

Human Performance & Limitations - Module I — Rhythms & Resilience

Body Clock, Sleep & Mental Health

Chapter 24 — The rhythms that govern the aviator: the circadian body clock and its disruption by jet lag and night duty, the architecture of NREM and REM sleep, mental health and its disorders — and the master reference tables for the whole psychology syllabus.

BOOK

Human Performance & Limitations

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EXAM

DGCA CPL / ATPL — HPL

CHAPTER

24 of 26 · Module I

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Plate 24.0 — The body keeps its own clock. Fly against it — through night duty and time zones — and performance pays the debt.

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23. Body Rhythm Disturbance — The Circadian Cycle

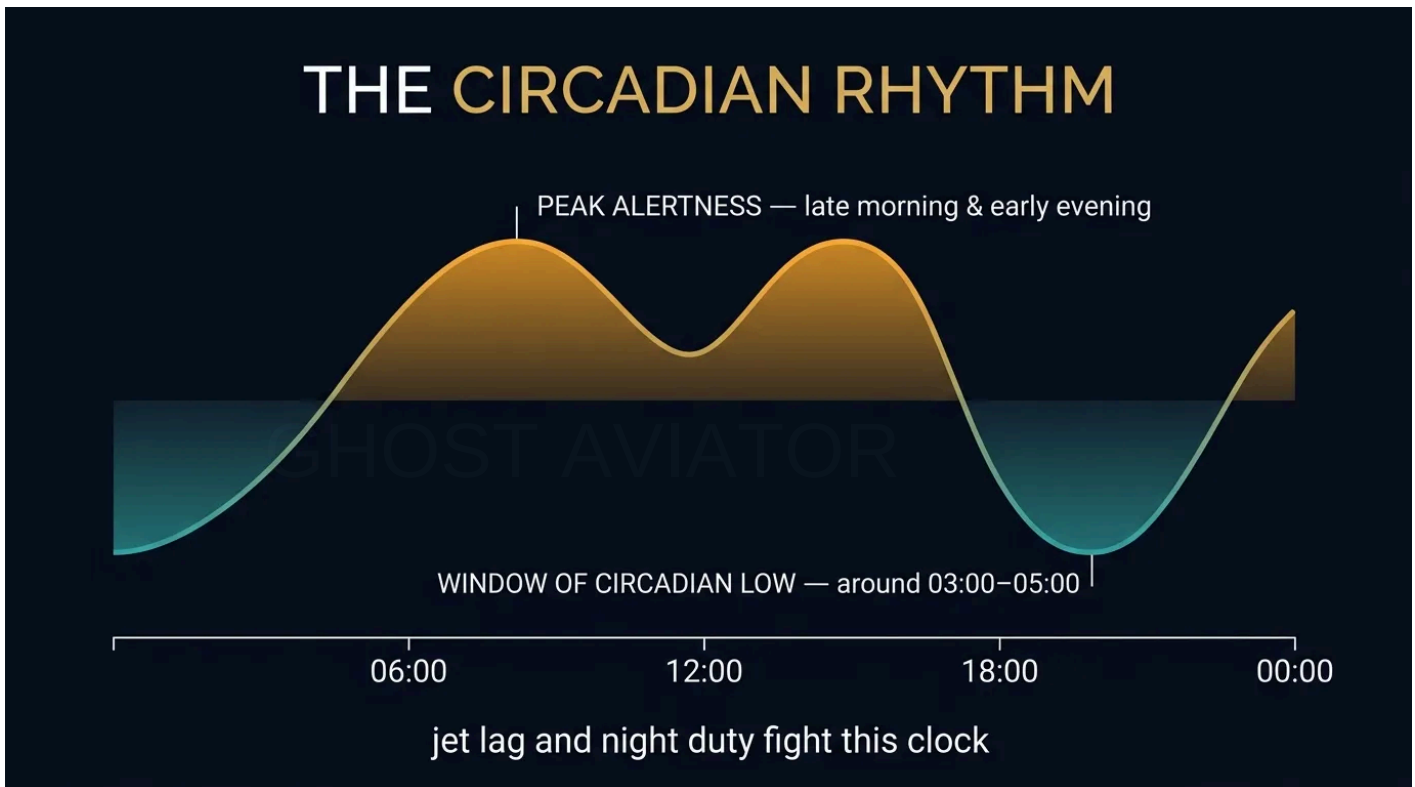


Figure 24.1 — The circadian rhythm: the body's ~24-hour clock of temperature and alertness, with the deep low in the small hours that jet lag and night duty disrupt.

