Validation of Fatigue Modeling Predictions in Aviation Operations

Managing Fatigue
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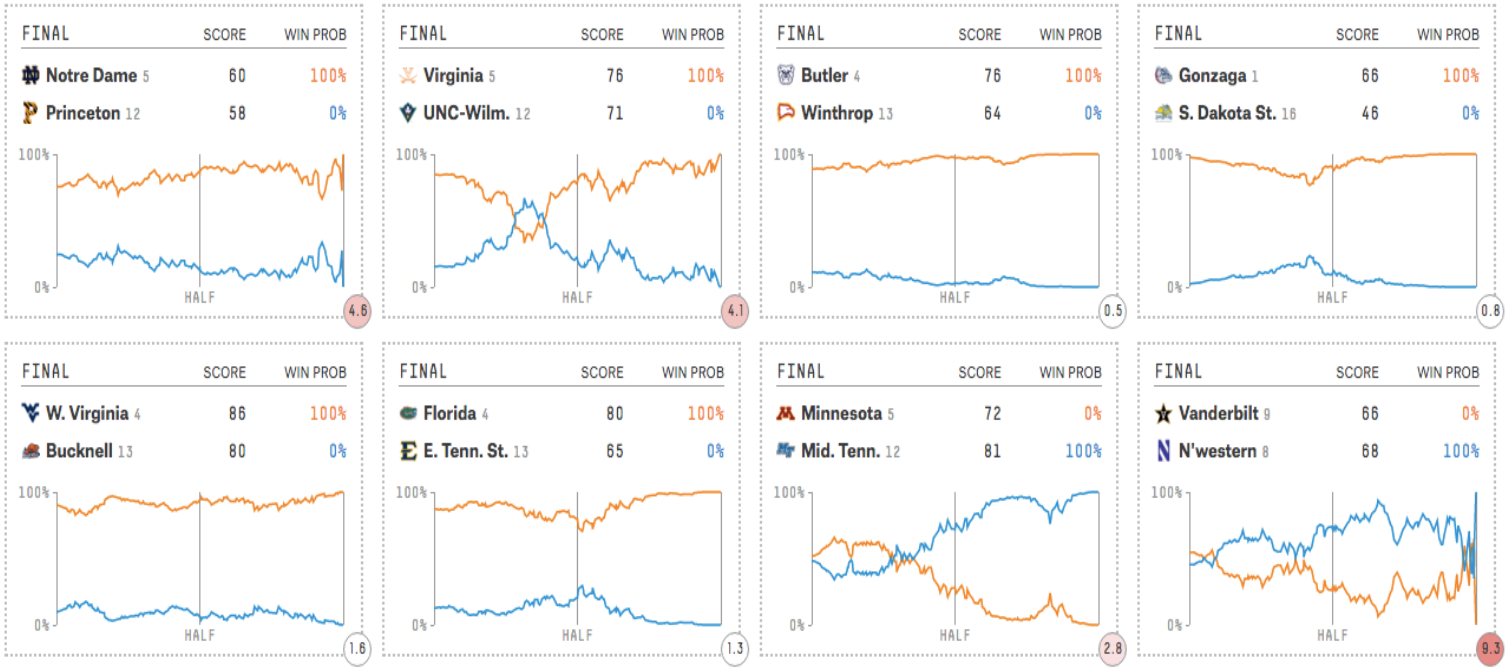
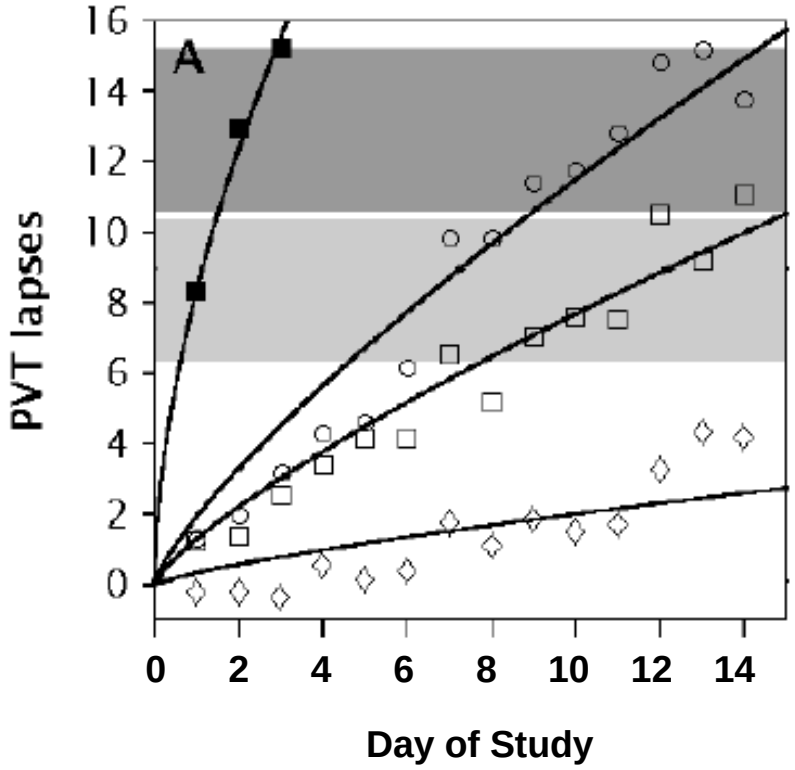
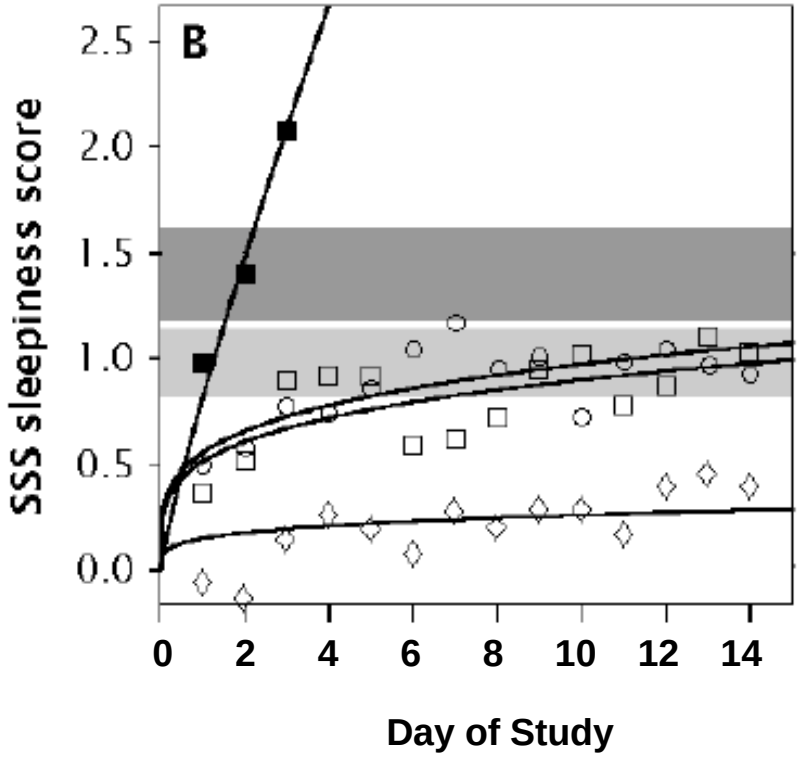
A modeling world?

