Charting the Human Performance Envelope: Results from simulator experiments

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Outline

- Background
- Human Performance Envelope
- Simulator experiments
- Database
- Extracted features
- Results
- Ongoing work
- Conclusion

Background

- Many safety critical domains rely on human operators (**Air traffic control**, **Aviation**, Maritime, Rail, Military, Medical, etc.)
- In Air Traffic Management, **incidents** are often the result of **2 or more factors**
- This has led to the notion of a **Human Performance Envelope (HPE)**
- Need to know when operators are approaching the **edges of acceptable human performance**, e.g. when should automation take over?

HPE

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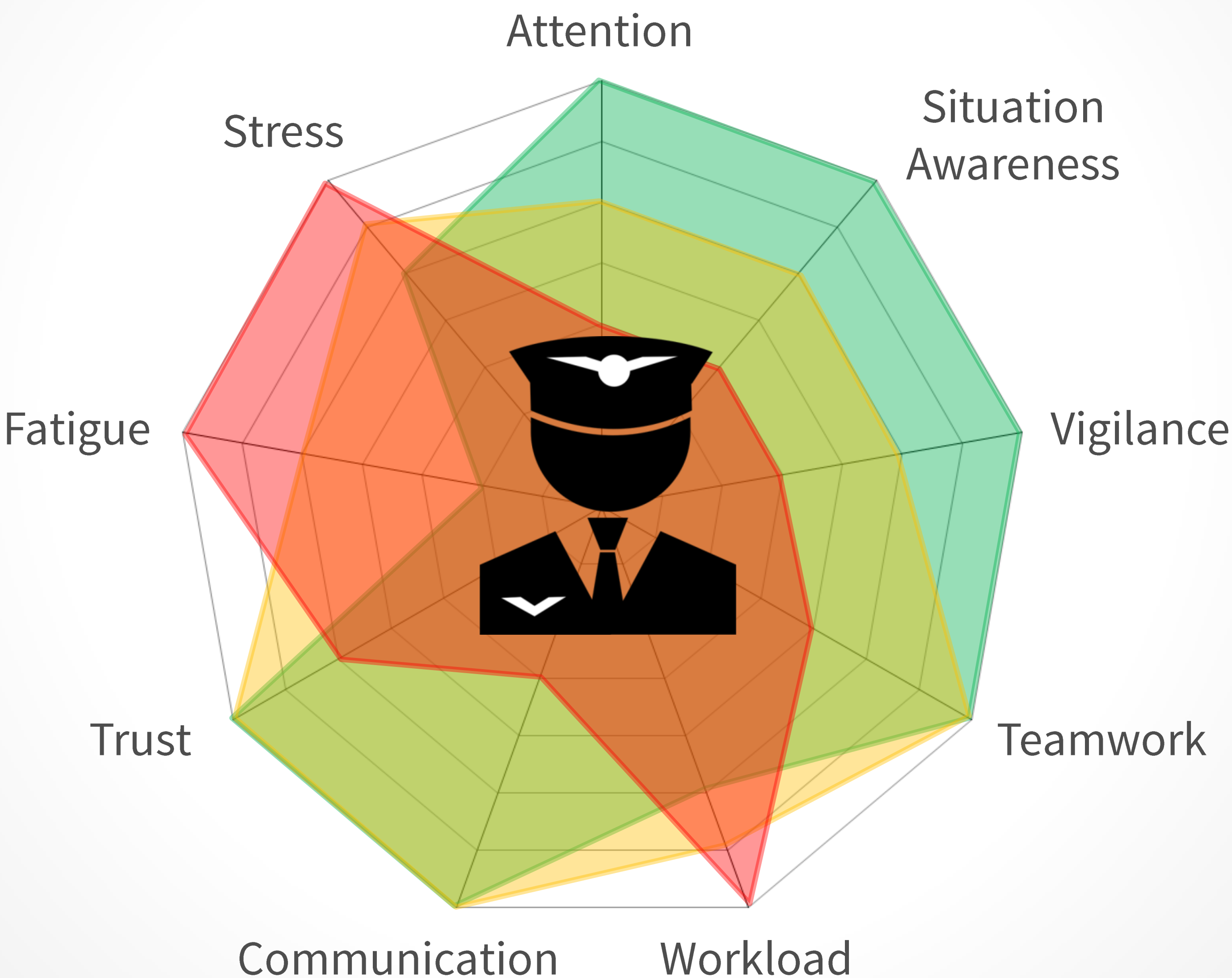
HUMAN PERFORMANCE ENVELOPE
FUTURE SKY SAFETY



Simulator experiments

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8 different runs were defined

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8
Turbulence throughout whole scenario		Medium	High	High			Medium	High
Approach and RWY change during initial approach (between IAF and FAF)				x				
Low fuel situation throughout whole scenario					x		x	x
Delay vectors during initial approach (between IAF and FAF)					x		x	x
Loud noise during final approach (between FAF and landing)					x			x
Low visibility throughout whole scenario						x	x	x
Localizer interference during final approach (between FAF and landing)						x	x	x
Wind shift during final approach (between FAF and landing)						x		x
	Baseline	***M WL***	***H WL***	***VH WL***	***H Stress***	***H SA***	***M WL, M Stress, M SA***	***H WL, H Stress, H SA***