WHAT THIS SECTION COVERS

The biological clock, the 24-hour vs 25-hour cycle, melatonin's role, jet-lag rules and re-synchronization rates.

23.1 Stimuli and Attention

Our bodies are continuously receiving stimuli through our **five senses**. This information is stored briefly in our sensory memory and, if we perceive it to be important, it is transferred to our short-term memory or Central Decision Maker. Some stimuli are better than others at getting our attention. We can split our attention between several different things by concentrating on them in rapid succession.

23.2 The Circadian Circle

The Circadian Circle represents our level of alertness throughout the day. Circadian rhythms are internally generated by a **self-sustaining (autonomous) biological clock** located in the **hypothalamus**, which functions as the main control centre for the autonomic nervous system by regulating sleep cycles, body temperature, appetite, etc., and acts as an endocrine gland by producing hormones. It takes into account biological elements such as **body temperature, heart rate and blood pressure** — which affect our level of alertness during the day.

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HAZARD — CIRCADIAN LOWS

Human performance degradation at circadian lows is one of the major challenges for the aviation industry.

23.3 24-Hour Circadian Reference

Time	Body Event
00:00	Midnight
02:00	Deepest sleep
04:30	Lowest body temperature
06:45	Sharpest rise in blood pressure
07:30	Melatonin secretion stops
08:30	Bowel movement likely
09:00	Highest testosterone secretion
10:00	High alertness
12:00	Noon
14:30	Best coordination
15:30	Fastest reaction time
17:00	Greatest cardiovascular efficiency and muscle strength
18:30	Highest blood pressure
19:00	Highest body temperature
21:00	Melatonin secretion starts
22:30	Bowel movements suppressed

As we sleep, our heart rate is lowered and hence our level of alertness is reduced. Blood pressure is also often lowered after mealtimes. **Human performance declines at night when the body and mind desire rest.**

23.4 Melatonin — "The Light of Night"

Melatonin is secreted from the **pineal gland** principally at night. The hormone is involved in **sleep regulation**, as well as in a number of other cyclical bodily activities and circadian rhythm in humans.

- Secretion increases soon after the onset of darkness.
- **Peaks in the middle of the night, between 2 and 4 a.m.**
- Gradually falls during the second half of the night.

This circadian rhythm of secretion plays an important role in its hormonal activity. Melatonin is exclusively involved in signalling the **'time of day' and 'time of year'** (hence considered to help both clock and calendar functions) to all tissues, and is thus considered to be the body's chronological pacemaker or **'Zeitgeber'**.

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23.5 Trans-Meridian Flight — Pilot Considerations

Factor	Value / Rule
Free-running circadian cycle (no time cues)	~ 25 hours
Cycle with normal time cues	~ 24 hours
Stop-over rule	If stop-over > 24 hours → move to new time as soon as possible
Crossing > 3–4 time zones with layover > 24 hours	Keep in swing with rhythm of the departure country for as long as possible; maintain regular living patterns
Re-synchronization rate	1 – 1.5 hours per day
Eastbound adaptation	~ 50 % slower than westbound; 1.5 days per time-zone east
Westbound adaptation	~ 1 day per time-zone
Difficulty	Readjustment after a time shift is normally more difficult with flights towards the East
Sleep duration	Governed primarily by the point within your circadian rhythm at which you try to sleep
Sensorimotor vs intellectual performance	Sensorimotor performance is better in the evening ; intellectual performance is better in the morning

Worked Example — Hyderabad → Berlin Layover Hyderabad (IST, UTC+5:30) to Berlin (CET, UTC+1) — a westbound trip of about 4.5 time zones with a **22-hour layover**.

- Layover < 24 hours → *do NOT shift to local time*. Stay on departure (IST) rhythm.
- Relevant time measure for your circadian rhythm: **IST (Indian Standard Time)**.

Reason: short layovers do not give the biological clock time to re-synchronize (only 1–1.5 hours/day shift is possible); attempting to shift will degrade alertness on the return leg.

EXAM TIP — EASTBOUND = WORSE

Eastbound travel adaptation is **50% slower** than westbound. East → 1.5 days per time-zone; West → 1 day per time-zone. "*Lose hours, lose sleep.*"

24. Sleep — NREM & REM

WHAT THIS SECTION COVERS

The two components of sleep, the four NREM stages, REM sleep timing and function, sleep inertia and the implications of sleep loss for pilots.