FiveThirtyEight



Why do we need models of human performance?

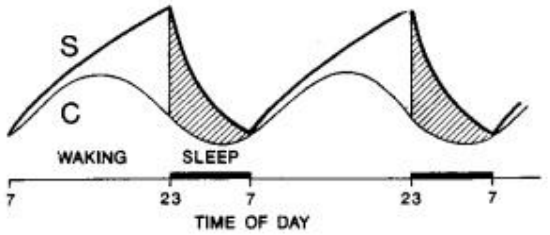




Van Dongen *et al*. 2003

Fatigue Modeling

- **First sleep/circadian models in 1980's**
- **Process S + Process C**
- **MIT Biomathematical Modeling Workshop (1999)**
  - **"identification of strong points and limitation of the models… comparison of their predictions with empirical data…"**
- **Fatigue and Performance Modeling Workshop (2002)**
- **Goal: to provide predictions of sleepiness, performance capability, and/or risk**



Borbély & Achermann, 1999

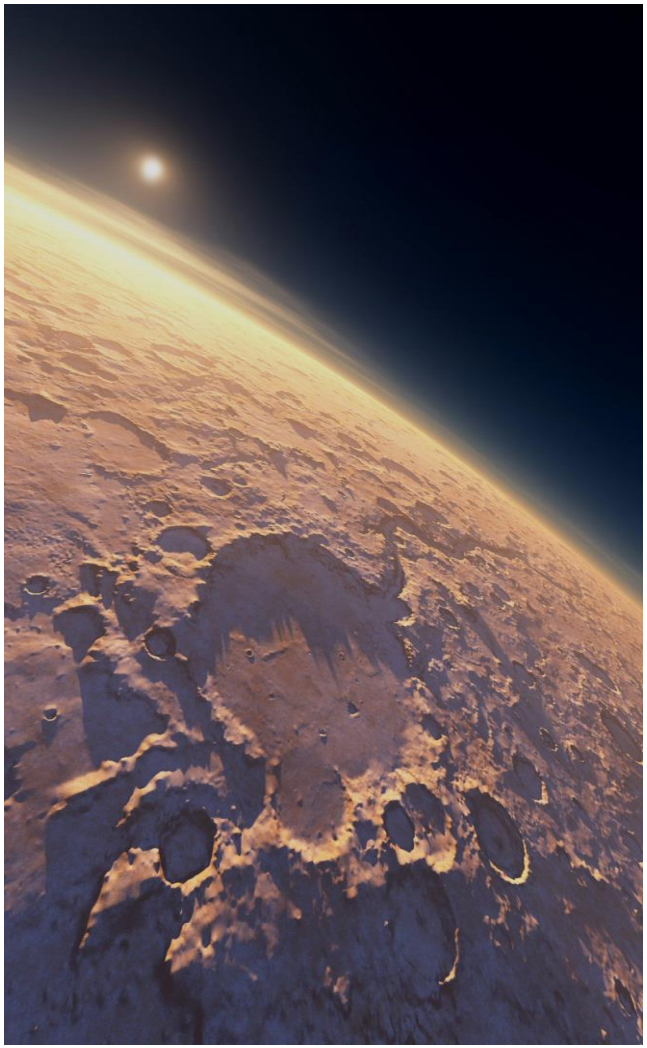
Individual Differences

- Sleep need: long vs short
- Circadian clock
  - Morningness/ eveningness
  - 5-hour range in phase
- Age
- Countermeasure use and effectiveness
  - Caffeine tolerance, other health conditions, etc.
- Effects on performance
  - Resilient/ vulnerable/ neither

