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DOCUMENT TITLE

HUMAN PERFORMANCE AND LIMITATIONS

CHAPTER 20 – CREW COORDINATION, CRM AND TEM

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BASIC PRINCIPLES OF CREW COORDINATION

20.1 Individual Differences

To understand and optimise the relationships that might exist on the flight deck, we need to have an understanding of the psychological factors affecting human beings in general and pilots in particular.

20.1.1 Intelligence

Intelligence is a property of mind that encompasses many related abilities, such as the capacities to reason, plan, solve problems, think abstractly, comprehend ideas and language, and learn. The definition of intelligence has long been a matter of controversy and this subject is beyond the scope of our course of study. While there is no common intelligence level for flight crews, aircrew must have a balance of competence in several areas.

A difficulty is that we may have two pilots with the same qualifications and much the same experience, but with different mental agility and how they might approach a problem. But again, understanding the psychological implications of this is not a requirement of this course of study.

20.1.2 Personality

Personality is important. It includes all those stable, behavioural characteristics that will be very important in determining the relationships that will exist with other crew members in the highly structured environment of the flight deck.

Personality consists of deep-seated characteristics we were either born with, or acquired in our early life. These are very hard to change and may appear as aggression, ambition, dominance, creativity etc. They can be situation related; for example, one for work and another for home. Different types of personality are required for different types of flying; commercial operations require personalities different to military flying.

20.1.3 Attitudes

These originate in our early life experiences and social environment and describe our likes and dislikes. They are learned characteristics (we are not born with them) and we will have most of them for the rest of our lives. Others are easily changed by training and peer group pressure, or other circumstances.

20.1.4 Beliefs

Beliefs are different from attitudes in that they do not infer favour or disfavour, but are simply statements of relationships between things, or our understanding of a particular circumstance. They are sometimes referred to as 'cognitions'.

20.1.5 Behaviour

Simply stated, what you do, how you interact with others, how you act, how you do what you do.

20.2 Intelligence and Aptitude

20.2.1 Intelligence

This is the ability to use knowledge to adapt effectively to the environment. The measurement of intelligence is important in the selection and training associated with aviation, but intelligence does not indicate any specific aptitude. For example, a highly intelligent person may have difficulty in becoming a good pilot—he simply may not have the right balance of the necessary aptitudes.

A common but often misunderstood measure of intelligence is known as the Stanford-Binet test, which reports an Intelligence Quotient (IQ). This is defined as:

IQ = (mental age/chronological age) x 100

Thus a child of 6 years with a mental age of 7 years and 6 months was said to have an IQ of 125. IQ gives a measure of mental age and not a measure of absolute intelligence.

20.2.2 Aptitude

Intelligence tests are concerned primarily with the assessment of general intellectual ability. Although these tests are useful in many respects, it is often necessary to obtain an indication of an individual's aptitude for a particular type of activity. Aptitude tests are much more specific in nature than intelligence tests; their content is usually determined by the requirements of the job.

20.3 Personality

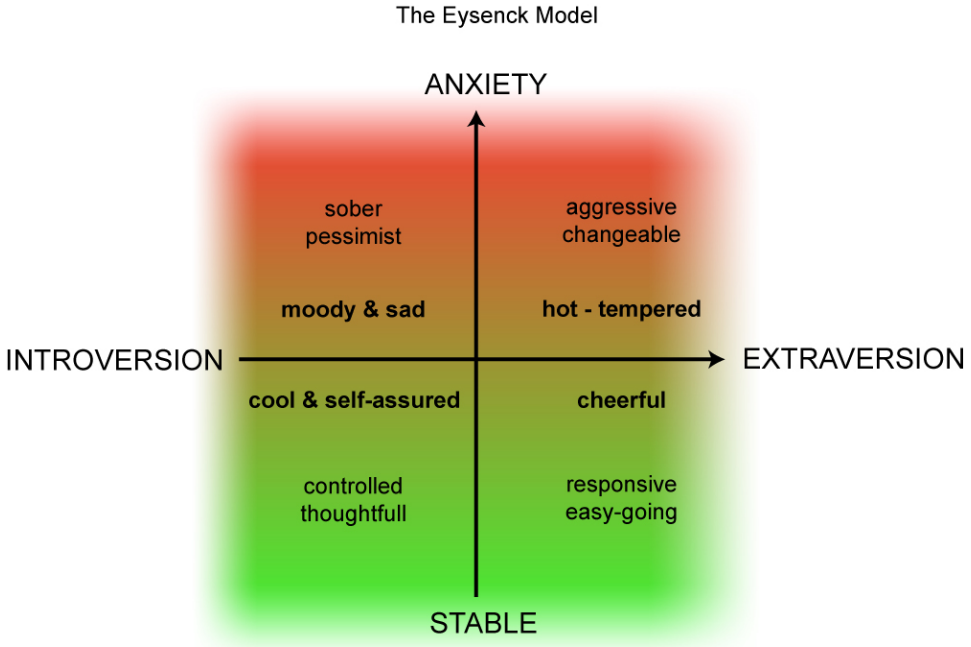
20.3.1 The Pilot Personality

Research has found that a pilot's personality type is distinct from that suited to many other occupations. The distinction is more pronounced in military pilots where a more active/masculine/aggressive profile is preferred, even in female pilots, rather than the cooperative/assertive/consultative profile compatible with civil aviation operations.