Sleep is basically divided into **two components**:

- **Rapid Eye Movement (REM) sleep**

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- **Non-Rapid Eye Movement (NREM) sleep**

Component	Purpose
NREM sleep	Body restoration — repair tissues, build bone and muscle, strengthen immune system
REM sleep	Brain restoration — strengthening, refreshing and organizing memory

NREM sleep is further divided into **four stages** from lightest to deepest. **Both types of sleep are required to recoup physical and mental energy.**

24.1 NREM Sleep Stages

Stage	Description	Duration
NREM Stage 1	Transition phase between wakefulness and sleep. Brain activity, eye movement and muscle activity become slower. A person is easily awakened. Waking up in this stage causes a person to feel that he/she has <i>not slept</i> .	10 minutes each time
NREM Stage 2	Light sleep — the first stage of true sleep. Occupies 50 % of the sleep patterns. Brain activity, eye movement become even slower; cardiac activity decreases.	10–25 minutes each time
NREM Stage 3	Beginning of deep sleep — slow-wave delta sleep. Brain activity and eye movement approaching zero. If awoken, the person may feel groggy and disoriented for a few minutes.	—
NREM Stage 4	Deep sleep — slow-wave delta sleep. No eye movement or muscle activity. If awoken, the person may feel groggy or disoriented for a few minutes.	—

24.2 REM Sleep (Paradoxical Sleep)

- Usually occurs 70–90 minutes into a sleep.
- Happens in cycles lasting for approximately 10 minutes initially to 1 hour.
- The eye moves rapidly from side to side and the brain wave form is similar to that when a person is awake.
- **Dreams occur.**

As we grow older, the time spent in REM sleep declines from 50 % of our sleep for infants, to 20 % of our sleep for adults.

24.3 Sleep Inertia

DEFINITION — SLEEP INERTIA

Refers to the transitional state between sleep and wake, marked by **impaired performance, reduced vigilance, and a desire to return to sleep.**

24.4 Key Points to Remember

SLEEP — CRITICAL FACTS

- The effects of sleep deprivation on performance **increase with altitude and with higher workload**.
- During paradoxical sleep rapid eye movements can be observed.
- The duration of a period of sleep is governed primarily by the point within your circadian rhythm at which you try to sleep.
- **Deep sleep allows for physical recovery and the reconstitution of neuron energy reserves.**
- Lack of sleep increases fatigue, concentration and attention. It has risks of **sensory illusions and mood disorders**. Disruption of sleeping patterns can lead to symptoms of drowsiness, irritability and lack of concentration — making an individual more prone to make errors.
- A person experiencing sleep loss is **unlikely to be aware** of personal performance degradation.
- Performance loss may be present up to 20 minutes after awaking from a short sleep (nap).
- The sleep cycles repeat during the course of a night's sleep. Each succeeding cycle contains a greater amount of REM sleep. **Frequent interruption of the REM sleep can harm a human being in the long run.** REM sleep is more important for the regeneration of mental and physical functions than all the other sleep stages are.

