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1. Crew Resource Management (CRM) — Introduction & Applicability

What this section covers

The definition and purpose of CRM, the cognitive vs interpersonal skill distinction, why CRM applies even to single-pilot operations, the link to the Tenerife disaster (1977), and the ICAO Standard compliance requirement.

1.1 Definition of CRM

Definition — CRM

CRM is the **effective use of all available resources** for flight crew personnel to assure a safe and efficient operation, **reducing error, avoiding stress, and increasing efficiency**.

CRM is concerned *not* with technical knowledge and stick-and-rudder skills, but with the **cognitive and interpersonal skills** needed to manage a flight within an organized aviation system.

Skill Type	Definition (per source)
Cognitive skills	Mental processes used for gaining and maintaining <i>situational awareness</i> , for <i>solving problems</i> and for <i>taking decisions</i> .
Interpersonal skills	Communications and a range of behavioural activities associated with <i>teamwork</i> .

Exam Tip — Overlap Rule

These skill areas **often overlap with each other AND with the required technical skills**. CRM is **not confined to multi-crew aircraft** — it also relates to **single-pilot operations**, which invariably interface with other aircraft and ground support agencies.

1.2 Applicability of CRM — Human Factors Framework

CRM is an **application of Human Factors (HF)** to the flight crew domain. The term "Human Factors" includes CRM along with other aspects of human performance.

Working Definition

CRM is the utilization of all resources available to the crew to manage human error. The objective of CRM training is to **contribute to incident and accident prevention.**

CRM is one practical application of Human Factors training — concerned with supporting **crew responses to threats and errors** that manifest in the operating environment.

✓ SOP — Training Weight

The requirement to develop human-performance knowledge and skills among flight crew members and other operational personnel has the **same weight** as that related to systems, normal, abnormal, and emergency procedures. Most operators comply mainly through **CRM Training** and **LOFT**.

1.3 Historical Origin — The Tenerife Catalyst

It took one of history's worst crashes — the **Tenerife disaster of 1977** — to raise CRM from a mostly unpracticed principle to a full-fledged program. It became apparent that pilots needed to learn more about how best to manage all the resources available to them in the cockpit, including:

- Other crew members
- Procedures
- The machine interface
- Themselves

1.4 Regulatory Status

⊘ ICAO Compliance Warning

CRM is now considered **essential training** for most aviation professionals who make an operational contribution — including **air traffic controllers and engineers**. **Non-compliance with the requirement to provide human-performance training would mean non-compliance with an ICAO international Standard.**

```

graph LR
    A[A[Aviation System]] --> B[B[Human Factors HF]]
    B --> C[C[CRM Training]]
    B --> D[D[Other HF Aspects]]
    C --> E[E[Error Avoidance]]
    C --> F[F[Threat Management]]
    C --> G[G[Error Management]]
    C --> H[H[Undesired A/C State Mgmt]]
    E --> I[I((Accident/Incident Prevention))]
    F --> I
    G --> I
    H --> I

```

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style C fill:#fff8e1,stroke:#f57c00,stroke-width:2px

Quick Revision Summary — Section 1

- **CRM = Effective use of ALL resources** → reduce error, avoid stress, increase efficiency.
- Focus on **cognitive + interpersonal skills**, not stick-and-rudder.
- Applies to **single-pilot operations too**.
- Driver event: **Tenerife 1977**.
- Mandatory for compliance with an **ICAO Standard**.
- Aim: **contribute to incident and accident prevention**.

2. A Conceptual Model of Human Factors — The ICAO SHEL Model

What this section covers

The SHEL model's origin (**Edwards, 1972**), its ICAO basis (**Doc 9859, Circular 216-AN31**), the four components (S–H–E–L), the four interfaces, why Liveware is the hub, and why mismatches matter.

2.1 Purpose of the SHEL Model

The SHEL model is a conceptual model of Human Factors that:

- Clarifies the **scope** of aviation human factors.
- Assists in understanding the relationships between the **flying subsystem** (system resources/environment) and the **human subsystem**.
- Provides a conceptual framework illustrating the various constituents and their **interfaces — the points of interaction**.

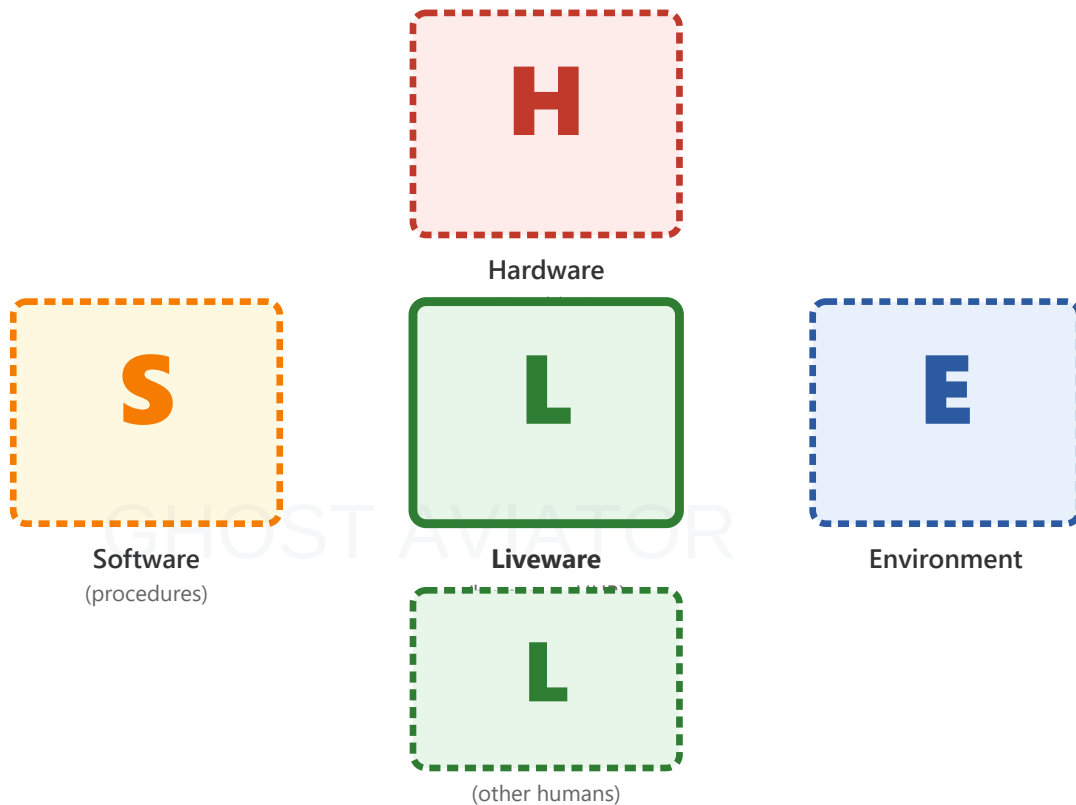
2.2 ICAO Reference — Source Authority

Reference	Detail
ICAO Source Document	ICAO Doc 9859 — Safety Management Manual (SMM)
Earlier Framework Reference	ICAO Circular 216-AN31
Original Developer	Edwards — 1972
Source Disciplines	Psychology · Engineering · Physiology · Anthropometry

2.3 The Four SHEL Components

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ICAO SHELL MODEL — Liveware at the Hub



Letter	Stands For	Source-Verbatim Description
S	Software	Procedures, manuals, checklist layouts, documents, symbology, computer programmes, maps and charts.
H	Hardware	Design of flight decks, physical structure of the aircraft, presentation of instruments, positioning and operating sense of controls, machinery, equipment, etc.
E	Environment	Both internal and external to the workplace.
L	Liveware (1st)	Man — the most critical, valuable and flexible component of the system.
L	Liveware (2nd)	Other humans in contact with the pilot.