Personality traits may:

- Be ingrained personal strategies for getting things done
- Be deeply ingrained characteristics, therefore unchangeable
- Indicate an individual's level of stability
- Influence interaction with others
- Indicate an individual's risk-taking tendencies.

20.3.2 Personality Dimensions



20.3.3 Two-dimensional model of personality

20.3.3.1 The Extraversion - Introversion Dimension

The extreme extrovert is outgoing, warm and sociable, impulsive, bold, uninhibited and assertive. The extreme introvert is reserved, shy, cautious and conservative and sometimes emotionally unstable.

20.3.3.2 The Anxiety - Stability Dimension

This extends from emotional stability and a carefree outlook, through to extreme anxiety with worry, tension, guilt and suspicion.

20.4 Attitudes

Our attitudes describe likes and dislikes. Attitudes are developed from our early life experiences and our social environment.

They are a learned and lasting tendency to respond predictably, either favourably or unfavourably, in given circumstances. We may become very rigid in some of our attitudes and these are often difficult to change. Others are more easily changed.

20.4.1 Influencing Attitudes

Groups have profound effects on attitudes, beliefs, interests, behaviour and goals. Group decisions are riskier than those made by individuals. This is known as 'Risky Shift'. In a group an individual often experiences a reduction in personal restraint and loss of inhibition. An individual in a group will be subjected to pressure to conform

Strongly held attitudes are resistant to change.

20.4.2 Hazardous Attitudes

There are six hazardous attitude types that can have a significant impact on CRM and other crew members:

20.4.2.1 Anti-Authority

The rules were made for everyone else except these people. 'I don't have to follow rules, I know better…"

These people always try to push a limit in small ways or make small deviations from the standard. The cure for this is to follow the rules.

20.4.2.2 Impulsive

They react to situations long before their brain engages. "I make quick decisions and get on with the job. I don't mess around"

The impulsive feels the need to "do something quickly". A pilot flying with this type of person may have their hands full. The antidote is to slow down and think before acting.

20.4.2.3 Invulnerable

Nothing appears to scare this type. "Nothing will happen to me—I'm a great pilot".

The invulnerable may be the VFR pilot who continues into deteriorating weather. We must recognise that we are all vulnerable.

20.4.2.4 Macho

This person is not a team player and is very difficult to deal with in the cockpit. “I am an ace pilot— I will be top of my course”.

The macho type and the anti-authority type may well be very competitive in the cockpit. This type is a short-sighted risk taker and needs to learn to avoid unnecessary risks.

20.4.2.5 Resignation (or being a fatalist)

These people operate with a dark cloud over their head and believe there is nothing they can do to change things. “It is going to happen anyway and I can’t do anything about it”.

They will also feel threatened by anyone, especially other people with opinions, ideas or suggestions different from theirs. It is “always me” with these individuals, and they feel picked on and singled out for no apparent reason. They need to be made to feel a part of the team so they believe they are having an influence.

20.4.2.6 Deference

People with this type of attitude believe others are better than they are and are hesitant to question the other person’s decisions. Usually they are never to blame, or never accept responsibility for any problem that may arise. “The Captain knows best—I’ll do what he says”.

They defer to the authority and opinions of others and make no attempt to use their own initiative. They lack assertiveness and allow others to control situations in which they are involved. By acting in this way they feel that they will not be held responsible if things go wrong. It's 'not their problem'.

20.5 Leadership and Teamwork

Another way to define personality is in terms of whether the individual is goal oriented or people oriented. A strongly goal oriented person will strive to achieve a task but show little regard for the feelings of others. The people oriented individual will consider the feelings of others, possible compromising the achievement of the desired goals.

Ideally pilots (particularly captains) should in normal circumstances be both goal and people oriented. But what makes a good captain?

Leadership is the process by which others are influenced to achieve goals in a specific situation.

Leadership style involves managing the interaction of personalities and attitudes. But all team members can demonstrate interactive effectiveness – it doesn't have to be just the captain.

Good leadership should not be confused with authority. Authority is usually assigned, but true leadership is learned, and this skill often takes time to develop.