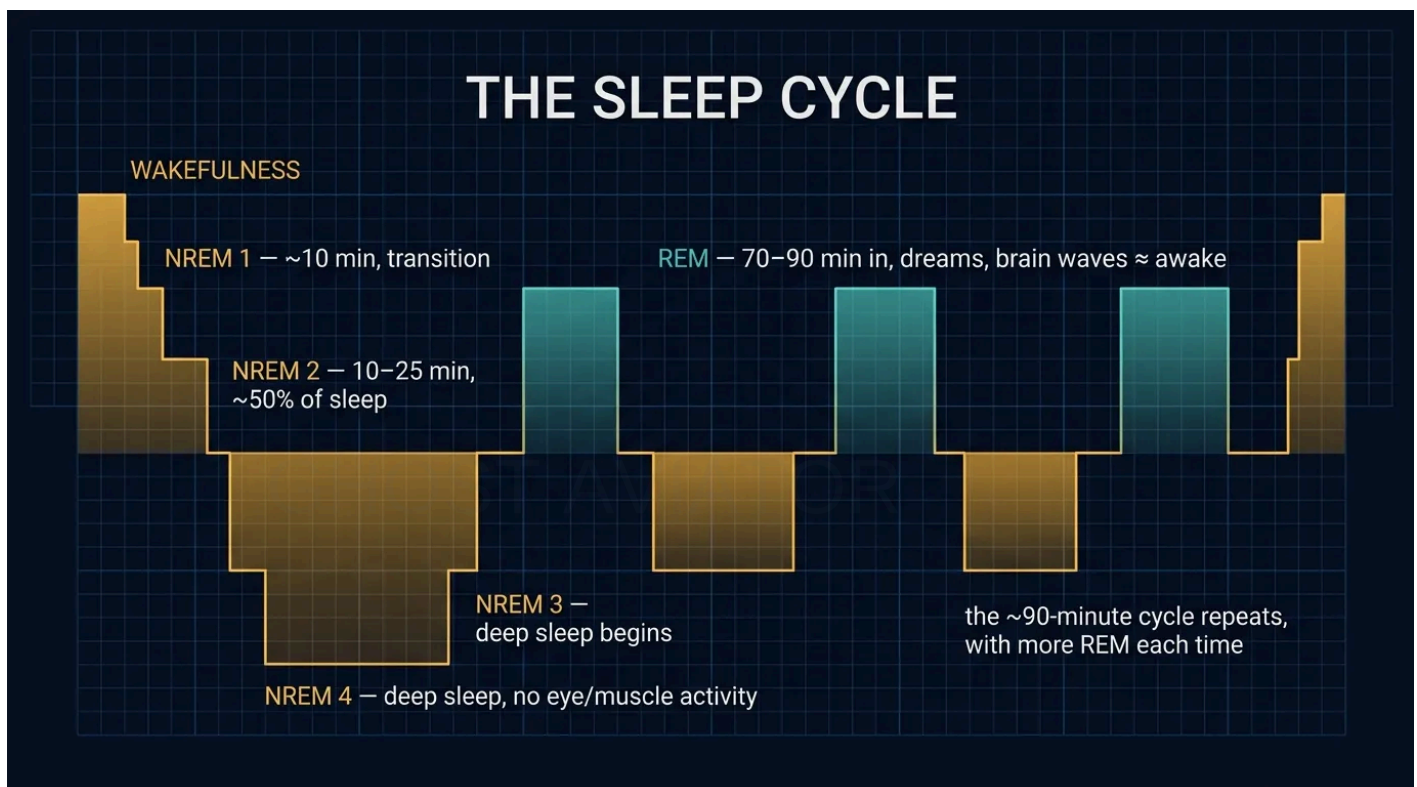


Figure 24.2 — The sleep cycle: wakefulness into NREM stages 1–3 and then REM, repeating roughly every 90 minutes through the night.

25. Mental Health Problems & Disorders

WHAT THIS SECTION COVERS

The risk of mental health problems among aviation personnel, the Germanwings 9525 case study, and where preventive efforts should focus.

Mental health problems and disorders among pilots, ATCOs, maintenance and other personnel in aviation may impair performance and therefore be a **threat to flight safety**.

25.1 Case Study — Germanwings Flight 9525

GERMANWINGS 9525 — 24 MARCH 2015

- **Route:** Barcelona–El Prat Airport (Spain) to Düsseldorf Airport (Germany).
- **Aircraft:** Airbus A320.
- **Date:** 24 March 2015.
- **Crash location:** 100 km north-west of Nice in the French Alps.
- **Casualties:** All 144 passengers and all 6 crew members were killed.
- **Cause:** The crash was deliberately caused by the co-pilot, Andreas Lubitz, who had previously been treated for suicidal tendencies and declared unfit to work by his doctor. Lubitz kept this information from his employer and instead reported for duty. Shortly after reaching cruise altitude and while the captain was out of the cockpit, Lubitz locked the cockpit door and initiated a controlled descent that continued until the aircraft hit a mountainside.

25.2 Why Pilots May Not Report Mental Health

There may be many reasons why a pilot may be reluctant to discuss mental health problems with the examining physician during the annual medical assessment, including **fear of losing his or her licence** with both personal and financial costs as a result. This may prevent the pilot from receiving adequate and timely help, and this could potentially make the problems worse and prolong the time for recovery.

BEST PRACTICE — REDUCING STIGMA

More could probably be done to increase knowledge about mental health problems and reduce stigma so that more pilots and other professionals working in aviation report mental health problems, get treatment, and return to work. This would probably increase individual well-being, but also **promote safety**.

