Final Report Safe Tower Baseline

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REVISION HISTORY

VERSION	DATE	PREPARED BY	COMMENTS
0.1	2020-10-14	Lothar Meyer	Initial Draft
0.2	2020-11-04	Lothar Meyer	Improvements and completion with material and feedback from the online presentation to EANS 21st Oct 2020
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01.01	2021-10-01	Lothar	Adjustments Public Database

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SUMMARY - ENGLISH

The project Safe Tower Baseline is a field study that has the objective to create an empiric baseline of air traffic controller work performance in a tower environment using Performance Shaping Factors. The PSF baseline comprises metrics such as workload/stress, fatigue, (uneventfulness) monotony using a large number of participants, and a large variety of conventional tower environments. The capturing of a baseline in conventional towers is a strategic first step to determine the influence of remote tower environments on work performance using the baseline as a benchmark reference. With a focus on remote tower implementation, the field study aims at airports that are typical candidates for remote tower operations usually featuring a low number of daily movements.

The planning of the field study had at the beginning a focus on investigating methods and equipment that is appropriate for the indication of chosen PSF using representative metrics such as visual attention, blink rates, body activity, workload queries among others. Sensor techniques were tested and prepared for use in the towers and smooth conduction of the field study. The sensors chosen involved outer scene cameras heading on the runway for capturing the activity on the runway, inner scene cameras for capturing the face of the air traffic controller in position, Microsoft Azure Kinect for the body activity as well as radio communication for capturing task load and voice stress.

The organization and planning of towers included even two towers, Tartu and Tallinn, in Estonia that were visited in the scope of a collaboration agreement with the Estonian ANSP EANS.

The processing pipeline comprises a three-step approach with the empiric data collection as the first step. The extraction of metrics from the sensor data to event and continuously time-distributed samples tables is the subsequent second step. This step also includes the anonymization of data using statistic classifiers for age, operational experience, tower, and others. The final step is the application of statistical significance tests that verify any time, inter-individual or intra-individual variance.

The conduction succeeded for 3 different towers in a period of 11 days using 12 air traffic controllers during 19 daytime shifts and one night shift.

For analysis, software tools were developed that suit the demands of metric extraction at the specific sensor and in the specific tower environment. This concerns especially the extraction of blink metrics, facial landmarks, and body activity. For eye-tracking analysis, special analysis software could be reused from the TRV- funded project “Eye Tracking for Risk Assessment” (ETRA) and successfully applied to the eye-tracking data collected.

The results so far are successful extraction of data sets and the qualitative review of those containing the following metrics: body activity (hand and head movements), facial landmarks (facial expression), blink rate, visual scan pattern (visual attention), pupil diameter, temperature and humidity in the operator room. An exemplary visualization of body activity is shown here
https://web02.droponline.se/shares/folder/mcuQiX0oBEc/

ISA workload queries were applied successfully during the shifts. The preliminary findings are based on a qualitative review while statistical significance tests for verification of the hypothesis and quantification of PSF-relevance are still outstanding.

The night shift gives reduced body activity and reduced eye gaze dynamics during the control tasks as compared to daylight operations. The ISA workload queries offer very low ratings around “under-utilized” with little variance throughout the entire period of all shifts.

The qualitative review discovered key competencies as a significant indicator of work performance that includes the capability to separate tasks of listening and monitoring. Another key competence is to prioritize tasks by recognizing stimulations from the

environment and to assess the relevance and classify the task in an overall sequence of foreseen activities. The best indicator for this competence is the relative time spent on monitoring activity which promotes situational awareness in the area of responsibility.

SAMMANFATTNING SVENSKA

Projektet Safe Tower Baseline är en fältstudie med mål att skapa en empirisk baslinjemätning för flygledares arbetsprestanda i en tornmiljö med hjälp av Performance Shaping Factors (PSF). PSF-baslinje omfattar mått som arbetsbelastning / stress, trötthet, (händelsefrihet) monotoni från ett stort antal deltagare och ett antal konventionella tornmiljöer. Att fånga en baslinje i konventionella torn är ett strategiskt första steg för att förstår påverkan för de olika tornmiljöer som är aktuella baslinjemätningen verkar då som referensvärde. Utvecklingen pekar på en förmodad ökad implementering av ”remote TWR” fjärrstyrd flygtrafiktjänst för flygplats. SafeTWR fältstudie syftar till öka kunskap om påverkan för de flygplatser som är typiska kandidater för ”remote TWR” dessa flygplatser har ett relativt lågt antal dagliga rörelser.

Planeringen av fältstudien innebar att första delen fokuserade på att undersöka metoder och utrustning som är lämplig för indikationen av vald PSF med representativa mätvärden som visuell uppmärksamhet, blinkhastigheter, kroppsaktivitet, arbetsbelastningsfrågor bland andra. Sensortekniker testades och förbereddes för användning i tornen och metodiken finslipades inför genomförandet av fältstudien. De valda sensorerna involverade yttre scenkameror riktade till banan för att fånga aktiviteten på banan, inre scenkameror för att fånga flygledarens ansikte i position, Microsoft Azure Kinect för kroppsaktivitet samt radiokommunikation för att fånga arbetsbelastning och röststress. Organisationen och planeringen av torn omfattade bla.a Tartu och Tallinn, i Estland. Ett samarbetsavtal upprättades med den estniska flygtrafiktjänsten EANS som reglerade användningen av data och personuppgifter.

Analys och bearbetningspipelinen består av tre steg med empirisk datainsamling som första steg. Extraheringen av mätvärden från sensordata till händelse- och kontinuerligt tidsfördelade provtabeller är det efterföljande andra steget. Detta steg inkluderar också anonymisering av data med hjälp av statistikklassificatorer för ålder, operativ erfarenhet, torn och andra. Det sista steget är tillämpningen av statistiska signifikanstester som verifierar tidsfördelad varianser (linjär och händelsedistribuerad), interindividuell eller intraindividuell varians.

Datainsamlingen genomfördes för tre olika torn under en period av 11 dagar med 12 flygledare under 19 dagskift och ett nattskift. För analys utvecklades programvaruverktyg som passar kraven för metrisk utvinning vid den specifika sensorn och i den specifika tornmiljön. Detta gäller särskilt extrahering och analys av blinkningar, ”facial landmarks” (mimik) och kroppsaktivitet. För ögonrörelseanalys användes en speciell analysprogramvara återanvändas från det TRV-finansierade projektet "Eye Tracking for Risk Assessment" (ETRA) och framgångsrikt tillämpas på den insamlade ögonrörelsedatan.

En extrahering av datamängder genomfördes i första hand kvalitativa data som har granskats och analyserats. Följande mätvärden är representerade: kroppsaktivitet (hand- och huvudrörelser), ansiktsmärken (ansiktsuttryck), ögonblinkningar, visuellt skanningsmönster (visuell uppmärksamhet), pupildiameter , temperatur och luftfuktighet i tornrum. En exemplarisk visualisering av kroppsaktivitet visas här (laddas ner 325 mb).

https://web02.droponline.se/shares/folder/mcuQiX0oBEc/
ISA-verktyget användes kontinuerligt under skiften för att samla data om arbetsbelastning. De preliminära resultaten baserars på en kvalitativ granskning medan test av statistisk signifikans för verifiering av hypotesen och kvantifiering av PSF-relevans kommer att analyseras framgent. Nattskiftet ger minskad kroppsaktivitet och minskad ögonblicksdynamik under kontrolluppgifterna jämfört med dagsljusoperationer. ISA-arbetsbelastningsfrågorna visar låga värden för "underutnyttjande" med liten variation under hela skiftperioden.

Den kvalitativa granskningen identifierade signifikanta nyckelförmågor och indikatorer för arbetsprestanda bl.a. möjligheten att separera lyssnings- och övervakningsuppgifter. En annan nyckelförmåga är att prioritera uppgifter genom att känna igen stimuli från miljön och att bedöma relevansen av stimuli samt klassificera uppgiften i en övergripande sekvens av förutsedda aktiviteter. Den bästa indikatorn för denna förmåga är den relativa tiden som läggs på att övervaka aktiviteter som främjar situationsmedvetenhet inom ansvarsområdet.

DELIVERABLES

NO	DELIVERABLE DESCRIPTION	REFERENCE IN REPORT
1	Capturing data involving representative PSF-metrics from the conventional tower	Chapter 3
2	To apply statistics and correlation analysis of the PSF-metrics indicating human performance in the conventional tower	Chapter 4 and 5
3	To provide a summarizing database of statistics that is appropriate for later benchmarking of human performance in the remote tower	Chapter 6

1 INTRODUCTION

The project Safe Tower Baseline has the objective to develop a strategy of empiric investigation that identifies the influence of Performance Shaping Factors (PSF) on the human performance of tower controllers in remote towers. The creation of the evidence shall be tackled by capturing empiric data in the scope of field trials that quantify selected PSF metrics in both the conventional (baseline) and the remote tower environment (target) for later comparison. Following this strategy, this project aims at the first step: The creation of the baseline in the conventional tower. This involves statistics and correlation analysis of the PSF-metrics indicating human performance in the conventional tower.
Performance Shaping Factors are defined according to Swain (Swain & Guttman, 1983)

> *"Any factor that influences human performance is designated as a performance shaping factor (PSF)"*

and involves firstly these three factors:

- Under or over stimulation of workload conditions. In the following, this factor will be simply termed *stress*[1].
- Fatigue
- Monotony and Alertness

With further distinguishing monotony into the following 'task conditions' (Eurocontrol, 2006):

- *Uneventfulness* – The coupling of monotonous (arousal-reducing) task characteristic with the opposing requirement for high arousal make this factor in particular stressful
- *Repetitiveness*

The focused towers of this study are presuming corresponding (in case) to the first condition "uneventfulness" due to the low number of traffic movements during the work shifts.

This report contains

- the methods applied in the field study
- an overview of the data collected from the conventional tower.
- Partly, the data analyzed and presented here at the example Tower Tartu, Tallinn and Kiruna

The methods and data collection contain also those provided by the field study project Human Centered Lighting (Trafikverket funded) due to the joint data collection activities in the conventional tower. The step of analysis does only cover SafeTowerBaseline-(HCL:Baseline) related metrics and statistics.

Figure 1 gives a brief overview of human physiologic reactions to stress and are considered as candidates for indication and measurement in this project.

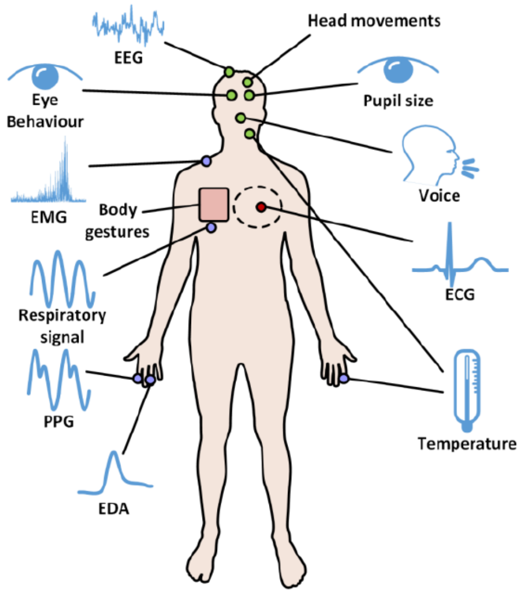


Figure 1: Common physiological and physical measurements related to stress investigates in this study (Giannakakis, Grigoriadis, Giannakaki, Simantiraki, & Roniotis, 2019)

[1] *„All external influences on the human are called stress. Depending on the individual characteristics and capabilities of the human, this stress results into individual workload for the respective human operator"* (Bubb, 2005, S. 134)

1.1 Hypothesis

The analysis will aim at the identification of significant variances and provide the steps necessary for a later follow up project

Hypothesis No 1: *Time Variance*
The indication of a time variance in the metric is a sign for varying work performance during the shift. For an indication of a change in time, the following reference periods are used:

- *Comparison of similar classes of situations/ control processes:* The comparison involves e.g. only landings or only take offs for harmonizing the task context. The problem might be that the towers with low number of traffic movements do not offer sufficient samples for a comparison
- *Comparison of long-term behavior*: The comparison aims at finding a general trend in time under the shift.

Hypothesis No 2: *Individual Variances*
The indication of the individual variance is distinguished into two aspects.

- In between controller variance (Inter- individual variance)
- Within controller variance (Intra- individual variance)

Hypothesis No. 3: *Work Position Variance*
The indication of a variance originated in the change of working position is possible when a time variance and individual variance can be subtracted. Within the present baseline, no change of working position is planned but strategically set and involved during this step of the study.

2 DATA COLLECTION METHODS

2.1 Target Metrics and Performance Shaping Factors

The methods of investigating human performance shaping factors were identified by using actual state of the art scientific publications. Best stress indicators are described here (Giannakakis, Grigoriadis, Giannakaki, Simantiraki, & Roniotis, 2019). The final list of indicators and related metrics are shown in the following table.

METRIC	INDICATOR	METHOD AND EQUIPMENT
Eye blink rate	Sleepiness, Attention (Stern, Boyer, & Schroeder, 1994; Zeeshan & Ziaul, 2016)	Inner Scene Video Camera
Facial expression	Sleepiness, Stress, Emotion (Zhang, Mei, Liu, Yuan, & Qian, 2019)	Inner Scene Video Camera
Body (Movement) Activity	Drowsiness[2] (Mittal, Kumar, Dhamija, & Kaur, 2016)	Body Tracking MS Kinect

[2] Drowsiness is defined as a transitional state between attentiveness and slumber, which is also linked with an inclination towards sleep (Mehreen, Anwar, Haseeb, Majid, & Ullah, 2019). The term is closely related to sleepiness and fatigue for that reason it is taken into account.

Visual Scan Pattern	Visual Attention (Head up Time and Eye Gaze Dynamics)	Eye Tracking Glasses
Pupil diameter	Stress (Pignoni & Komandur)	Eye Tracking Glasses
Pitch/ Speed of voice	Stress (Van Puyvelde, Neyt, McGlone, & Pattyn, 2018)	Tower Frequency Recordings
Temperature and Humidity	Heat Stress	Temperature Data Logger

The metrics and related methods and equipment were also selected using practical experience on how to technically handle the equipment and software solutions to help to analyze the data. Additionally, there were practical aspects such as possible complications in the tower environment and how much the air traffic controller is impacted according to a review in the car driver drowsiness research domain:

> *"The fundamental working principle of all the techniques is to detect abnormality in the driving pattern. In order to do so, these techniques uses different measures such as (i) Subjective, (ii) Behavioral, (iii) Physiological, and (iv) Vehicular. Subjective measures alerts the driver and does not give exact estimate. Physiological measures uses invasive techniques and disturbs the driver. Vehicular measure requires complex and costly infrastructure. Behavioral measures have been found to be the easiest and cost effective to detect driver drowsiness. Among various behavioral measures such as eye state, eyeblink rate, yawning and head movement, the head movement based techniques have found to be more precise in detecting driver drowsiness"* (Mittal, Kumar, Dhamija, & Kaur, 2016).

These metrics are complemented with the task demand of the external context (stimulation)

METRIC	INDICATOR	METHOD
Runway Usage	Traffic Load	Outer Scene Video Camera
Communication	Verbal Task Load	Tower Frequency Recordings and other audio recordings
Flight Strip System	Traffic Clearance State	Flightstrip Camera

2.2 Methods and Procedures

The complete list of methods and equipment used in the data collection is presented in the following tables, containing also measurement methods used in the scope of the collaboration project HCL only. The following table gives an overview of 4 sections that feature different attributes of intrusiveness.

1) Measurements requiring the active involvement of the air traffic controller (Meaning the controller shall spend significant attention on the test)

Method	Details	Time Demand	When Applied

Pre-Questionnaire	Includes Demographic Questions, Questions on Eye-Strain, and Current Mood	Max. 10 Min	Should be filled in before shift starts or within first 30 Minutes
During-Questionnaire	Includes Questions on Eye-Strain, and Current Mood	Max. 2 Min	Should be filled in during shift every two hours
Post-Questionnaire	Questions on Eye-Strain, Mood, Operational Irregularities and Comment Field	Max. 10 Min	Should be filled in after shift ended or within last 30 Minutes
Computer Testbattery	Includes 5 Question on Alertness and Sleepiness as well as a Reaction Time Task (runs 3 minutes)	Max 5 Min per run	Should be done… – before shift starts – every two hours during shift – after shift ended
Workload Query	Verbal response on workload using a standardized method (e.g. ISA or Cooper Harper Scale)	Few Seconds	Every half hour

2) Physiologic measurements (body wearables) involving the air traffic controller passively.