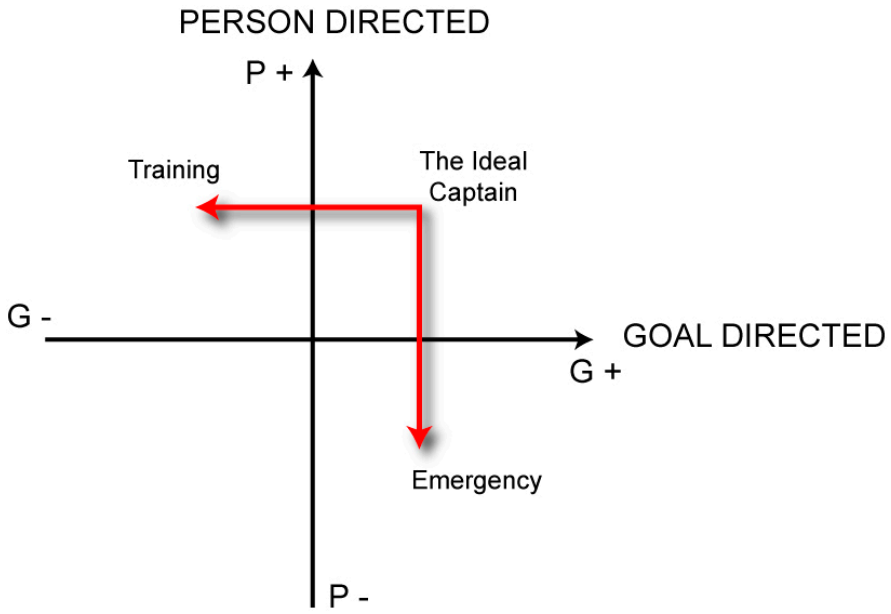
20.5.1 Interactive Style

An interactive style can be described in terms of the above two dimensions, that of goal directed behaviour and that of person directed behaviour.

Some individuals may have a great determination to remain popular with the team and to help team members to the greatest possible degree, but has little regard for the task or goals at hand. He would be regarded as having a P+ G- style.

The appropriate style may vary with the situation. In normal airline operations, a captain should be a P+ G+. In the case of an emergency, the goal of saving the aeroplane takes precedent and the thoughts and feelings of the crew (although still important) take second place. He would then properly become a P- G+ individual.

Basic interactive styles can be summarised by the use of a graph as shown below.



Two dimensional model of interactive style

20.5.1.1 P+ G -

- Friendly relationships with other crew members all the time.
- Leaves the work to others—**too democratic**, wants everybody to have input to a problem.
- Gives in to others easily.

20.5.1.2 P- G+

- Ignores other people's feelings, attitudes and thoughts
- Wastes other' expertise—too autocratic
- Usually won't listen to others' views—often dominates others
- Getting the job done is everything. However, this might be appropriate during emergencies when tough-mindedness is required.

20.5.1.3 P- G -

- Poor attitude to crew
- Poor attitude to the job—too lenient and casual
- Bends the rules—can't be bothered with them
- Poor morale in the crew will often be the result.

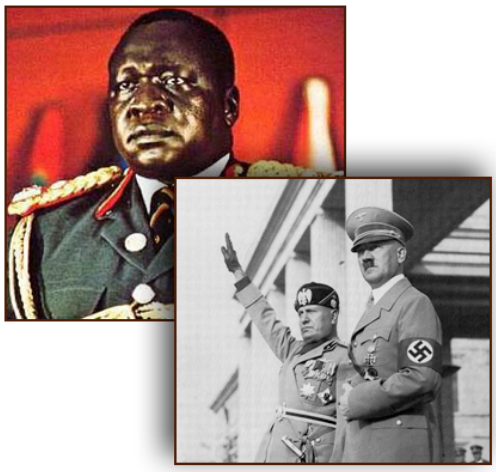
20.5.1.4 P+ G+

- Equal concern for crew and task
- Democratic—ideal leadership style in normal situations
- As concerned with maintaining the respect and cooperation of the crew as he is with achieving high operating standards.

20.5.2 Extreme Leadership Styles

20.5.2.1 Authoritarian Style:

- Dogmatic, pushy
- Aggressive to subordinates
- Submissive to superiors
- Inhibiting, undesirable.



20.5.2.2 Paternalistic Style:

- Expects unquestioning obedience
- Generous with praise
- Frustrating to work with.

20.5.3 Delegation

A good cockpit leader has the ability to delegate tasks to others, both for balancing crew workload and to provide variety and experience to the other members of the crew. A large, modern RPT aircraft is too complex to be flown by one person and a balanced sharing of cockpit tasks is essential.