M WL: Medium WorkLoad
H WL: High WorkLoad
VH WL: Very High WorkLoad
H Stress: High Stress
High SA: High/reduced Situation Awareness

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Database

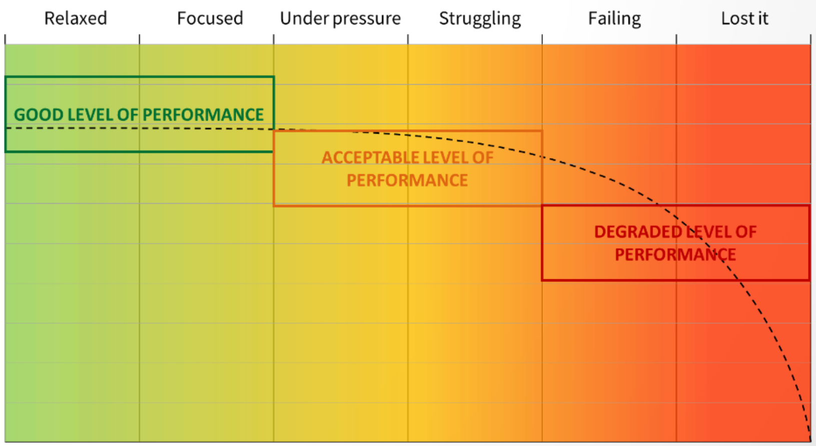
Performance data obtained from the simulator:

- Speed
- Heading or track
- Altitude
- Vertical speed
- Localizer
- Glideslope
- Application of procedures

Database

Subjective data:

- NASA-TLX
- ISA
- 10D-SART
- Samn-Perrelli
- Debriefings
  - Performance curves
  - Behavioral markers



Database

Physiological data:

- Eye tracking glasses (electro-oculogram, EOG)
    - Pupil dilatation
    - Blinking rate
    - Gaze direction

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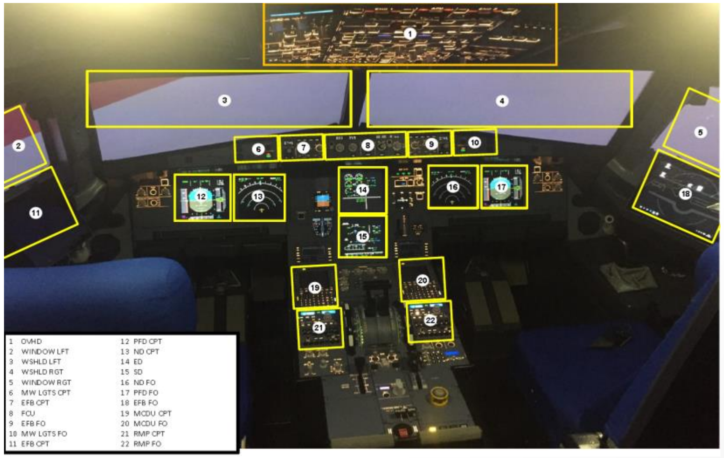

Database

Physiological data:

- CSEM vest:
  - Two electrocardiograms (ECG) leads
  - A transthoracic bio-impedance
  - Skin temperature
  - Accelerometer
  - Multi-channel photoplethysmograhy (PPG)