NASA Risk Reduction Requirements for Space Flight

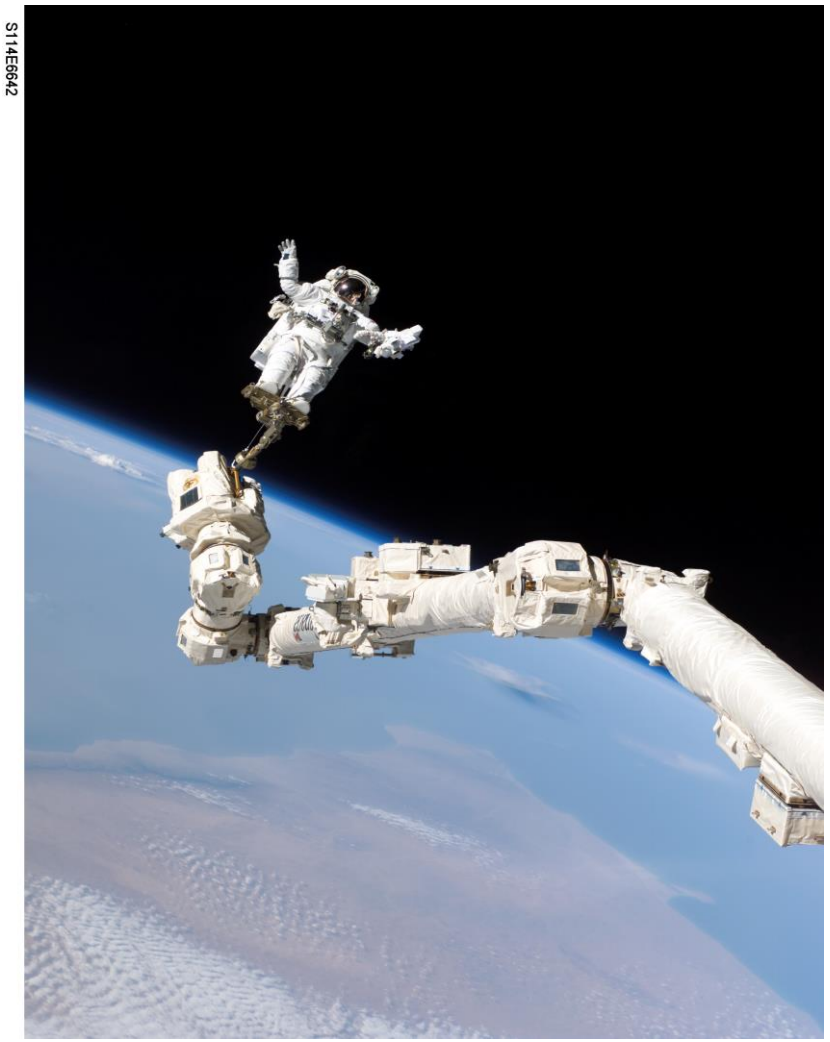
- We need to develop individualized scheduling tools that predict the effects of sleep-wake cycles, light and other countermeasures on performance, and can be used to identify optimal (and vulnerable) performance periods during spaceflight

- We need to identify an integrated, individualized suite of countermeasures and protocols for implementing these countermeasures to prevent and/or treat chronic partial sleep loss, work overload, and/or circadian shifting, in spaceflight



Challenges to Modeling Performance in Space

- Micro-gravity
- Excitement
- Stress
- Sleep fragmentation
- Intermittent light exposure
- Novelty of new environment
- Changes in vestibular function
- Mission requirements/schedule
- Circadian phase misalignment
- Uncontrolled countermeasure use
  - Wake and sleep promotion



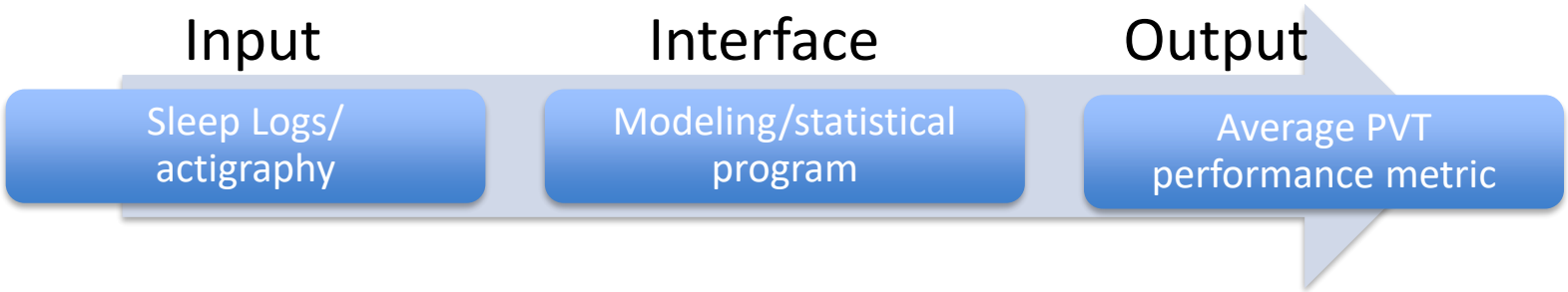
Modeling Use and Cautions

- FAA: "…models can serve as useful tools when evaluating the placement and timing of critical flight phases…**one can plan with the model but must confirm the effect**" (AC 120-100; 2010)

- ICAO: "models can be helpful tools in FRMS…[as] it is hard to visualize the dynamic interactions of processes like sleep loss and recovery, or the circadian biological clock. **To use models properly requires some understanding of what they can and cannot predict**" (2015)

Study Goals

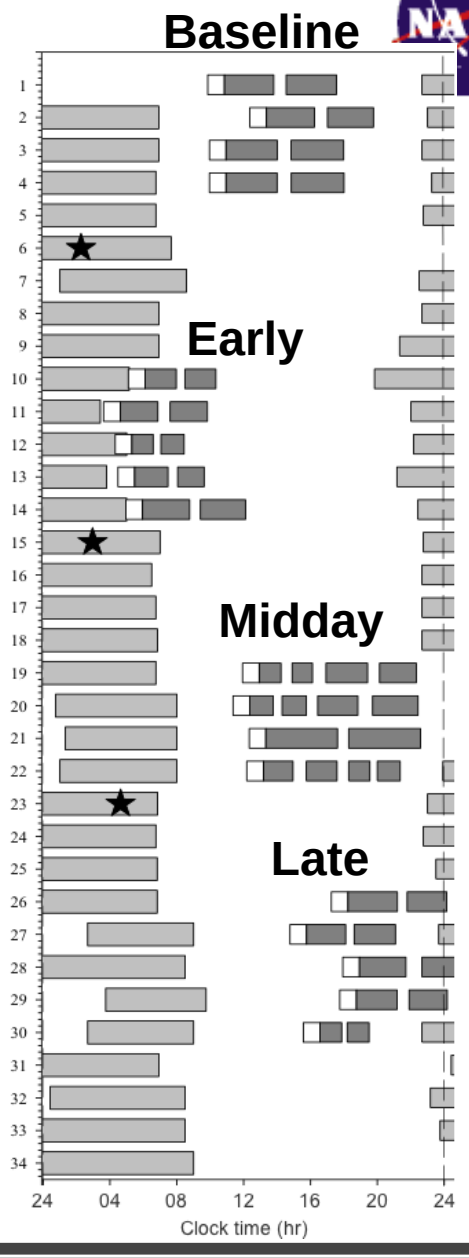
- Compare model performance predictions to PVT outcomes derived from 3 field and 2 lab study data sets
  - Challenging schedules with range of imposed sleep schedules including non-24 hr ops
- 4 models studied