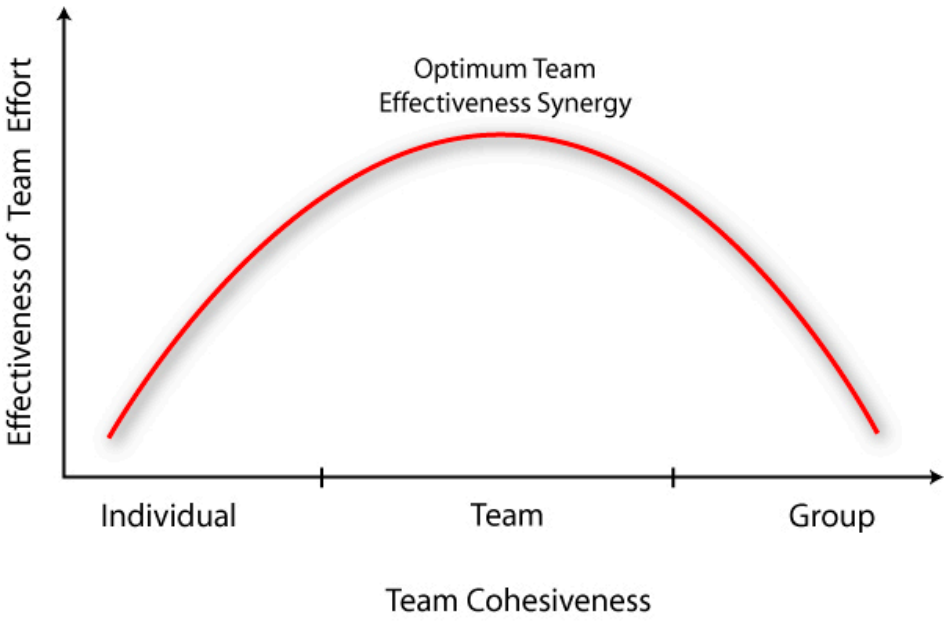
20.6 Teamwork: Group Decision-Making

When human factors are discussed they are often linked to CRM (Crew Resource Management). Good CRM involves teamwork and group decision making. Teamwork is the combined effort and organised co-operation of a group of people working together in pursuit of a common goal.

Synergy 1 + 1 = 3

This aids the optimum performance of a good team, which is greater than the sum of the individual performances. This is usually the case for small teams, but as the size of the group increases it will become cumbersome and the overall performance will deteriorate.

Teamwork Graph



20.6.1 Group Decision-Making Summary:

- Better solutions from the group than usually produced by one person
- The group decision will be better than the average of the solutions from the individuals within the group
- The group decision will rarely better than that of the most able crew member – group dynamics will tend to find a consensus decision.
- Multi-person crew improves the chance of having an able person present.

20.7 Factors affecting the quality of the group decision

20.7.1 Conformity:

- Individuals will often submit to the influence of others.
- Groups tend to reward conforming behaviour in new members, rather than dominance.
- Conformity will be most obvious in a crew of four.

20.7.2 Compliance:

- Groups are likely to agree to a request from a group member.
- Compliance can be manipulated by asking for a bizarre request, followed by a lesser but still peculiar request.

20.7.3 Status:

- Status determines persuasiveness. The higher ranking individual will persuade the lower ranking person.

20.7.4 Risky shift:

- The group empowers the individual member to overcome feelings of insecurity – he/she will feel safer in the group.
- A group will collectively assume more risk than an individual will.
- Blame will be spread in the case of a bad outcome – no one individual will take all the blame.
- Feelings of anonymity in a group—individuals can ‘keep their head down’.
- More of a problem when members are extroverts—they will influence the weaker members.
- Risk taking is often seen as a desirable social value.
- The media often highlights adventurous individuals.
- Leading characters in films and on TV are usually risk-takers.

20.7.5 Group Duration - ~~Fixed Unit Crews~~:

- Disadvantages - Bad relationships will worsen over time.
- Possible deterioration of effective communication as individuals become over-familiar.
- Good relationships may lead to short-cuts with standard operating procedures.

20.8 Improving Teamwork

- Everyone must learn to accept feedback in the form of a critique. However, negative feedback should be constructive.
- Critiques should consist of ongoing frank, constructive discussions among crewmembers.
- Each crewmember must try to show good leadership qualities.
- The cockpit leader must delegate to share tasks and to provide variety and experience to other crewmembers.

20.9 Cockpit Culture

The cockpit is a working environment where safety is the prime aim. Any cultural value, which is counterproductive to or not compatible with the achievement of this aim, should be discouraged and discarded. The cockpit will develop its own culture, which will require some people to put aside personal attitudes that may be desirable in the context of their social background, but hazardous on the flight deck.

Gratuitous deference to authority and the reluctance to speak out when in doubt are just two things that have, in the past, resulted in numerous hull losses and the loss of many lives.

20.9.1 Crew Member Effectiveness

Crew member effectiveness is influenced by many factors such as personality, which have already been discussed. Other factors include:

20.9.1.1 Pride

Can work in two ways:

- Doing the job extremely well
- Not admitting problems and hiding errors.

20.9.1.2 Peer Group Pressure:

- May result in some personal attitudes being changed
- You stop an individual from admitting problems
- Often results in an individual conforming to the wishes of the group.

20.9.1.3 Employer Pressure:

- Increased stress from the perceived need to meet timetables, standards and other employer requirements.

20.9.1.4 Complacency, Overconfidence and Boredom: Negative

- Leads to reduced alertness and an awareness of danger
- Increased automation and equipment reliability can result in reduced alertness amongst the crew.

20.9.1.5 Competence:

Can be measured in three ways:

- As others see you
- As you actually are
- How you see yourself.

20.9.1.6 Status:

- Will arise from a formal allocation of seniority or rank
- Can arise from your current role. You may not have formal seniority or rank, but you are in a commanding position that has arisen from the particular job you have been chosen to do.

20.9.1.7 Culture:

- Social values
- Attitudes
- Practices.

20.9.2 The factors that determine crew interaction:

- Status—arising from either formal or informal reasons
- Personality—extrovert or introvert
- Role (e.g. are you PF or PNF)
- Perceived ability—how good are you in the eyes of others.