25.3 Where to Focus Preventive Efforts

Serious mental health disorders (e.g. *psychosis*) are relatively rare and their onset is difficult to predict. **Preventive efforts should be aimed at more common mental health problems such as:**

- **Depression**
- **Anxiety**
- **Substance misuse**

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| Master Reference Tables & Mnemonics

PURPOSE

Every numerical value and key rule from the chapter consolidated for quick exam-night revision.

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M-1. Master Numerical Reference

Topic	Value	Section
Iconic memory duration	0.5 – 1 second	5
Visual channel share of information processing	70 – 80 %	5
Short-term memory duration	10 – 20 seconds	12
Short-term memory capacity	7 ± 2 items	12
Long-term memory capacity	Unlimited (retrieval may fail)	12
Acceptable workload (crew resources)	~ 60 %	11
Human error rate – simple/repetitive	1 in 100	11
Human error rate – after practice	1 in 1,000	11
Startle reflex – motor task recovery	5 – 10 seconds	10
Age-related response slowing	20 – 60 years	14
Anthropometric design population	Central 90 % (disregard 5% lowest & 5% highest)	20
Free-running circadian cycle	~ 25 hours	23
Cued circadian cycle	~ 24 hours	23
Circadian re-sync rate	1 – 1.5 hours/day	23
Eastbound adaptation	~ 1.5 days/time-zone (50% slower than west)	23
Westbound adaptation	~ 1 day/time-zone	23
Stop-over threshold for adjusting to local time	> 24 hours	23
Lowest body temperature time	04:30	23
Highest body temperature time	19:00	23
Melatonin peak	02:00 – 04:00	23
Melatonin secretion starts	21:00	23
Melatonin secretion stops	07:30	23
NREM Stage 1 duration	10 minutes	24
NREM Stage 2 duration / share	10–25 min / 50 % of sleep	24
REM onset after sleep start	70 – 90 minutes	24
REM cycle duration	10 min → up to 1 hour	24
REM share – infant vs adult	50 % vs 20 %	24

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Post-nap performance loss	Up to 20 minutes	24
Life stress scoring – free / normal / high / serious	<60 / 60–80 / 80–100 / >100	22
Germanwings 9525 — date	24 March 2015	25
Germanwings 9525 — crash distance	100 km NW of Nice	25
Germanwings 9525 — casualties	144 pax + 6 crew	25
Cockpit restraint	5-point harness with negative-G strap	20

M-2. Mnemonics & Memory Aids

Concept	Mnemonic
Aviation Psychology aims	D-P-U-I → Describe, Predict, Understand, Influence
Information-processing stages	D-P-D-A-F → Detection, Perception, Decision, Action, Feedback
Workload drivers	DPST → Difficulty, Parallel, Series, Time
Anderson model phases	C-A-A → Cognitive, Associative, Automatic
STM expansion tools	"Chunk & Chain" → Chunking + Association
Long-term memory types	S-E-P → Semantic, Episodic, Procedural
SA-killers	SBF-EPI → Stress, Boredom, Fatigue, Emotional, Poor comm., Interruptions
Decision-making seven steps	R-C-A-D-S-E-F → Recognize, Consider, Analyze, Develop, Select, Execute, Follow-up
Communication barriers	4-A + 2-I-R → Aggressiveness, Arrogance, Anti-authoritarian, (im)Pulsiveness, Invulnerability, Resignation
Human-centred automation qualities	"A-SPA-CFDIE²" → Accountable, Subordinate, Predictable, Adaptable, Comprehensible, Flexible, Dependable, Informative, Error-resistant, Error-tolerant
Control design principles	S-F-S-I-V-S-S-W → Standardization, Frequency, Sequence, Importance, Visual-tactile, Symbolism, Simultaneous, Warnings
Stress observables	"P-FISH-DP-FB" → Perspiration, Flushed Skin, Dilated Pupils, Fast Breathing
Sleep stages	1-2-3-4-R → NREM 1 (transition) → 2 (light, 50%) → 3 (onset deep) → 4 (deep) → REM (dreams)
Jet-lag rule	"East is Least, West is Best" → East 50% slower; 1.5 d/zone east vs 1 d/zone west
Mental health priority targets	D-A-S → Depression, Anxiety, Substance misuse