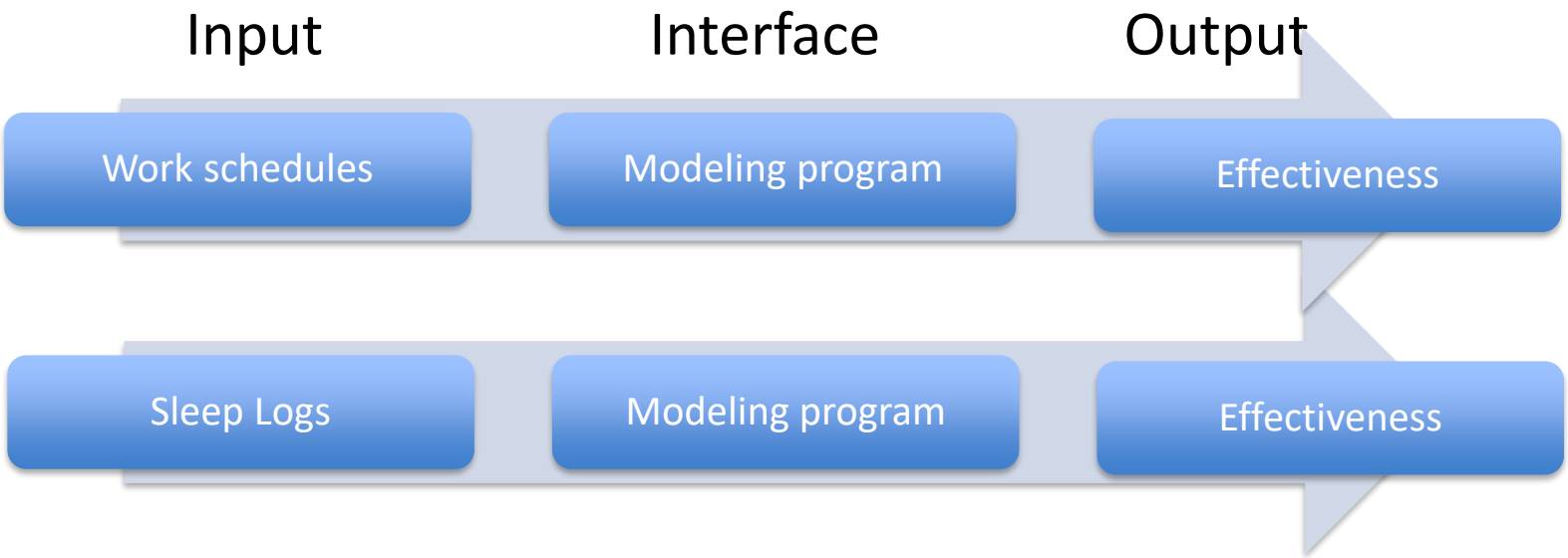
- 3-day acclimation period removed for analysis
- Inform use of models for long-range space travel

Short-haul Airline Operations

- n = 44 pilots
- Controlled schedule
- Uncontrolled countermeasures, uncontrolled sleep
- 5-minute PVT upon waking, top of descent, post-flight, before bed
- Actigraphy (with light) and sleep diaries collected for model input



Approach: using SAFTE/FAST



- Predicted effectiveness: percent of well-rested baseline performance, refers to mental capability or speed of cognitive performance
- Predictions based on group average data