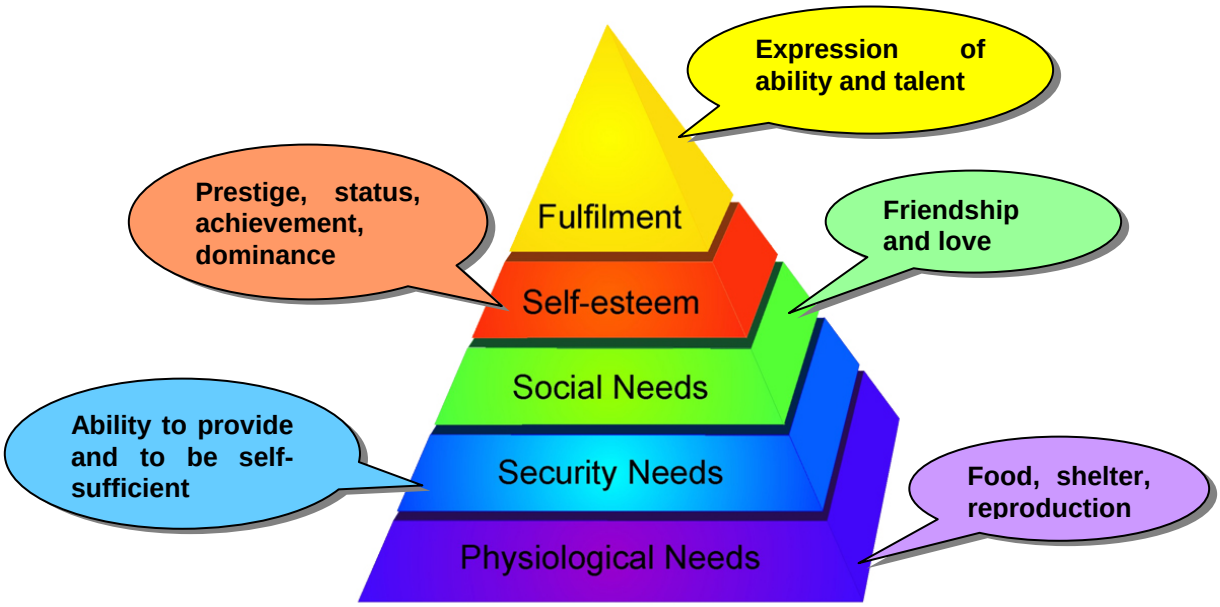
20.10 Motivation: Why We Do What We Do?

The study of motivation is concerned with the psychological and physiological needs and investigates why, rather than how, actions are performed.

20.10.1 Maslow's Hierarchy of Needs

Maslow (1943) proposed a theory of motivation, based on a hierarchy of needs, which have been applied in occupational settings.

Maslow postulated that the individual strives to work upwards in the hierarchy, satisfying the needs at each level in turn. It is not necessary to satisfy everything at each level before moving on to the next.



Maslow's Hierarchy of Needs

20.10.2 Herzberg Two-Factor Theory

The Herzberg Two-Factor theory proposed in 1959 represents another approach to the problem of motivation. Herzberg asked workers to describe job-related factors that produced positive or negative attitudes, and to indicate the effects of these factors. They found that positive attitudes were generated by factors such as achievement, promotion, feeling respected and part of 'the team'. It is interesting to note that salary is not a strong motivator. While money is important, once you are established in a job that provides a certain level of salary, the mind soon turns to the other factors that are stronger motivators.

Herzberg's motivating factors are consistent with the higher level needs in Maslow's hierarchy.

20.10.2.1 Motivating Factors:

- Job satisfaction
- Achievement and promotion
- Feeling part of a team or group
- Achieving recognition and responsibility
- The nature of the job.

20.10.2.2 Non-Motivation Factors (Hygiene Factors):

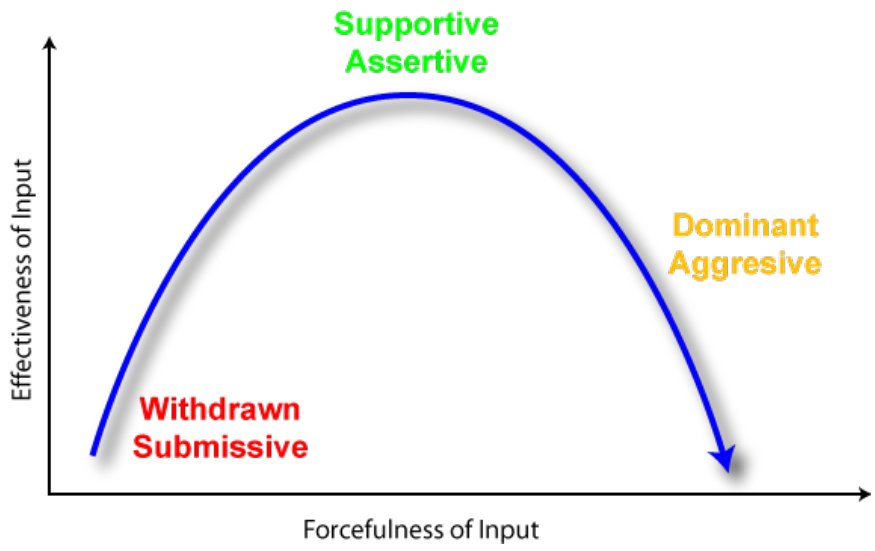
- Salaries
- Company policies
- Working conditions
- Job insecurity
- Staff-management relationships.