Method	Details	Time Demand	When Applied
Eye-Tracking Glasses	Test person wears eye-tracking glasses. The glasses themselves are detached from the frame. Hence, only the frame is used. 	Max. 30 minutes per session. Setting up takes less than a minute.	20 min before until 10 after expected runway usage by movement.
Breast Belt (Heartrate Recorder)	Breast Belt measures Heartrate and gives indication on alertness and stress	Needs to be put on at beginning of shift (takes 1 Minute), Device	Entire work shift of the subject

		records until end of shift	
Wrist Joint Bracelet (Light Recorder)	Records the Total Light Exposition over the shift 	Needs to be put on at beginning of shift (takes 1 Minute), Device records until end of shift	Entire work shift of the subject test person

The following periods are to be distinguished:

Before and after measurements – The help of the controller is needed to first set up the respective sensors at the body and, secondly, to take them off again. While setup and taking off, the controller spends parts of the attention related to these actions. All actions take place at the working position and the capacity to understand the operational situation and to act are assured due to the assistance of the study member at the place.

During the measurements – The air traffic controller is able to operate fully as normal.

3) Controller Working Position (CWP)-Measurements without any involvement of air traffic controller but mounted or/and executed next to the controller working position

Method	Details	When Applied
Inner Scene Video	Two Cameras directed on the ATCOs face and frontal part of body at the CWP. Using tripods for the mounting.	Constant Video and Ambient Audio Recording during shift
Kinect Body Pose Recording	System Records the Body Pose and Analyses the Room, installed behind desk. Using tripods or wall mountings for the mounting.  	Constant Recording during shift

Outer Scene Cameras Cameras Recording Threshold of both RWYs, to monitor the traffic situation. Using tripods for the mounting.	Constant Recording during shift
Flight Strip Camera Camera recording the flight strip bays This camera is connected to an external microphone situated in the front of the CWP. Using tripods for the mounting.	Constant Recording during shift
Temperature and Humidity Sensor (USB Stick size) mounted on the desk of the working position.	Constant Recording during shift
Light spectrum measurement is taken next to the head position of the air traffic controller utilizing a handheld CRI illuminance meter (Konika Minolta CL-70F). The hand device doesn't need a stationary mounting at the CWP. 	Every 1 hour

2.3 Step-wise Analysis Approach

The analysis is planned to base on a process chain that consists of the following steps

Step 1: The empiric data collection and questionnaires are collected in the tower environment as outlined in the data collection specification.

Step 2: Event and continuous timely-distributed samples are extracted from the empiric data collection and processed as standard text-formatted data tables that are time-synchronized.
The extraction includes an anonymization step that shall exclude the names of the subjects, exact day and time of recording as well as the identifiers of flights from the data collection. Randomly generated codes are used to relate data to its subject person (e.g. “ABC”) and to replace callsign identifiers (e.g. “123”). Statistical classifiers are used to distinguish e.g. the period of the year (e.g. Jan – Mar, Apr-Jun, Jul – Sep, ….) and the daytime (e.g. day periods 9 – 12, 12 – 15, 15 – 18, …). Time codes are defined relative to a reference time of the event (e.g. touch-down time, take-off time). Demographic data is statistically classified using periods of 10 years for age and operational experience.

Step 3: The statistical analysis bases mainly on the extracted data (Step 2) but also on the questionnaires.

3 FIELD STUDY

3.1 Organization

The execution was planned according to the following scheme.

- Informing and presenting the field study and related methods to the Stf Head of Operations, 14th October 2019
- Informing, consulting, and coordinating a schedule to the Tower CO ATS in Halmstad and Kiruna, Umeå
- Informing, consulting, and coordinating a schedule to the Tower CO ATS in Tartu and Tallinn in Estonia, Estonia at EANS.

For the study collaboration with EANS, a research collaboration agreement was signed about the data treatment and deletion of the raw media data. With regard to the current progress (see conclusion section) and the promising outcome, the deadline for deletion was extended by EANS to 21st October 2021. The field study methods were approved by the Estonian ethic committee and an *Informed Consent* was signed by the tower controllers in Estonia. The agreement even contained a paragraph about the use of the collected data which shall be handed over to EANS in case of accident and incident investigation.

The schedule was set as follows with the number of air traffic controllers planned to participate voluntarily:

TOWER	NUMBER OF ATCOS PARTICIPATING
Tartu, EETU	2
Tallinn, EETN	3
Kiruna, ESNQ	5
Tartu, EETU	2
Tallinn, EETN	4
Halmstad, ESMT	3

The schedule was constantly updated by the progressing coordination with CO ATS of outstanding towers Malmö, Umeå, and Östersund.

3.2 Equipping and Conduction

The equipment was mounted and used in coordination and agreement with the tower controller in position before the shift. Study procedures were applied to decrease the intrusiveness of the equipment installed and used during operations. These procedures were developed and evaluated with the participating tower controllers during past field studies: The projects.

- Digit (2017-2018) and
- CAPMOD (2019)

provided a total of ca. 20 hours of recording time in the conventional towers of Linköping ESSL and Bromma ESSB. The experience collected during these occasions was adapted to the current study design.

The participant controller was introduced and trial fitted with the body wearables for increasing confidence and for having the chance to adjust the equipment to increase personal comfort. The electric power supply was set to power plugs in the tower infrastructure that was uncritical to the air traffic systems. These were in practice the same as the power connectors for heating, coffee machines, or office material.

The periods of recordings cover the entire shift. An exception is the eye-tracking glasses that were put on 10 min before expected runway occupation time until 10 min after. A nominal period of 20 min per recording season is expected for avoiding the well-known eye fatigue effect.

Figure 2 gives an overview of the tower position equipped in the scope of the study.

Figure 2: Overview of the CWP measurements at the example of Tower Tartu EENU in Estonia

3.3 Data Collection

The current progress of the projects records the following state of data collection

VISIT NO	TOWER	NUMBER OF ATCOS PARTICIPATING	SHIFTS	DAY INDICES
1	Tartu, EETU	2	2	1,2
2	Tallinn, EETN	3	6	3,4
3	Kiruna, ESNQ	5	5	5,6,7
4	Tartu, EETU	2	3	8,9,10
5	Tallinn, EETN	4	4	11

The day indices are connected to the shift indices according to the following scheme.

DAY	TOWER	SHIFTS INDICES
1	Tartu, EETU	1
2	Tartu, EETU	2
3	Tallinn, EETN	3,4,5
4	Tallinn, EETN	6,7,8

5	Kiruna, ESNQ	
6	Kiruna, ESNQ	
7	Kiruna, ESNQ	
8	Tartu, EETU	16
9	Tartu, EETU	17
10	Tartu, EETU	18
11	Tallinn, EETN	19,20,21,22

For the data from the towers Tartu and Tallinn, a research cooperation agreement with EANS describes the data handling and anonymization of data in detail. This requires LFV to delete the recorded media data by the 21st of October 2021 latest.
The day indices are used for labeling the data files and associating different measures to the same day.

The following participant characteristics can be documented

Time in years	0 – 9	10 – 19	20 – 29	30 – 39	40 – 49	50 – 59
Age	0	0	5	2	2	3
Overall Experience	6	3	2	1	0	0
In Position Work Experience	7	2	3	0	0	0

With 5 feminine and 7 masculine participants, the sex distribution is relatively even. In total there were 20 shifts with 19 daylight shifts distributed from 6 am to 10 pm CET. And one night shift from 11:30 pm till 5 am.

During the recording, technical problems arose which are summarized in the following:

METHOD	KIND OF PROBLEM	CAUSE	MITIGATION
Radio Communication	Bad quality of the recording	Poor cable connection to the radio scanner device	Usage of Inner/Outer Scene Camera Recordings
Eye Tracking Glasses	Switched off unexpectedly	Battery failure	Additional checks of batteries and transcription of battery use
Inner Scene Camera	Switched off unexpectedly	Not identified	No mitigation available
MS Kinect One V2	Switched off unexpectedly	Immature body tracking software	Replace the old MS Kinect One v2 with the newer MS Kinect Azure

These technical problems caused the data collection to be partly incomplete for certain intervals.

The quantity of data generated exceeded the initial planned data storage (8 Terabyte) volume by a factor of three. The main reasons are the MS Kinect Azure that generates 400 GB within 4 hours including RGB video data, thermal infrared picture, and cloud points from LiDAR. The second significant data volume generator was the inner scene cameras that used each 4K recordings that generated a volume of 4 GB per 8.5 minutes.

Figure 3: Study in Estonia in Tartu (top left) and Tallin (others)

4 ANALYSIS

The data collection was stored in a structured directory system which makes it easy to find the media recordings by day or tower and participant. For some media recordings, it was necessary to develop the appropriate tools that help to extract the samples of the target metrics from the media. This chapter presents both the tool development and preliminary results.

4.1 Tool Development and Analysis Procedure

The development makes use of state-of-the-art computer vision technology for automatic extraction. The advantage is the analysis of large amounts of recordings including many hours of material in a fast and effective way. The downside of this approach is the necessary development of the tools and its evaluation.

4.1.1 Eyeblink rate

The underlying technology is provided by the following computer vision libraries: OpenCV, Python, and dlib. The template implementation is provided by an eye blink

detector authored by Adrian Rosebrock on April 24, 2017 (https://www.pyimagesearch.com/2017/04/24/eye-blink-detection-opencv-python-dlib)
From there, the given implementation was enhanced and adapted with a list of features:

- Supporting 4K video recordings
- Dumping of the Eye Aspect Ratio to an output file

The recognition of eye states is performed using a real-time algorithm (Soukupova & Cech, 2016).

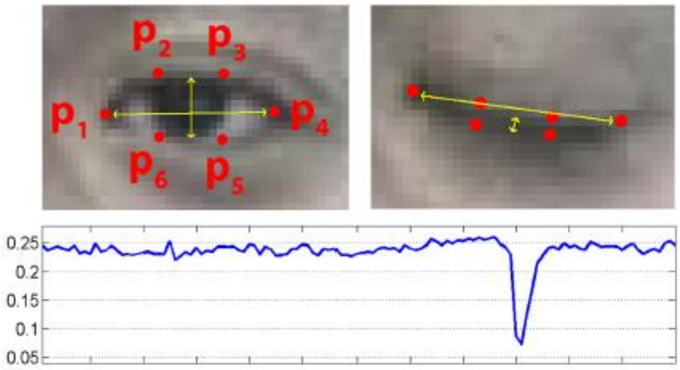


Figure 4: Eye Aspect Ratio (EAR) over time for detecting blinks (Soukupova & Cech, 2016)

Figure 5: Eye Detection and Eye Aspect Ratio

4.1.2 Facial Expression

The recognition of facial landmarks for facial expression recognition is implemented using the same library as for the eye blink rate by Adrian Rosebrock on April 17, 2017 (https://www.pyimagesearch.com/2017/04/17/real-time-facial-landmark-detection-opencv-python-dlib/).

Alternatives were tests such as the face expression recognizer that classifies the face according to an emotional classification scheme including ‘angry’, ‘disgust’, ‘fear’, ‘happy’, ‘sad’, ‘surprise’ and ‘neutral’ (Wu, 2018).

Accordingly, the same extensions are implemented here.

Figure 6: The facial landmark detection uses 64 points to match the human face

The technical tests were accomplished with high reliability of the face detection. With an increasing angle between the camera direction of view and face, the points become first unreliable (which is indicated by a confidence value) and finally lost if the angle further increases.

4.1.3 Body Activity

The recognition of the body pose and activity are implemented using the MS Kinect Azure SDK. The body pose is processed offline due to the missing GPU capacity during recording with the help of the offline processor (https://github.com/microsoft/Azure-Kinect-Samples/tree/master/body-tracking-samples/offline_processor)
This outputs a json format file with the coordinates of body joints and bones in a cartesian coordinate system. From April 2020 on, the "simple 3d viewer" (https://github.com/microsoft/Azure-Kinect-Samples/tree/master/body-tracking-samples/simple_3d_viewer) was published and extended with output functions such as image and metrics output.

4.1.4 Visual Scan Pattern

The identification of the visual scan pattern is performed using

- the Eloquence program (Westin, Vrotsou, Nordman, & Lundberg, 2019) and
- the Dwell Time-Share diagrams (Attention Analysis) (Meyer, et al., 2019) developed in the scope of the project DIGIT.

The eye-tracking gaze data was preprocessed by a mapping from the head-mounted camera coordinate system to a world coordinate system. This succeeded by an AoI Analysis tool developed in the scope of the project Eye Tracking for Risk Assessment (ETRA). The program supports the detection of predefined AoI in the video scene picture using visual point features (AKAZE). This technique could be applied successfully at the Tobii Pro Glasses 2 and output to so-called *State Tables* that are fed to the program Eloquence for further analysis and the Attention Analysis plotting the Dwell-Time-Share Diagrams

Figure 7: AoI Analysis example from Linköping ESSL (Project ETRA) with an automated detection of visual reference areas using AKAZE point features.

Figure 8: Tartu Tower with Out-The-Window view and recognized Areas of Interests.

4.1.5 Pitch/ Speed of Voice

The development of a pitch and speed of voice recognition is done manually and with partial help of Voice Stress Analysis Techniques. Implemented codes under review are

- https://github.com/atrzaska/VoiceStressAnalysis

4.1.6 Temperature and Humidity

The temperature and humidity at the working place were recorded using a measurement stick located on the desk of the working position. Periods of recording was the entire day or several days.

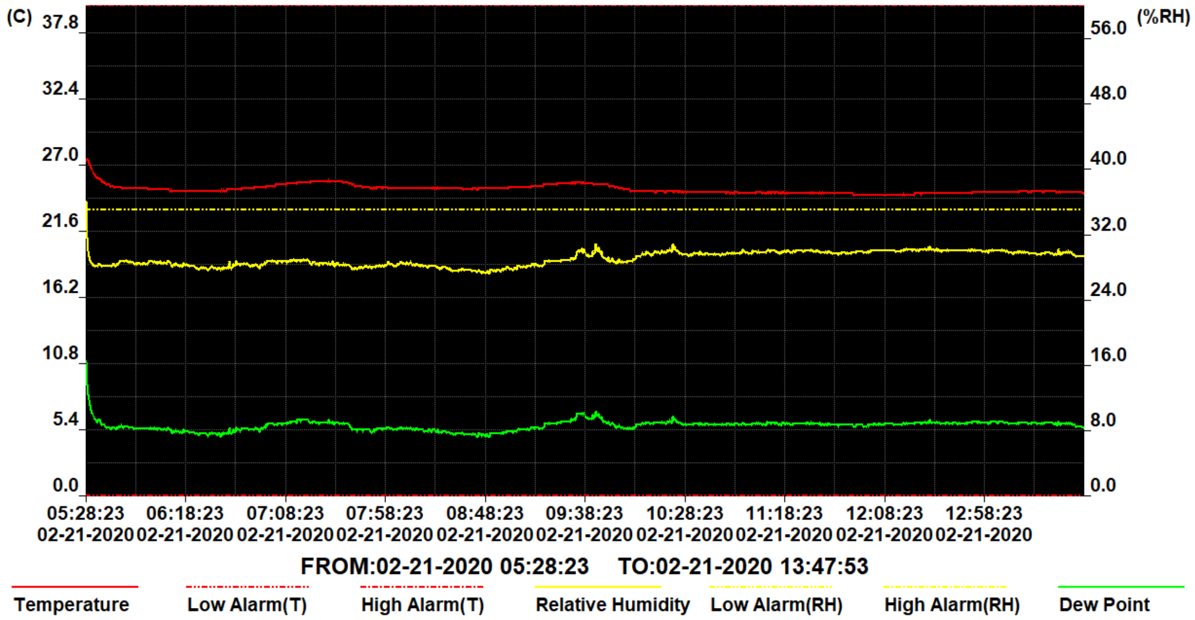


Figure 9: Temperature and Humidity measurement over the day

4.1.7 Runway Usage

The outer scene camera was used to automatically detect movements on the runway. The algorithm used relies on the Optic Flow descriptors according to Farneback