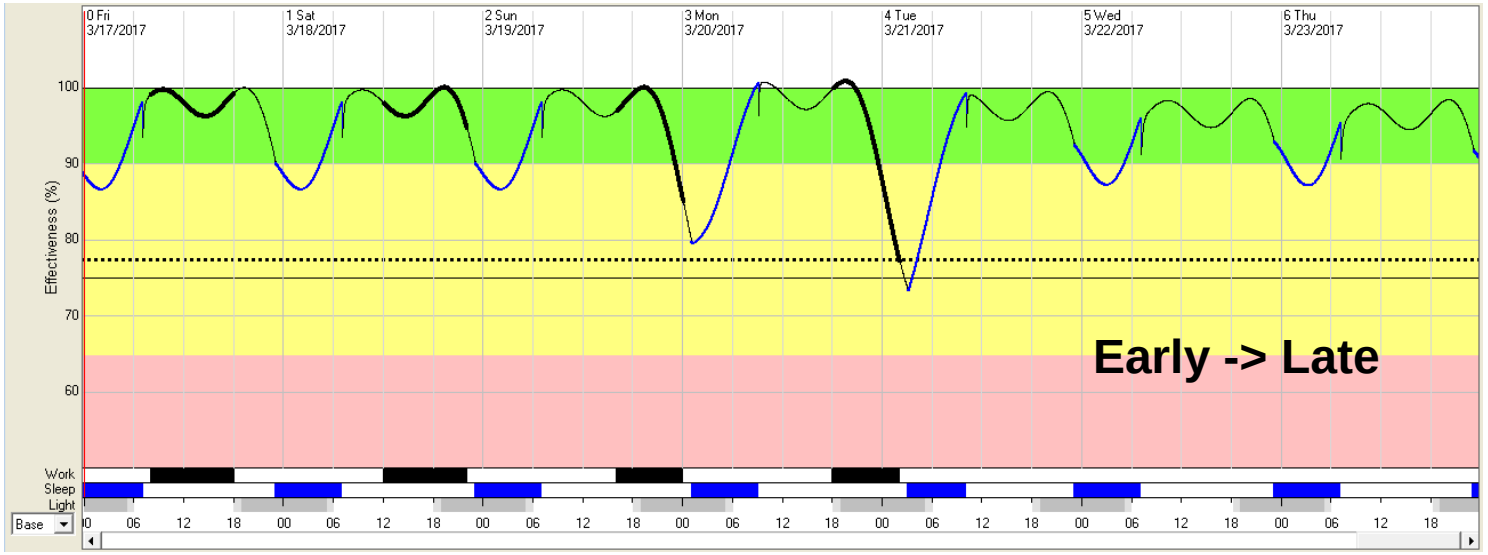
San José State UNIVERSITY

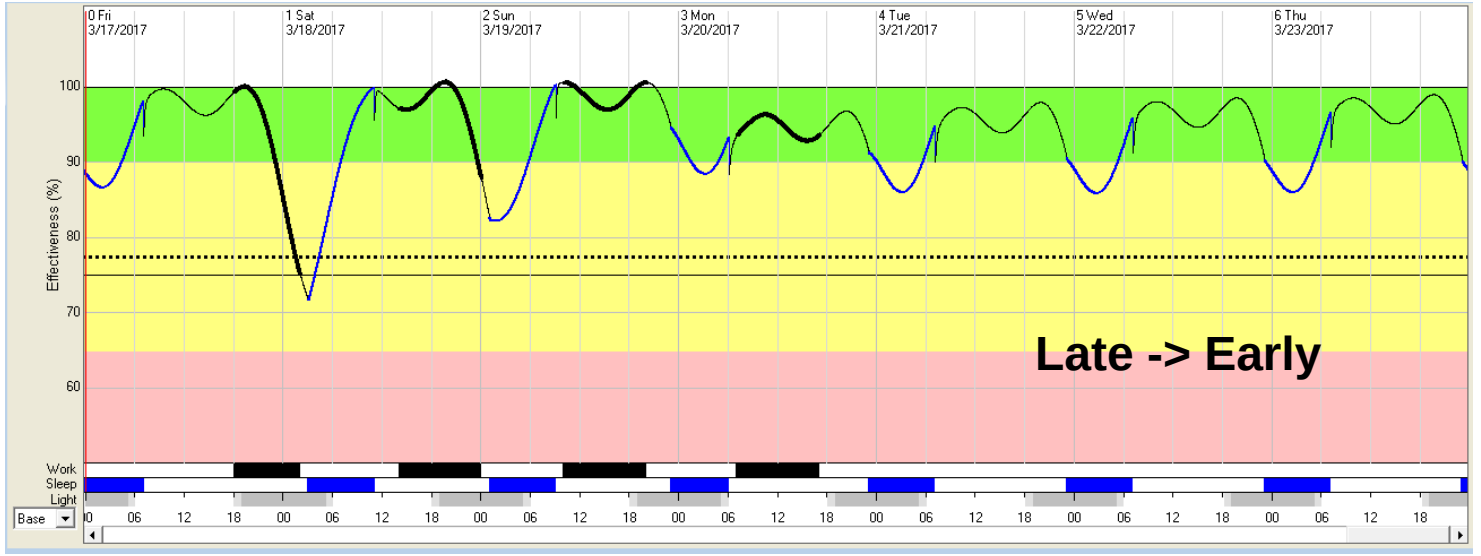
NASA

Airline pilot wins major legal victory on fatigue

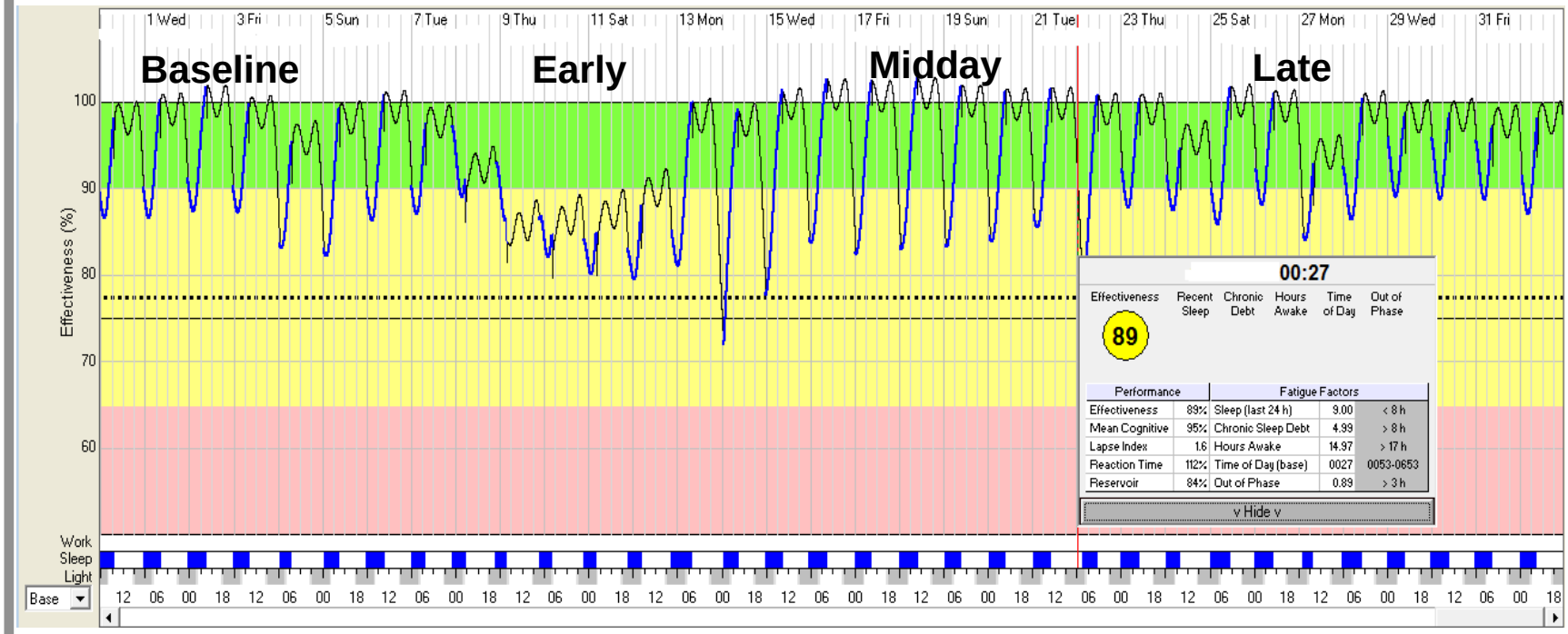
"…took the difficult decision not to fly after three extremely early starts in a row, including one 18-hour day, and what would have been a 19-hour day to follow…fatigue modeling software showed that because of the run of duties he had done, if he had flown his rostered flight he would have landed at the end of his duty with a predicted performance loss..."