20.10.2.3 Boredom - A Negative Motivator

Boredom can result from being constrained, a lack of direction, repetitiveness, a lack of sense of completion, the nature, or perceived nature of the job.

Humans are not efficient monitors and the decreased stimulation of the automatic cockpit leads to boredom and monotony, affecting morale and performance. Under conditions such as these the ability to maintain effective **vigilance for more than 30 minutes is rare.**

20.11 Behaviour Types



20.11.1 Submissive Behaviours

People who show submissive behaviour do not express their honest feelings, needs, values and concerns and do not pursue their own legitimate rights. They usually defer to the needs and rights of others.

Other types of submissive people do express their needs, but do it in such an apologetic and diffident manner that they may not be taken seriously.

20.11.2 Aggressive Behaviours

Aggressive people express their feelings, needs and ideas, (usually in an unpleasant manner), without considering the needs of others. They almost always win arguments. The aggressive person is sometimes abusive, rude, and sarcastic. They may berate people for poor service, dominate subordinates and family members, and insist on having the final word on topics of conversation important to them.

20.11.3 Assertive Behaviours

The assertive person uses methods of communication which enables them to expresses their personal needs, values and concerns and to maintain self-respect and the satisfaction of their needs and rights without abusing or dominating other people. Assertiveness is a way of confirming one's own individual worth and dignity while simultaneously confirming and maintaining the worth of others.

20.12 Pilot Judgement

Pilot judgement is an integral part of decision making. It is the process of recognising and analysing all available information about oneself, the aircraft, and the flying environment, followed by an evaluation of alternatives and implementing a timely and correct decision

A judgement decision usually involves a problem of choice, an unknown element, usually a time constraint, and stress.

20.12.1 Poor Judgement Chain

Most aircraft accidents result from a combination of circumstances rather than a single cause. Aircraft accident investigators call this the "Swiss cheese effect".

In reality, accidents are usually the result of a chain of causes, involving a variety of pilot-aircraft-environment factors and often involving a series of errors in judgement by the crew: (Refer to the Gulf Air accident)

- One poor judgement increases the probability that another will follow.
- As the poor judgement chain grows, alternatives for safe flight decrease.
- Breaking the poor judgement chain is, in itself, an act of good judgement.

While inexperienced pilots have more handling accidents than experienced pilots, accidents caused by poor decision-making do not decrease significantly with experience.

20.13 Communication

On 29 January 1971, a Canadian Pacific Airlines DC8 was finishing its landing run on Sydney's runway 16 after a Pacific crossing.
From the control tower came the clearance, 'Empress 301, take taxiway right, call 121.7'
The crew of the aircraft claim they thought they heard, 'Empress, clear backtrack if you like, call 121.7.' So they began to backtrack.
Ninety-seven seconds later a B727, which had been cleared to take off on the same runway, collided with the fin of the DC8, damaging the under-fuselage of the 727. Two hundred and forty people were aboard the two aircraft, but no one was hurt.
Communication was named as one of the contributing causes of that accident.

'70% of accidents occurred because information was improperly transferred from one crew member to another or was not transferred at all.'
National Aeronautics and Space Administration

20.13.1 Verbal Communication

Good communication is a question of **what is heard and understood, not what has been said.**

Aviation relies very heavily on verbal communication (about 95% in the air), much of which is passed under quite difficult conditions. Factors that can inhibit communications can be classed as external and internal.

External factors include noise, overloaded radio frequencies, poor pronunciation, distractions of a busy work environment, or an unfamiliar accent.

Internal factors are mainly associated with the perception or the understanding of what was said. One of the most common internal factor errors is that of the error of expectancy. This occurs when the listener hears what he expected to hear, not what was actually said.

To minimise the possibility of this type of error, standard phrases are used in radio transmissions and also in the multi-crew cockpit. The runway collision that occurred in Teneriffe in 1977 was in part due to the non-standard radio phraseology in use at that time. Since that accident, there has been a lot of work done on standardising radio language. Airlines have also made efforts to standardise the 'call' and 'response' phrases used in the multi-crew cockpit.

20.13.2 Non-Verbal Communication

Communication can be both verbal and non-verbal. Non-verbal communication encompasses all of the elements of what we call ***body language***. *(Good communication relies 7% on the words, 38% on intonation and 55% on body language).*

Body language includes (but is not limited to):

- Hand signals and movements
- Eye contact
- Facial expression
- Touch
- Position of arms and legs—whether crossed or uncrossed, hands closed or open
- Gestures
- Body orientation, posture, leaning
- Head movement.