Memory Aid — SHELL (with second L)

Think "**S-H-E-L-L**": Software → Hardware → Environment → Liveware (you) → Liveware (others).

Join live classes for guided practice and doubt clearing.

2.4 The Four Interfaces

Interactions between human beings and other SHEL elements are at the heart of Human Factors. The interfaces are:

Interface	Pairing	Examples (operational)
L-H	Humans & Machines	Cockpit layout, controls, displays, instruments, congested cockpit, eye reference position
L-S	Humans & Materials	Checklists, manuals, SOPs, NOTAMs, automation, computer software, warning logic/symbology
L-L	Humans & Colleagues	Crew co-ordination, briefings, communication (incl. noise interference), worker-management
L-E	Humans & Operating Environment	Weather, time of day, circadian rhythm/jet lag, illumination, vibration, aerodrome facilities

2.5 Liveware as the Hub — Why the Match Matters

Core SHEL Principle

The Liveware (human element) is the HUB of the SHEL model. The remaining components must be **adapted and matched** to this central component.

Mismatch = Source of Human Error

In this model the **match or mismatch** of the blocks (the interface) is **just as important as the characteristics of the blocks themselves**. A mismatch can be a source of human error **leading to an accident or an incident**.

Humans suffer considerable performance variation and many limitations — most of which are now predictable. The Liveware must be carefully matched to other components to **avoid stress in the system and eventual breakdown**.

Quick Revision Summary — Section 2

- **SHEL** = Software, Hardware, Environment, Liveware (+ second Liveware).
- Developed by **Edwards, 1972**; described in **ICAO Doc 9859** and Circular **216-AN31**.
- Four interfaces: **L-H, L-S, L-L, L-E**.
- **Liveware is the HUB** → all other components must adapt to humans.
- **Mismatch at any interface = source of human error.**

3. Factors Relating to the Individual (Liveware)

What this section covers

The four factor categories that shape pilot performance — **Physical, Physiological, Psychological, Psychosocial** — and every sub-element listed in the DGCA source. Source notes the **physiological and psychosocial factors are more pronounced** in effect.

Many factors influence aviation personnel: **Physical, Physiological, Psychological, Psychosocial**. However, the effect of **physiological and psychosocial** factors is more pronounced.

```

flowchart TB
    A[Liveware  
Individual Factors] --> B[1. Physical]
    A --> C[2. Physiological]
    A --> D[3. Psychological]
    A --> E[4. Psychosocial]
    B --> B1[Anthropometry &  
Sensory limits]
    C --> C1[Body state:  
nutrition, fatigue,  
drugs, illusions]
    D --> D1[Mind state:  
perception, attention,  
workload, personality]
    E --> E1[Social pressures:  
family, finance,  
conflict]

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    style C fill:#fff8e1,stroke:#f57c00,stroke-width:2px
    style E fill:#fff8e1,stroke:#f57c00,stroke-width:2px

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3.1 Physical Factors

Anthropometric attributes: Height, weight, age, sex, build, sitting height, functional reach, leg length, shoulder width, strength, co-ordination.

Sensory Limitations — Vision

- Visual threshold
- Visual acuity (seeing details)
- Focus time, light adaptation
- Peripheral vision, speed, depth perception
- Empty field myopia
- Glasses, contacts
- Auditory threshold, understanding
- Vestibular (ear senses), smell, touch, kinesthetic (body feelings)
- G-tolerances

3.2 Physiological Factors

Sub-Factor	Source-Verbatim Elements
Nutritional	Food intake 24 hours , hours since last meal, dehydration, on a diet / weight loss.
Health	Disease, fitness, pain, dental conditions, blood donation, obesity, pregnancy, stress coping (emotional/behavioural signs), smoker.
Lifestyle	Friendships, relations with others, change in activities, life habits.
Fatigue	Acute (short term), chronic (long term), skill (due to task), activity level (mental/physical).
Duty	Duration of flight, duty hours, leave periods, activities.
Sleep	Crew rest, nap duration, sleep deficit, disruption, circadian dysrhythmia (jet lag) .
Drugs	Medication over the counter, medication prescription, illicit drugs, cigarettes, coffee, others.
Alcohol	Impairment, hangover, addiction.
Incapacitation	Carbon monoxide poisoning, hypoxia/anoxia, hyperventilation, loss of consciousness, motion sickness, food poisoning, nauseating fumes, toxic fumes.
Decompression / Diving	Decompression, trapped gas effects, underwater diving.

Physiological Illusions

Type	Examples (verbatim)
Vestibular	Somatogyral (vertigo), somatogravic, the leans, Coriolis illusion, elevator illusion, giant hand.
Visual	Black hole, autokinesis, horizontal misplacement, circularvection, linearvection, landing illusions, chain-link fence illusion, flicker vertigo, geometric perspective illusion.

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🚫 Self-Medication Prohibition

Over-the-counter (OTC) medicines from a chemist **are NOT permitted** for a pilot before flight. Even OTC items from an aircraft first-aid box **must NOT** be taken to fly. **All medication must be prescribed by an aviation medicine specialist, whose advice on fitness to fly is binding.**

3.3 Psychological Factors

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Sub-Factor	Elements (source)
Perceptions	Types: Non-perception, misperception, delayed perception.
Reaction Time	To detect → to make an appropriate decision → to take the appropriate action.
Disorientation	Situational awareness, spatial, visual, temporal, geographic (lost).
Attention	Attention span, inattention (general/selective), distraction (internal/external), channelized attention, fascination, fixation, vigilance, boredom, monotony, habit pattern interference/substitution, time distortion.
Information Processing	Mental capacity, decision making (delayed/poor), judgment (delayed/poor), memory capacity, forgetting, co-ordination — timing.
Workload	Task saturation, underload , prioritization, task components.
Experience / Recency	In position, in aircraft type, total time, on instruments, on route, aerodrome, night time, emergency procedures.
Knowledge	Competence, skills/techniques, airmanship, procedures.
Training	Initial, on-the-job, ground, flight, transition, learning transfer, recurrent, problem areas, emergency procedures.
Planning	Pre-flight, in-flight.
Attitudes / Moods	Mood, motivation, habituation, attitude, boredom, complacency.
Expectations	Mind set / expectancy, false hypothesis, "get-home-itis", risk-taking.
Confidence	In aircraft, equipment, self; overconfidence, showing off.
Mental / Emotional State	Emotional state, anxiety, apprehension, panic, arousal level / reactions, self-induced mental pressure / stress.
Personality	Withdrawn, grouchy, inflexible, hostile, sarcastic, negative, aggressive, assertive, impulsive, excitable, careless, immature, risk-taker, insecure, follower, disorganized, late, messy, anti-authoritative, resigned, invulnerable, "macho".

High Arousal Overload — Attention Narrowing

Under **high arousal / cognitive overload**, attention does **NOT** sharpen — there is a **real danger of attention becoming narrowed** (channelized attention, fixation). Optimum arousal applies to *moderate* difficulty tasks; for highly difficult cognitive tasks the optimum arousal is *lower*.

3.4 Psychosocial Factors

- Mental pressure
- Interpersonal conflict
- Personal loss
- Financial problems
- Significant lifestyle changes
- Family pressure

Memory Aid — "PPPP" of Liveware Factors

Physical → Physiological → Psychological → Psychosocial.

Remember: "**Physiological and Psychosocial effects are MORE pronounced.**"

Quick Revision Summary — Section 3

- Four Liveware factor families: **Physical, Physiological, Psychological, Psychosocial**.
- **Physiological + Psychosocial** effects are most pronounced.
- Personality red flags: **5 hazardous attitudes** ⇒ anti-authoritative, impulsive, invulnerable, macho, resigned.
- **OTC self-medication = prohibited**; only aviation-medicine-specialist prescription is acceptable.
- High arousal ⇒ **attention narrows**, not sharpens.

4. Factors Related to Individuals and Their Work — The Four

Interfaces

What this section covers

Each of the four SHEL interfaces (L–L, L–H, L–S, L–E) with its full source content, including the **GPWS milestone** of the **1980s** for hull-loss reduction.

4.1 Liveware–Liveware (Human–Human) Interface

Sub-Element	Source-Verbatim Items
Oral Communication	Noise interference , misinterpretation, phraseology (operational), content, rate of speech, language barrier, readback/hearback.
Visual Signals	Ground/hand signals, body language.
Crew Interactions	Supervision, briefings, co-ordination, compatibility/pairing, resource management, task assignment, age, personality, experience.
Controllers	Supervision, briefing, co-ordination.
Passengers	Behavior, briefing, knowledge of aircraft, procedures.

Worker–Management (still within L–L)

Sub-Element	Items
Personnel	Recruitment/selection, staffing requirements, training, policies, remuneration/incentives, crew pairing, scheduling, seniority, resource allocation, operational support/control, instructions/directions/orders, managerial operating pressure.
Supervision	Operational supervision, quality control, standards.
Labour Relations	Employee/employee-management, industrial action, unions/professional group.
Pressures	Mental pressure — operational, morale, peer pressure.
Regulatory Agency	Standards, regulations, implementation, audit, inspection, monitoring, surveillance.

⚠ **Exam Tip — Noise in Cockpit**

High noise level in a cockpit is treated as a Liveware–Liveware mismatch because it primarily disrupts oral communication between humans. (Noise is listed as the very first item under "Oral communication" in L–L.)

4.2 Liveware–Hardware (Human–Machine) Interface

✓ **Landmark Equipment — GPWS**

In the **1980s**, the **Ground Proximity Warning System (GPWS)** marked a **substantial decrease in hull loss rates**. This is a classic L–H interface improvement.

Sub-Element	Items
Switches, Controls, Displays	Instrument/controls design, location, movement, colors, markings, illumination, confusion, standardization.
Workspace	Workspace layout, standardization, communication equipment, eye reference position, seat design, restrictions to movement (congested cockpit), illumination level, motor workload, information displays, visibility restrictions, alerting and warnings, personal equipment interference (comfort), data link, operation of instruments ("finger trouble").

 Exam Tip — "Congested cockpit restricting movement"

This is a **Liveware–Hardware** mismatch (workspace/physical layout). Do **not** confuse it with Environment (which would be heat/cold/glare etc.).

4.3 Liveware–Software (Human–System) Interface

Sub-Element	Items
Written Information	Manuals, checklists , publications, regulations, maps and charts, NOTAMs, standard operating procedures, signage, directives.
Computers	Computer software, user friendliness.
Automation	Operator workload, monitoring task, task saturation, situational awareness, skill maintenance, utilization.
Regulatory Requirements	Qualification in position, qualification in management, certification, medical certificate, licence/rating, non-compliance, infraction history.

 Exam Tip — "Error in checklist"

A checklist is part of **Software**. Therefore an error in a checklist is a **Liveware–Software** mismatch. Inefficient warning logic / symbology is also classified under L–S because warning systems are software-driven.

4.4 Liveware–Environment (Human–Environment) Interface

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Category	Sub-Element	Items
Internal	—	Heat, cold, humidity, ambient pressure, illumination, glare, acceleration, noise interference, vibrations, air quality, pollution, fumes, ozone, radiations.
External	Weather	Weather briefing, FSS facilities, weather actual/forecasts, visibility, ceiling, turbulence (wind, mechanic), whiteout.
	Other Factors	Time of day, lighting/glare, other air traffic, wind blast, terrain/water features, obstacles.
	Infrastructure	<i>Dispatch facilities:</i> type, use, quality. <i>At the gate:</i> APU, towing, refueling, support. <i>Aerodrome:</i> runway/taxiway characteristics, markings, lighting, obstructions, approach aids, emergency equipment, radar, ATC, FSS, weather, airfield facilities. <i>Maintenance:</i> support equipment, parts availability, operational standards, procedures and practices, QA practices, servicing and inspection, training, documentation.

🚫 Critical Interface Mismatch Examples (memorize for exam)

- **Error in checklist** → L-S
- **Congested cockpit / restricted movement** → L-H
- **High cockpit noise** → L-L (disrupts communication)
- **Inefficient warning system** → L-S (warning logic/symbology is software)
- **Disturbance of biological rhythm (jet lag)** → L-E (caused by the time-zone environment)