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M-3. Quick Definitions Recall Sheet

Term	One-Line Definition
Aviation Psychology	Applied psychology focused on human behaviour in aviation systems.
Workload	Mental effort needed to process information.
Perception	Conversion of sensory information into a meaningful structure.
Selective Attention	Continual sampling of inputs to judge relevance.
Divided Attention	Time-sharing of central decision channel between tasks.
Vigilance	Capability of remaining alert above a threshold for a period.
Complacency	Self-satisfaction with one's performance + unawareness of danger.
Motor Programme	Behavioural sub-routine learnt by practice and held in LTM.
Reaction Time	Delay between detection, stimulus and muscle contraction.
Startle Reflex	Reflex-like blink + body jerk to abrupt stimulus.
Human Reliability	Individual functioning in the manner he/she is supposed to.
Hallucination	False perception characterised by distortion of real sensory stimuli.
Cognition	Mental process of acquiring knowledge by reasoning, intuition or perception.
Risk Assessment	Probability of risk $\times$ Impact if it occurs.
Situational Awareness	Accurate appraisal of self, environment and own performance.
Automation	Controlling apparatus/process by electronic/mechanical devices replacing the human organism.
Anthropometry	Study of human measurement (static, dynamic, contour-surface).
Eye Datum	Defined eye position around which the cockpit is designed.
Trait Anxiety	Personality trait of high neuroticism (persistent worry).
State Anxiety	Transient anxiety present in anyone at any time.
Arousal	Person's readiness to respond effectively to a stress factor.
Fatigue	Deep tiredness from cumulative stressful lifestyle/environment.
Zeitgeber	Body's chronological pacemaker — melatonin signals time of day/year.
Sleep Inertia	Transitional state between sleep and wake with impaired performance.

M-4. Risk Formula

Risk Assessment Formula $\text{Risk} = \text{Probability of Occurrence} \times \text{Impact if it Occurs}$

Variables:

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- **Probability** — likelihood the hazard manifests (low / medium / high).
- **Impact** — severity of consequence (minor / major / catastrophic).

Worked example — Marginal weather decision:

Probability of icing on route = High (forecast supports it).

Impact if encountered without anti-ice = Catastrophic.

→ Risk = High × Catastrophic = **Unacceptable**. Decision: **Don't fly**, or re-route below freezing level / with active anti-ice.

M-5. Final Quick-Revision Summary Box

EXAM-NIGHT ONE-PAGE RECAP

Memory: Iconic 0.5–1 s · STM 10–20 s, 7 ± 2 · LTM unlimited.

Workload: Acceptable $\approx 60\%$ · DPST drivers · symptoms = funneling, regression, mental blocking, panic.

Error rate: 1/100 raw → 1/1,000 after practice. Errors are cumulative.

Startle: Motor task back to normal in 5–10 s. Fear potentiates.

Anderson Skill: Cognitive → Associative → Automatic.

Anthropometry: central 90 %, discard top & bottom 5 %.

Restraint: 5-point harness + negative-G strap.

Display rule: Digital for quantitative · Analogue for qualitative. Standardization is the #1 design rule.

Three-pointer altimeter: more misreads than single-pointer.

Stress observables: perspiration, flushed skin, dilated pupils, fast breathing.

Life stress: <60 free · 60–80 normal · 80–100 high · >100 serious. Spouse death = 100.

Circadian: Free-running 25 h · cued 24 h · Lowest body temp 04:30 · Highest 19:00 · Melatonin peak 02–04 · Zeitgeber = Melatonin (pineal gland).

Jet-lag: 1–1.5 h/day re-sync · East 1.5 d/zone (50% slower) · West 1 d/zone · >24 h stopover → shift; <24 h → stay on departure rhythm.

Sleep: NREM 1 = 10 min · NREM 2 = 10–25 min, 50% · REM at 70–90 min · REM 50% infant → 20% adult · Post-nap loss up to 20 min.

Mental health priority: Depression, Anxiety, Substance misuse. Germanwings 9525 (24 Mar 2015, A320, 100 km NW Nice, 144 pax + 6 crew).

Communication barriers: Aggressiveness, Arrogance, Anti-authoritarian, Impulsiveness, Invulnerability, Resignation.

Murphy's Law: if it can be operated wrongly, sooner or later it will be.

Golden Maxim: A superior pilot uses his superior judgment to avoid situations that would require his superior skills.

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