Extracted features

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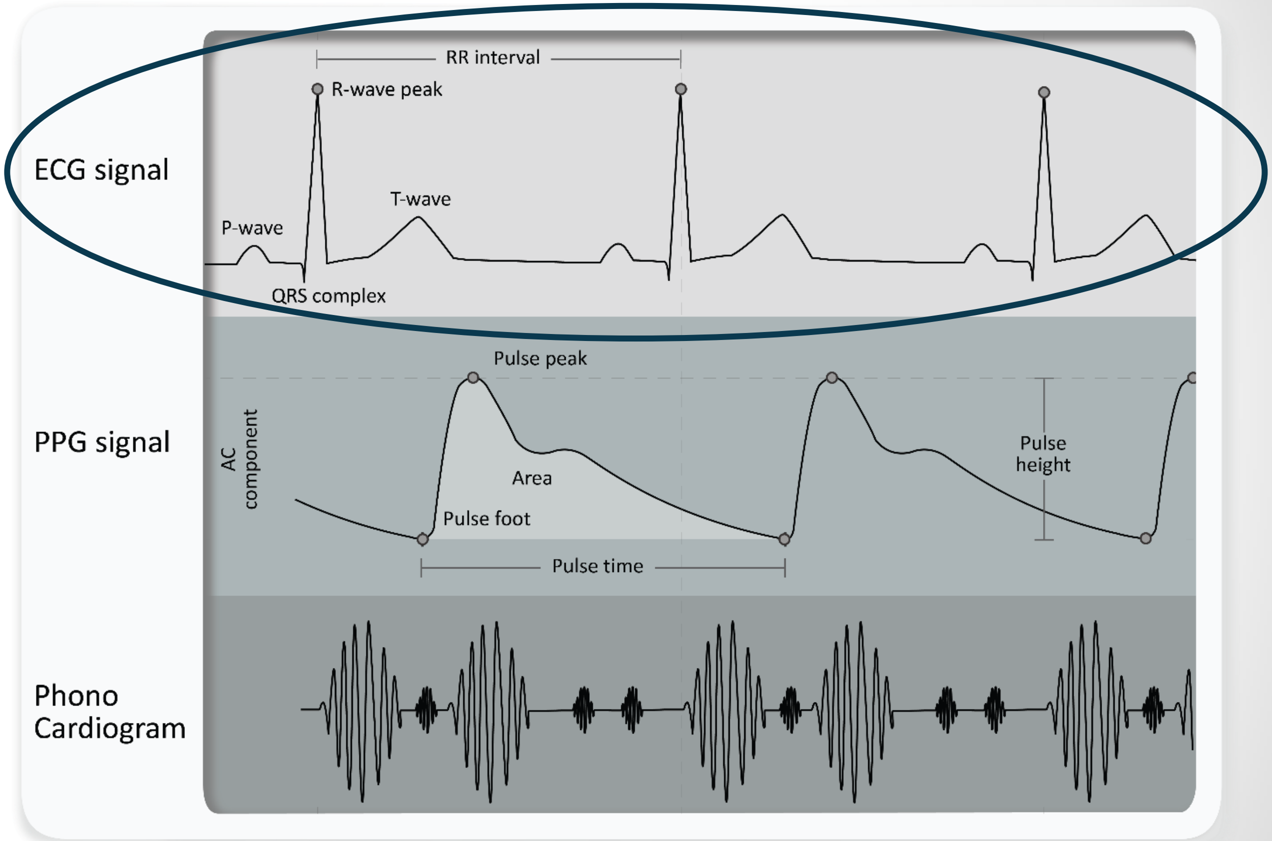
ECG signal

- RR intervals (*ms*)
- Heart Rate, HR (*bpm*)



Extracted features

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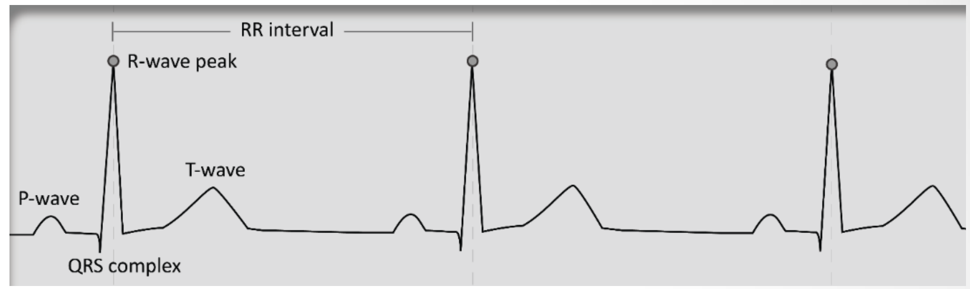
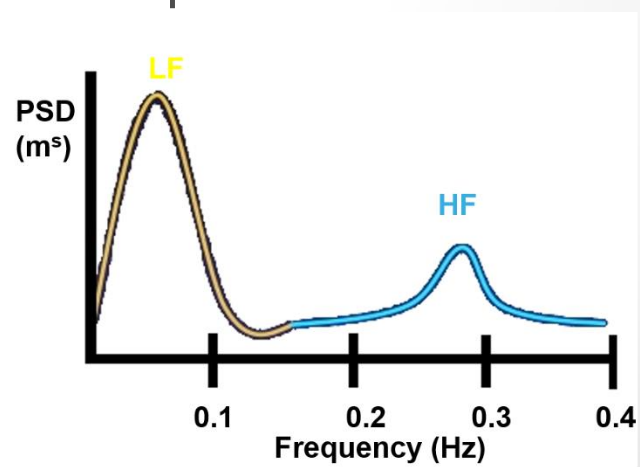
Heart rate variability (HRV)



- HRV in time domain:
  - SDNN (standard deviation of NN intervals, *ms*)