```

flowchart TB
    L((LIVEWARE
    HUB)):::hub
    LH[L-H
    Hardware]:::lh
    LS[L-S
    Software]:::ls
    LL[L-L
    Other Humans]:::ll
    LE[L-E
    Environment]:::le
    L --- LH
    L --- LS
    L --- LL
    L --- LE
    LH --> EX1[Congested cockpit
    Cockpit design]
    LS --> EX2[Checklist error
    Warning logic]
    LL --> EX3[High noise
    disrupting comm]
    LE --> EX4[Circadian dysrhythmia
    Weather]

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Quick Revision Summary — Section 4

- L-L = humans + humans (comm, briefings, worker-management, noise interference).
- L-H = humans + machines (cockpit, controls, displays; GPWS milestone **1980s**).
- L-S = humans + procedures/software (checklists, NOTAMs, SOPs, automation, warning logic).
- L-E = humans + environment (weather, jet lag, glare, vibration, aerodrome).

5. Effectiveness of the CRM System

What this section covers

The PIC's authority recalibration, the three foundations of CRM success, the four determinants of an effective CRM programme, and the four formal aims of CRM training.

5.1 Authority Recalibration — Captain, F/O, Cabin Crew

Both tradition and regulation give full authority to the **Pilot-in-Command**, who must understand and accept that **questions and observations are NOT a threat to his final authority**.

The "Old Days" Failure Mode

The role of the First Officer in the old days was to obey the captain's "*gear up and shut up*" commands without question. The role of the cabin crew was to bring coffee and meals to the flight deck. **No one dared contravene the captain's dictates, even to provide essential safety information.** Predictable result: **lots of unwanted accidents and many lost lives.**

Fundamental CRM Concept

No single human being has the full picture, and every single person has something useful to contribute to developing it. Working with other people to assemble a complete picture is absolutely necessary to take advantage of all available information needed for safe operation.

