Joint Session

Fatigue Risk Management Systems: Measurement and Evaluation of Effectiveness

Potential for Modeling Tools

Steven R. Hursh, Ph.D.
Institutes for Behavior Resources

10:45 - 11:05

June 18, 2008

Presented at the FAA Fatigue Management Symposium: Partnerships for Solutions; Vienna, VA: June 17-19, 2008

Steven R. Hursh, Ph.D.
Biography

Dr. Steven R. Hursh is the President of the Institutes for Behavior Resources and Adjunct Professor of Behavioral Biology, Johns Hopkins University School of Medicine. Dr. Hursh has over thirty-five years experience as a researcher, is author of over 65 articles, book chapters and books and is a former associate editor of the *Journal of the Experimental Analysis of Behavior.* For the last twelve years, Dr. Hursh also has been the technical leader of an effort to model the relationship between sleep deprivation, time of day and performance funded by the US Army, Air Force, and Federal Railroad Administration. His patented **S**leep, **A**ctivity, **F**atigue, and **T**ask **E**ffectiveness (*SAFTE*) model has been accepted by the Department of Defense as the standard warfighter fatigue model and it has been validated by the Department of Transportation as an effective fatigue risk management tool. He is also a leader of a *NSBRI/NASA* funded project to study team performance in a simulated space exploration environment with a focus on factors that support effective team work, cooperation, and resilience. This program applies modern simulation technology to study behavioral dimensions of group activities, including autonomy versus structure, workload, fatigue, communication, and motivation. Dr. Hursh is also the co-inventor of the **F**atigue **A**voidance **S**cheduling **T**ool (***FAST***) used by government agencies (*FRA, FAA, DOD*) and industries to assess and manage fatigue.

Dr. Hursh is well known in the behavioral community for his work on Behavioral Economics, having written critical empirical and theoretical papers over thirty years of research with animal and human subjects. He has recently published (with Silberberg) a broad statement on "Economic Demand and the Essential Value of Reinforcers", in the *Psychological Review* (2008).

As President of the Institutes for Behavior Resources, Inc., he directs original research on fatigue, cooperative team performance, behavioral economics, and drug abuse. He has had twenty-three years of experience as a research manager in the Army: consultant to the Army Surgeon General for Research Psychology, Director of the Division of Neuropsychiatry at the Walter Reed Army Institute of Research, and as a medical staff officer in the Pentagon, Office of the Assistant Secretary of the Army (Research, Development, and Acquisition). After retirement from the Army, Dr. Hursh spent 12 years with Science Applications International Corporation as a program manager prior to being selected to head the Institutes for Behavior Resources, a nonprofit behavioral research, services, and educational institution.

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Potential of Modeling for Aviation Fatigue Risk Management

June 18, 2008

Steven R. Hursh, Ph.D

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- Federal Aviation Administration
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- NSBRI
- NASA
- Archinoetics, LLC
- NTI, Inc.
- Foster-Miller, Inc.

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Symptoms versus Root Causes

Symptoms
Operational Consequences

- Measurable changes in Performance
- Lapses in attention and vigilance
- Delayed reactions
- Impaired logical reasoning and decision-making
- Reduced "situational awareness"
- Low motivation to perform "optional" activities
- Poor assessment of risk or failure to appreciate consequences of action
- Operator inefficiencies

Root Cause Analysis

- Fatigue is one potential root cause.
- No direct measure, physiological marker, or "blood test" for fatigue.
- Often it is missed as a contributing factor.

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Modeling: Objective Metric of Fatigue

- <u>To manage fatigue risk, you need to *measure risk*.</u>
  - No physiological marker or performance indicator.
  - BUT, The conditions that lead to fatigue are well known.
  - Fatigue models simulate the physiological conditions that modulate performance and alertness.
  - The model estimates the level of degradation in performance and provides an *estimate of* ***schedule induced*** *fatigue risk*.
- <u>Modeling is the only way to forecast risk.</u>

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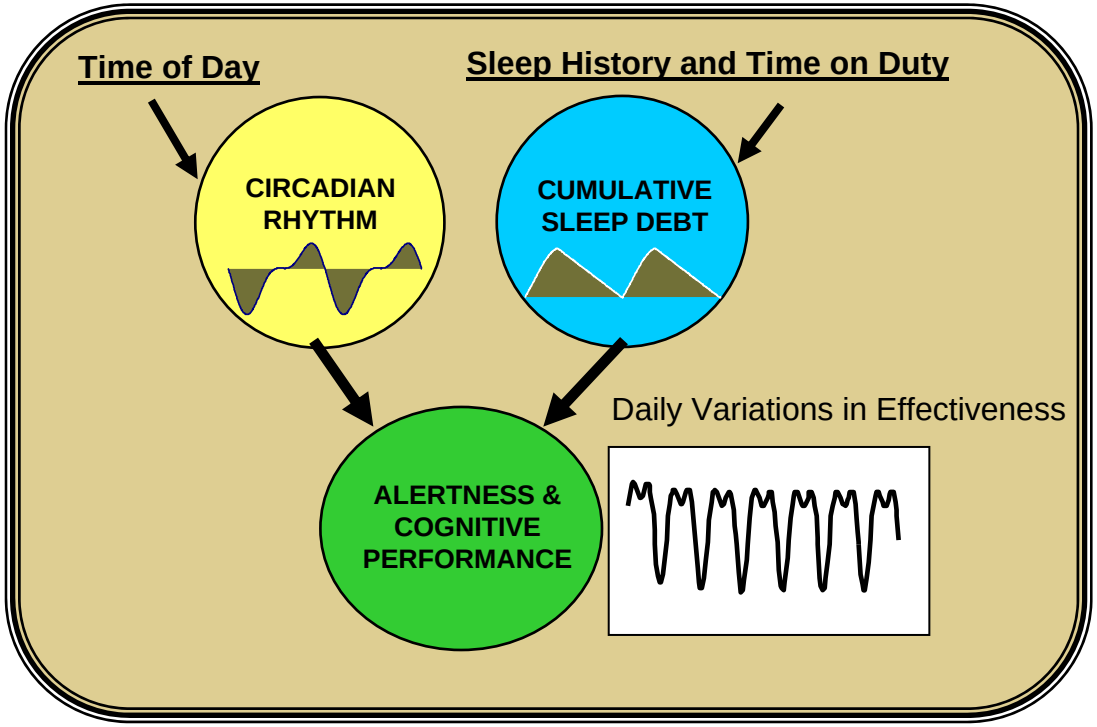
Biomathematical Models of Fatigue

- Based on twenty years of development.
- Validated against laboratory & simulator measures of fatigue.
- Recently shown to predict accident risk and severity.