Body language is most effective when both parties can see the other clearly. While body language is important in all aspects of our lives, it is often difficult to achieve on the flight deck because of the side-by-side seating arrangements.

20.13.3 Component skills of communications

Good communication requires:

- Clarity and correct phraseology in what is said
- The listener receives and understands exactly what the speaker intended to be understood.

20.13.4 Listening:

- Good listening is interactive
- Good listening techniques must be learned
- It is critical in an emergency.

20.13.4.1 Poor Listeners:

- Pre-plan; they worry about what they want to say.
- Detour; they steer the conversations away from the prime topic, back to what they want to talk about
- Do not listen carefully.

20.13.4.2 Good Listeners:

Are active listeners and use the following methods to indicate their interest:

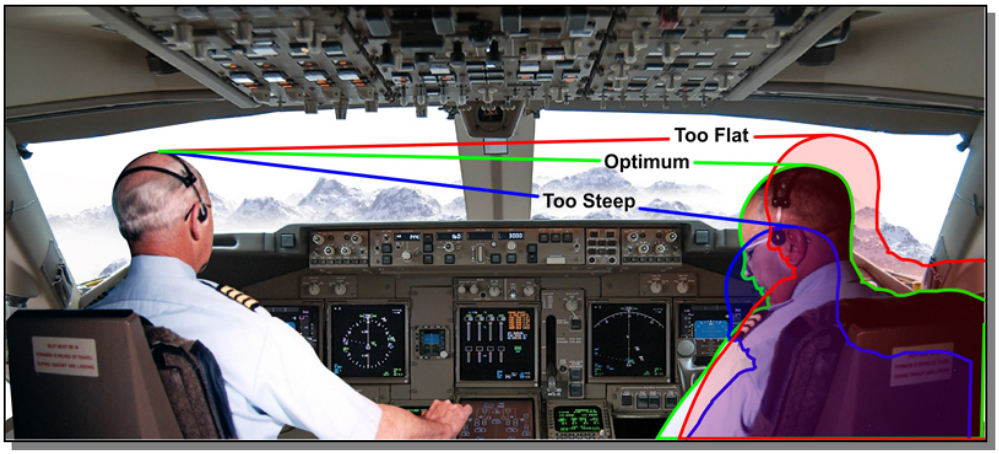
- Ask questions
- Paraphrase: that is to restate the speaker's position so that you understand the speaker
- Make eye contact
- Use positive body language.

20.13.5 Barriers to GOOD Communication:

- Conflicting or differing attitudes held by the speaker and the listener
- Personalities of the speaker and listener
- Body language
- Status of the respective parties
- Non-ideal trans-cockpit authority gradient.

20.13.6 Trans-Cockpit Authority Gradient

The trans-cockpit authority gradient is the authority relationship between the two pilots. It is considered to be too flat when the pilots are equally qualified and there is no clear definition of seniority or who is in charge. It is considered too steep where the senior pilot is too authoritative and the first officer is unassertive. Further problems occur when different nationalities fly together.



Non optimum gradients have been present in a number of accidents.

> The 1982 Palm Air Boeing 737 accident in Washington, in which the unassertive co-pilot's concern about the aircraft's performance during take off was not delivered firmly enough and therefore not recognised by the Captain, involved deference which resulted in a non-ideal trans-cockpit authority gradient.

20.13.7 The Two Communication Rule

The 'Two Communication Rule' is a policy employed by some western airlines to improve lines of communication and ensure important observations are drawn to the attention of all that need to know. It means that all operational communication must receive a response. If the PNF makes an observation to the PF and the PF does not respond, then the PNF repeats the observation. If no response is forthcoming after the second time, then the PNF is obliged to take control of the aircraft.

20.13.8 Team Communications

We can often classify a person's conversation according to whether they are:

- Putting forward their own views
- Seeking the views of others.

Sometimes these two modes are called **PUSH** and **PULL**.

PUSH mode is being used when you:

- Give a command
- Make a statement
- Give your diagnosis.

PULL mode is used when you:

- Ask a question
- Make a proposal
- Seek a response from other members of the crew.

Some of us tend to operate more often in the PUSH mode. This means that we put forward our own ideas at the expense of not hearing or bothering to find out what others think. If a captain is to get the most from his crew, he will encourage them to contribute by using PULL mode techniques.

20.13.9 Asking Questions

Questions can be **open** or **closed**. A closed question, such as “What’s the ETA?” gets a definite, usually short, answer. But an open question, such as “Why do you think that would work? invites the listener to give a more comprehensive explanation.

Open questions usually start with words like:

- How?
- Why?
- Can you explain?
- Will you tell me about?

20.13.10 Making a Proposal

The difference between giving a command and making a proposal is simply that the proposal gives the listener some say in the matter.

20.13.11 Conflict Resolution

Read once

Good communication encourages every crewmember to participate and give opinions so conflict is inevitable. Conflicts can become destructive if outside factors are introduced, or if it is over **who** rather than **what** is right. Conflict can seriously affect the quality of decisions.