5.2 Three Foundations of Continued CRM Success

```

flowchart LR
    A[Strategic Action  
for CRM Success] --> F1[Foundation 1  
Errors are NORMAL]
    A --> F2[Foundation 2  
NON-PUNITIVE response]
    A --> F3[Foundation 3  
Equip crews with  
countermeasures]
    F1 --> R[Continued CRM Success]
    F2 --> R
    F3 --> R

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1. **Operational error passes through the complete human and technology operational process.** CRM aims to present errors as **normal occurrences** and to develop strategies for managing them.
2. A **non-punitive response** to operational error sets the best foundation to identify conditions that breed errors within an organization.
3. Airlines that **tolerate operational error and implement non-punitive policies** are likely to better equip flight crews with appropriate countermeasures to deal with operational errors.

5.3 Four Determinants of an Effective CRM Programme

Determinant	Source Description
a) Operational Relevance	Deliberate avoidance of classroom games , non-operational activities, and personality assessment.
b) Use of Own Experience	Utilization of own incidents and accidents that reflect the typical safety issues of the airline — the airline is determined to learn from its own errors .
c) Threat Assessment	Crews allowed to assess threats and their management. Open discussion of threats within the airline and how these are detected, addressed and mitigated.
d) Error Management	Examination of both effective and ineffective error countermeasures — thus maximizing learning.

5.4 Four Aims of CRM Training

✓ **Formal Aims (verbatim from source — CPL/ATPL exam direct quote)**

CRM training has clear aims in terms of specific skills to develop for the purpose of:

1. **Error avoidance**
2. **Threat management**
3. **Error management**
4. **Undesired aircraft state management**

⚠ **Exam Trap — Wrong combinations**

Beware options like "system management" or "environment management" — these are NOT among the four aims. The correct list always ends with "**undesired aircraft state management**".

📌 **Quick Revision Summary — Section 5**

- PIC's authority is final, but **questions/observations are not a threat** to it.
- 3 Foundations: **Errors normal · Non-punitive · Equip crews.**
- 4 Determinants: **Operational relevance · Own experience · Threat assessment · Error management.**
- 4 Aims: **Error avoidance · Threat mgmt · Error mgmt · Undesired aircraft state mgmt.**

6. CRM Skills — The Fifteen Competencies

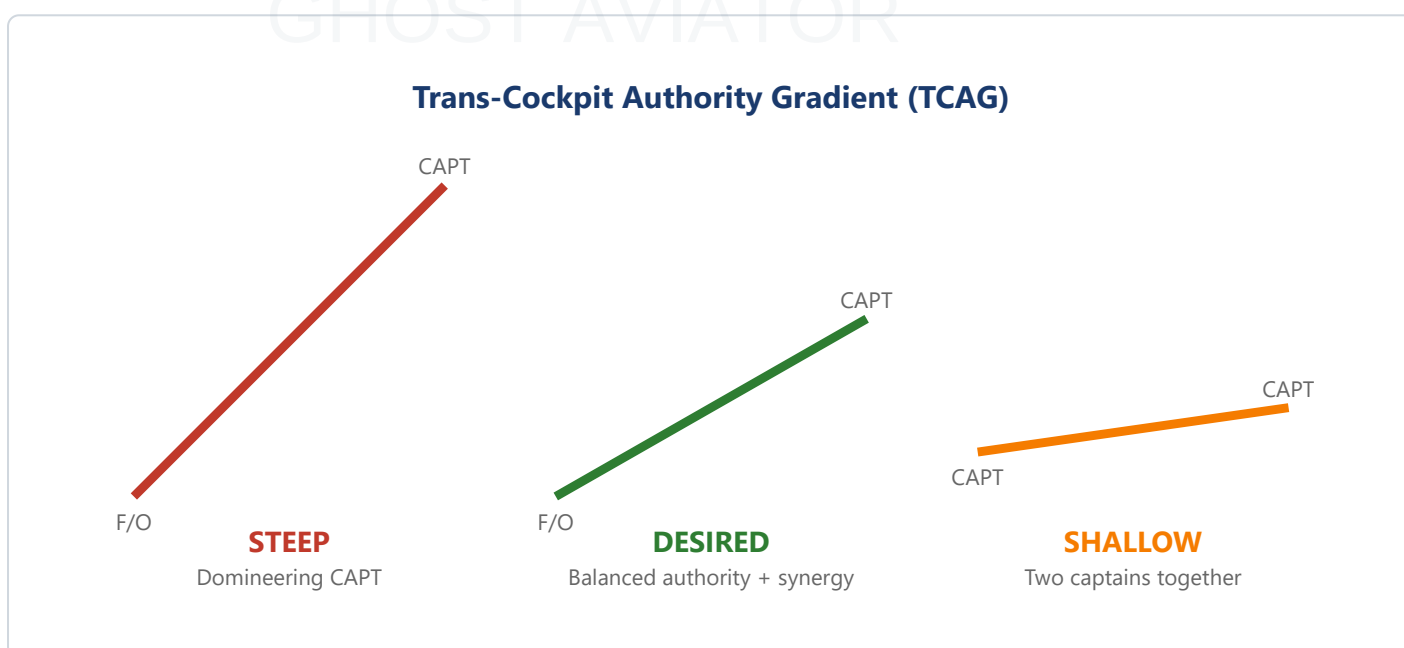
📋 **What this section covers**

The 15 specific CRM skill competencies that govern the scope of CRM training, including the important concept of the **Trans-Cockpit Authority Gradient (TCAG)**.

Skill	Competency Description (source-aligned)
1. Leadership / Command	Uses appropriate authority to ensure focus on task and crew member concerns. Supports others in completing tasks.
2. Decision Making	Detects deviation from desired state, assesses the problem, generates alternatives, identifies risks, selects best course of action; subsequently reviews chosen course for learning.
3. Communication	Clear and effective language; plans stated, ambiguities resolved; demonstrated in interactive briefings and debriefings.
4. Situation Awareness	Comprehends present system & environmental conditions; anticipates future changes; projects changes as the flight progresses.
5. Team Building	Establishes task priorities; utilizes crew resources; improves interpersonal relations.
6. Workload Management	Prioritizes and delegates; keeps everyone "in the loop"; continuously monitors flight progress.
7. Vigilance	Consciously avoids complacency; watches over system/environment changes; informs other crew members of potential threats and errors.
8. Automation Management	Uses automation to assist in managing flight, especially in high workload. Tracks mode changes; "keeps ahead of the curve".
9. Human Performance	Aware of personal and human limitations; recognizes stress loads; assertive when approaching limitations.
10. Trans-Cockpit Authority Gradient (TCAG)	The authority relationship between captain and first officer. Steep with domineering captain + unassertive F/O; shallow with two captains; desired = balanced gradient where captain's authority is recognized but good relationships and synergy retained.
11. Briefings	Sets open and interactive communication; checks understanding by soliciting questions/comments; focuses on operational issues.
12. Setting Bottom Lines	Aware of crew actions and potential breaches of minima; verbalizes concerns when risks increase vulnerability to error.

Skill	Competency Description (source-aligned)
13. Contingency Management	Constant awareness of changes; assesses threats and plans for contingent actions.
14. Evaluation of Plans	Examines course of action; solicits input to analyse how threats/errors were managed.
15. Assertiveness	Queries others in ambiguous situations; constructively asserts views; contributes to overall team effectiveness.

6.1 Spotlight — Trans-Cockpit Authority Gradient (TCAG)



✓ Desired TCAG

A gradient where the captain's authority is recognized, but **good relationships and synergistic working are retained**. This requires a balance of **task-oriented and relationship-oriented behaviors**, the amount of which depends on the crew-members and the situation.

📌 Quick Revision Summary — Section 6

15 CRM skills to remember: **Leadership · Decision Making · Communication · Situation Awareness · Team Building · Workload Management · Vigilance · Automation Management · Human Performance · TCAG · Briefings · Setting Bottom Lines · Contingency Management · Evaluation of Plans · Assertiveness.**

7. Threat and Error Management (TEM) — Threats

■ What this section covers

The TEM concept (CRM = manage resources; TEM = manage threats), the foundational acceptance that threats and errors will occur, the formal definition of a **threat**, and the **six types of threats** per the DGCA source.

7.1 TEM Concept

Definition — TEM

CRM is about managing resources; TEM is about managing threats. Safe flight operations require the recognition of threats and the appropriate use of error-management countermeasures to **avoid, trap and mitigate** the effects of human error.

The fundamental purpose of CRM training is to improve flight safety through the effective use of error-management strategies in individual as well as systemic areas of influence. Hence, it is only reasonable to refocus CRM as **Threat and Error Management (TEM) training**.

✓ Practical Summation of TEM

TEM is the practice of **thinking ahead** in order to predict and avoid errors and operational threats, and to manage any that occur. A foundation of TEM is the **acceptance that threats will occur, and errors will be made**. Hence TEM is **NOT an attempt to eliminate** threats and errors but is concerned with the **management of them**.

7.2 Definition of a Threat

Definition — Threat

Threats are **external events, outside the influence of the crew, that require crew management**. They increase the complexity of the operational environment and have the potential to foster flight crew errors.

Examples of real-life threats include bad weather, time pressures to meet departure/arrival slots, delays, and (more recently) security events.

7.3 The Six Types of Threats

#	Type	Examples (source-verbatim)
1	Environmental	Adverse weather, terrain, airport conditions, heavy traffic/TCAS events, unfamiliar airports.
2	ATC	Command events/errors, language difficulties, similar call signs.
3	Aircraft	Aircraft malfunctions, automation events.
4	Crew Support	Dispatch events/errors, ground events/errors, maintenance events/errors.
5	Operational	Time pressure, irregular operations, flight diversions, missed approaches.
6	Cabin Events	Flight attendant errors, passenger events.