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Fatigue Modeling Applications

- The US DOD as adopted a biomathematical model to assess fatigue in warfighters.
- The US Department of Transportation has invested in validating fatigue models.
- NASA will use fatigue models to assess performance risk in space flight.
- Several US and foreign agencies use modeling to investigate fatigue contributions to accidents.
- Commercial Fatigue Risk Management tools.

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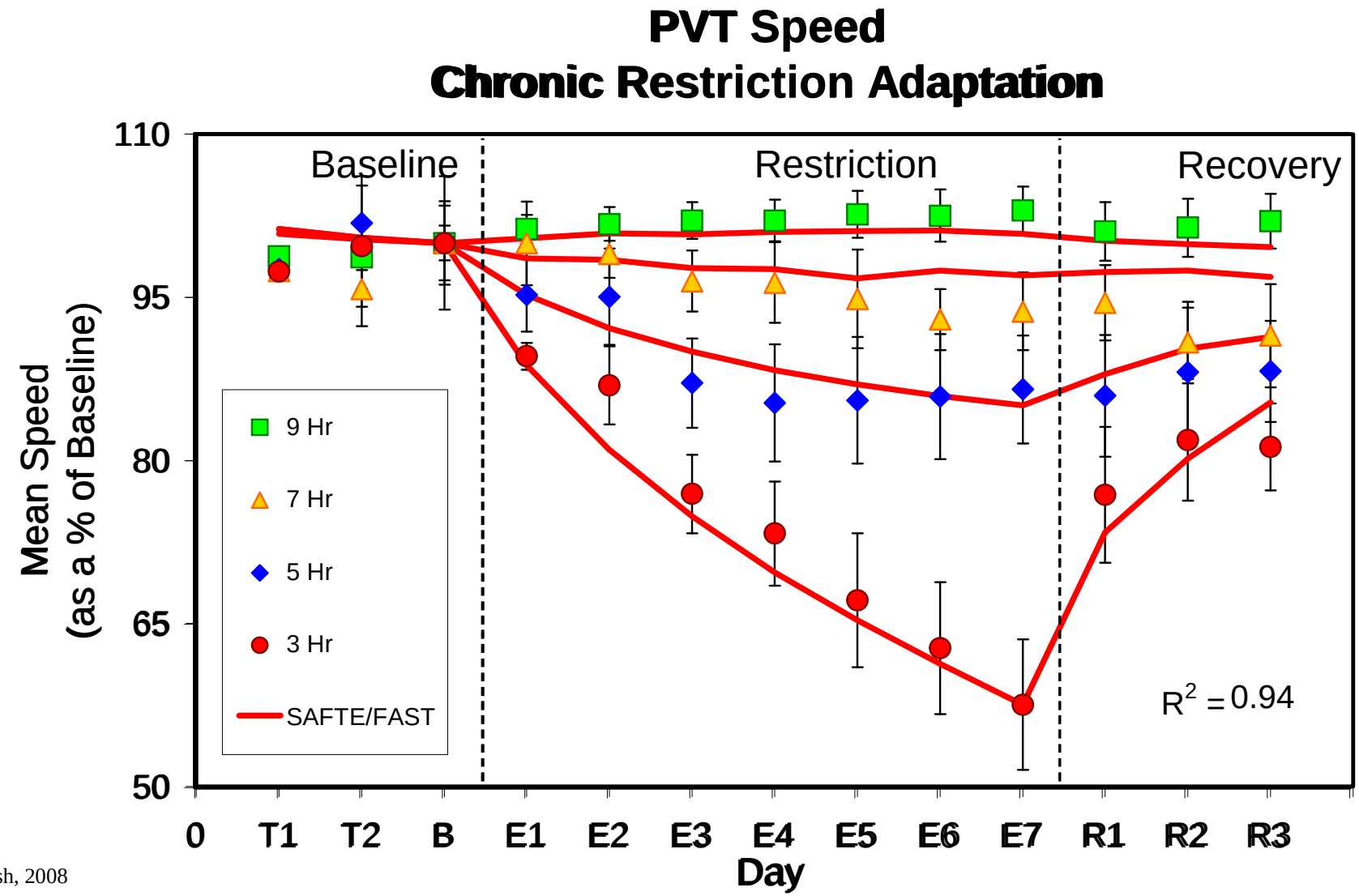
Walter Reed Restricted Sleep Study

Fatigue Model Predicts the Average Results



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Two-Stage Approach to Operational Fatigue Modeling

- Input: Compile a sequence of duty periods
- Stage 1 Model:
  - Estimate the opportunities to sleep – both quantity and timing of sleep based on off-duty time and other factors.
- Stage 2 Model:
  - Estimate performance effectiveness during duty periods based on estimated sleep history.
  - Estimate the relative risk of error/accidents associated with reductions in performance effectiveness.