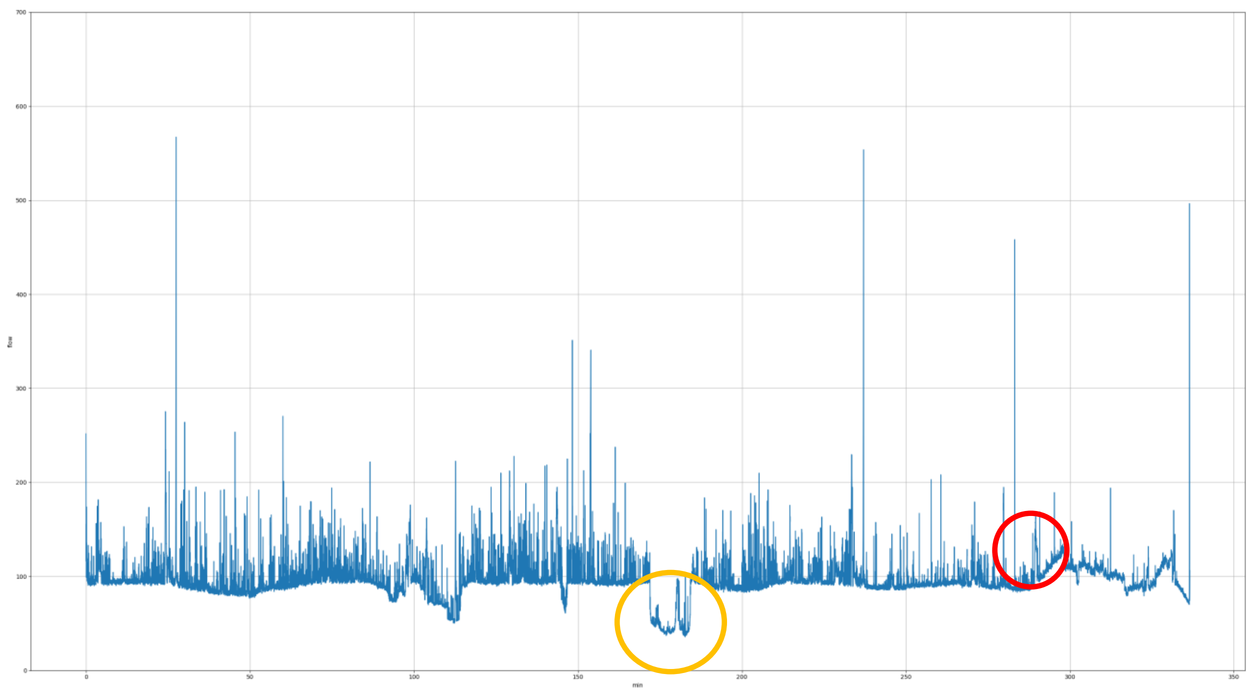


Figure 10: Optic flow at Kiruna airport right outer scene camera. Overexposure by sunlight (orange). Hercules C130 vacating runway via Bravo (red)

This algorithm is useful to transcript any movement on the runway independent of the tower controller's attention and clearances (Figure 10) such as the vacating Hercules C130 shown in Figure 11. The algorithm is still to be improved since disturbing events potentially hide runway related events such as sunlight or dust, mirroring from the inner tower scene or moving clouds.

Figure 11: Hercules C130 vacating runway at timecode 290 minutes (red circle in figure Figure 10)

4.1.8 Radio Communication

The extraction of the clearances given by the tower controller was performed manually and outputted to table formatted event classification.

4.1.9 Flight Strip Video

The flight strip video is an additional mean that complements the radio communication and determines the clearance state of all movements in the CTR and maneuvering area (Figure 12)

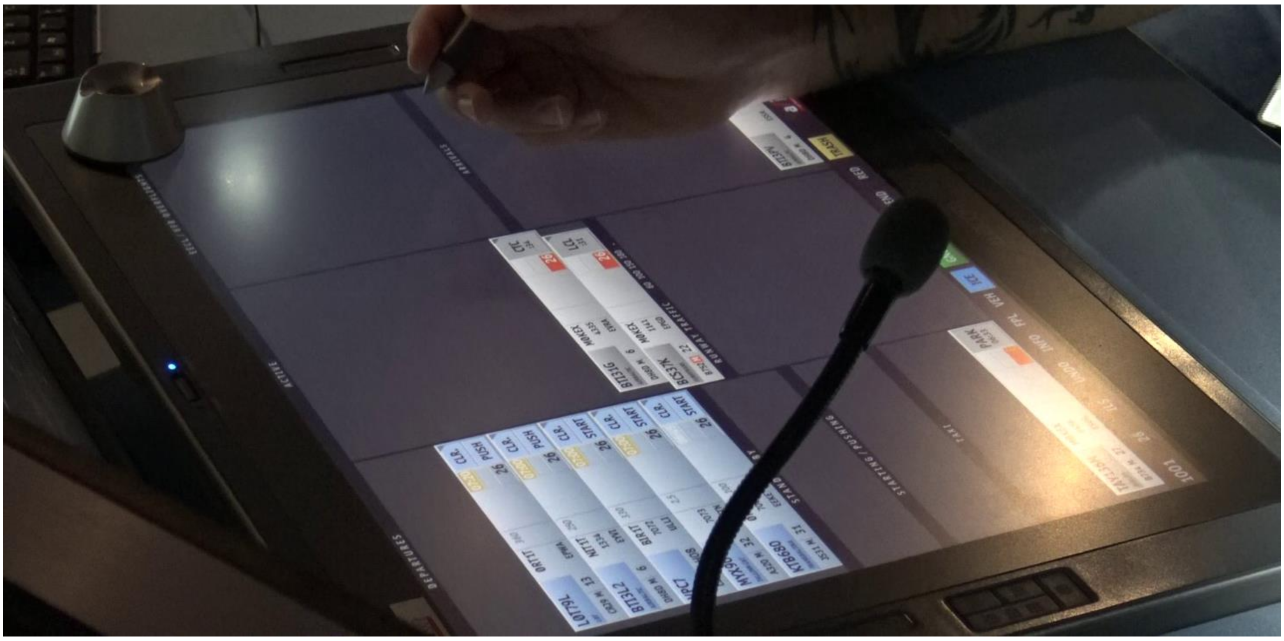


Figure 12: Flight Strip recording for a visual indication of the planning and clearance status

4.1.10 Microsoft Kinect

The use of the Microsoft Kinect Azure device is probably the most advanced sensor in the study that is not attached to the body of the air traffic controller. The device comprises 3 sensor systems:

- RGB video camera
- Infrared camera
- Lidar for depth data.

The Microsoft AI Package consists also of a body tracking-module that recognizes human body shapes in the point cloud. The point cloud is provided to a neural network that fits a skeleton model into the human shape that describes the most likely pose of the human body corresponding to the points observed. Figure 14 gives 6 examples from Kiruna Tower using the Kinect Azure and showing one air traffic controller in position. It is possible to track several persons at a time, indicated by different colors of the skeleton model. Other persons than the air traffic controller are indicated by orange or green color sitting or standing next to the table. The right-center picture, Figure 14, shows an example of 6 different viewing angles providing different perspectives on the same spot. A complete reconstruction of the inner scene using the point cloud is possible, identifying the following joints of the skeleton of all actors in the close vicinity (4m range) of the device

- Body core position
- Neck
- Shoulders
- Arms
- Hands

and many other joints including even the orientation. Figure 13 gives an overview of the skeleton model definition.

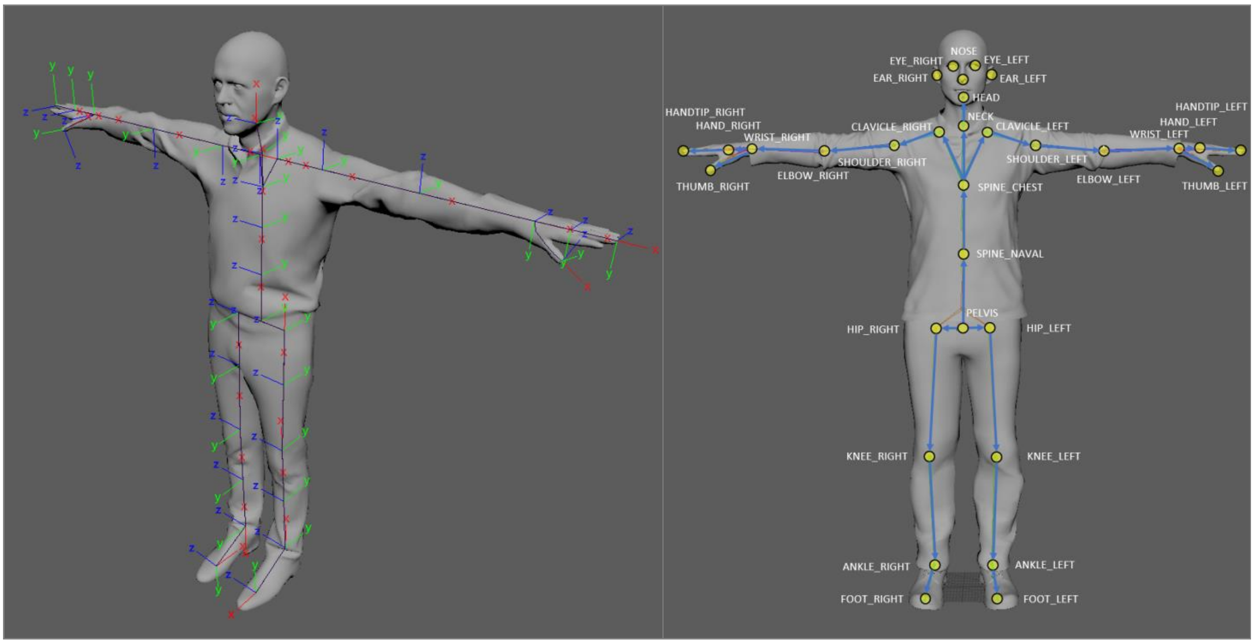
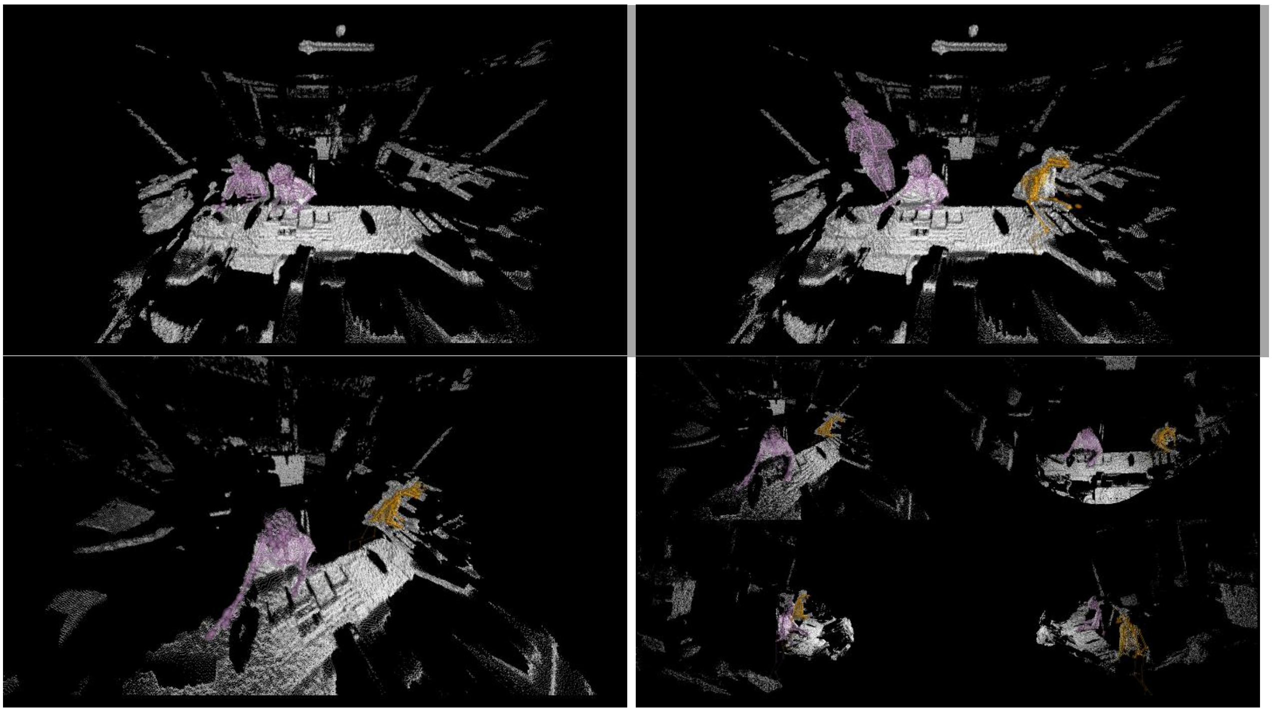


Figure 13: Joint elements and Joint Coordinates provided by the Body Tracking Module, Azure Kinect (Microsoft, 2019)

The expected value for this project is the extraction of a physical body activity metric expressing the kinematic movement of the joints in a 3D space. This might be a valid metric for

- monotony or
- controller drowsiness

if the body activity falls below a certain threshold. Although a threshold might be difficult to identify, the value of this metric is recognized in the research domain of car driver safety. Current findings show that the best indicator for mental activity is the movement of the head. Other indicators might be the movement of arms and hands.



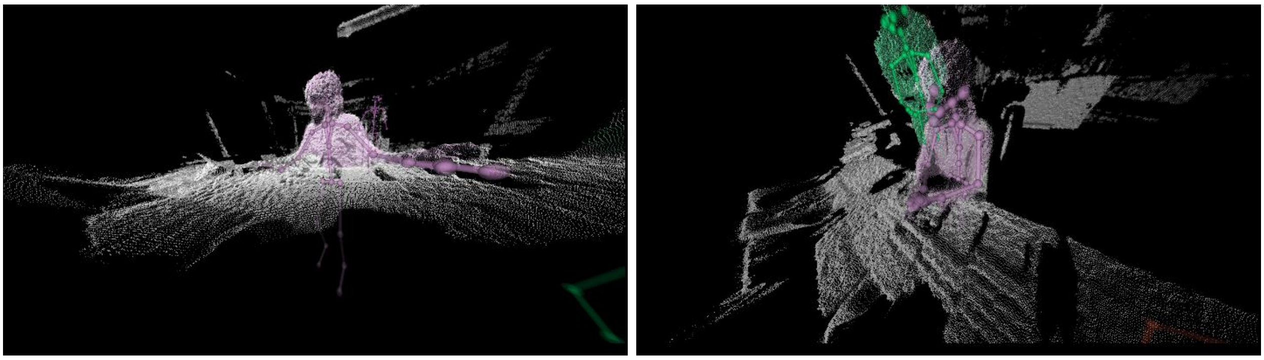


Figure 14: 6 Examples of Body Tracking in Kiruna Tower with an Air Traffic Controller sitting in the position

4.2 ISA Workload

The ISA workload scale was used every half hour according to the scheme described in (Eurocontrol SKYbrary, 2012) . The results are shown in Annex C.

LEVEL	WORKLOAD	SPARE CAPACITY	DESCRIPTION
5	Very High (Overload)	None	Behind on tasks; losing track of the full picture.
4	High (Fully Loaded)	Very Little	Non-essential tasks suffering. Could not work at this level very long.
3	Fair (Reasonable)	Some	All tasks well in hand. Busy but stimulating pace. Could keep going continuously at this level.
2	Low (Light Work)	Ample	More than enough time for all tasks. Active on ATC task less than 50% of the time.
1	Low (Light Work)	Very Much	Nothing to do. Rather boring.

The most obvious to see is the low workload responses during the entire shifts and days, seldom exceeding level 2 and not varying much despite movements being controlled on the runway and airspace.
With this background, the scale was extended with day 5 by a workload level “0”, expressing the absolute absence of any task load.