```
graph TD
    T[T] --> T1[1. Environmental]
    T1 --- T1_desc[Weather · terrain · TCAS]
    T --> T2[2. ATC]
    T2 --- T2_desc[Cmds · language · callsigns]
    T --> T3[3. Aircraft]
    T3 --- T3_desc[Malfunctions · automation]
    T --> T4[4. Crew Support]
    T4 --- T4_desc[Dispatch · ground · maint.]
    T --> T5[5. Operational]
    T5 --- T5_desc[Time pressure · diversions]
    T --> T6[6. Cabin Events]
    T6 --- T6_desc[FA errors · pax]
```

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Memory Aid — "EACOC + Cabin" (6 threats)

Environmental · **A**TC · **A**ircraft · **C**rew Support · **O**perational · **C**abin.

Quick Revision Summary — Section 7

- CRM manages resources • TEM manages threats.
- TEM accepts that threats/errors **will occur** — it does NOT seek to eliminate them.
- Threat = **external, outside crew influence, requires crew management**.
- 6 threat types: Environmental, ATC, Aircraft, Crew Support, Operational, Cabin Events.
- TEM countermeasures: **avoid • trap • mitigate**.

8. Error Management — The Five Categories of Errors

What this section covers

The definition of operational error, the five formal error categories under TEM, and what happens when errors go unmanaged — the **Undesired Aircraft State**.

8.1 Definition

Definition — Operational Error

Within the TEM concept, flight crew operational error is defined as **an action or inaction by the crew that leads to deviations from organizational or flight crew intentions or expectations**.

Operational errors **may or may not lead to adverse outcomes**.

8.2 The Five Error Categories

#	Category	Source-Verbatim Definition
a	Intentional Non-compliance Error	Willful deviation from regulations and/or operator procedures.
b	Procedural Error	Deviation in the execution of regulations and/or operator procedures. The intention is correct, but the execution is flawed. Includes errors where the crew forgot to do something.
c	Communication Error	Miscommunication, misinterpretation or failure to communicate pertinent information within the flight crew, or between the flight crew and an external agent (e.g., ATC or ground operations).
d	Proficiency Error	Lack of knowledge or psycho-motor ("stick and rudder") skills.
e	Operational Decision Error	A decision-making error not standardized by regulations or operator procedures that, as such, unnecessarily compromises safety.

8.3 The Three Conditions That Define an Operational Decision Error

Decision Error — At Least ONE Condition Must Exist

1. The crew had **more conservative options** within operational reason and decided NOT to take them.
2. The decision was **NOT verbalized** and therefore **not shared** between crew members.
3. The crew had time but **did not use it effectively to evaluate** the decision.

Source example: A crew's decision to fly through known windshear on an approach instead of going around.

8.4 The Undesired Aircraft State (UAS)

🚫 Consequence of Unmanaged Errors

If the crew is unable to **avoid, trap or mitigate** the error (i.e., unmanaged errors), the consequential outcome may lead to an **Undesired Aircraft State**. Typical situations:

- Incorrect aircraft configurations
- Unstable approaches
- Vertical, lateral or speed deviations

```
flowchart LR
    T[THREAT  
External]:::red --> M{Crew Manages  
Threat?}
    M -- Yes --> S[Safe Flight]:::green
    M -- No --> E[ERROR]:::red
    E --> EM{Crew Manages  
Error?  
avoid/trap/mitigate}
    EM -- Yes --> S
    EM -- No --> UAS[UNDESIRE  
D AIRCRAFT STATE]:::red
    UAS --> R{Recovery?}
    R -- Yes --> S
    R -- No --> ACC[Incident /  
Accident]:::red

    classDef red fill:#fdecea,stroke:#c0392b,stroke-width:2px
    classDef green fill:#e8f5e9,stroke:#2e7d32,stroke-width:2px
```

🧠 Memory Aid — "I PCPO" (5 errors)

Intentional non-compliance · **P**rocedural · **C**ommunication · **P**roficiency · **O**perational decision.

Quick Revision Summary — Section 8

- Operational error = **action or inaction** → **deviation**.
- 5 error categories: **Intentional non-compliance** · **Procedural** · **Communication** · **Proficiency** · **Operational decision**.
- "Forgot to do something" → **Procedural error**.
- Unmanaged errors → **Undesired Aircraft State** (configuration / unstable approach / deviations).

9. Line-Oriented Flight Training (LOFT)

What this section covers

The definition of LOFT, the source of scenarios, and the critical distinction that LOFT is **NOT a check-ride** but a validation of training programmes.

9.1 Definition

Definition — LOFT

Line-Oriented Flight Training refers to **non-jeopardy, facilitated aircrew training** which involves a **full mission simulation** of situations representative of line operations. LOFT places special emphasis on situations involving **communications, management, and leadership**.

In short — LOFT means realistic, real-time, full-mission training.

9.2 Scenario Sources

LOFT scenarios may be developed from many sources, but **accident and incident reports provide a realistic and appropriate starting point**.

9.3 LOFT is NOT a Check-Ride

Critical Limitation — Non-Jeopardy

LOFT **should NOT be used as a method of checking the performance of individuals**. Instead, it is a **validation of training programmes and operational procedures**.

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✓ Post-LOFT SOP

An individual or crew needing additional training after a LOFT session shall be afforded that opportunity **immediately, with no stigma or recrimination.**