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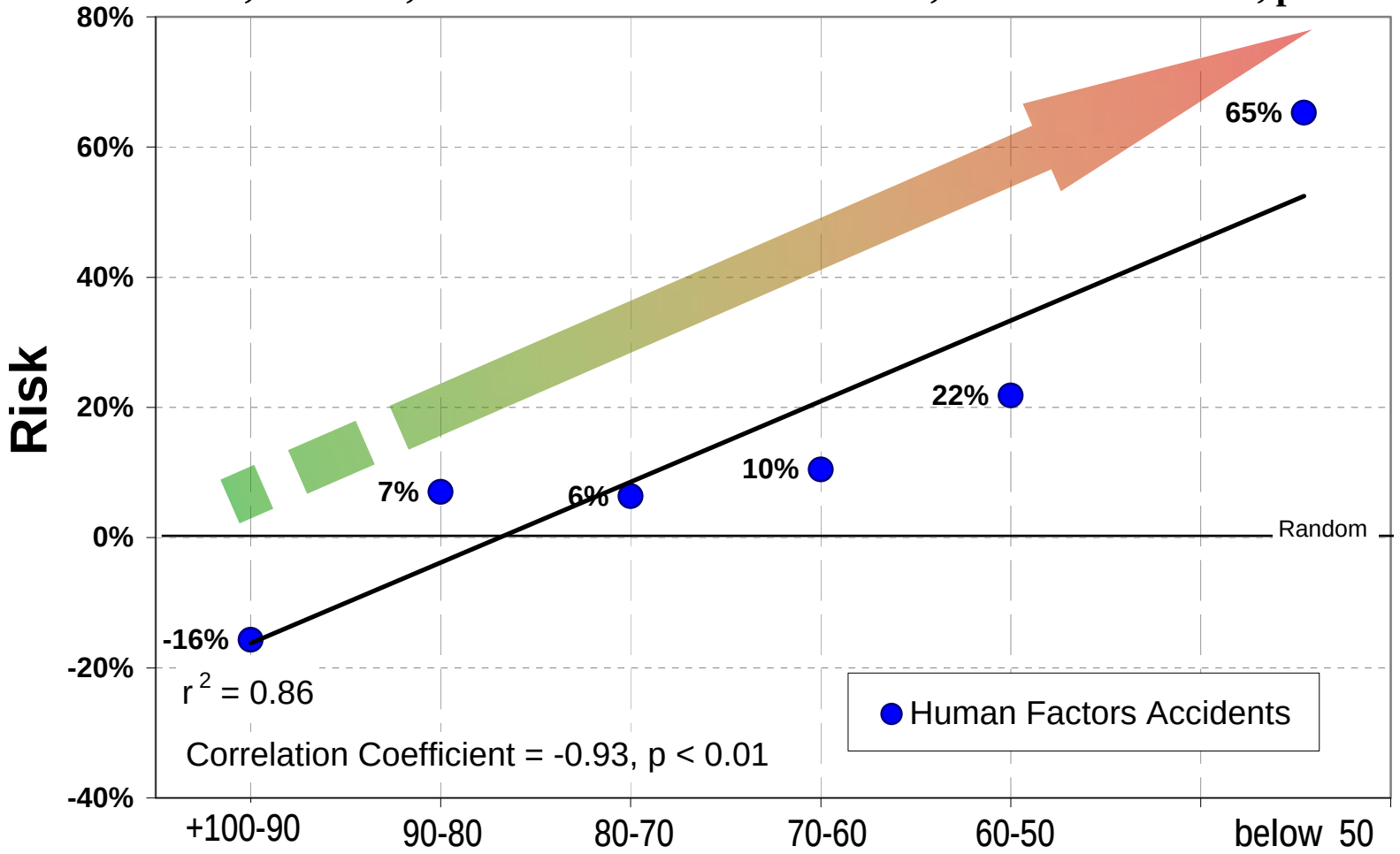
Human Factors Accident Risk is Significant Function of Decreasing Effectiveness

FRA funded study of 400 HF & 1000 NHF Railroad Accidents, 57,000 shifts, 1 million 30 min work intervals, Correlation = -0.93, p < 0.01