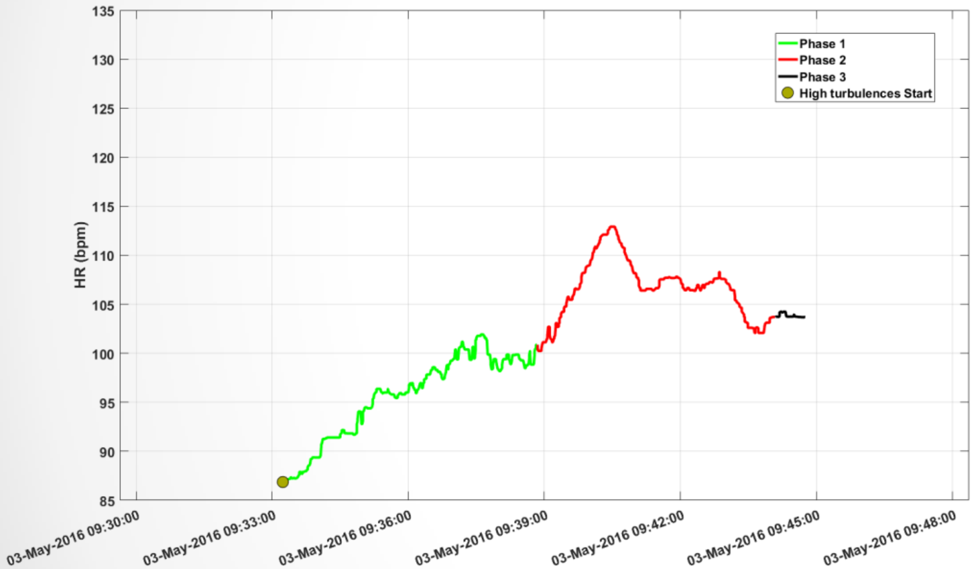
Spectral estimation



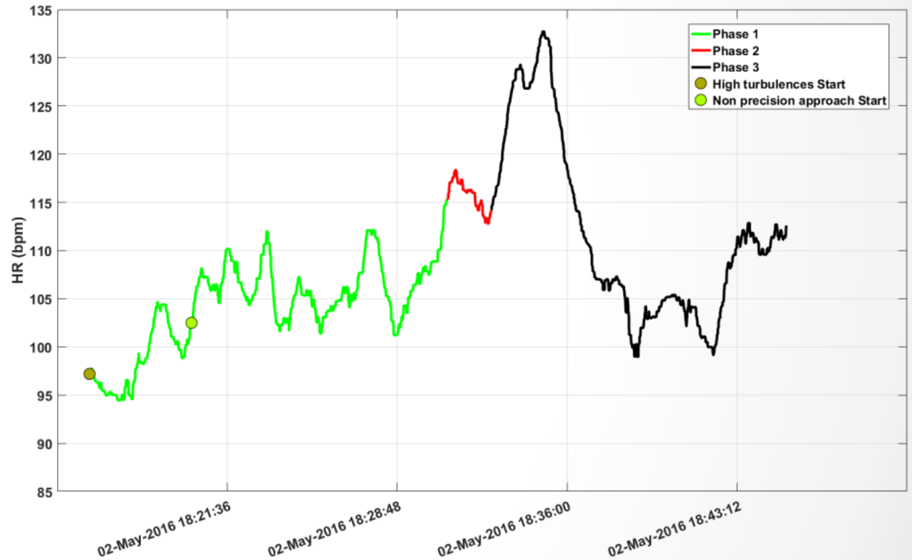
- HRV in frequency domain:
  - HF (High frequency, 0.15 – 0.4 Hz, ms^2)
  - LF (Low frequency, 0.04 - 0.15 Hz, ms^2)
  - VLF (Low frequency, 0.0033 - 0.04 Hz, ms^2)

Results on a single pilot

Run 3: High workload



Run 4: Very High workload



Phase 1 = Start -> TOD glideslope
Phase 2 = TOD -> Decision altitude
Phase 3 = Decision altitude -> End

Results on a single pilot

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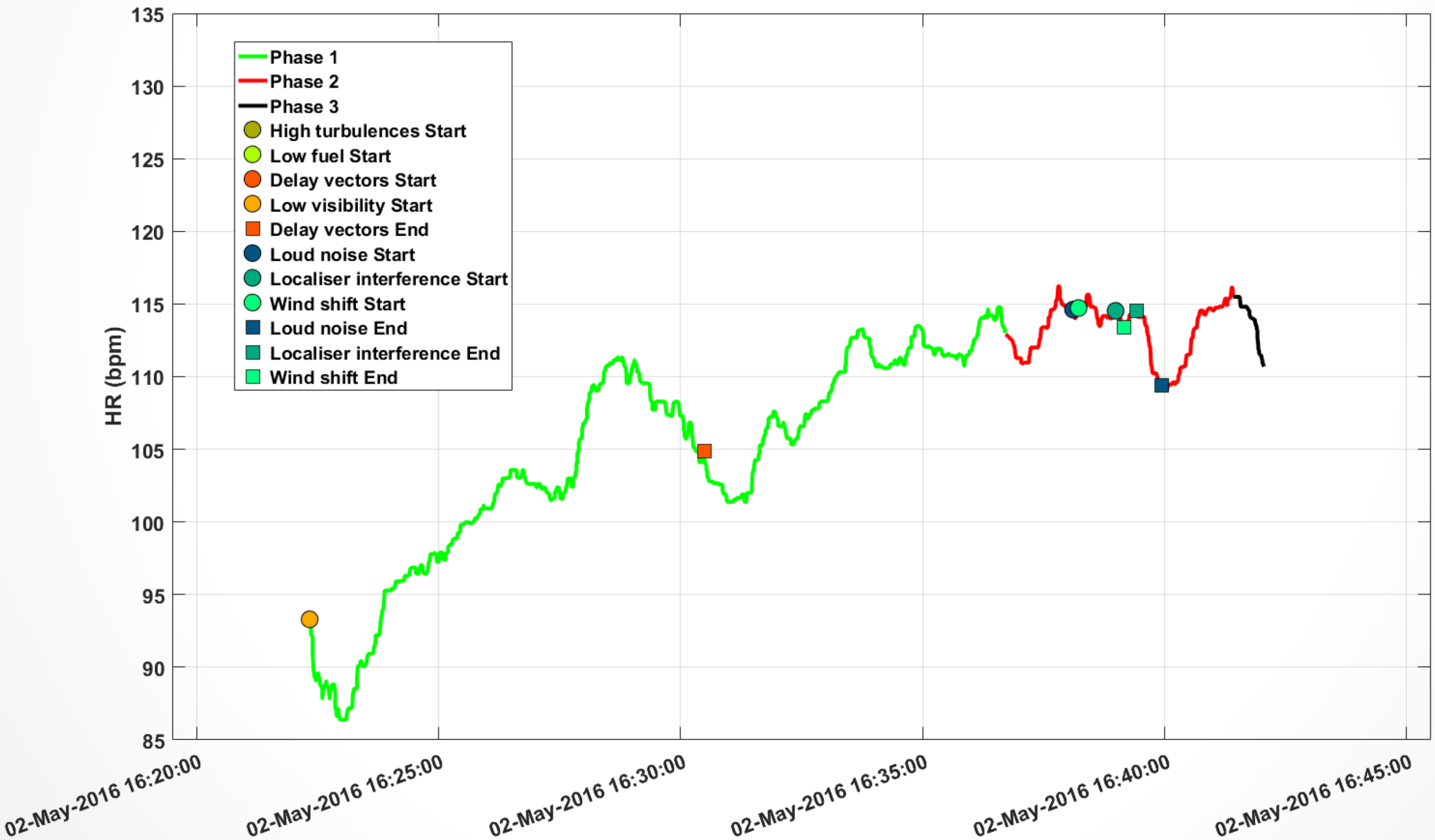
Run 8: High workload, high stress, high/reduced SA