```
graph TD
    LR[flowchart LR]
    A[A[Accident/Incident  
Reports]] --> S[S[LOFT Scenario  
Design]]
    S --> F[F[Full Mission  
Simulation]]
    F --> T[T[Crew Training  
Non-jeopardy]]
    T --> E{E{Additional  
Training Needed?}}
    E -- Yes --> P[P[Provide Immediately  
No stigma]]
    E -- No --> V[V[Validates  
Training & SOPs]]
    P --> V
    style F fill:#e8f1fb,stroke:#2c5aa0
    style V fill:#e8f5e9,stroke:#2e7d32,stroke-width:3px
```

📌 Quick Revision Summary — Section 9

- LOFT = **non-jeopardy**, full-mission, **realistic real-time** training.
- Emphasis: **communications, management, leadership.**
- Sources: **accident/incident reports.**
- **NOT a check on individuals** — it validates training and procedures.
- Additional training after LOFT = **immediate, no stigma.**



Practice Questions & Detailed Answers

How to use this section: Attempt each question first by covering the answer panel. Read your option, then reveal. Even if correct, read the explanation and distractor analysis — exam tricks live in the wrong options. Cross-reference back to the relevant study section using the anchor links.

Total: 21 MCQs · Source: DGCA Human Factors (Chapter 24) Question Bank

Q1. Human errors:

- A. Are now considered as being inherent to the cognitive function of human and can be totally eliminated by CRM training.
- B. Are now considered as being inherent to the cognitive function of human and are generally inescapable.
- C. Are likely to be eliminated in the near future by higher degree of automation.

✓ Correct Answer: **(B)** Are now considered as being inherent to the cognitive function of human and are generally inescapable.

Explanation: The foundational premise of modern Human Factors and TEM is that errors are a **normal and inescapable** by-product of human cognition. CRM does not try to *eliminate* errors — it equips crews to **manage** them (avoid, trap, mitigate). See [Section 5 — Foundation 1: errors are normal occurrences](#) and [Section 7 — TEM is NOT an attempt to eliminate errors](#).

Why the other options are wrong:

- **(A)** — CRM does NOT "totally eliminate" errors. This contradicts the foundational TEM premise.
- **(C)** — Automation has historically *relocated* errors, not eliminated them (see Q16). New automation creates new types of error.

Instructor's Note: Any option containing the words "eliminated", "totally", or "completely removed" alongside human error is almost always a distractor. Bank this rule.

Q2. The error in checklist is related to an interface mismatch between:

- A. Liveware – Liveware.
- B. Liveware – Software.
- C. Liveware – Environment.

✓ Correct Answer: **(B)** Liveware – Software.

Explanation: Checklists are explicitly listed under the **Liveware–Software** interface as part of "Written Information" (along with manuals, NOTAMs, SOPs, charts). Therefore an error in a checklist is a human–software mismatch. See [Section 4.3 — L–S Written Information](#).

Why the other options are wrong:

- **(A)** — L–L is about humans interacting with humans (communication, briefings); a paper/electronic checklist is not a human.
- **(C)** — Environment relates to weather, glare, vibration, ambient noise, time of day — not procedures or documentation.

Instructor's Note: Whenever the question mentions checklists, manuals, NOTAMs, SOPs, charts, computer programs → think **L–S**.

Q3. CRM training has under-mentioned clear aims in terms of specific skills to develop for the purpose of:

- A. Error avoidance, threat management, system management and undesired aircraft state management.

- B. Error avoidance, threat management, error management and environment management.
- C. Error avoidance, threat management, error management and undesired aircraft state management.

✓ Correct Answer: **(C)** Error avoidance, threat management, error management and undesired aircraft state management.

Explanation: These are the four formal aims of CRM training, listed verbatim in the DGCA source. See [Section 5.4 — Four Aims of CRM Training](#).

Why the other options are wrong:

- **(A)** — Includes "system management" which is NOT one of the four aims.
- **(B)** — Includes "environment management" which is NOT among the four aims.

Instructor's Note: Memorize the EXACT four: **Error Avoidance** → **Threat Mgmt** → **Error Mgmt** → **Undesired Aircraft State Mgmt**. The pattern goes from prevention → reaction → recovery.

Q4. A congested cockpit restricting movement is an interface mismatch between:

- A. Liveware – Software.
- B. Liveware – Environment.
- C. Liveware – Hardware.

✓ Correct Answer: **(C)** Liveware – Hardware.

Explanation: A congested cockpit is a **workspace / physical design** issue. The source explicitly lists "workspace layout" and "restrictions to movement" under Liveware–Hardware. See [Section 4.2 — L–H Workspace](#).

Why the other options are wrong:

- **(A)** — Software involves documents and procedures, not physical space.
- **(B)** — Environment refers to ambient conditions (heat, humidity, glare, vibration), not the cockpit's internal physical layout.

Instructor's Note: A useful tag: "Physically touchable" + "machine/airframe-related" = **L-H**. Cockpit layout, controls, displays, seats — all L-H.

Q5. High noise level in a cockpit is a mismatch between:

- A. Liveware – Liveware.
- B. Liveware – Environment.
- C. Liveware – Hardware.

✓ Correct Answer: **(A)** Liveware – Liveware.

Explanation: This is a classic DGCA trap. Although noise *originates* from the environment/machine, the **mismatch it causes is at the human-to-human communication interface**. The source lists "Noise interference" as the very first item under **L-L Oral Communication**. High cockpit noise degrades inter-crew communication — that's the operational mismatch. See [Section 4.1 — L-L Oral Communication](#).

Why the other options are wrong:

- **(B)** — A tempting choice since noise is an "environmental" stressor, but the operational impact (and the source's classification) is on inter-human communication.
- **(C)** — Hardware would apply only if the question was about cockpit design causing noise, not the noise itself.

Instructor's Note: The DGCA rule of thumb: **noise affecting comms** → **L-L**. This is one of the most frequently misanswered questions in the bank — note it.

Q6. Inefficient warning system in the cockpit is a mismatch between:

- A. Liveware – Liveware.
- B. Liveware – Environment.
- C. Liveware – Software.

✓ Correct Answer: **(C)** Liveware – Software.

Explanation: A "warning system" — its logic, symbology, alerting cues, and procedures — is fundamentally a **software** concept (computer programs, symbology, procedural alerts), all of which are listed under Liveware–Software. While the physical chime or light is hardware, the **warning system as a whole** (the question's phrasing) is classified as L–S. See [Section 4.3 — L–S Computers / Automation / Written Information](#).

Why the other options are wrong:

- **(A)** — Warning systems do not involve human-to-human interface.
- **(B)** — Environment is about external/ambient conditions, not engineered alerts.

Instructor's Note: Treat warning systems, automation logic, EICAS/ECAM alerts, FMS messages, and computer prompts as **L–S**. The physical button/light hardware is L–H, but the alerting system is L–S.

Q7. A disturbance of the biological rhythm is a mismatch between:

- A. Liveware – Hardware.
- B. Liveware – Software.
- C. Liveware – Environment.

✓ Correct Answer: **(C)** Liveware – Environment.

Explanation: Circadian dysrhythmia (jet lag) is caused by **time-zone changes** in the external environment. The body's biological rhythm is desynchronized from the new local time — a clear human-vs-environment mismatch. See [Section 3.2 — Sleep / Circadian Dysrhythmia](#) and [Section 4.4 — L-E Time of Day](#).

Why the other options are wrong:

- **(A)** — Hardware has nothing to do with body clock disruption.
- **(B)** — Procedures/manuals cannot cause biological-rhythm disturbance.

Instructor's Note: Jet lag = environment-induced. Treat time of day, day/night, time-zone effects consistently as **L-E**.

Q8. The main consideration in modern airline operations should be:

- A. Efficient utilisation of resources.
- B. Maximum utilisation of resources.
- C. Safety.

✓ Correct Answer: **(C)** Safety.

Explanation: Safety is the cardinal principle of aviation. Efficiency and resource utilisation matter, but never above safety. The entire CRM/TEM/LOFT framework exists to **contribute to incident and accident prevention** (see Section 1.2). Safety is the overarching objective.

Why the other options are wrong:

- **(A)** — Efficient utilisation matters but is subordinate to safety.
- **(B)** — "Maximum" utilisation can even push against safety margins (e.g., rostering crews to fatigue limits).

