  - Cardiac rhythm (arrthymias)

Monitor Pilot

Detect Problem

Take Action

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BASIC APPROACH TO MAINTAINING AIRCREW PERFORMANCE

Pilot flying successfully

Events occur that could degrade performance

System predicts deteriorating pilot performance

System takes action to **prevent** deterioration

Events occur that degrade performance

System detects degraded pilot performance

System takes action to **reverse** deterioration

BASIC STEPS IN "OPERATOR STATE MONITORING"

Monitor Pilot → Detect Problem → Take Action

Need
- Predictive data
- Aircrew-compatible sensors

MONITORING THE PILOT

- Data needs
  - Depend on degraded states to be detected
    - e.g, fatigue, hypoxia, excessive workload (or underload)
  - Frequently cited
    - ECG (HR, HRV)
    - EEG
    - Pupillary changes and eye movements
    - Oxygen level in tissue/blood
    - Temperature
- Sensors
  - Myriad vendors with different sensor combinations
  - Compatibility depends on aviation platform environment

BASIC STEPS IN "OPERATOR STATE MONITORING"

Monitor Pilot → **Detect Problem** → **Take Action**

Need
- Thresholds for concern
- Algorithms for processing

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ISSUES WITH DATA PROCESSING AND STATE IDENTIFICATION

- Significant hurdles to overcome
  - Airworthiness certification for opaque systems potentially affecting aircraft
  - Individual differences
    - Within subject variability
      - Ex: circadian variations, mood, caffeine
    - Between subject variability
      - Ex: test pilots vs student pilots – different responses
    - Interfering conditions
      - Medications
      - Health problems affecting data

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EXAMPLE: HEART RATE

Normal Heartbeat

Tachycardia

Bradycardia
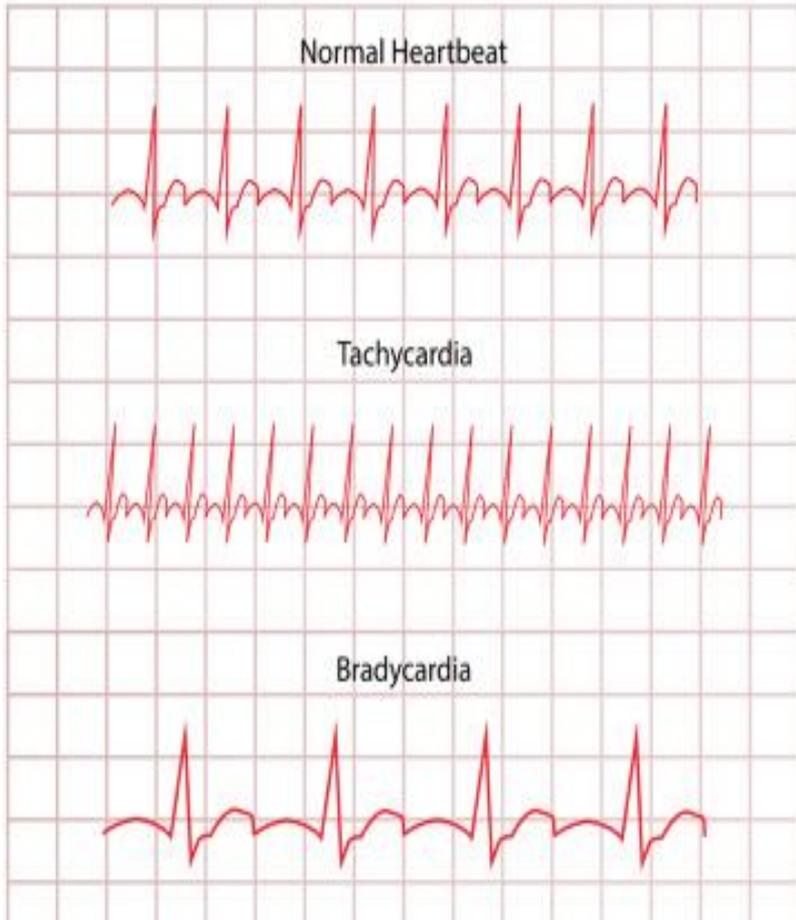
"Normal"

"Stress" for normal aviator
> (also dehydration, heat, workload
> physical exertion, fatigue)

"Normal" for marathon runner
"Normal" when on certain medications
> (even if maximally stressed)