LEVEL	WORKLOAD	SPARE CAPACITY	DESCRIPTION
0	None	Complete	Absolute zero task demand

4.3 Example Body Activity

Annex A shows the body activity index of all the recordings using the MS Kinect Azure. The index is shown as the velocity of 4 body parts over time, namely:

- Neck
- Right Eye
- Right Hand
- Left Hand

Additionally, the rotational positions (Pitch, Yaw and Tild) and yaw speed of the head are shown in the second diagram. The figures vary between -90 to 90 degrees with a nominal value around 0. Periods of head down and up are indicated by the head pitch against the horizontal plane lying aroung -20°. A more detailed example is given for the Kiruna safety-relevant event in Annex D under a period of 10 minutes around the event. A validation with help of video data and eye-tracking could be accomplished showing that a pitch above -20° is related to eye gaze fixation outside the window view (runway, apron, taxiways, airspace or similar). There are also hidden times when the controller is looking out the window without the indication of the head up by the head pitch. An explanation is given by the eye gaze angle in which the controller is looking with a steep angle in relation to the head orientation. This means that not all fixations that are directed out of the window can be indicated by the pitch angle. An exemplary video with the situation recorded by the MS Kinect with body pose (skeleton) and the 3 axes coordinate system of the head orientation:
https://web02.droponline.se/shares/folder/mcuQiX0oBEc/

The diagrams in Annex A are chronologically sorted beginning with the earliest shift recorded. The time axis is coded as local time (CET). Velocities around 5 m per second are recorded showing usual peaks of body movement at the position.
The overview does not give any indication about the identity of the air traffic controller since the sensor does not notice a change of the human in position. Adding contextual information to the diagram about the individual being recorded is still outstanding. This is a prerequisite to conclude on a day-related trend of the body activity related to a certain air traffic controller.

4.4 Example Eye Aspect Ratio

In Annex B, two exemplary distribution of the eye aspect ratio is shown over a time of about 10 minutes. The eye aspect ratio is around 0.3 during a period of being fully awake. A blink can be detected when EAR passes a threshold of 0.1. The detection of the eye is not continuous stable since the camera is covering a certain area only and the air traffic controller is moving between instruments frequently with the face heading towards different directions. A multi-camera setup is required to complement the missing periods to an overall picture of the EAR. Long periods of EAR measurements are possible without disturbance of the air traffic controller.

4.5 Example Eye Tracking Analysis Tartu Tower

This example is about a departure and a landing situation in Figure 15. Identifiable the episodes in the minutes before take-off and landing that are characterized by the intensification of head-up time checking the runway and airspace. These are indicated by the green and yellow box. Between start and landing, the controller spends attention on the radar screen (red box) for monitoring the traffic situation. Intensive periods of focusing on a single AoI with minor variance are an indication of monotony.
On the first hand delivers eye tracking a good indication of visual attention. But also pupil diameter and blink rates can be used to conclude on stress effects. The eye-tracking glasses to provide the metric that provides the pupil diameter in millimeters with a sampling frequency of 50 Hz.

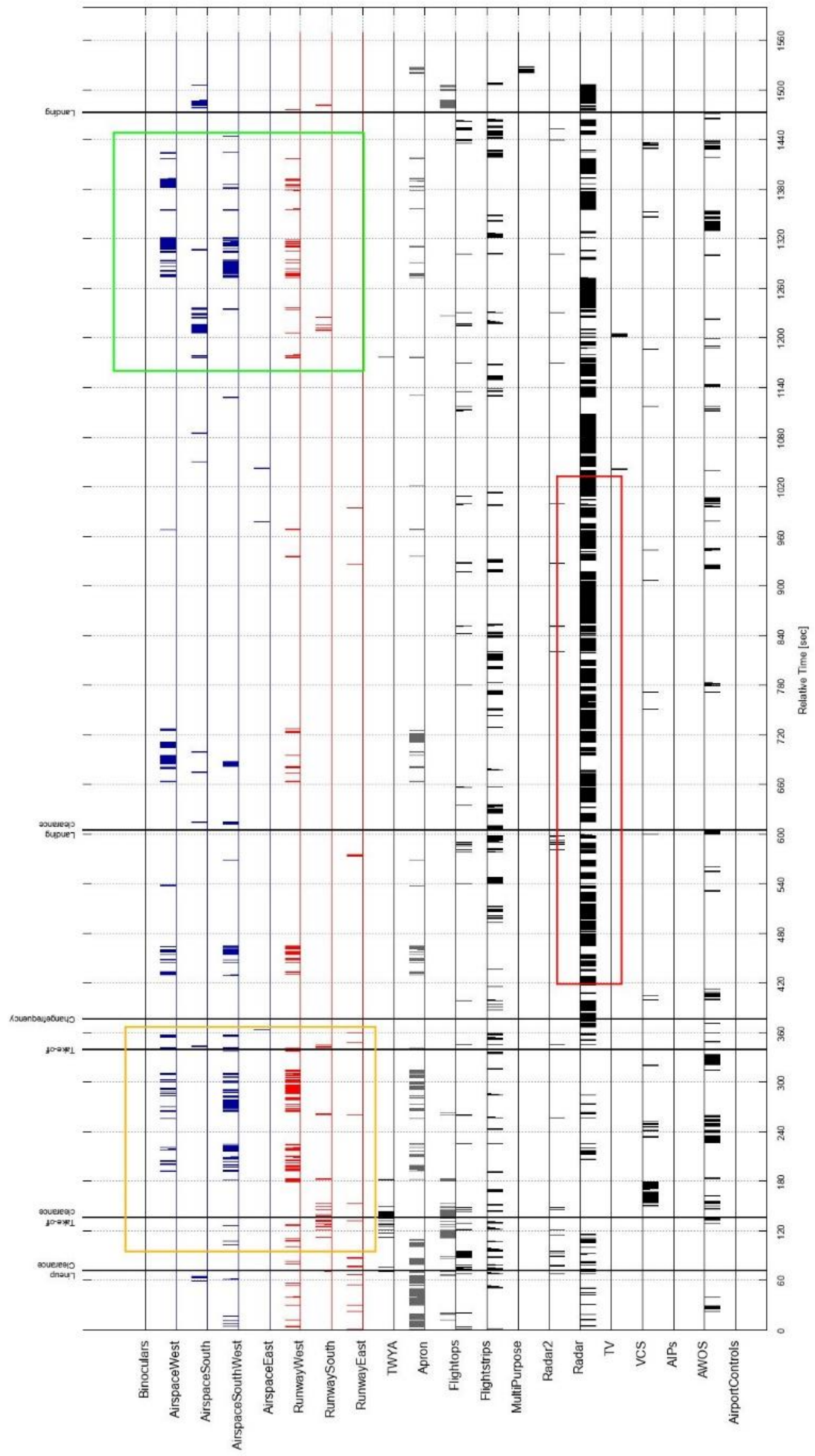
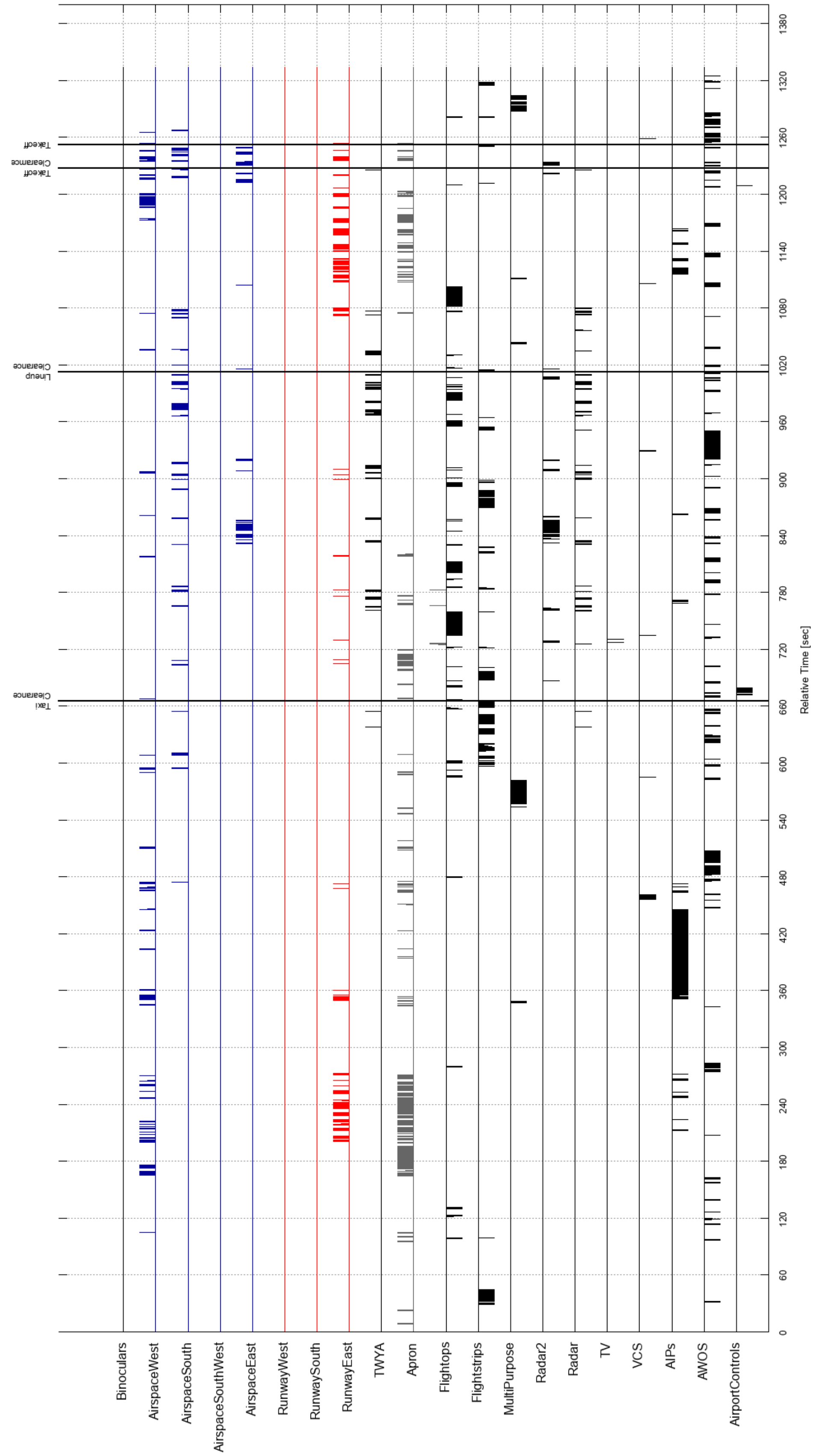
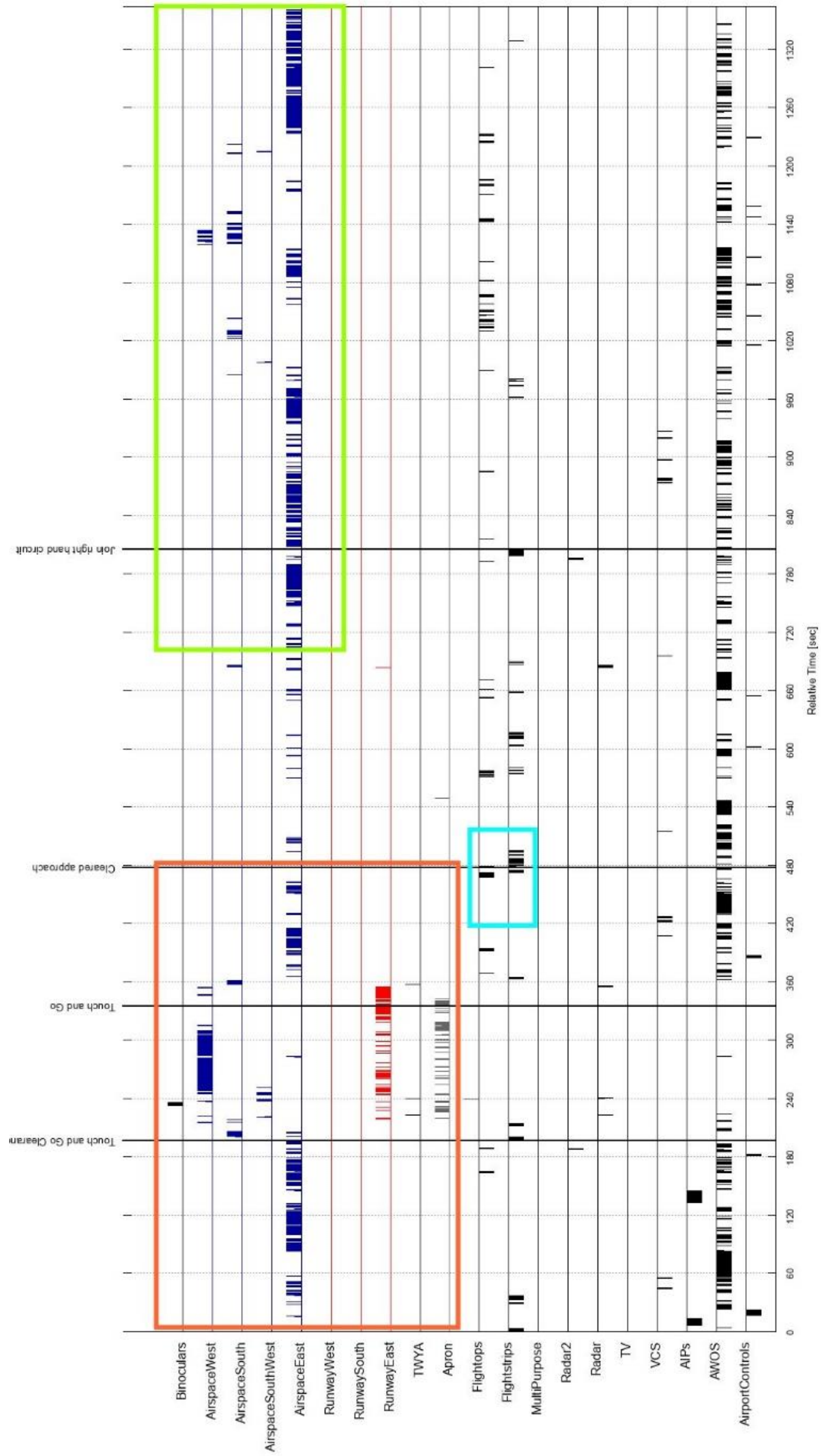


Figure 15: AoI Diagram Attention Analysis with one Departure and one Landing


Takeoff
Clearance
Takeoff
Clearance
Lineup
Clearance
Taxi
Relative Time [sec]
0
60
120
180
240
300
360
420
480
540
600
660
720
780
840
900
960
1020
1080
1140
1200
1260
1320
1380
Binoculars
AirspaceWest
AirspaceSouth
AirspaceSouthWest
AirspaceEast
RunwayWest
RunwaySouth
RunwayEast
TWYA
Apron
Flightops
Flightstrips
MultiPurpose
Radar2
Radar
TV
VCS
AIPs
AWOS
AirportControls


Binoculars
AirspaceWest
AirspaceSouth
AirspaceSouthWest
AirspaceEast
RunwayWest
RunwaySouth
RunwayEast
TWYA
Apron
Flightops
Flightstrips
MultiPurpose
Radar2
Radar
TV
VCS
AIPs
AWOS
AirportControls
Relative Time [sec]
Cleared approach
Touch and Go
Touch and Go Clearan

4.6 Example Analysis of a Safety-Relevant Event

A safety-relevant event occurred on the runway involving
- a car that was cleared for taxiing on the runway and
- an airplane that was cleared for taxiing and lineup on the runway.

Figure 16 shows the outer scene camera on the right 5 seconds before the event with the car and the airplane involved.
The “Unsafe Act”[3] was a misunderstanding between the tower controller in position and the car driver about a taxi clearance given to the car driver.