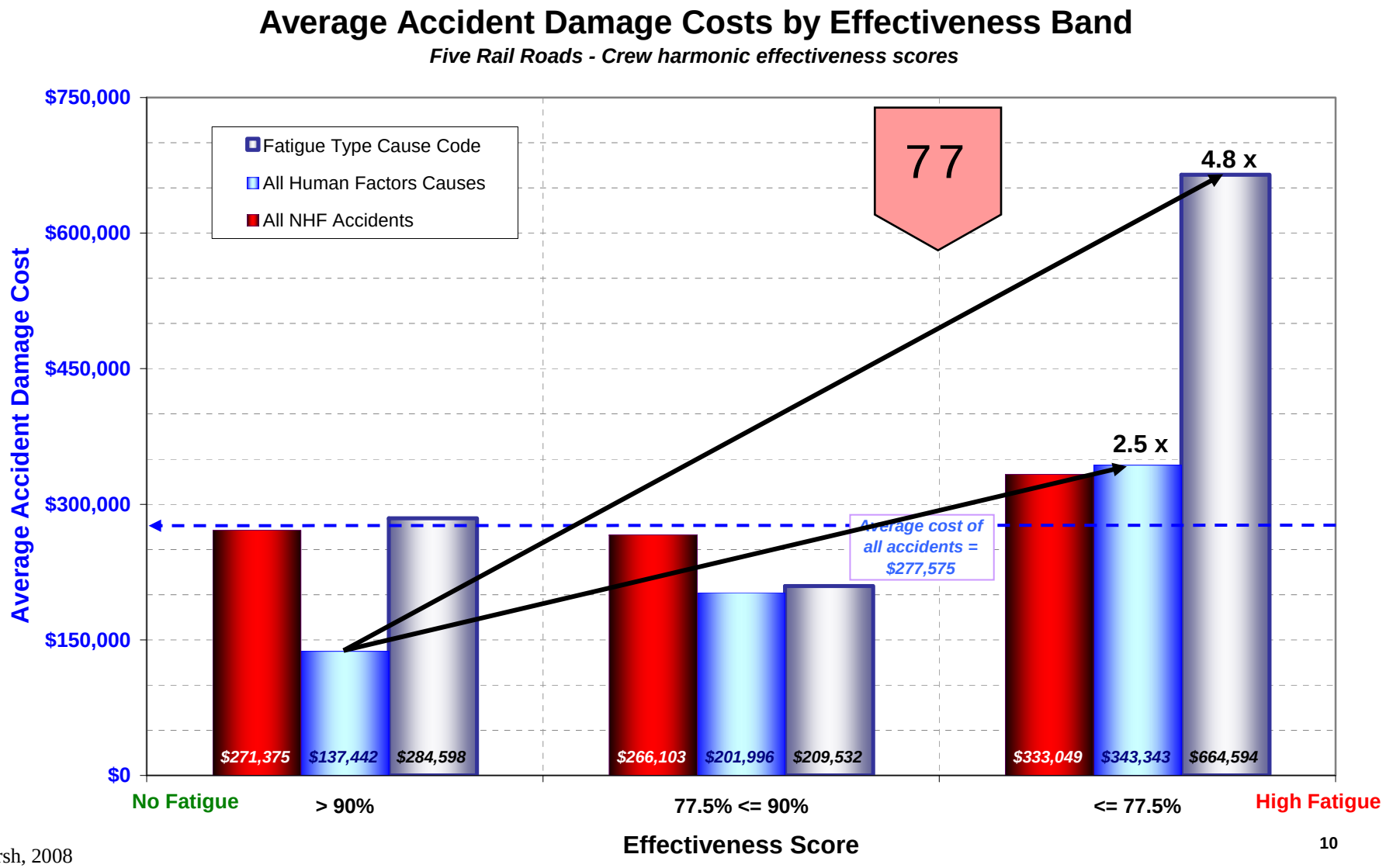


No Fatigue **Model Effectiveness Score** *High Fatigue*

Modeling Predicts Accident Severity

All accidents below 77.5 are more costly than average

FRA Funded Study



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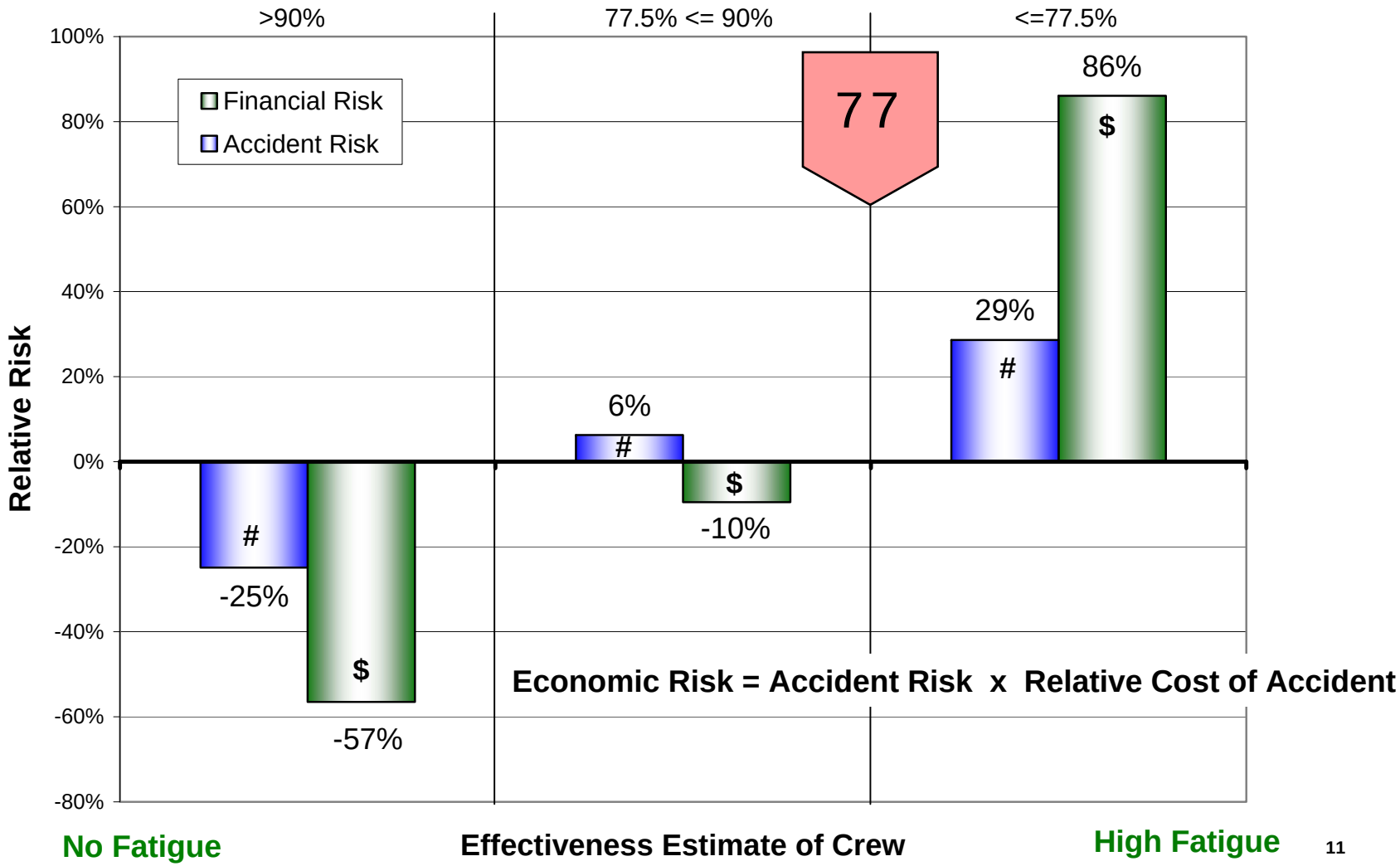
Economic Risk Increases with Fatigue
Human Factors Accidents