Instructor's Note: "Safety first" is non-negotiable in any DGCA exam — if Safety appears as an option in a question about priorities, it is almost always correct.

Q9. The elements of the SHEL model are:

- A. Software, hardware, electronics, and livewire.
- B. Shareware, hardware, education, and limitations.
- C. Software, hardware, environment, and livewire.

✓ Correct Answer: **(C)** Software, hardware, environment, and livewire.

Explanation: S-H-E-L stands for **Software, Hardware, Environment, Liveware**. Note: option (C) uses the variant spelling "livewire" exactly as printed in the source question bank — the intended term is "Liveware". This is the only option that has all four correct categories. See [Section 2.3 — The Four SHEL Components](#).

Why the other options are wrong:

- **(A)** — "Electronics" replaces Environment incorrectly.
- **(B)** — Three wrong terms: Shareware, Education, Limitations are not in SHEL.

Instructor's Note: The official DGCA source spells it "Liveware". The Q-bank's "livewire" is a printing variant, not a real change in meaning. Both refer to the human element.

Q10. Which is true regarding the interaction between various elements of the SHEL model?

- A. All components of the SHEL model are equally important, as conflict and error can arise from the various mismatches.
- B. The hardware is the hub for interactions between the different components of the system, hence other components should be matched to design most suitable hardware.

C. The liveware is the hub of the SHEL model; therefore, the nonhuman components should be adapted and matched to this central component.

✓ Correct Answer: **(C)** The liveware is the hub of the SHEL model; therefore, the nonhuman components should be adapted and matched to this central component.

Explanation: The source explicitly states: "*The liveware (human element) is the hub of the SHEL model. The remaining components must be adapted and matched to this central component.*" See [Section 2.5 — Liveware as the Hub](#).

Why the other options are wrong:

- **(A)** — Misleading: while mismatches matter, components are NOT equally important — Liveware is the hub.
- **(B)** — Wrong: Hardware is NOT the hub. Designing other components to suit hardware reverses the Human Factors principle.

Instructor's Note: "Liveware is the hub" is a single-sentence answer to many SHEL questions. Bank it.

Q11. CRM and LOFT training are designed to improve:

- A. The quality number of individuals performance.
- B. Individual performance in adverse conditions.
- C. The quality of crew performance.

✓ Correct Answer: **(C)** The quality of crew performance.

Explanation: Both CRM and LOFT target **crew** (collective) performance, not individuals. LOFT specifically is described as a validation of training programmes and procedures, NOT a check on individuals. See [Section 1](#) and [Section 9](#).

Why the other options are wrong:

- **(A)** — Focuses on "individuals" — wrong target; awkwardly worded too.
- **(B)** — Again focused on individuals and limited to "adverse conditions" only; CRM applies always.

Instructor's Note: Remember: CRM = "Crew" Resource Management. The word crew is built into the acronym. The answer in any "what does CRM improve?" question will involve **crew**, not individuals.

Q12. Four important disciplines from which information is drawn in understanding human performance and behavior are:

- A. Psychology, engineering, physiology, and anthropometry.
- B. Sociology, mathematics, biology and industrial design.
- C. Physics, biochemistry, physiology, and anthropometry.

✓ Correct Answer: **(A)** Psychology, engineering, physiology, and anthropometry.

Explanation: The four disciplines underpinning Human Factors are: **Psychology** (mind, behaviour), **Engineering** (machines, systems), **Physiology** (body function), and **Anthropometry** (body measurements — reach, fit, size). These provide a complete coverage of mind + body + machine + fit. Anthropometric attributes (height, weight, reach, etc.) are explicitly listed in [Section 3.1 — Physical Factors](#).

Why the other options are wrong:

- **(B)** — Sociology and mathematics are not core HF disciplines in the SHEL framework.
- **(C)** — Physics and biochemistry are too narrow/specific; psychology is missing entirely.

Instructor's Note: Mnemonic — "**PEPA**": **P**sychology, **E**ngineering, **P**hysiology, **A**nthropometry.

Q13. Pilots have now become responsible for the management of hardware and software interfaces, through which they are required to direct the operation of the aircraft. These technological advances have:

- A. Significantly eliminated human errors.
- B. Given rise to new forms of error.
- C. Are aimed to eliminate pilots from the cockpit.

✓ Correct Answer: **(B)** Given rise to new forms of error.

Explanation: Automation and advanced cockpit interfaces have **relocated** errors rather than eliminated them, introducing new categories such as mode confusion, automation surprises, and over-reliance on FMS. The source's automation discussion under L-S highlights operator workload, monitoring task, task saturation, situational awareness and skill maintenance as new concerns. See [Section 4.3 — L-S Automation](#).

Why the other options are wrong:

- **(A)** — Same trap as Q1: nothing "eliminates" human error.
- **(C)** — Aviation does NOT aim to eliminate pilots; automation assists them.

Instructor's Note: Pair this with Q16 (automation relocates and adds workload). The pattern is consistent: more automation → different errors, not fewer.

Q14. About what proportion of civil air accidents result from inadequate human performance?

- A. 89%
- B. 73%
- C. 57%

✓ Correct Answer: **(B)** 73%

Explanation: The widely accepted figure cited in DGCA Human Factors material and reflected in this Q-bank is approximately 73% of civil air accidents attributable to inadequate human performance. This is the reason CRM/TEM training carries the same regulatory weight as systems and emergency procedure training (see [Section 1.2](#)).

Why the other options are wrong:

- **(A) 89%** — Overstated; not the DGCA figure for this question.
- **(C) 57%** — Understated.

Instructor's Note: Lock this number — 73%. It is one of the few numerical figures asked directly in DGCA Human Factors exams.

Q15. What is meant by the trans authority gradient?

- A. It is the authority exercised by the captain over all flight operations.
- B. It is the authority relationship between captain and other crew members.
- C. It is the authority relationship between captain and first officer.

✓ Correct Answer: **(C)** It is the authority relationship between captain and first officer.

Explanation: The source defines Trans-Cockpit Authority Gradient (TCAG) precisely as "*the authority relationship between captain and first officer*" — not all crew, not unilateral captain authority. The gradient may be steep, shallow, or balanced (desired). See [Section 6.1 — TCAG](#).

Why the other options are wrong:

- **(A)** — Describes captain's general command authority, not the *gradient*.
- **(B)** — "Other crew members" is too broad; TCAG is specifically captain ↔ first officer.

Instructor's Note: Bookmark this exact phrasing — "between captain and first officer" — it's a direct DGCA quotation.

Q16. Introducing Automation in a cockpit:

- A. Always reduces potential for human error and workload.
- B. Generally relocates potential for error and increases workload.
- C. Eliminates human error but workload increases.

✓ Correct Answer: **(B)** Generally relocates potential for error and increases workload.

Explanation: Automation does NOT eliminate errors — it shifts them to new domains (mode confusion, monitoring failures, complacency). It also **increases certain workloads**: monitoring tasks, mode awareness, data entry, programming, and managing automation itself. This matches the L-S Automation source items: operator workload, monitoring task, task saturation, situational awareness, skill maintenance. See [Section 4.3 — L-S Automation](#).

Why the other options are wrong:

- **(A)** — "Always" is wrong; automation reduces some workloads but adds others.
- **(C)** — "Eliminates" is wrong (same trap as Q1, Q13).

Instructor's Note: Mantra — "Automation **relocates** error, it does not eliminate it." Pair with Q13.

Q17. High Arousal Overload results in:

- A. A real danger of attention becoming narrowed.
- B. An attention becoming sharpest.

C. An optimum arousal for more difficult or intellectually (cognitive) tasks.

✓ Correct Answer: **(A)** A real danger of attention becoming narrowed.