With the mandate of this project,

> *“Evaluating empiric methods to reconstruct operational situations and resulting human performance and its impact on safety by lapses and errors”,*

the situational factors were reconstructed (situational reconstruction) with a focus on a potential contribution of controller behavior to the course of events. The reconstruction and the succeeding discussion are supported by state-of-the-art knowledge in the scientific domain of human work and performance shaping factors. As the identification of factors and effects is the result of an inductive conclusion (observation to model explanation), verification is mandatory posterior with the help of interviews with the respective controllers in the position at that specific time.
For the situation reconstruction, an attention analysis was performed using the eye-tracking data, inner/outer scene video camera, the MS Azure Kinect Body Tracking (Annex D), and voice recordings.
The analysis involves two air traffic controllers, a student controller under training, and the related instructor (OJTI – On the Job Training Instructor), being in the position that specific day under the time of the event. The attention analysis is shown in Figure 17 and Figure 18 indicating the visual focus of both controllers and related activity over a reference period from 270 sec. before until 30 sec. after the event. The body pose and related head rotation of the student are documented in Annex D showing the head pitch and yaw corresponding to the attention analysis. The Annex D has to be interpreted under limitations outlined in 4.3.
The following factors were identified from the diagram that contributed to the generation of the misunderstanding as well as the related attentional focus of both the student and OJTI:
- A taxi clearance was given by the student controller related to the car driver. This communication action was directly followed by the phone call for the coordination of departure with the ATCC ESOS (t = -20 sec.). The phone call began when the readback of the car driver was still outstanding. The readback being a mandatory part of the clearance communication procedure, neither the student controller nor the instructor noticed the absence of the missing readback. A possible explanation for this deviation from the procedure is the occurrence of a so-called *target fascination*[4] leading to a loss of situational awareness that was

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[3] An unsafe act … is an error or a violation committed in the presence of a potential hazard (Reason, 1990, S. 206)
[4] In aviation, fascination is a condition in which a person fails to respond adequately to a stimulus, even though all the necessary cues for proper action are present. This means that target fascination (sometimes referred to as Type A fascination) is perceptual in nature, and refers to a situation where a person becomes so concentrated on one aspect of the total situation that it neglects other aspects in its perceptual field. It becomes so occupied with one aspect of the work that it fails to perceive other aspects. This, in turn,

induced by the student's mental focus being set on the phone call. A strong indicator for this working anomaly is the continuous and gapless head-down time on the respective flightstrip of the flight to coordinate under the ongoing phone call while no visual contact to the car and airplane was established.

- Additionally, the psychological *Zeigarnik* effect could have played a role. The effect describes, that the human remembers interrupted tasks better than completed tasks. Possibly did the controller cognitively complete the tasks by instructing the car driver to hold position even though that the readback was still outstanding. In connection with concurring tasks (i.e. phone call for the coordination of the departing aircraft) present, this effect was perhaps even intensified and led to less monitoring of the vehicle on the runway.
- The instructor had large parts of the visual focus head down under the complete reference period. The visual focus was exceptionally looking head up under repeating short periods (max 5 sec.) on the apron/runway after the airplane was cleared for taxiing.
- The instructor initiated a discussion about the possible routing for the car vacating the runway which led in consequence to the "catching"-effect of directing the students visually focus to the instructor (Figure 18, "Student"-axis, the period between -48 to –24sec).

Two contributive psychological effects are indicatable and point of discussion here:

- *Time pressure* – The student rushed for coordination of the departure while setting the focus away from the communication actions with the car driver. This might be contributing to the arousal of "target fascination" which is a well-known and documented cause for accidents and incidents in aviation history. Visual and cognitive tunneling occurs, referring to the fact that a stressed person stops carrying out secondary tasks and processes the cues that are most immediate and familiar (Rendon-Velez, et al., 2018)
- *Attentional Distraction* – The discussion was initiated by the instructor about a possible option to taxi out (reroute) the car took mental capacity away from the situational development on the runway as part of the course of events. This increased the time pressure situation for the student.

The just mentioned factors and effects are indicated using the situation reconstruction and thus represent a subset of a possibly larger set of factors and its corresponding psychologic effects. The empiric documentation allows continuing to examine the situation concerning other effects.
Methodologically, the situation reconstruction could be accomplished by a combination of the data sources and identifying effects as a possible part of the causal catenation. In this unique case, the methods and equipment used demonstrates the capability to reconstruct the situation for a detailed resolution of the situational factors which leads to the possibility to achieve a higher level of understanding the safety-relevant event for developing tailor-cut measurements and thus to help to avoid similar events in the future.

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results in a flawed mental model of the current situation, which, if not corrected, can lead up to an accident. (Transport Canada, 2015)

Figure 16: Car and airplane from a snapshot of the outer scene camera

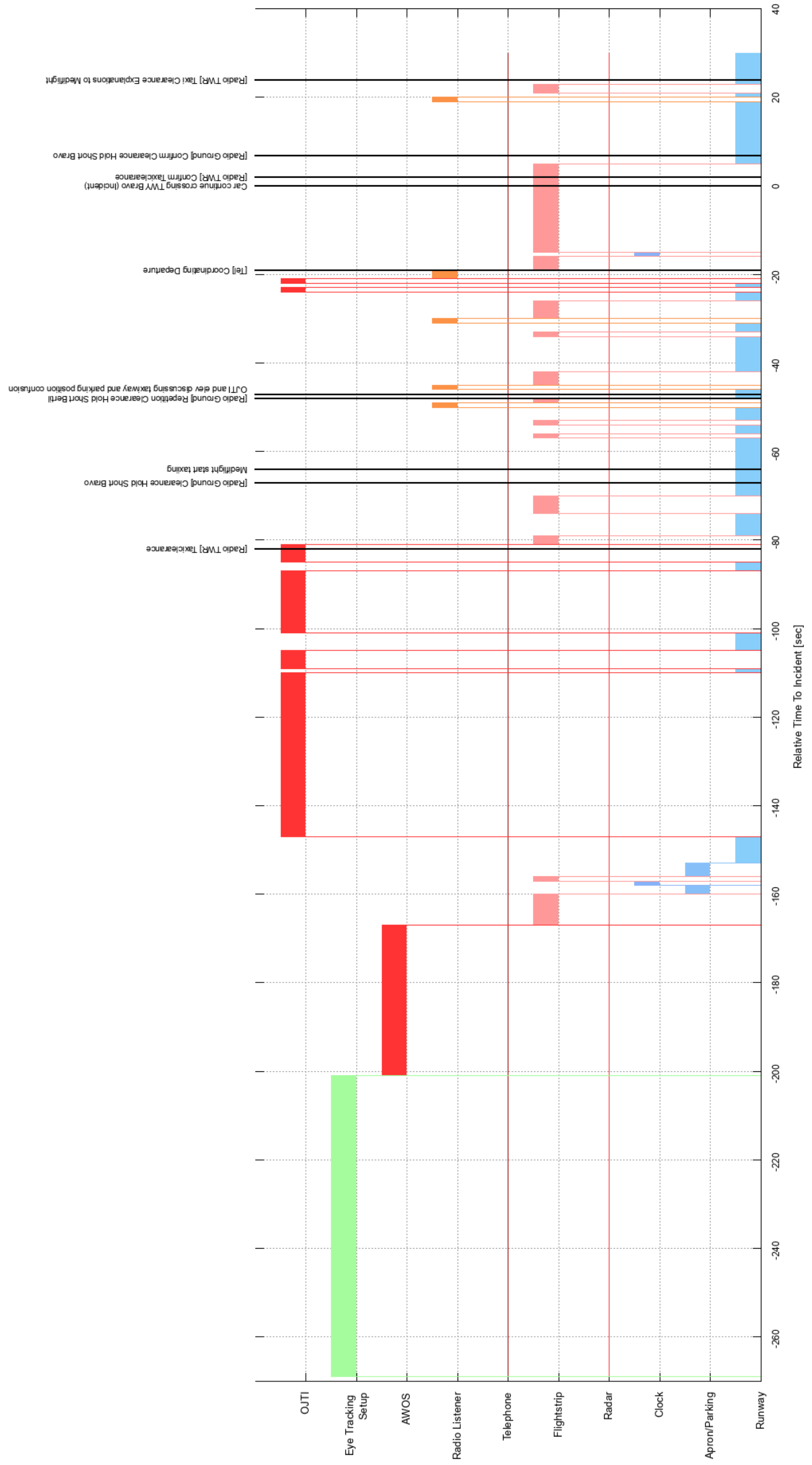

Figure 17: Attention Analysis of the student

Figure 18: Attention Analysis of the OJTI

5 CONCLUSIONS

This report contains a summary of the methods and technical equipment used to extract the foreseen Performance Shaping Factors. The data collection setup, the sensor used, and the analysis software used are described in detail aiming at the measurement of physiologic indicators from the air traffic controller in position.
Evidence about the statistical significance is still missing at this point in the project due to a lack of resources to apply the test methods based on the data. The main reasons for this result are the time and efforts needed to

- Plan, organize and execute the field study at the respective towers
- To manage the amount of data generated with an appropriate infrastructure
- The development and tests of the analysis tools for automatic extraction of the metrics
- The analysis of the data (the matters in particular for the safety-relevant event occurred in Kiruna on the 21st Jan 2020 and its intensive analysis of the course of events)
- The quality assurance of the metrics shown

The following table gives an overview of the progress and the status achieved so far.

	DATA COLLECTED STEP 1 (11 DAYS)	TOOL DEVELOPMENT STEP 2	EXTRACTED DATA STEP 2	STATISTIC ANALYSIS (STEP 3)
Facial expression/ Mimic Activity (Inner Scene Cameras)	Yes (70%), partial loss due to camera failure	Accomplished	20 %	0 %
Blink Rate (Inner Scene Cameras)		Accomplished	70 %	0 %
Body Activity (MS Azure Kinect)	Yes (4 out of 11 days), loss of first 4 days due to Kinect damage	Accomplished	100 %	0 %
Visual Scan Pattern (Eye Tracking)	Yes (8 participants eye tracking)	Accomplished	25 %	0 %
Pupil diameter (Eye Tracking)		Accomplished	0 %	0 %
Pitch/ Speed of voice (Radio Tower Frequency and Inner Scene Camera	Yes	Under investigation	0%	0 %
Temperature and Humidity	Yes (7 out of 11 days)	Accomplished	100 %	0 %

The following sections address the expected results defined in the project specification using, for now, qualitative argumentation and descriptive results.

5.1.1 Understand the interrelation of working conditions and Performance Shaping Factors on Human Performance in tower control using a large set of tower controllers from different tower environments

The dataset was created with the help of 12 air traffic controllers at 3 different airports. Tallinn is a large airport with 47,867 movements a year. Kiruna and Tartu are low-traffic-volume airports with just a few movements a day. The first measurement to understand the effect of PSF on work performance is the ISA workload. Contrary to expectations, the results so far show no significant difference in the ISA workload. Surprisingly, the ISA workload results in Tallinn do not reflect the increased traffic volume compared to Tartu and Kiruna. The only difference could be observed for involved in the study on day 5 (Annex C, Controller F). There is at the moment no clear clue about the reasons for this increased level but an assumption is that the controller has not much work experience in the position and feels not completely confident in the position.
The preliminary review of the night shift shows that there is a clear reduction in body activity and eye gaze activity.
The main contribution can be given by this project after finalizing the statistic analysis.

5.1.2 Evaluating empiric methods to reconstruct operational situations and resulting human performance and its impact on safety by lapses and errors

The results so far show promising data that suits the next step 3. After this step, significant results will allow for concluding on the valid indication of PSF. The methods and technical equipment could demonstrate the capability to measure the air traffic controller in position with its dedicated purpose and thus to reconstruct the situation. Some finds will be presented in the following.

During the review of the body tracking and eye tracking, it becomes obvious that attention (visual) and body pose are interconnected due to the nature of the human draws attention by acting with all parts of the body as a coordinated process. This means that visual attention is directed on a place of interest in coordination with the corresponding body movements that may also indicate the acoustic attention by an inherent significant pose.

Two key competencies could be observed:

- *Capability to separate visual and acoustic attention:* This is for example the monitoring of a situation while communicating
- *Prioritization of tasks*: The attention may be cached by stimulation (acoustic or visual) that triggers searching for the origin and assessing the need to react.

Both competencies are crucial for the controller in a position to achieve a smooth flow of the sequence of tasks and their activities. An appropriate indication for these capabilities is the periods spent on simple situation monitoring which enables the controller to continuously react to potential threats or errors originated in the dynamic scene within the area of responsibility.

The methods applied showed the capability to analyze situations concerning both competencies and understand how good control services are assured under all circumstances. This kind of analysis can be performed for single situations only due to the enormous time necessary to extract the metrics needed. An example demonstration is provided by the analysis of the incident in Kiruna where elementary behavior phenomenon, psychological effects, and factors could be identified that might be relevant for understanding the course of events. Latent errors stay in the background hidden

without any consequence due to the absence of a corresponding hazard situation that turns the error into action. James Reason describes this as an *unsafe act* (Reason, 1990, S. 206) that occur frequently before the actual safety-relevant event but generated no safety-relevant effect without the corresponding situational factors needed.
The real value of the here evaluated methods lies in the deduction of the observed effects to other situations where similar behavior could be observed and verified in its existence and significance.

5.1.3 Ability to benchmark innovative automated solutions in the remote tower by comparing Performance Shaping Factors

According to the hypothesis outlined in section 1.1, the capability to identify work position-related variances is set for this project. The further statistical analysis of the metrics extracted is still outstanding and subject to further research.

The following overview delivers findings on the suitability of PSF based on the observations so far on a preliminary basis. The best promising candidate for measuring the PSF stress so far are

- *Eye pupil diameter* – A reaction of the body to stress is indicatable with a short delay. The drawback is that only rather short periods of recording are available using the eye-tracking equipment. This due to eye fatigue and practical limitations.
- *Body activity* – Any stress reaction is indicatable by the velocity of the hand and head movements which increase the speed.

The best-promising candidate for measuring the PSF fatigue are:

- *Eye gaze dynamic* – A reaction of the body to fatigue is rather long fixations and fewer saccades. This could be observed from the night shift.
- *Eyeblink rate* - A reaction of the body to fatigue is a rather high frequency of blinks. This could be observed from the night shift.

The best promising candidate for (uneventfulness) monotony is:

- *Visual attention* – A reaction to monotony is less time spend on drawing the attention on out-the-window (head downtime)
- *Body Tracking* - A reaction to monotony is less time sitting in position and related to this, less work-significant body pose

The ISA workload scale did at this point not fulfill the expectations of a suitable method to show the stress level of a controller. The reason is the low variance provided by the metric.
Another method that Safe Tower will correlate is the PVT (Psychomotor Vigilance Test) executed in the scope of TRV-funded project *Human Centered Lighting*. A correlation analysis with the there provided metric “alertness” will give clues about the goodness of indicating stress and fatigue effects.
The ability to benchmark automated solutions is likely to be verified by applying statistical significance tests to the data extracted.

5.1.4 Identifying the causes of low performance by “in-situ” reconstructing outlier situations

The analysis of the Kiruna incident delivered psychological effects at the related factors by a detailed reconstruction of the situation. This was supported by the tools and visualization developed under the project period.

5.1.5 Creating empiric transparency of human performance in digital remote towers

This step of the study does provide step one, the baseline.

Nevertheless, the methods and equipment used do allow for the extraction of representative metrics that can also applied to the remote tower and create a similar database as in the baseline conventional tower. All metrics are fully adaptable and comparable in the scope of hypothesis 3 (section 1.1).

6 DIGITAL DATABASE

The database contains a set of time-distributed data from the days of recordings.

– ISA queries

– Eye Aspect Ratio: Calculation of eye aspect ratio.
  <time code>
  <left eye>
  <right eye>
  <left-right mean>

– Eye Tracking AoI Analysis: The state table contains a time axis with the binary states of the respective AoIs. An overview of the Tower Environment with AoI definitions is provided.
  <time code>
  <State 1>
  <State 2>
  <State 3>
  …..
  <State n>

– Body Activity: Following format per row
  <time code>
  <frame>
  <Neck Velocity>
  <Right Eye Position Velocity>
  <Left Eye Position Velocity>
  <Right Hand Velocity>
  <Left Hand Velocity>
  Neck Position <x>, <y>, <z>
  Right Eye Position <x>, <y>, <z>
  Right Hand Position <x>, <y>, <z>
  Left Hand Position <x>, <y>, <z>
  Head Rotation <yaw deg>, <roll deg>, <pitch deg>
  Head Rotation Velocity<yaw deg>, <roll deg>, <pitch deg>

- PVT: Following rows per column.
  <Day n>
  <Time>
  <Shift index>

For accessing the URL, please use the following link:
https://web02.droponline.se/shares/folder/348PWNFQify/

7 LESSON LEARNED

The project had the following lesson learned in regards to the objective set in the project specification.