FRA Funded Study

Economic Risk of Fatigue - Human Factors Accidents



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Duty Schedule Evolution

- Monitor all schedules continuously.
- Model performance predictions from schedules.
- Focus on most extreme cases of risk.
- Mitigate risk or select for schedules with less risk.
- Gradually improve the fitness of the schedule population by consistently eliminating extremes.
- *Changes are gradual and proportional to risk.*

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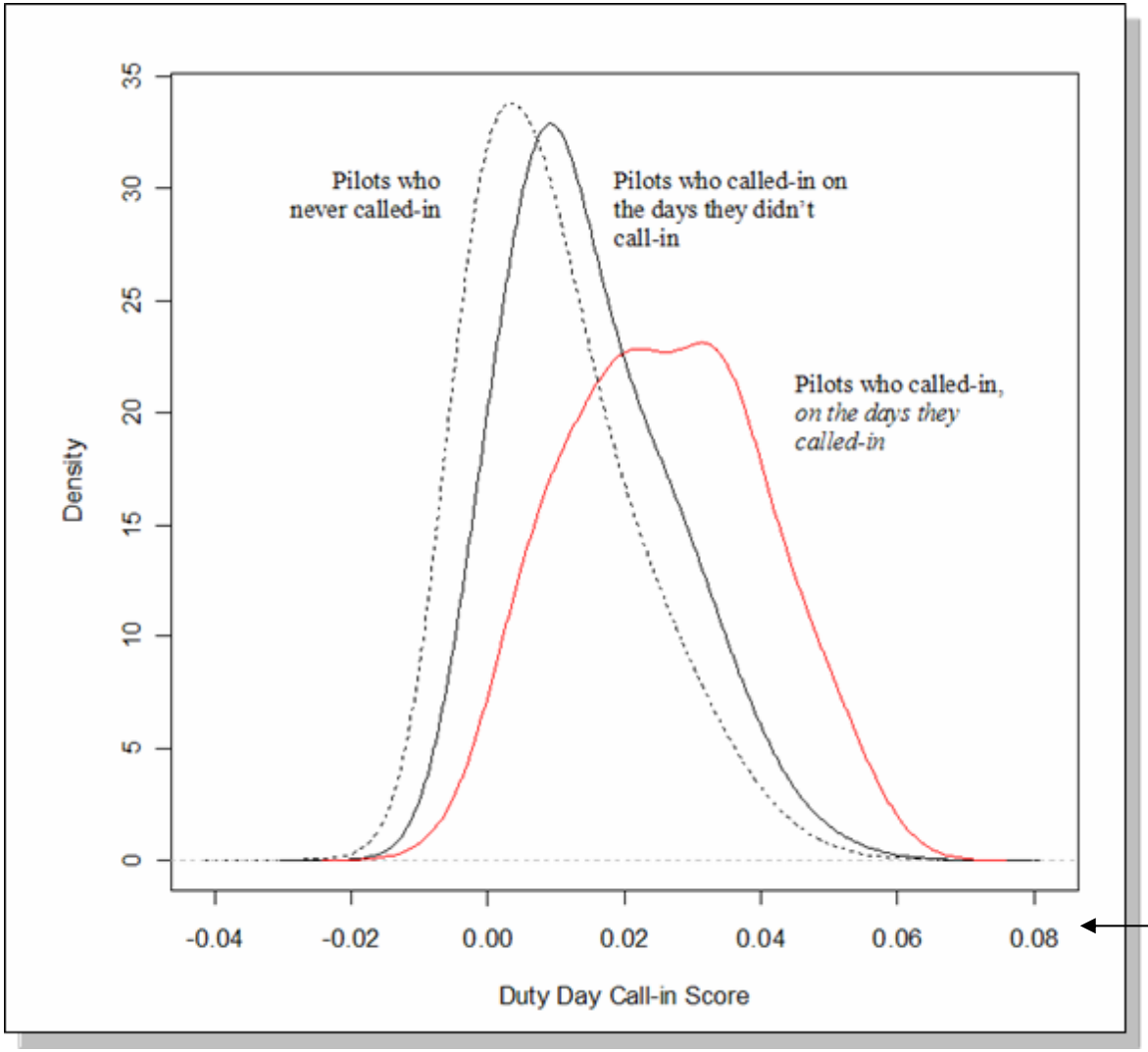
Model Score Distributions Distinguish Pilots Who Report Fatigue

The area of each distribution sums to the total for that group.



79% Accuracy

Fatigue Score is based on fatigue model effectiveness *combined with workload* – daily rates of take-offs and landings.

Fatigue Score

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Future Requirement: Epidemiological Study of Aviation Risk

- The study with railroad accidents suggests that modeling can make meaningful predictions of risk.
- Requirement for Aviation:
  - Broad assessment of performance deviations (LOSA, ASAP, or FOQA) in relation to prior duty schedules.
  - The results would validate and calibrate fatigue models for aviation risk.