Comparing Schedules

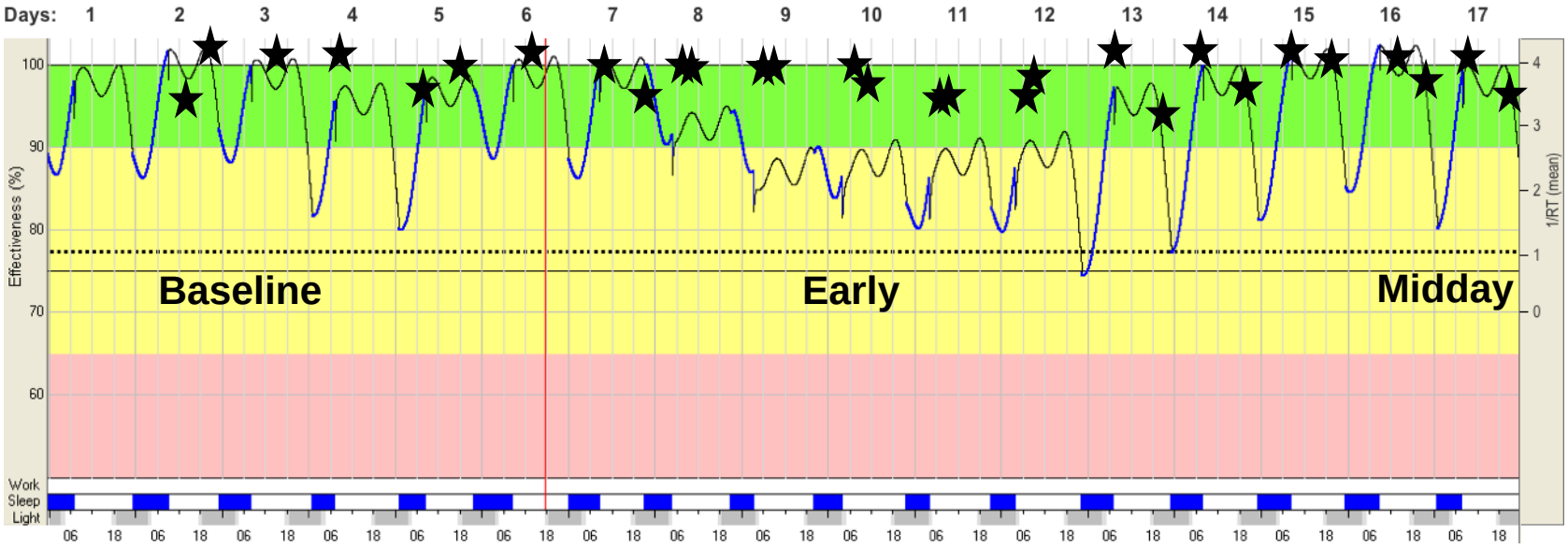




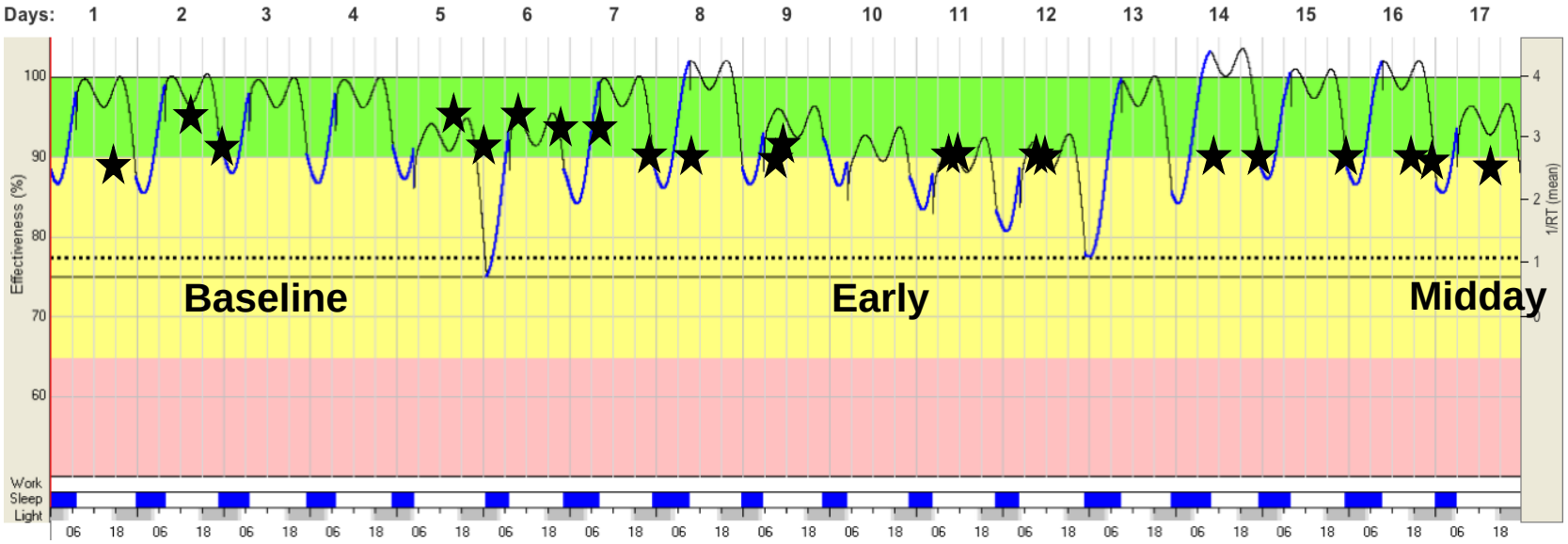
Short-Haul Airline Pilot



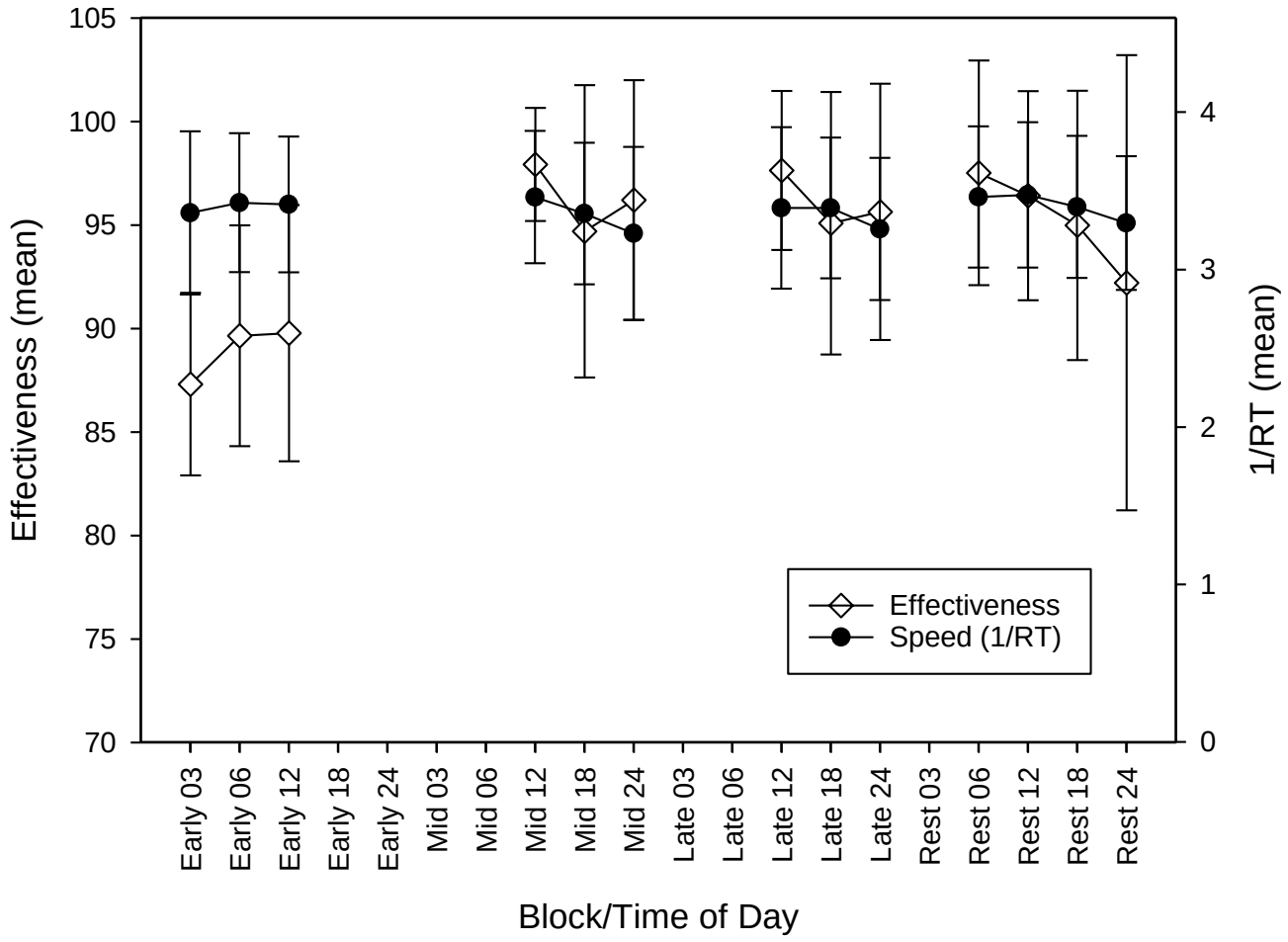
Short-Haul Airline Pilot: Resilient



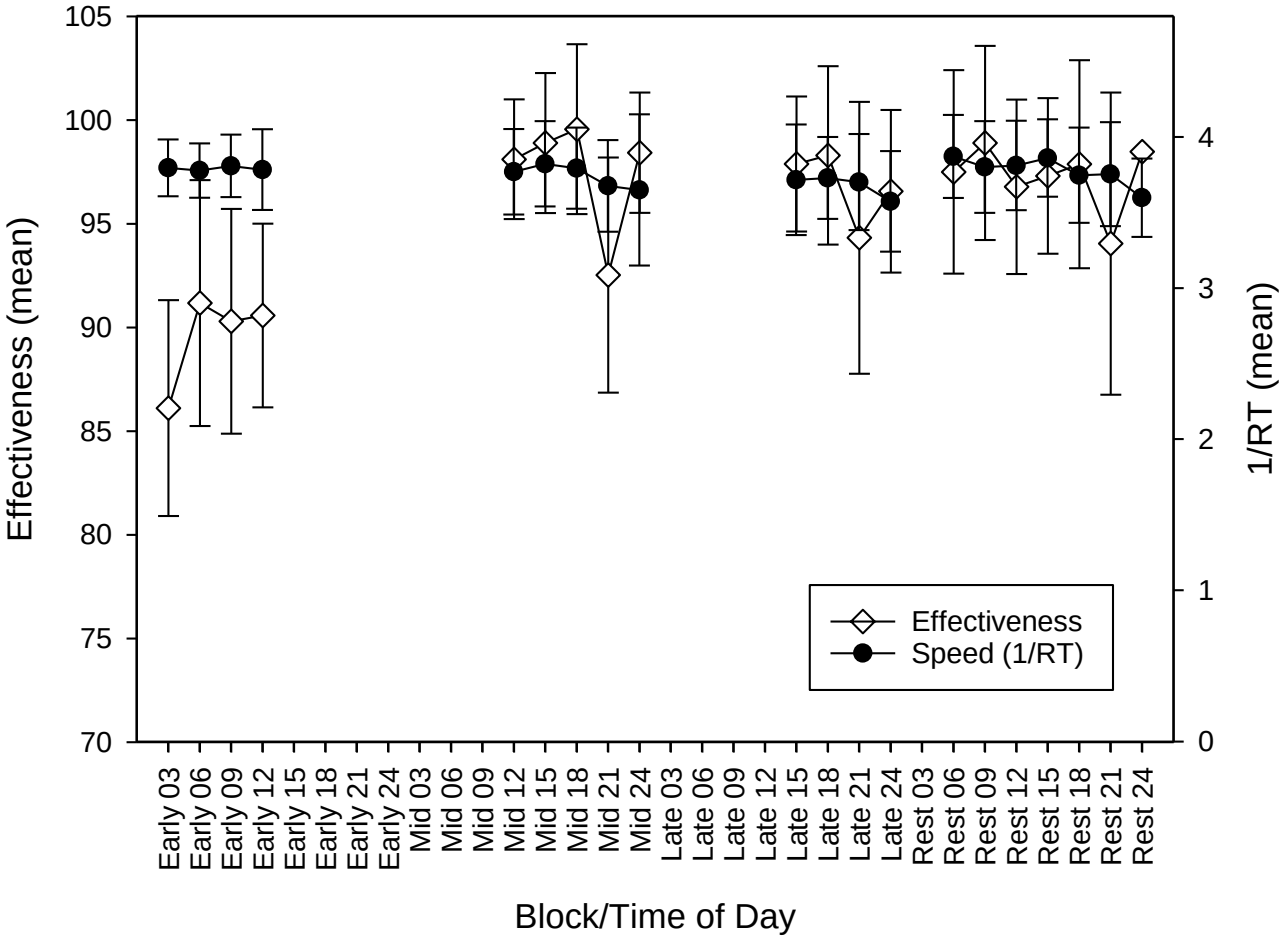
Short-Haul Airline Pilot: Vulnerable



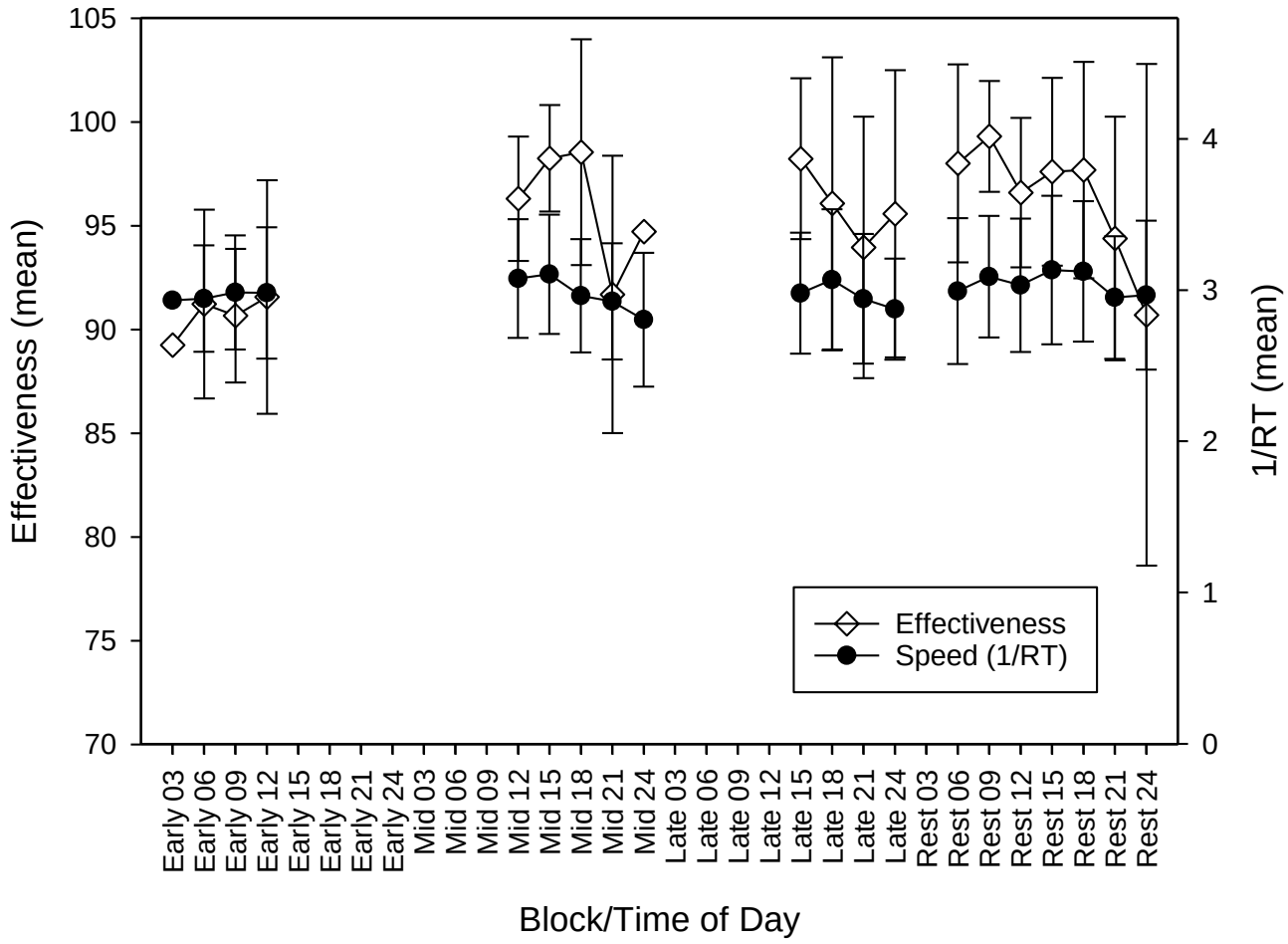
All Pilots:
Predicted Effectiveness vs Actual Response Speed



Resilient:
Predicted Effectiveness vs Actual Response Speed



Vulnerable:
Predicted Effectiveness vs Actual Response Speed



Findings

- Models can provide reasonable “big picture” information on schedules
  - Not appropriate for individual-level modeling
- Group results and predictions in concert for most aspects of studied schedule
- Model output is only as good as the input
  - Individual differences
  - Countermeasure use
- Similar findings from other models

Final Steps

- Complete analyses
  - Scaling measures for consistent comparisons
  - Measures of fit for predicted vs actual
- Other datasets include non-24 hour schedules and other countermeasures
  - Final analyses near completion
  - Comprehensive report

Acknowledgements

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NASA JSC

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