Monitor Pilot

Detect Problem

Take Action

Need
- Responses appropriate for predicted or detected state
- Responses must be validated to ensure desired response from aircrew
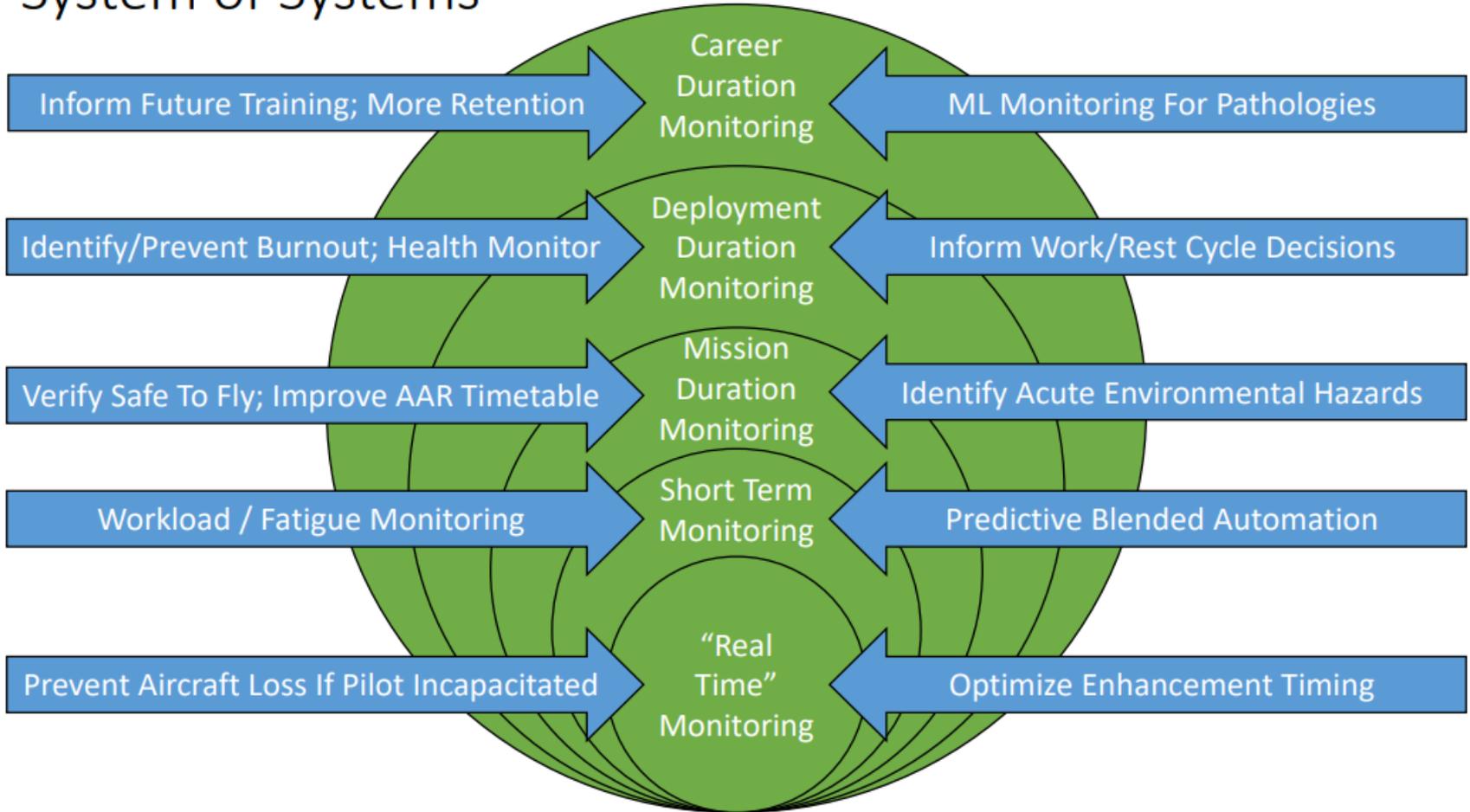
ADDITIONAL CONCERNS

- Systems may ultimately need to be individualized
    - May need frequent recalibration

- Monitoring aircrew is complicated
    - Resistance from aircrew
        - Concerns about grounding
        - Health-related uses and privacy concerns

- System MUST NOT interfere with pilot's performance

- System MUST be superior to simple manual control of workload/displays/task allocation by aircrew

System of Systems

Career Duration Monitoring
- Inform Future Training; More Retention →
- ← ML Monitoring For Pathologies

Deployment Duration Monitoring
- Identify/Prevent Burnout; Health Monitor →
- ← Inform Work/Rest Cycle Decisions

Mission Duration Monitoring
- Verify Safe To Fly; Improve AAR Timetable →
- ← Identify Acute Environmental Hazards

Short Term Monitoring
- Workload / Fatigue Monitoring →
- ← Predictive Blended Automation

"Real Time" Monitoring
- Prevent Aircraft Loss If Pilot Incapacitated →
- ← Optimize Enhancement Timing

WHAT DOES THIS MEAN FOR CIVIL AVIATION AND THE FAA?

- High potential for increased safety in the future
- Potential benefit to aeromedical certification

- High technical risk in short term
- Must leverage enormous investment in human monitoring around world
  - Industry, Sports, DoD

- Aviation community must conduct research targeted at our environment
  - Physical environment
  - Social environment
  - More rigorous than most other applications

WHAT DOES THIS MEAN FOR CIVIL AVIATION AND THE FAA?

2017 SAS Paper, "Emerging issues and Future Opportunities"

The focus of this strategic research effort is to enable development of a real-time, system-wide safety assurance system. The ongoing advances in sensor and networking technology, computation, communications, and integration can be combined with advanced data analytics to accelerate access and protection of sensitive data. This will enable discovery, alerting, and mitigation of anomalous events at a progressively more rapid pace, and will enable unprecedented insight into system operations, health, and safety. An additional component of this future real-time information system will be the integrated monitoring of the human operator state, providing human performance data to the automated system. These advances, applied broadly within the aviation system and combined with system-of-systems modeling and prognostics, offer a new vision of real-time, system-wide safety assurance. Strategic research in this area will deliver a progression of capabilities that accelerate the detection, prognosis, and resolution of systemwide threats.