- *Preparation of data collection activities* – For future activities, the preparation shall include a safety assessment that evaluates possible effects of the equipment and methods procedures on air traffic controllers and operations. In this project, the safety assessment was performed after the last recordings in Tallin and Tartu to continue the study in Umeå, Östersund, Malmö/Sturup, and Halmstad. Unfortunately, the Corona pandemic made it impossible to access the operational rooms for research purposes. With regards to the project's foreseen period and day of the final report, data collection activities were canceled all over.
  There shall be a clear mandate by the responsible tower unit coordinator (CO ATS) in regards to the participants, the conditions during the study, the time, and the methods and equipment used.
- *Execution of data collection activities* – In the interest of gaining quality assured results, an elementary interest is to capture operational activities of the air traffic controllers with a minimum disturbance possible. A workshop was performed the 27th January 2020 after Kiruna with the assistance coworkers of this project and Human Centered Lighting for summarizing the experience made so far. In this scope, the following data collection procedures shall be defined for the execution in the future:
  - A *Code of Conduct* shall describe the required communication, presence, and behavior of members of the study in operational rooms. This shall assure a standardized influence on the air traffic controller with the information required for participating in the study. And it shall minimize the influence of the study member's presence on the recordings itself (e.g. Video recordings, talking).
  - *An Informant Consent* –shall assure that the air traffic controller is aware of his/her rights while participating in the study.
  - A checklist of all data sources recorded/capture for a later check on completeness
  - An agreement on data treatment in case of incident or accident investigation
- *After the data collection activities* – A questionnaire on the possible influence of the equipment or methods on the work of the air traffic controller.

Partly, these points were applied correctly but it shall become a standard procedure for the future that is documented for quality assurance and that the operational safety is maintained at all points.

8 PUBLICATIONS

In the scope of the project, three publications and related presentations were prepared:

- DATS Workshop 2021, Norrköping
- Transport Forum 2022, L. Meyer, *Higher Levels of Automation and Safety: Good Partners?*, Linköping, Jan 2022. Status: Accepted.
- Journal Publication: L. Meyer, Peukert M., Tamm M., Kohv T., Josefsson B, *Investigating Monotony in Tower Control Comparing a Small and Medium-sized Airport* : In Applied Ergonomics Human Factors in Technology and Society, Status: In Progress.

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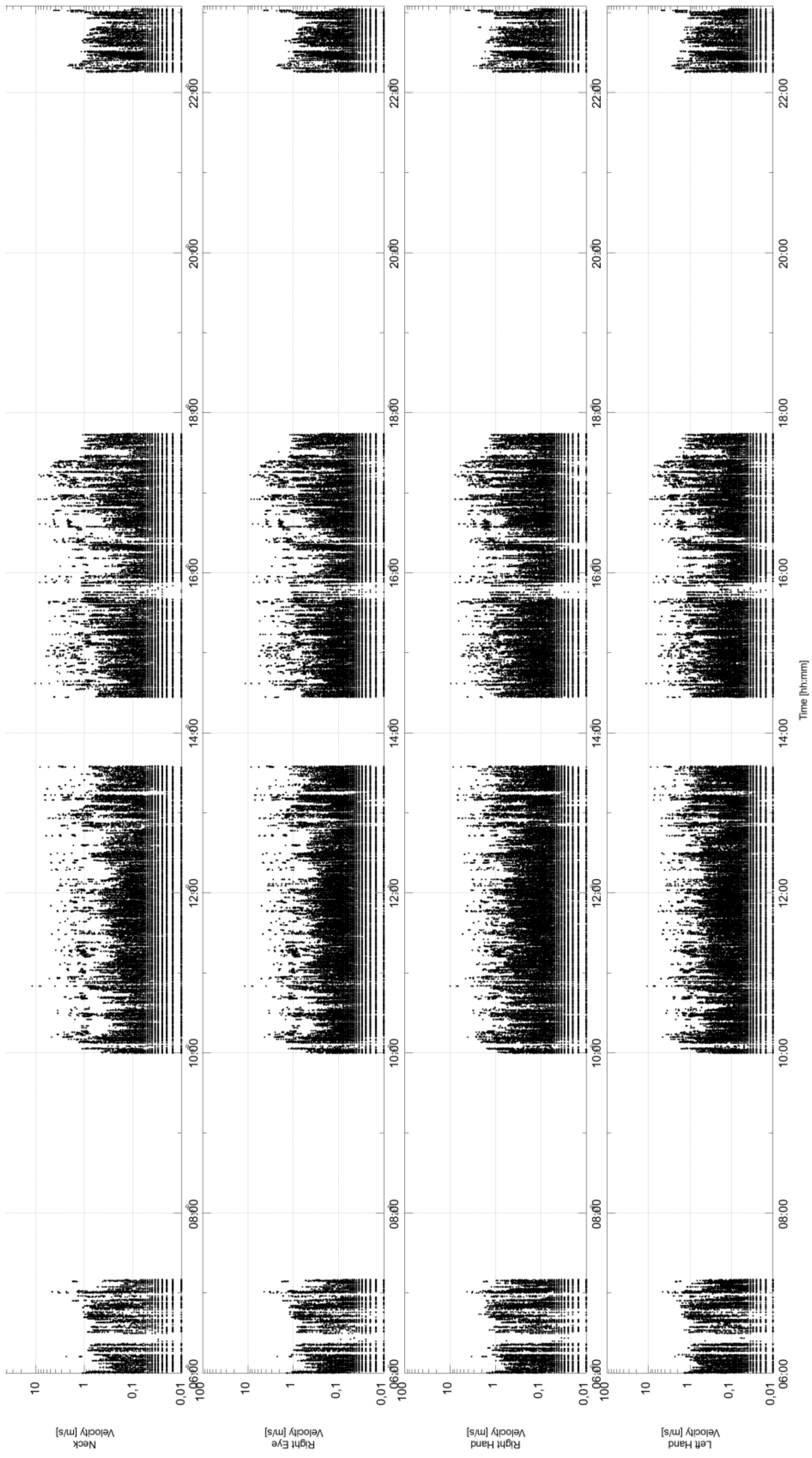
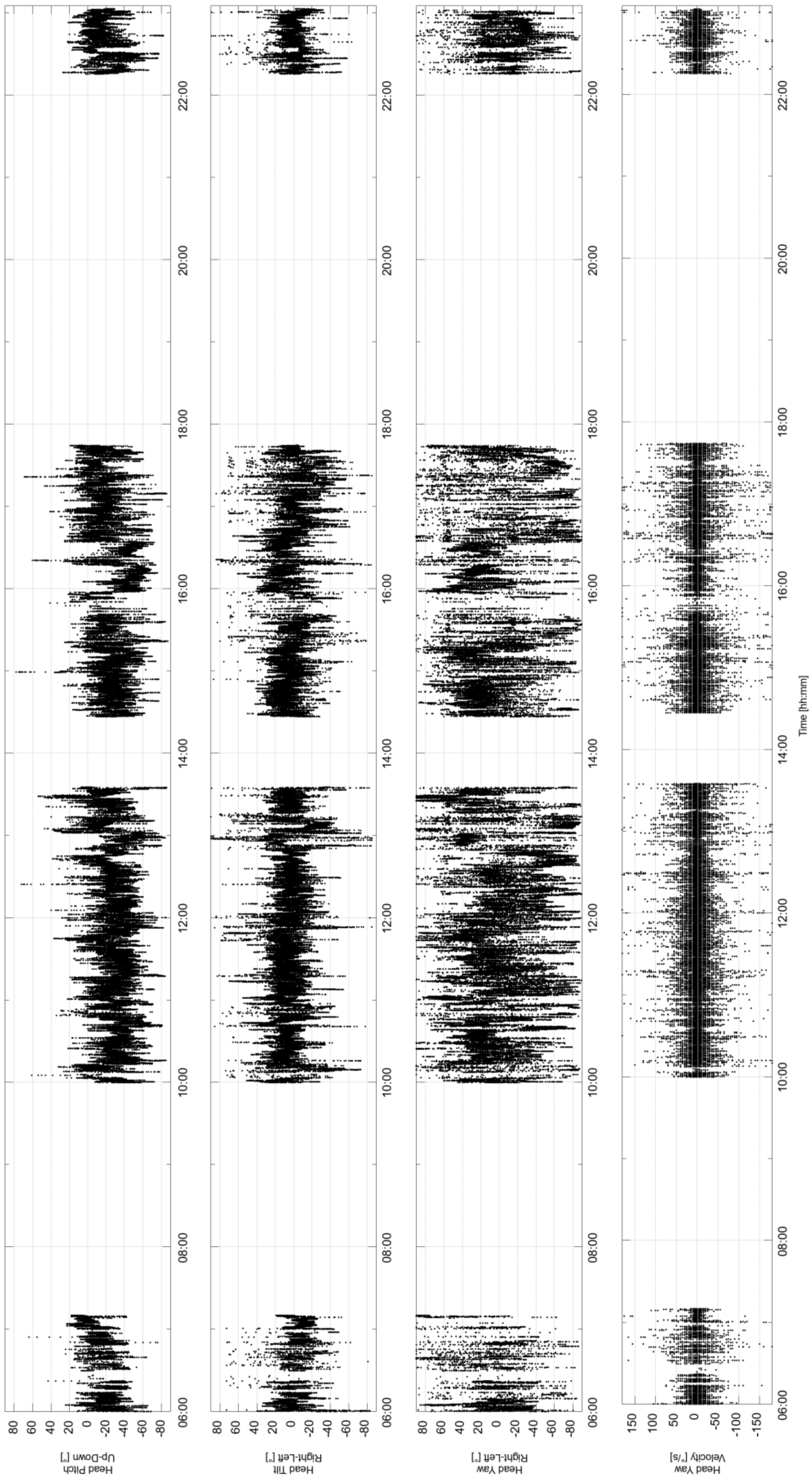
ANNEX A: KINECT BODY TRACKING ACTIVITY

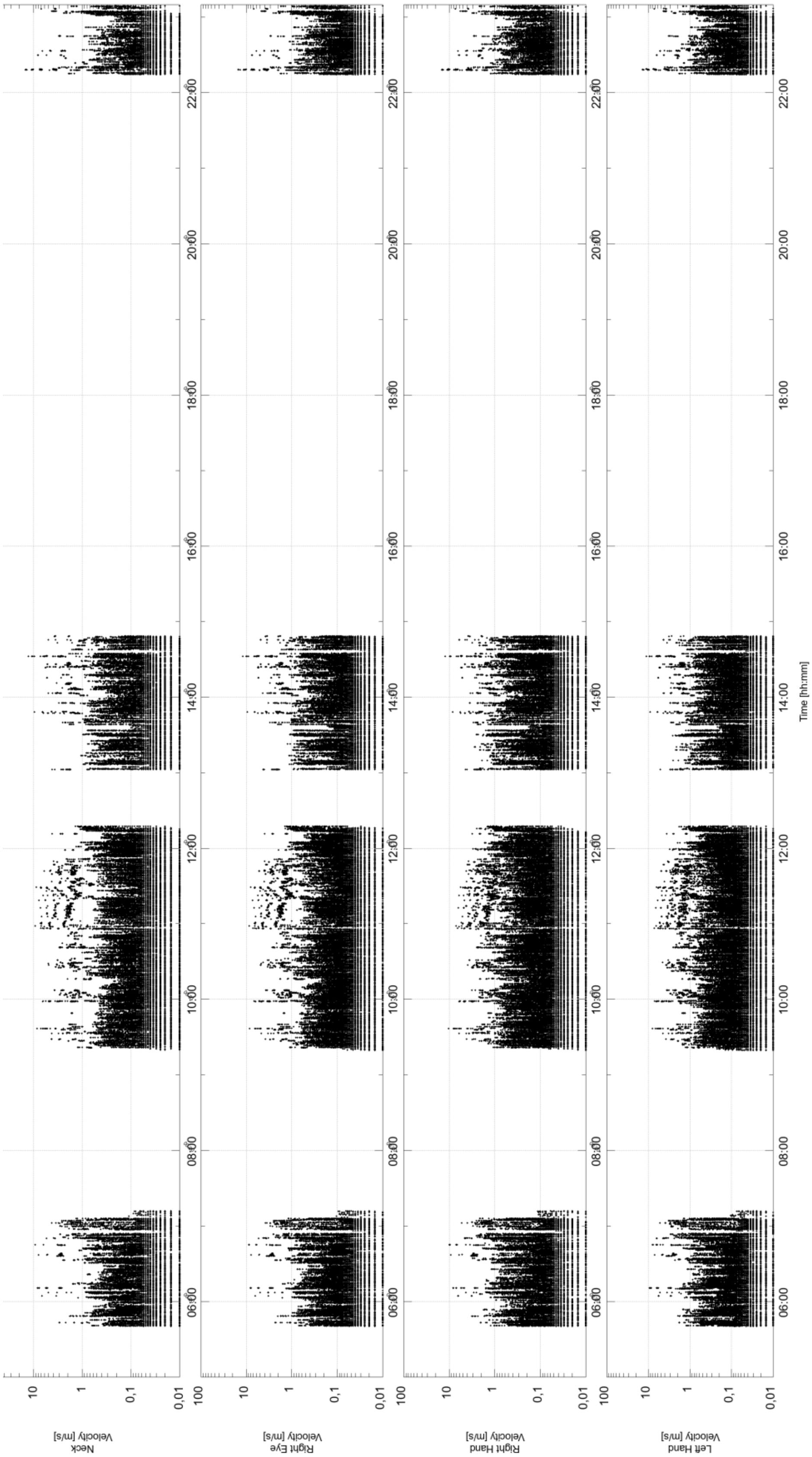
Day 5

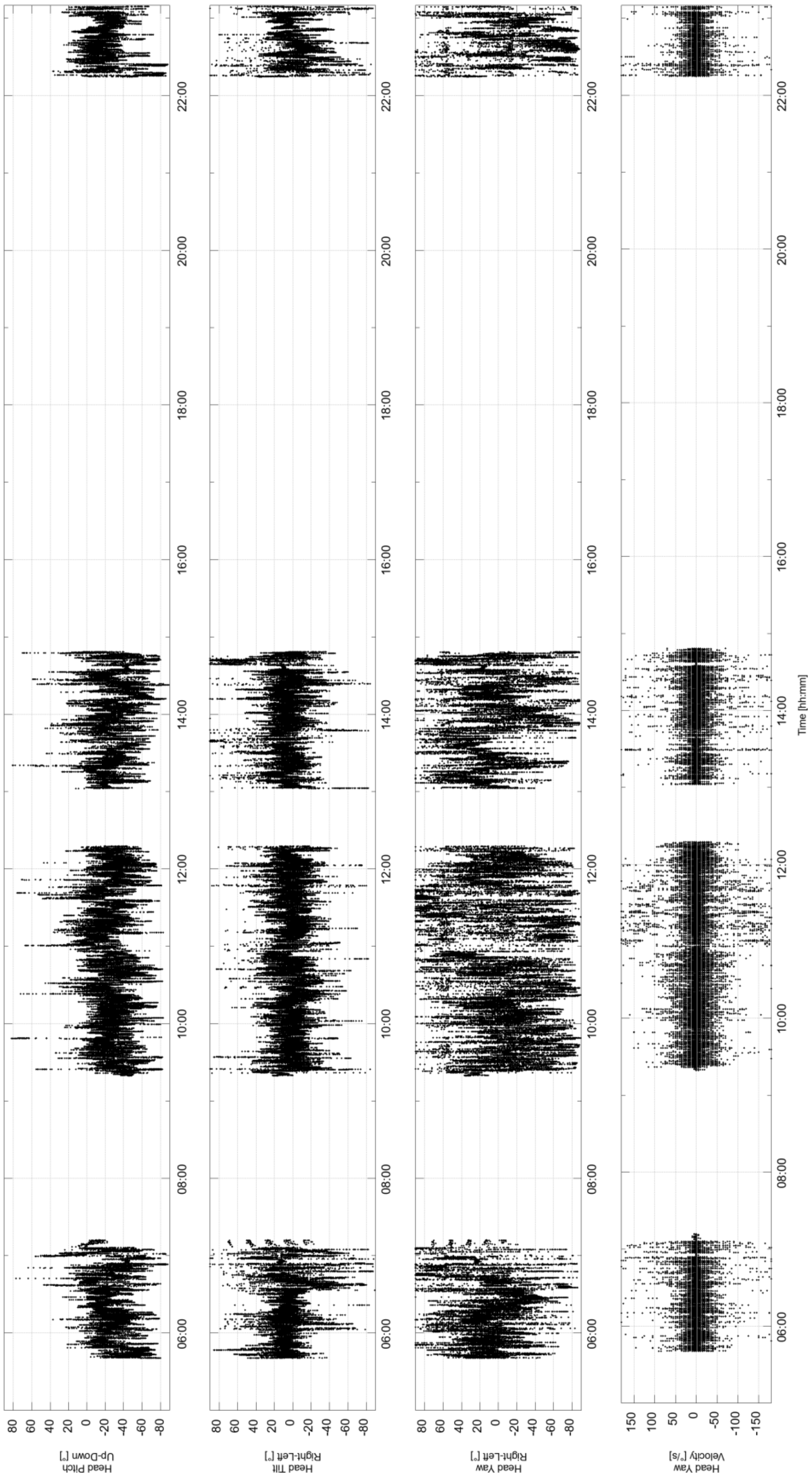




Head Pitch
Up-Down [°]
Head Tilt
Right-Left [°]
Head Yaw
Right-Left [°]
Head Yaw
Velocity [°/s]
Time [hh:mm]
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00