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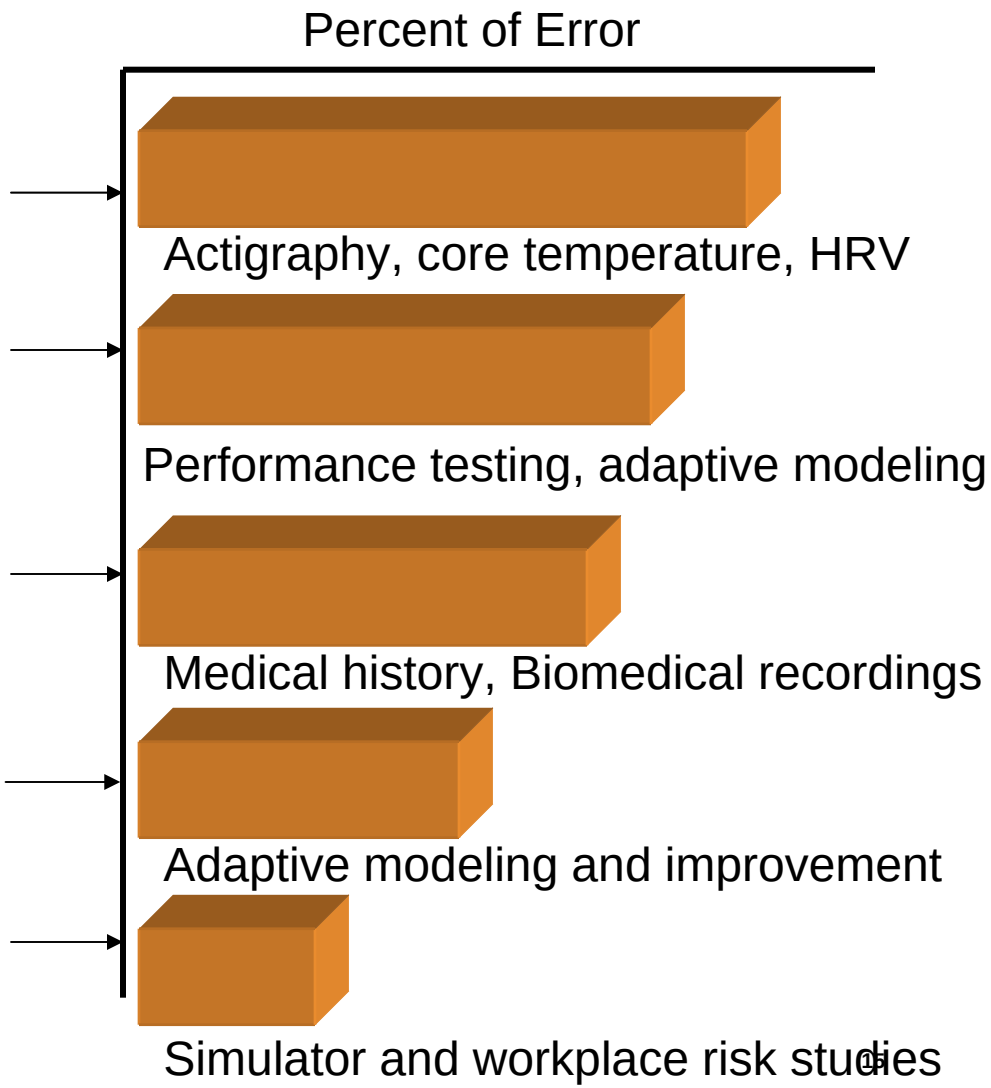
Modeling is Imperfect for Individual Cases
Sources of Uncertainty

Uncertainty

- State of individual: sleep history and circadian phase/amplitude
- Trait differences between individuals: sleep need and recovery rate
- Other personal factors
  - Age, gender, health
  - Medications
- Inaccuracies in our modeling and analysis
- Lack of knowledge about task demands and performance risk



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Tracking the State of the Individual

- **Sleep History: Actigraphy**
  - Unobtrusive measures of activity that provide relatively accurate estimates of sleep quantity and quality (fragmentation).
  - Once only a research tool, off-the-shelf accelerometers have reduced the cost to close to $100 per unit.

- **Circadian Process:** Light sensors and near infrared sensors may soon be able to detect drivers and physiological responses to circadian rhythms.

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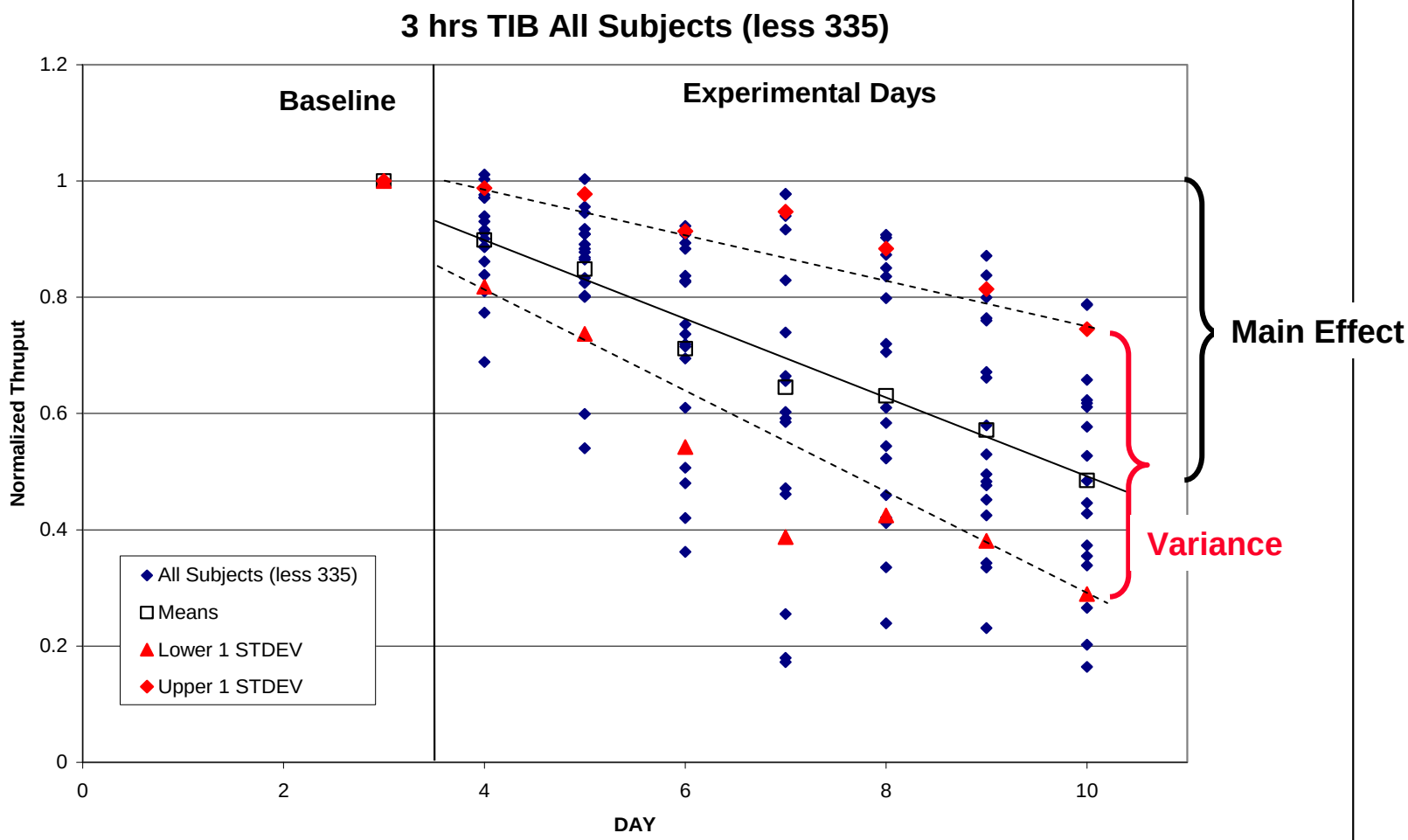
Assessing Between Subject Variability in Sensitivity to Sleep Restriction