Results on a single pilot

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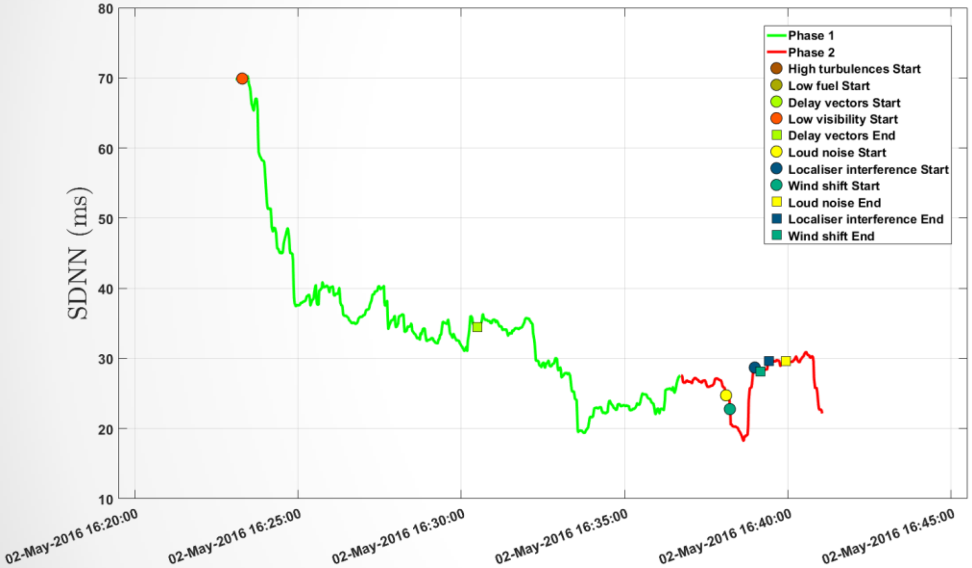

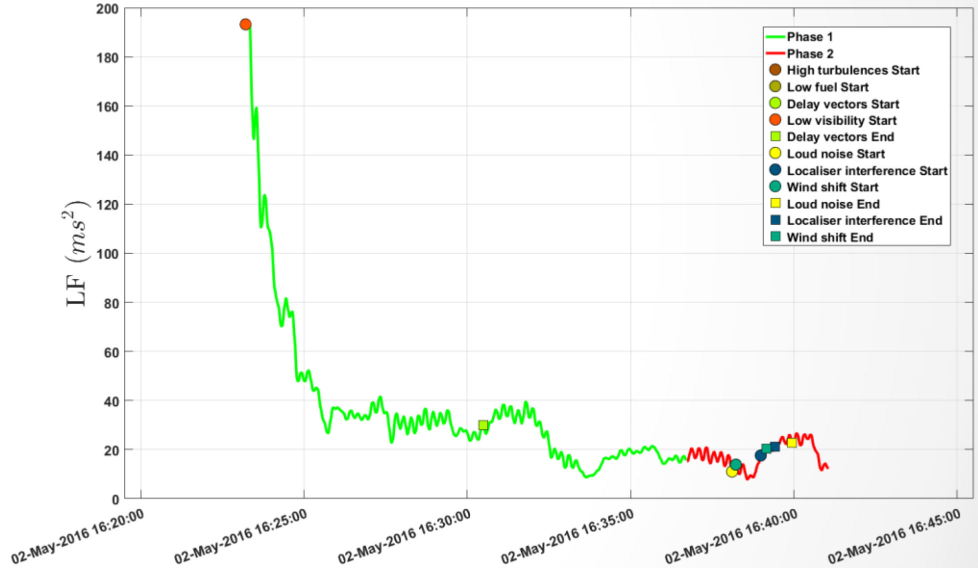

Phase 1 = Start -> TOD glideslope
Phase 2 = TOD -> Decision altitude
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Results on a single pilot