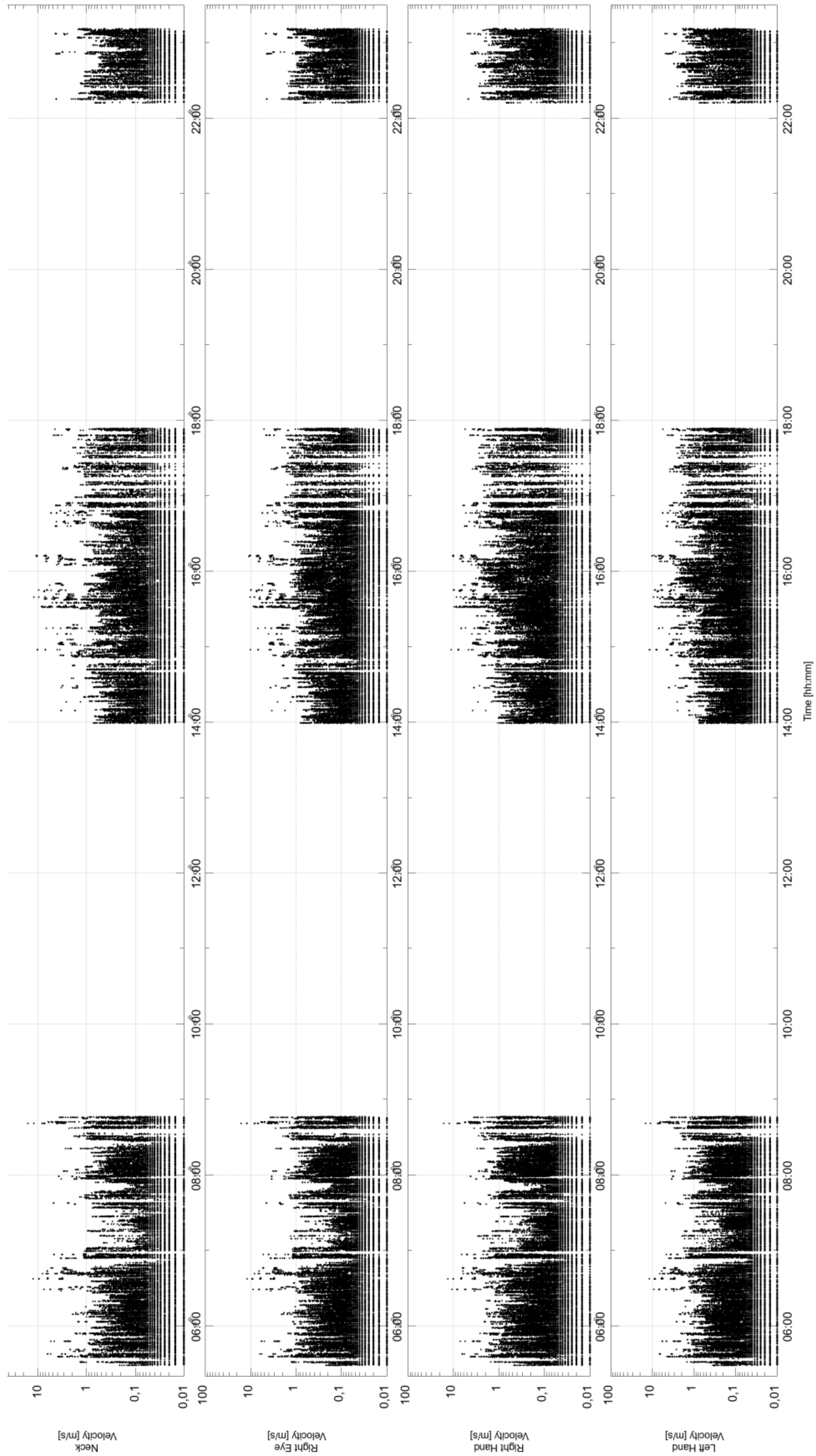
Day 6

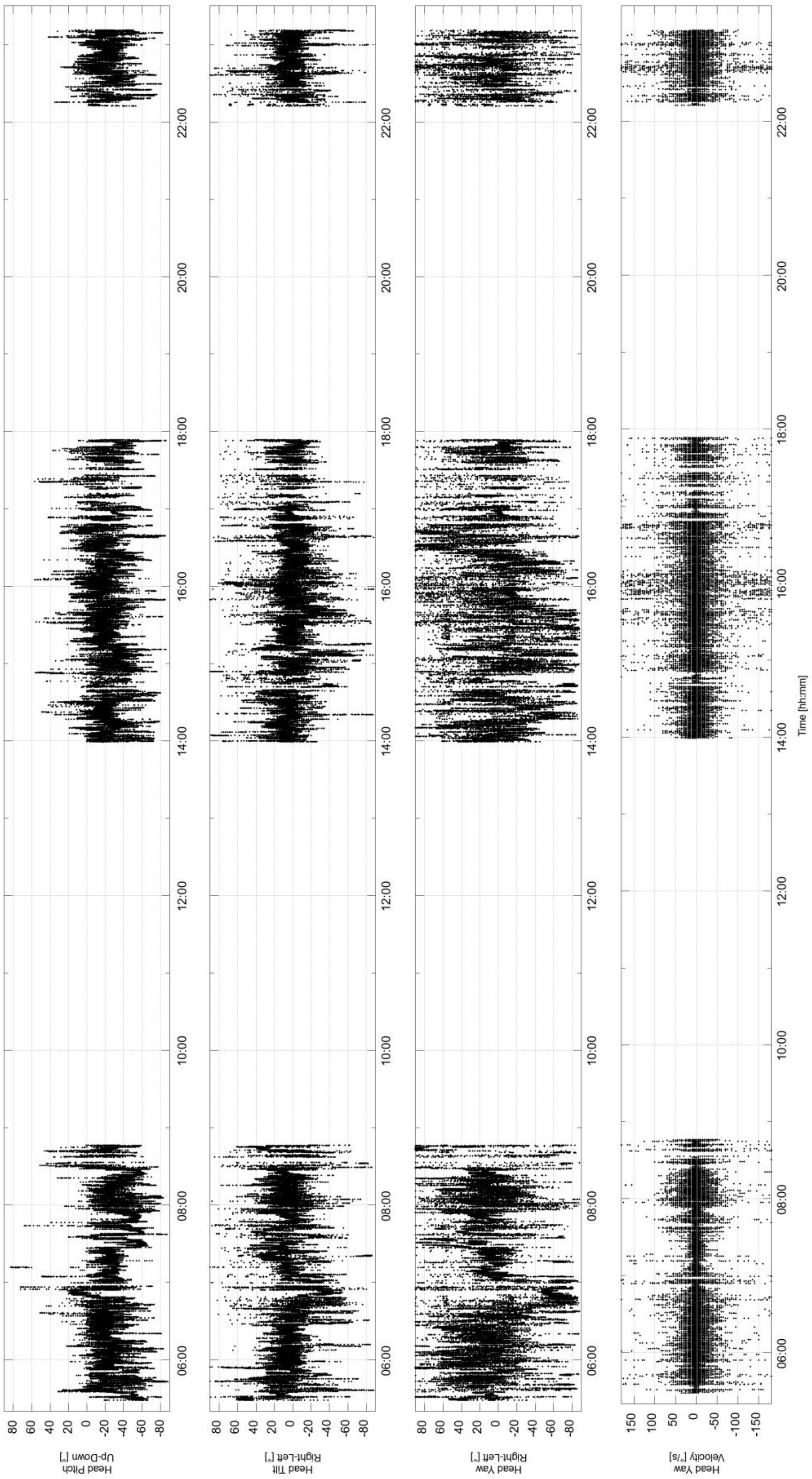

Neck
Right Eye
Right Hand
Left Hand
Velocity [m/s]
100
10
1
0,1
0,01
Time [hh:mm]
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00



Head Pitch
Up-Down [°]
Head Tilt
Right-Left [°]
Head Yaw
Right-Left [°]
Head Yaw
Velocity [°/s]
Time [hh:mm]

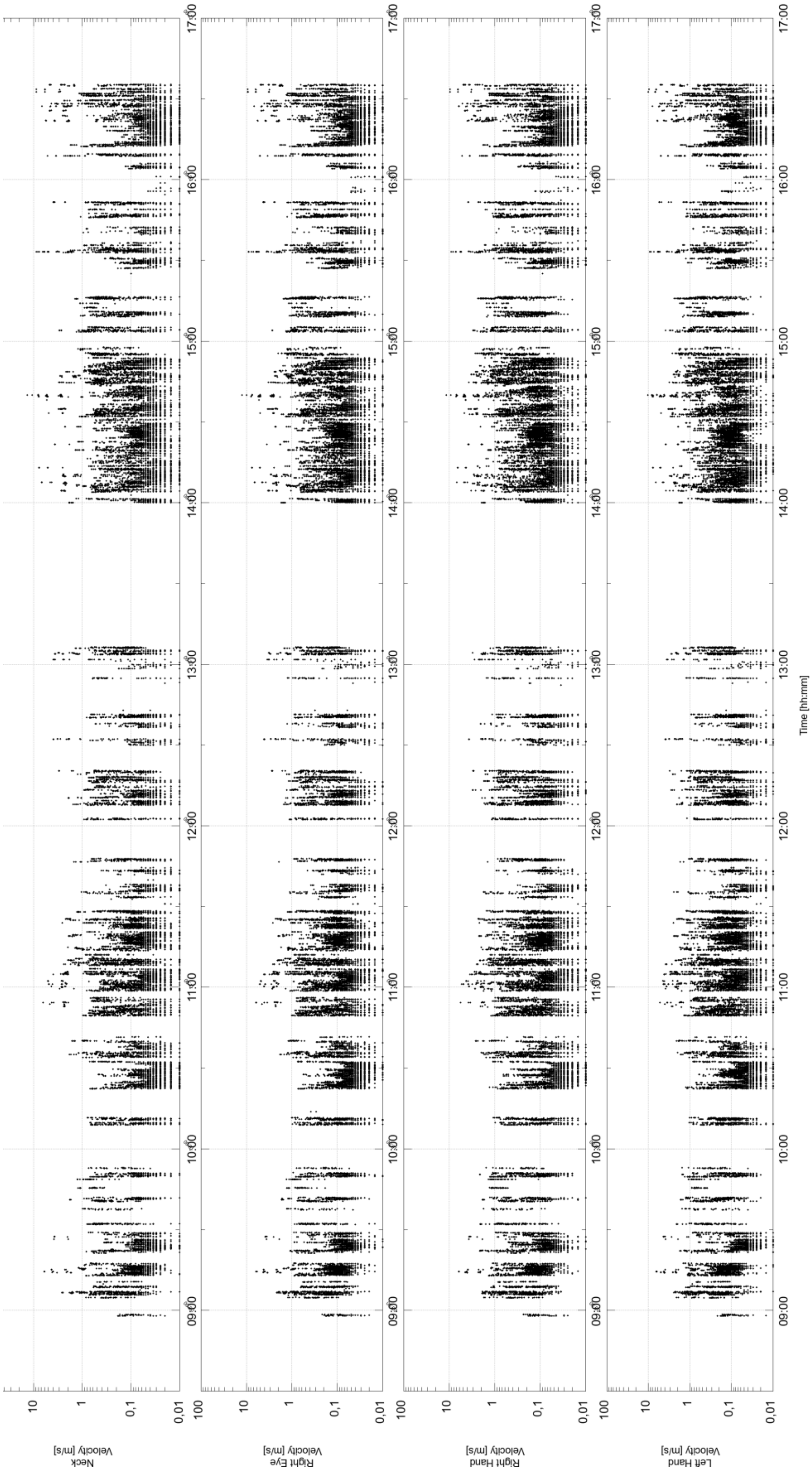
Day 7

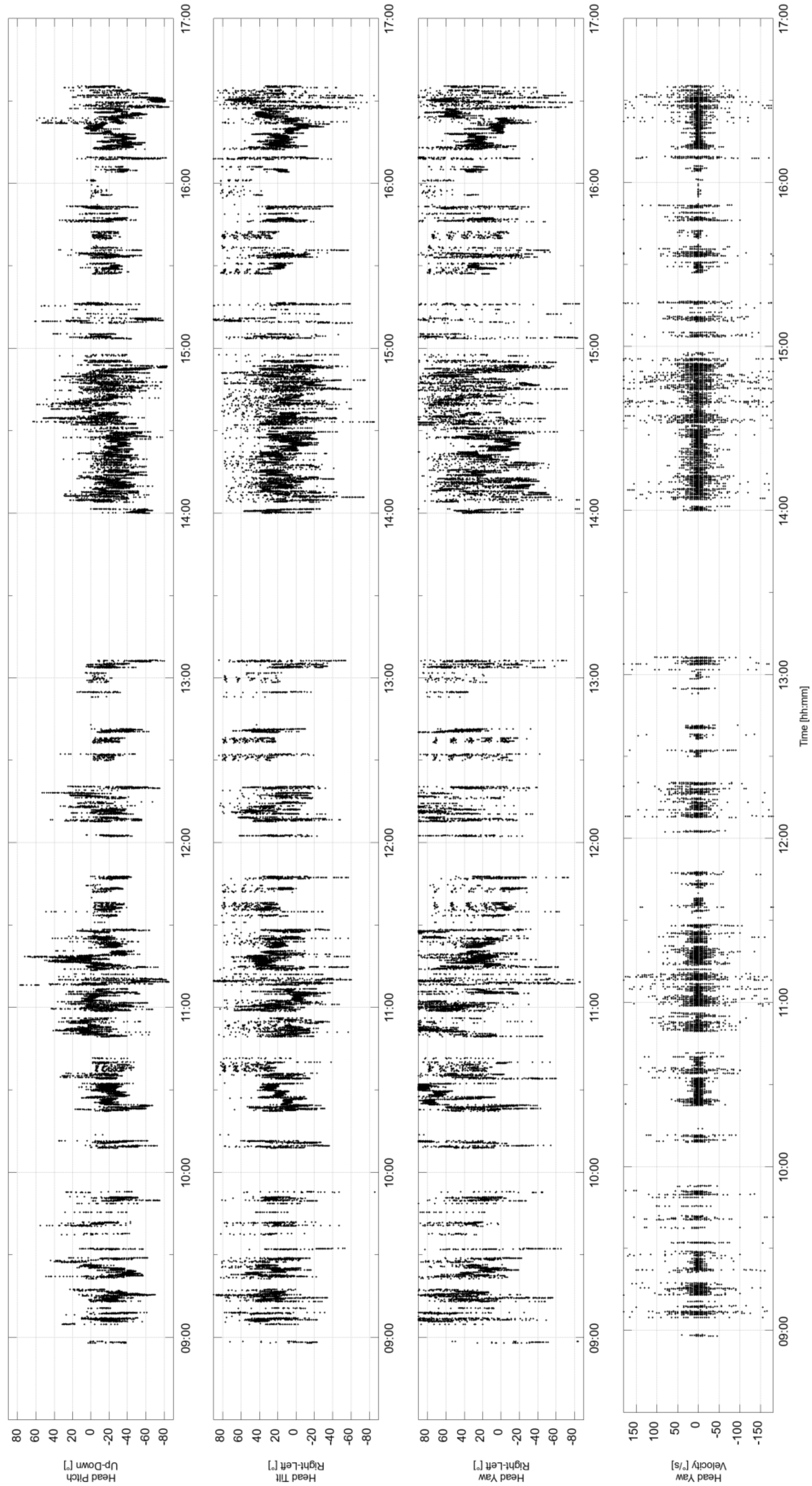

Neck
Right Eye
Right Hand
Left Hand
Velocity [m/s]
Time [hh:mm]
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
100
10
1
0,1
0,01