Research Needs. Continued development of advanced safety analysis and assurance tools such as data mining and analysis, automated prognostics, and safety risk modeling will substantially improve the ability to gain insights and develop mitigations from the growing amount of available aviation system data. These developments will dramatically improve safety assurance by reducing the time to analyze, identify, and mitigate safety risks.

Research is needed to enable the integration of advanced tools into a more highly automated safety assurance system that will enable continuous systemwide safety assessment. This advance can lead to rapid identification of safety issues and corrective actions before the issues become hazards. Such an automated system will evolve to be near-real-time as confidence increases in continuously validated system judgments. Biomedical research is also needed to develop the psychological and physiological measures from the human operator that will inform the automation system.

As the automated safety assurance system becomes integrated with real-time operations to help create an aviation system that exhibits the autonomic properties of self-protection and self-healing. In this future, research to determine how human operators and autonomous systems will collaborate to ensure an optimal mix of actions – from immediate operational adjustments to far-term system and infrastructure changes – will minimize safety risks.

MANAGING AIRCREW WORKLOAD:
OTHER IMPORTANT STRATEGIES

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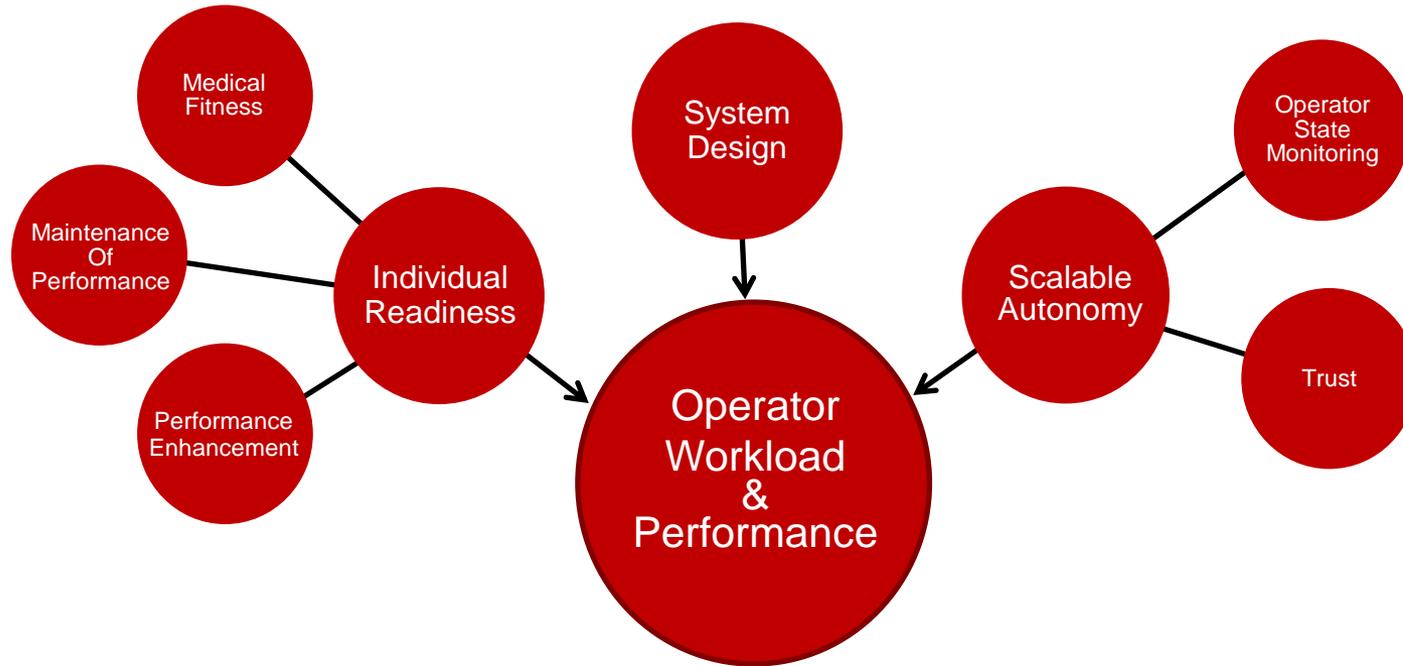
UNOFFICIAL RECOMMENDATIONS AND THOUGHTS

- Invest in research needed to incorporate operator state monitoring in civil aviation in the future

- Leverage active research by others for similar applications

- Continue investment in complementary aeromedical research to maintain pilot performance in real-world aviation operations

- SAS should continue to emphasize research in this area

- Thoughts from CAMI?

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COMMENTS / QUESTIONS?

John Crowley MD MPH

john.s.crowley.civ@mail.mil

THE U.S. ARMY AEROMEDICAL RESEARCH LABORATORY
FORT RUCKER, ALABAMA