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Two Approaches to Individual Differences

- ***Near-term solution:*** **reflect both the mean and variance of prediction from fatigue models, based on population studies.**

- ***Far-term solution:*** **adaptive modeling based on feedback from the individual, either external performance testing or embedded measures of task activities.**

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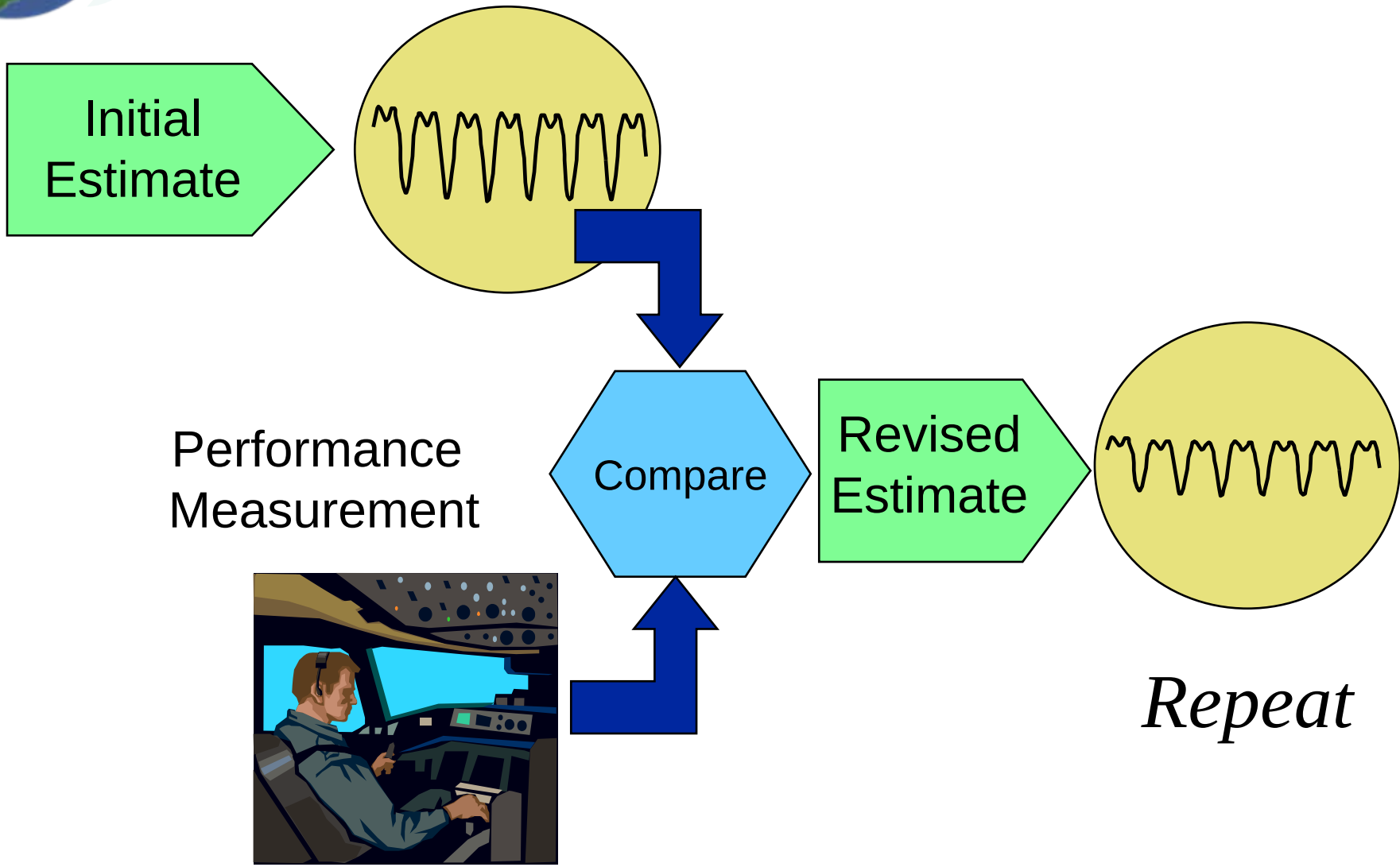
Adaptive Modeling for Individual Differences



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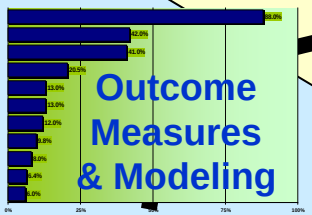
Fatigue Risk Management (FRM)