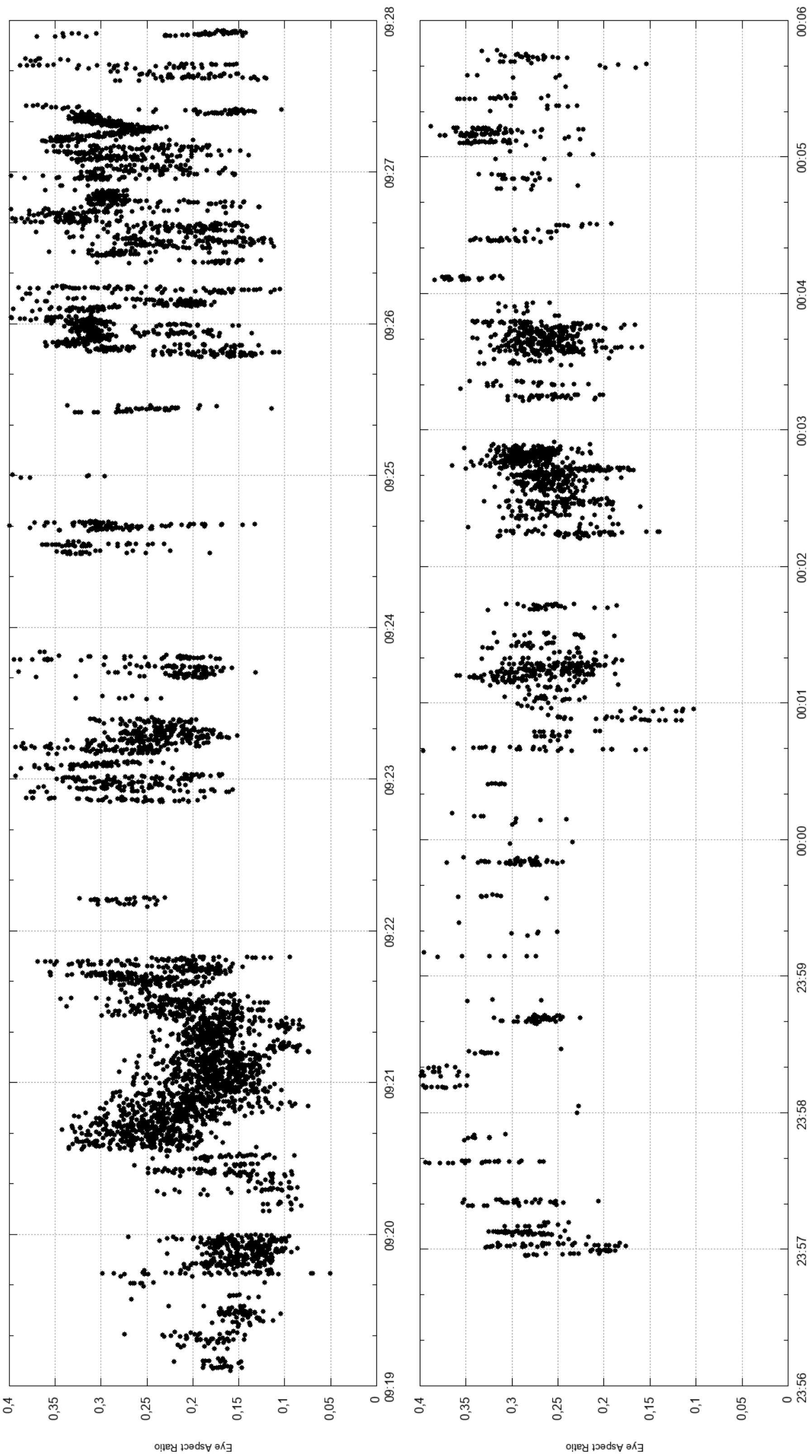
Head Pitch
Up-Down [°]
Head Tilt
Right-Left [°]
Head Yaw
Right-Left [°]
Head Yaw
Velocity [°/s]
Time [hh:mm]

Day 8

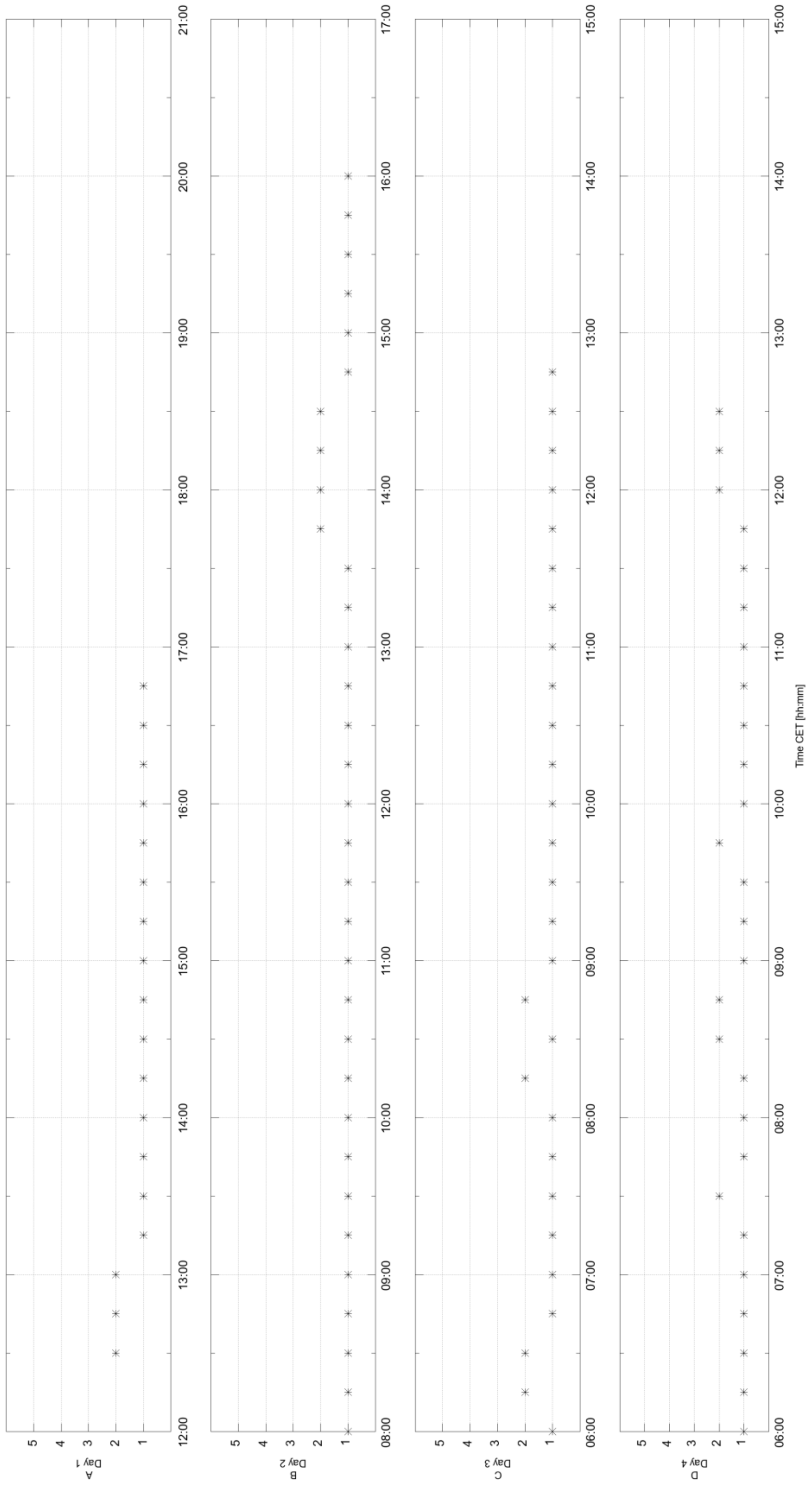

Time [hh:mm]
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
Neck
Velocity [m/s]
Right Eye
Velocity [m/s]
Right Hand
Velocity [m/s]
Left Hand
Velocity [m/s]
100
10
1
0,1
0,01

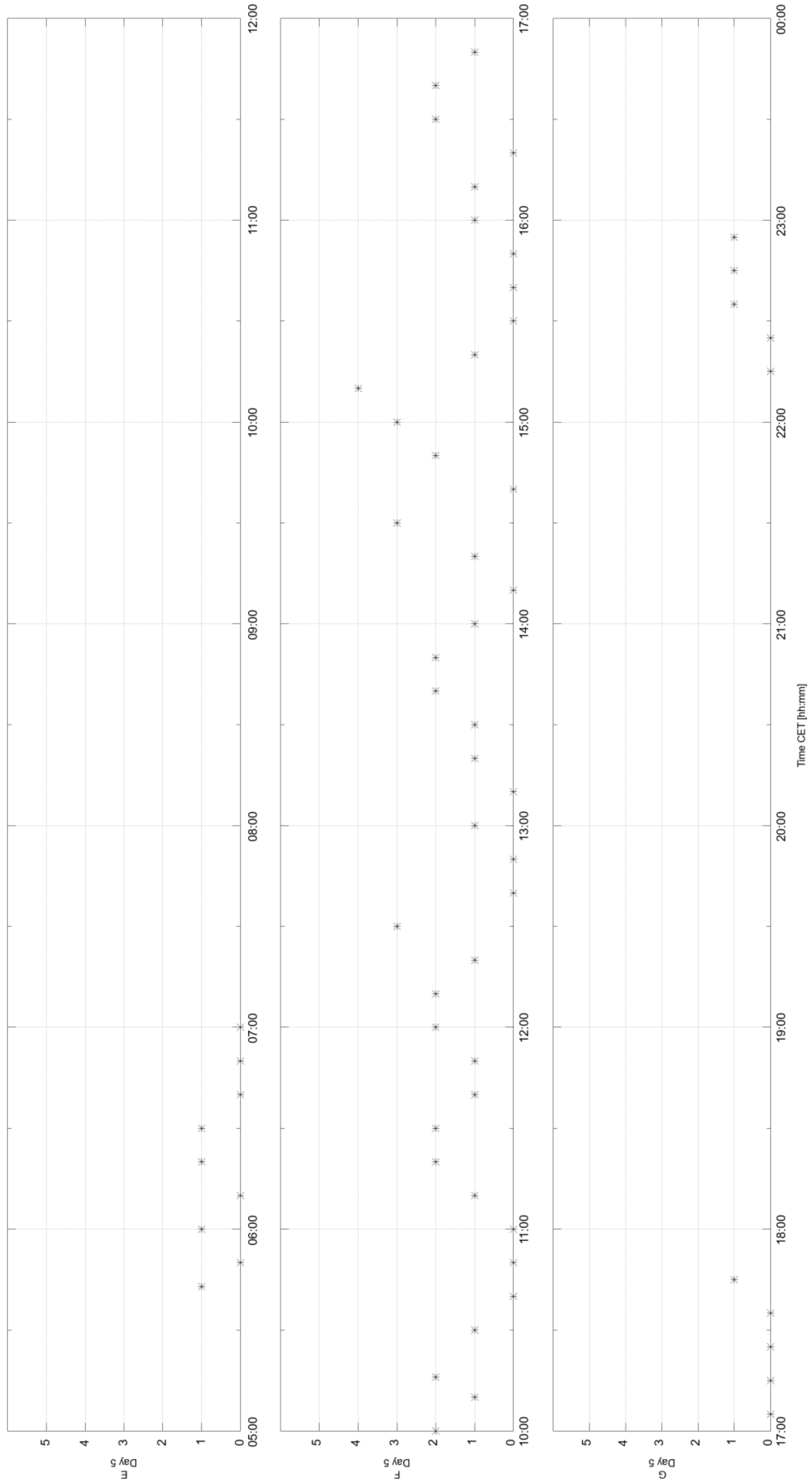

Head Pitch Up-Down [°]
Head Tilt Right-Left [°]
Head Yaw Right-Left [°]
Head Yaw Velocity [°/s]
Time [hh:mm]

ANNEX B : 2 EXAMPLES EYE ASPECT RATIO

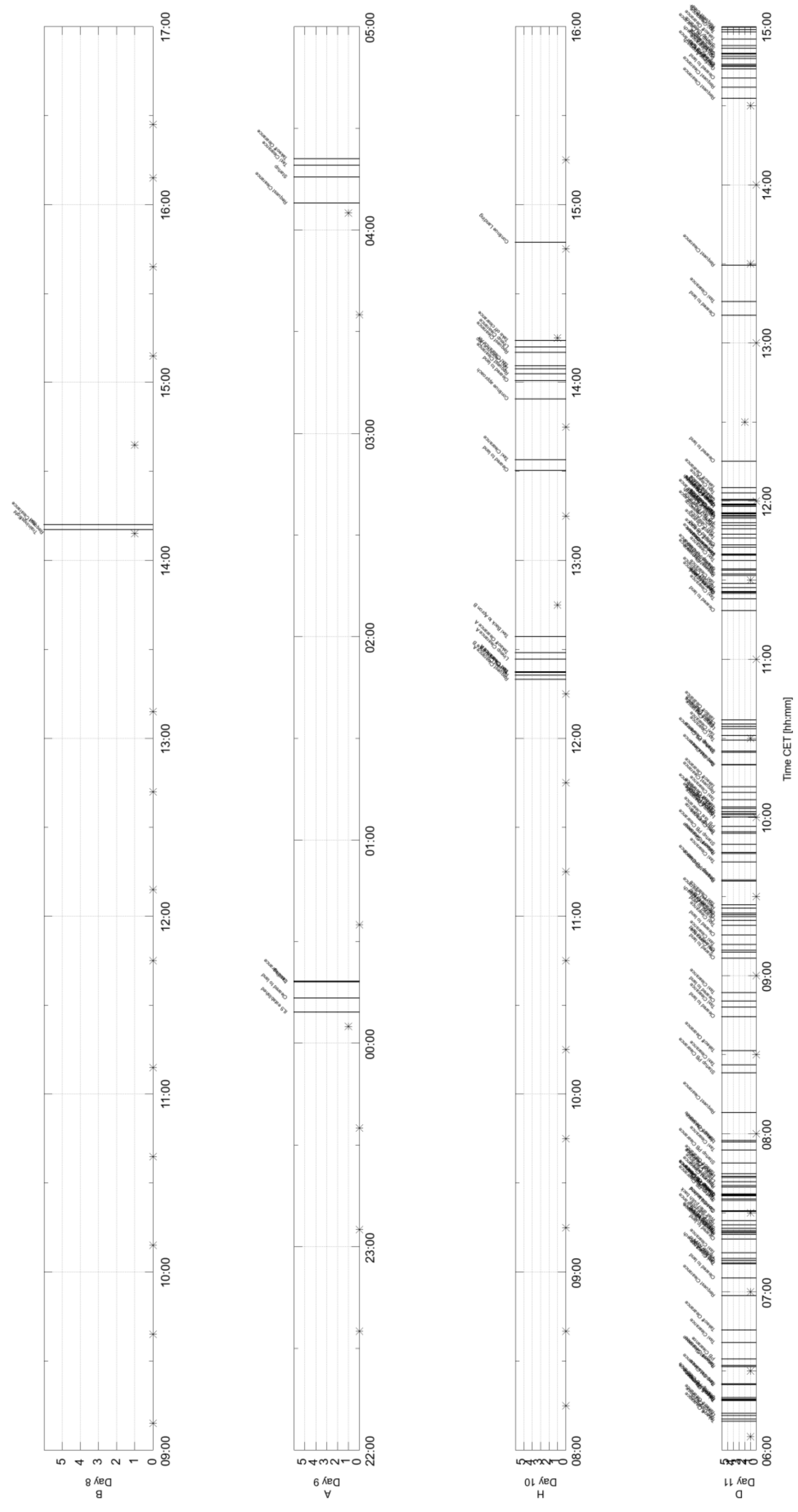


ANNEX C: ISA WORKLOAD





Day 5
E
F
G
Time CET [hh:mm]


Time CET [hh:mm]
Day 8
B
Day 9
A
Day 10
H
Day 11
D

ANNEX D: SAFETY RELEVANT EVENT MS AZURE KINECT BODY TRACKING