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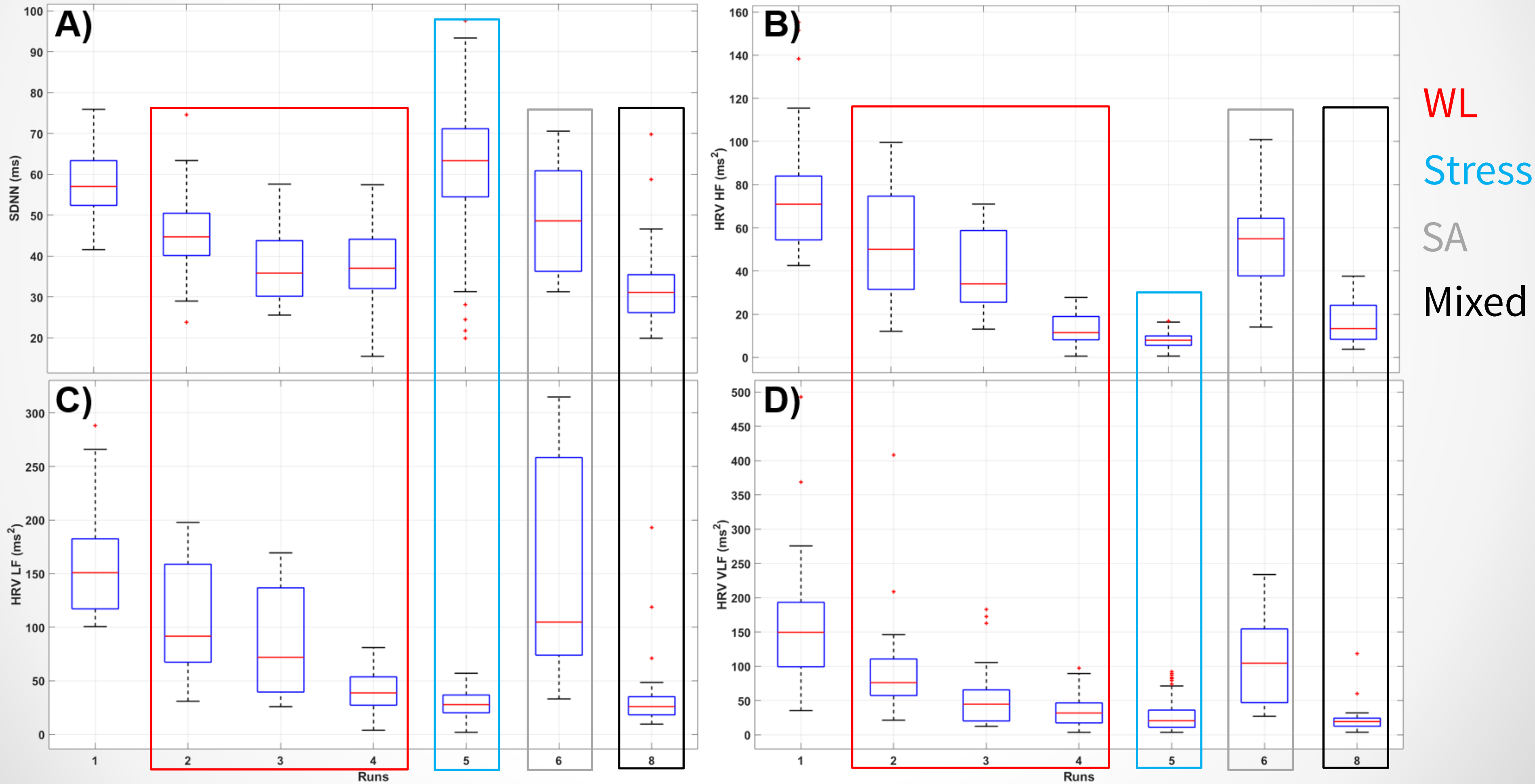
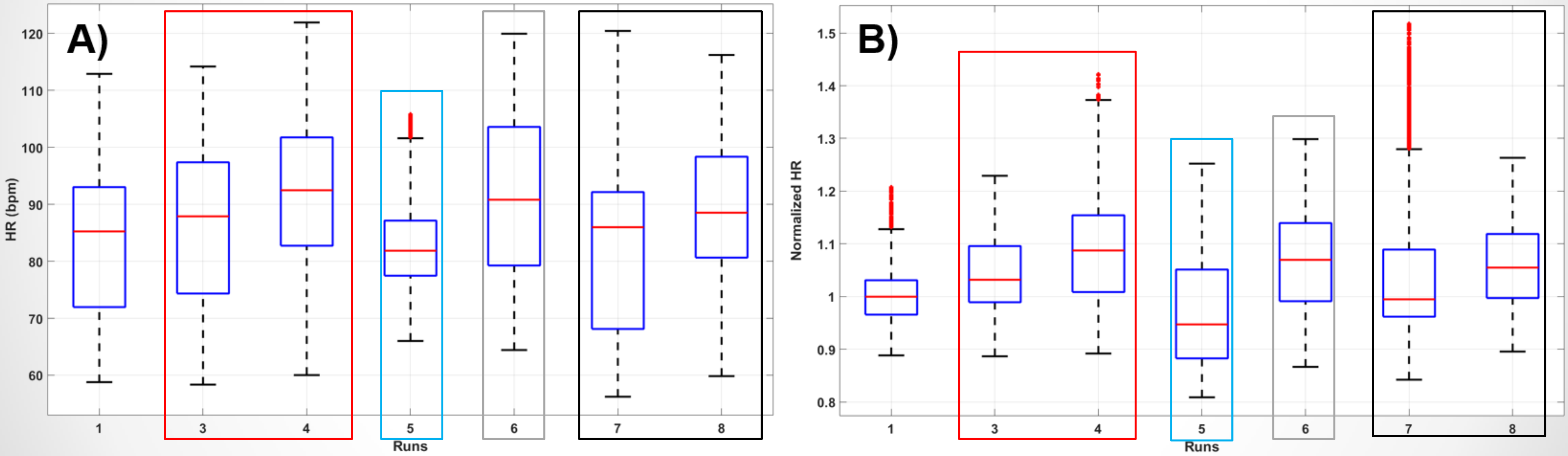
HRV features