Evidence-based Five-M Approach



Measure

Define the situation
Schedule evaluation
Sleep Monitoring
Other fatigue factors

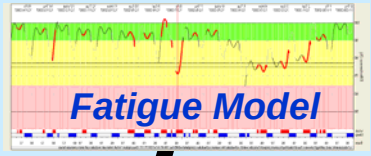
Monitor

Assess operational indicators
Individual self-evaluation
Feedback to process

Involves all stakeholders at each stage: management, labor, aided by science

Model

Model the fatigue problem
Analyze sources and Fatigue factors



Modify/Mitigate

Operating practices
Labor agreements
Individual "life style" decisions

Manage

Collaborate for solutions
Obtain commitment to solve problem

Enablers

Employee training
Medical screening

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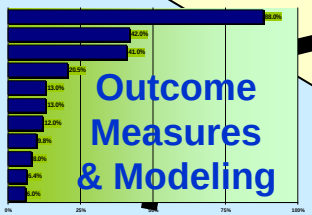
Fatigue Risk Management (FRM)

Evidence-based Five-M Approach



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Involves all stakeholders at each stage: management, labor,

Model

Model the fatigue problem
Analyze sources and
Fatigue factors

Mitigation Proportional to Risk

Gradual Performance Improvement

Dynamic Adaptation to Conditions

Individual "life style" decisions

solve problem

rs
training
Medical screening

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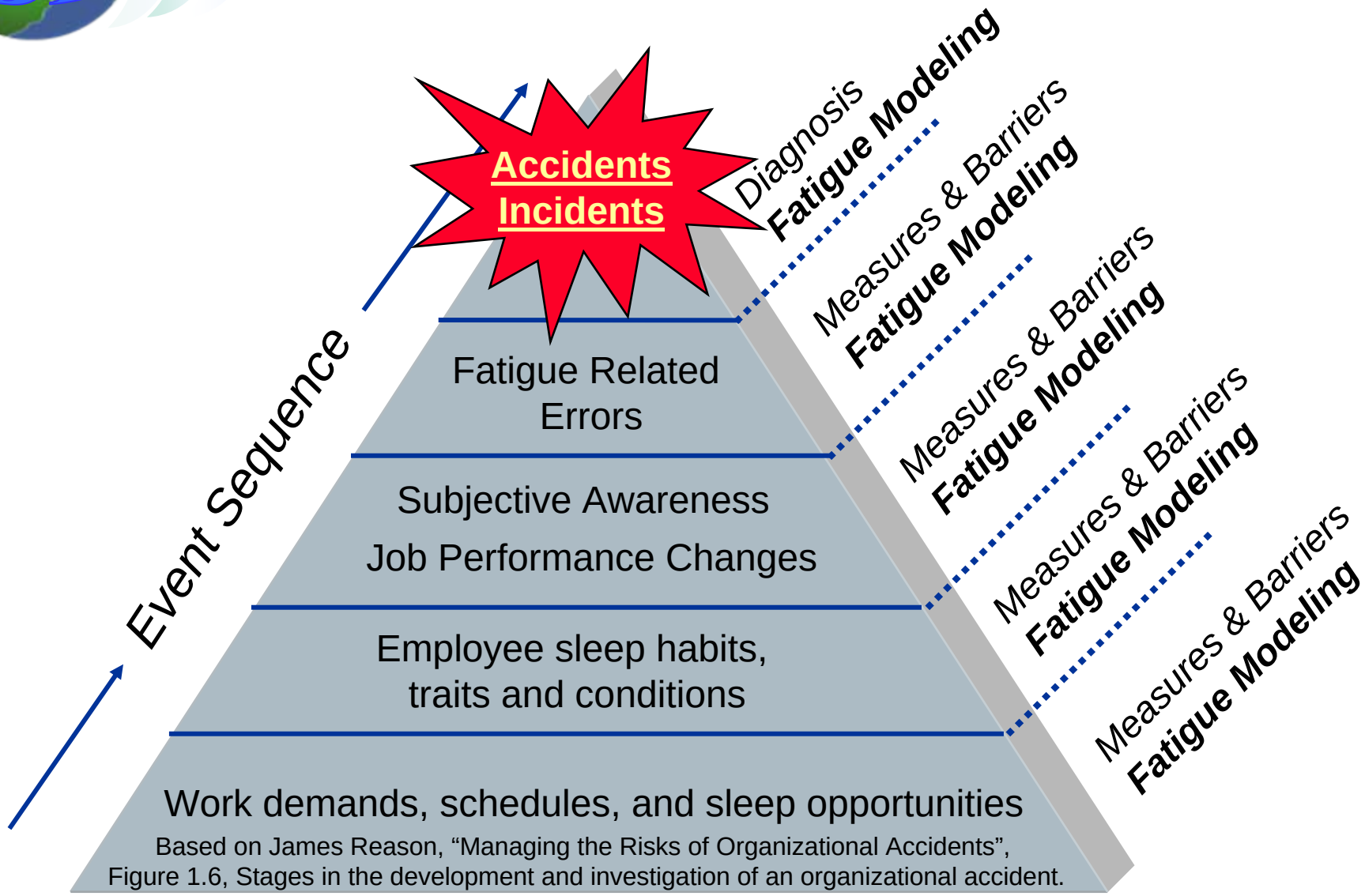
Fatigue Risk Pyramid: Modeling and Barriers



Based on James Reason, "Managing the Risks of Organizational Accidents", Figure 1.6, Stages in the development and investigation of an organizational accident.

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Applications of Fatigue Modeling Now

- **Modeling is not a panacea, but it is an essential part of the system.**
- **Prediction/Forecasting**
  - Forecast Risk for Duty Schedules (work assignments)
    - “city pairs” – flag trips that may cause fatigue
    - monthly bid lines – flag fatiguing trip combinations
  - Generic Shift Schedules
    - “design principles” to optimize shift work schedules
- **Prevention and Mitigation**
  - Change schedule
  - Train and inform individuals to maximize utilization of rest opportunities
  - Mitigate the risk through system design

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Thank You

Questions?

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