Explanation: Under high arousal/overload, attention **narrows** (channelization, fixation) — the opposite of "sharpening". This is consistent with the Yerkes-Dodson inverted-U: high arousal degrades performance on cognitively demanding tasks. The source lists "channelized attention" and "fixation" as failure modes under [Section 3.3 — Attention](#).

Why the other options are wrong:

- **(B)** — Attention does NOT become "sharpest" under overload — it narrows.
- **(C)** — Difficult cognitive tasks have a *lower* optimum arousal, not higher.

Instructor's Note: The classic exam phrase to recognise: "channelized attention" or "tunnel vision under stress" → both indicate the narrowing referenced in option (A).

Q18. A pilot suffering from a mild headache before flight can:

- A. Take Over The Counter medicines from the chemist and fly.
- B. Take Over The Counter medicines from the first aid box in the aircraft and fly.
- C. Should take medicines prescribed by an aviation medicine specialist and take his advise for flying.

✓ Correct Answer: **(C)** Should take medicines prescribed by an aviation medicine specialist and take his advice for flying.

Explanation: OTC medicines can have side effects (drowsiness, blurred vision, impaired reaction time) that compromise flight safety. A pilot must consult an **aviation medicine specialist**, who can prescribe an appropriate medication AND determine whether the pilot is fit to fly. The headache itself may also be a symptom requiring grounding. See [Section 3.2 — Drugs / Health](#).

Why the other options are wrong:

- **(A)** — Self-medication with chemist-bought OTC is prohibited.
- **(B)** — The aircraft's first-aid box is for passenger/emergency use, not pilot self-medication; also fails the specialist-prescription requirement.

Instructor's Note: Golden rule — "**Pilot + medication**" answer is **ALWAYS: consult Aviation Medicine Specialist**. No DGCA exam question on this topic deviates from this.

Q19. Categories of errors defined by TEM are:

- A. Intentional non-compliance error, Procedural error, Communication error, Proficiency error and Operational decision error.
- B. Intentional non-compliance error, Procedural error, Communication error, Proficiency error and vigilance error.
- C. Instrument error, Procedural error, Communication error, Proficiency error and vigilance error.

✓ Correct Answer: **(A)** Intentional non-compliance, Procedural, Communication, Proficiency, and Operational decision error.

Explanation: TEM defines exactly five error categories per the source: **Intentional Non-compliance · Procedural · Communication · Proficiency · Operational Decision**. See [Section 8.2 — Five Error Categories](#).

Why the other options are wrong:

- **(B)** — "Vigilance error" is NOT a TEM category. Vigilance is a CRM skill (see Section 6), not an error category.
- **(C)** — "Instrument error" is also not a TEM error category.

Instructor's Note: Mnemonic — "**I PCPO**": Intentional non-compliance, Procedural, Communication, Proficiency, Operational decision. Drill this once and you own every TEM error

question.

Q20. Operational Threats outside the control of flight crew are:

- A. Adverse weather, Terrain, Airport conditions, Heavy traffic/TCAS events, Unfamiliar airports etc.
- B. Time pressure, Irregular operations, Flight diversions, Missed approaches etc.
- C. Aircraft malfunctions, Automation events etc.

✓ Correct Answer: **(B)** Time pressure, Irregular operations, Flight diversions, Missed approaches etc.

Explanation: The question specifically asks about the "**Operational**" category of threats. Per the source's Threat Type #5 (Operational), examples are exactly: *Time pressure, Irregular operations, Flight diversions, Missed approaches*. See [Section 7.3 — Threat Type 5: Operational](#).

Why the other options are wrong:

- **(A)** — These are **Environmental** threats (Type 1), not Operational.
- **(C)** — These are **Aircraft** threats (Type 3), not Operational.

Instructor's Note: Read the question's key adjective. "Operational" threats = the schedule/ops world (time, diversions, missed approaches). "Environmental" = weather/terrain. "Aircraft" = malfunctions/automation. Match the category to the listed items.

Q21. What airplane equipment marked a substantial decrease in hull loss rates in the eighties?

- A. GPWS
- B. TCAS

C. SSR

✓ Correct Answer: **(A)** GPWS (Ground Proximity Warning System).

Explanation: The source directly states: "In **1980s** Ground Proximity Warning System (GPWS) marked a substantial decrease in hull loss rates." GPWS attacked the leading cause of fatal accidents at the time — Controlled Flight Into Terrain (CFIT). See [Section 4.2 — L-H GPWS milestone](#).

Why the other options are wrong:

- **(B) TCAS** — Addresses mid-air collision risk (TA/RA), not CFIT. Came into widespread mandate in the 1990s.
- **(C) SSR** — Secondary Surveillance Radar is a ground-side ATC surveillance technology, not aboard-aircraft hull-loss reduction equipment.

Instructor's Note: Decade-equipment pairing: **1980s** → **GPWS** (anti-CFIT). The DGCA loves direct decade quotes from the chapter — remember this verbatim.

GHOST AVIATOR

10. Master Reference Tables · Mnemonics · Answer Key

10.1 Consolidated Numerical & Named-Entity Reference

Value / Term	Significance	Section
1972	Year SHEL model first developed by Edwards	§2.2
1977	Tenerife disaster — catalyst for CRM as a full program	§1.3
1980s	GPWS introduced — substantial hull-loss-rate reduction	§4.2
73%	Proportion of civil air accidents from inadequate human performance	Q14
24 hours	Look-back window for food intake (nutritional factor)	§3.2
ICAO Doc 9859	Safety Management Manual — describes SHEL model	§2.2
ICAO Circular 216-AN31	Original framework referenced for SHEL	§2.2

10.2 Interface-Mismatch Quick-Lookup Table

Scenario	Interface	Why
Error in checklist	L-S	Checklist = software (written information)
Congested cockpit / restricted movement	L-H	Workspace layout = hardware
High cockpit noise	L-L	Disrupts inter-crew oral communication
Inefficient warning system	L-S	Warning logic / symbology = software
Biological rhythm disturbance (jet lag)	L-E	Caused by time-zone environment
Aircraft instrument design flaw	L-H	Physical instrument = hardware
Misinterpreted ATC phraseology	L-L	Human-to-human oral communication
Cockpit glare / vibration	L-E	Internal environment factor
FMS programming error	L-S	Computer software
Captain-F/O authority imbalance	L-L	TCAG — between two humans

10.3 Mnemonics Collected

GHOST AVIATOR

Topic	Mnemonic
4 Liveware factor families	"PPPP" — Physical, Physiological, Psychological, Psychosocial
5 SHEL letters	SHELL — Software, Hardware, Environment, Liveware (you), Liveware (others)
4 HF disciplines	"PEPA" — Psychology, Engineering, Physiology, Anthropometry
4 Aims of CRM training	"E-T-E-U" — Error avoidance, Threat mgmt, Error mgmt, Undesired aircraft state mgmt
6 Types of Threats	"EACOC + Cabin" — Environmental, ATC, Aircraft, Crew Support, Operational, Cabin
5 Error Categories (TEM)	"I PCPO" — Intentional non-compliance, Procedural, Communication, Proficiency, Operational decision
5 Hazardous Attitudes	"AIMRI" — Anti-authoritative, Impulsive, Macho, Resigned, Invulnerable
TEM countermeasures	"ATM" — Avoid · Trap · Mitigate
3 Foundations of CRM success	Errors are normal · Non-punitive response · Equip with countermeasures

10.4 Answer Key Summary (for Self-Test Review)

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
B	B	C	C	A	C	C	C	C	C	C

Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21
A	B	B	C	B	A	C	A	B	A

10.5 Final Exam-Day Cheat Card

Join live classes for guided practice and doubt clearing.

- **CRM** = effective use of ALL resources → reduce error, avoid stress, increase efficiency.
- **SHEL** = Software / Hardware / Environment / Liveware — **Liveware is the HUB**.
- **Mismatch** = source of human error.
- **Tenerife (1977)** made CRM mainstream; **GPWS (1980s)** cut hull losses; **~73%** of civil accidents stem from inadequate human performance.
- **TEM = manage threats; CRM = manage resources**. TEM does NOT try to eliminate errors — only manage them via **Avoid · Trap · Mitigate**.
- **6 Threat types**: Environmental, ATC, Aircraft, Crew Support, Operational, Cabin.
- **5 Error categories**: Intentional Non-compliance, Procedural, Communication, Proficiency, Operational Decision.
- **Unmanaged error** → **Undesired Aircraft State** (config / unstable approach / deviations).
- **LOFT** = **non-jeopardy**, full-mission training; **NOT a check** on individuals.
- **TCAG** = captain ↔ first officer authority gradient. **Desired = balanced** (not steep, not shallow).
- **Pilot + headache** → see aviation medicine specialist; no self-OTC.
- **Automation relocates error; does NOT eliminate it**.

— End of Study Notes —

Chapter 24 · CRM · TEM · LOFT

Compiled by Ghost Aviator for DGCA CPL/ATPL aspirants

Fly safe. Manage threats. Trap errors. Stay ahead of the curve.