Results of group analysis

WL Stress SA Mixed



Results of group analysis

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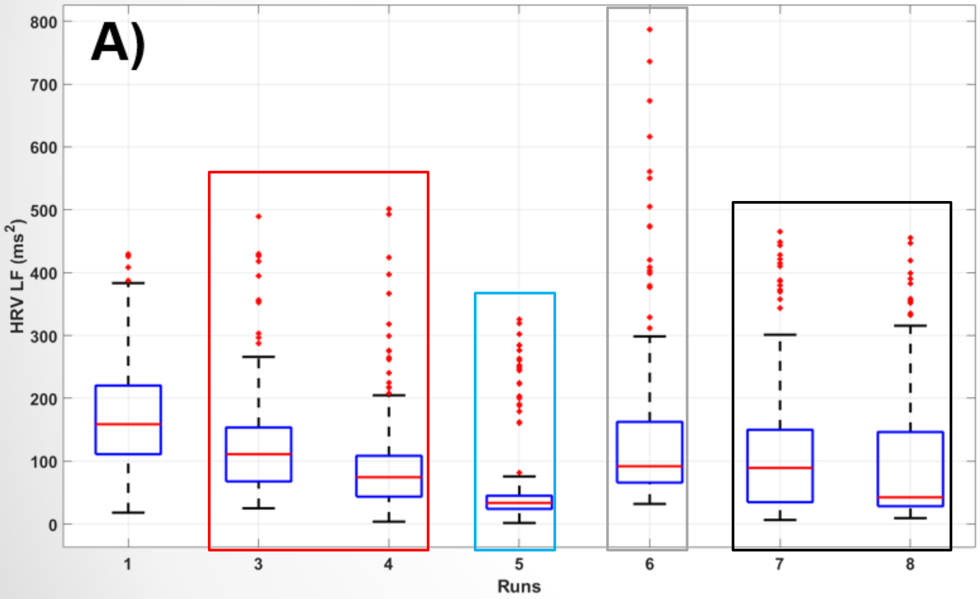

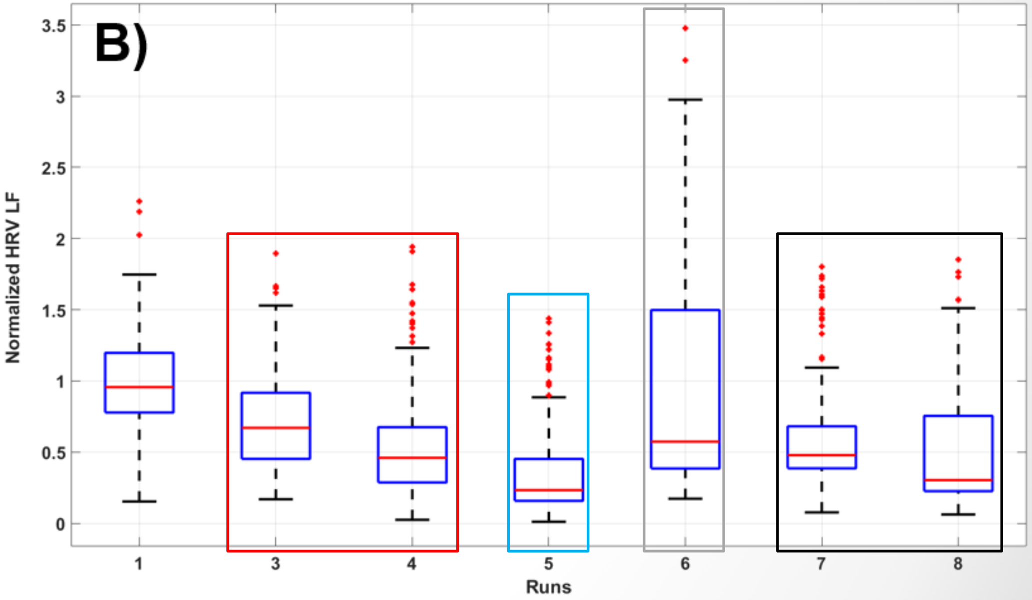

Ongoing work

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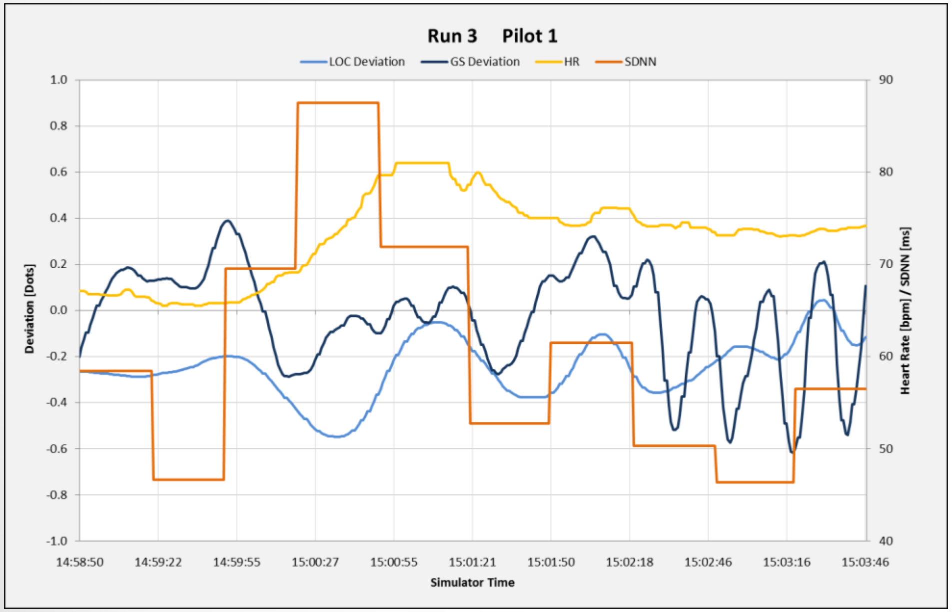
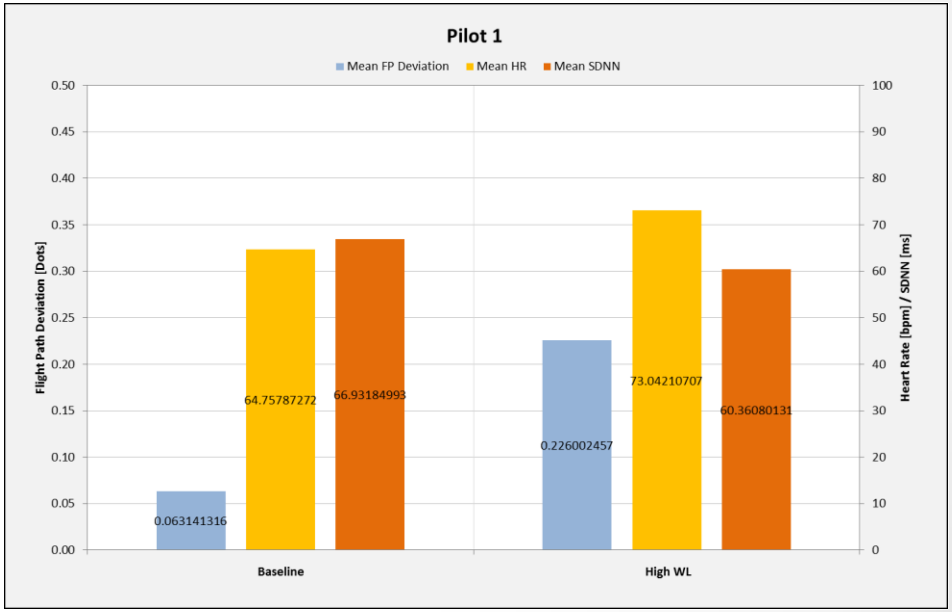
Performance vs physiological parameters





Conclusion

- Physiological measures such as HR, SDNN, HF, LF and VLF are sensitive to an increase in workload and/or stress.
- **High/reduced SA** (Run 6) was very often **not significant** to the baseline.
- **HR and SDNN** were particularly sensitive to the **increase in workload.**
- **HRV features** derived from the spectral analysis (HF, LF and VLF) showed a significant response to the **increase of stress**.
- Normalization of the HR is important in the group analysis (reliable baseline is required).

Thank you