Positive conflict resolution:

The pilot in command should:

- Encourage others to express opinions.
- In the event of conflict keep discussing issues needing resolution within the cockpit.
- Bring out all areas of disagreement.
- Acknowledge and express all feelings that are deep enough to affect your thinking. Everyone needs to know why you feel so strongly.

Good conflict resolution leads to deeper thinking, mutual respect, higher self-esteem, and strengthens team effectiveness.

20.13.12 Summary of Effective Team Communication

How to be assertive:

- Focus on your wants or objectives
- Be positive, clear and expressive
- Explain negative consequences
- Avoid put downs.

How to be supportive:

Read

- Focus on the needs of others
- Show understanding
- Be problem-centred
- Don't put yourself down
- Compliment when appropriate
- Summarise, inquire, propose, and read back.

How to give advice:

- Start by being problem-centred
- Adopt supportive style
- Describe behaviour non-judgementally
- Use specific information statements
- Have positive focus.

How to handle criticism:

- Be supportive in manner then later, if necessary, assertive
- Use supportive body language
- Read back if critic becomes aggressive
- Summarise regularly
- Make accurate and short responses
- Don't allow negative advice - turn it into positive advice.

20.14 Crew Resource Management

20.14.1 What Is CRM?

The object of CRM is to assist the captain to come to the best decision using all the resources available to him. Early CRM training and programs viewed the cockpit as an isolated universe and the term used was cockpit resource management. However, analyses of some serious accidents (in particular, the British Midland Boeing 737 accident at Kegworth, UK) revealed the concept that the resources available to the captain for problem solving were not limited to the cockpit, but extended to the whole crew, including the cabin attendants. Now, the concept of 'crew' includes persons and facilities outside of the aeroplane, such as Air Traffic Controllers, Maintenance Engineers, Meteorologists and any other relevant experts that might be able to provide assistance during in-flight emergencies.

Modern CRM programs are a logical vehicle for the training of crews in safety-related behaviour, and remain one of the primary lines of defence against external threat and crew error, at a time when some have asserted that CRM is a failed concept. This assertion arises because accidents still occur, but this contention is based on a misunderstanding of human capabilities and limitations.

As humans, we are prone to error and no training, however detailed or intensive, will change human nature. Humans will continue to make errors and accidents will continue to occur while we operate complex systems.

Our aim is to reduce the frequency of aircraft accidents.

CRM has been described as a means of improving teamwork in the cockpit. While effective teamwork is important, it is not the primary goal of CRM training. A better description of current, effective CRM is:

> 'CRM consists of the effective utilisation of all available human, informational, and equipment resources towards the goal of safe and efficient flight. More specifically, it is the active process employed by crewmembers to identify existing and potential threats and to develop, communicate and implement plans and actions to avoid or mitigate perceived threats. CRM also supports the avoidance, management and mitigation of human errors. The secondary benefits of effective CRM programs are improved morale and enhanced efficiency of operations'
>
> **University of Texas Human Factors Research Project: 257**

There have always been definitional problems as to what should be included in a good CRM program, and this definition problem still exists although it continues to be refined and clarified. One reason for this problem is the major difference in national and airline cultures, operating conditions and routes flown. There are usually differences in airlines within the same country.

In short, CRM programs will (and should) be different for each airline. In general, programs should recognise:

- The main purpose is to increase flight safety and the effectiveness of crews.
- Crews should be operating teams and not a collection of technically competent individuals.
- CRM exercises should include all crew members.
- CRM training should instruct crew members how to behave in a way that fosters crew team effectiveness.
- Crew members should practice the learned skills necessary to be team leaders as well as team members.
- CRM training should include both normal and non-normal operations.
- CRM instructors should be adequately trained.

In general, a good CRM program should include at least the following three phases:

- An awareness phase where issues are defined and discussed.
- A practice and feedback phase (and not a passive classroom exercise).
- A continual reinforcement phase where on-going and sustained CRM principles are ensured.

There has been much discussion within the aviation industry as to what a good CRM program should include. As a guide, ICAO has outlined the following as a minimum requirement:

Communications:

- Cultural influence
- Role(age, crew position, etc)
- Assertiveness
- Participation
- Listening
- Feedback.

Situational awareness:

- Awareness of surrounding environment
- Reality vs. perception
- Fixation
- Monitoring
- Incapacitation.

Problem Solving/Decision Making/Judgement:

- Conflict resolution
- Review (time constrained).

Leadership/Followership:

- Team building
- Managerial and supervisory roles
- Authority
- Assertiveness
- Barriers
- Cultural influence
- Roles
- Professionalism
- Credibility
- Team responsibility.

Stress Management:

- Fitness to fly
- Fatigue
- Mental state.

Critique:

- Pre-flight analysis and planning
- Ongoing review
- Post-flight.

20.14.2 Core Competencies

An effective use of CRM programs will rely heavily on the generally accepted core competencies required for safe and efficient aircraft operations. These competencies can be summarised as:

- Technical knowledge
- Aircraft handling
- Leadership and assertiveness
- Communications
- Decision making
- Monitoring
- Workload management
- Threat and error management.

20.15 Threat and Error Management

20.15.1 Concepts of Threat and Error Management (TEM)

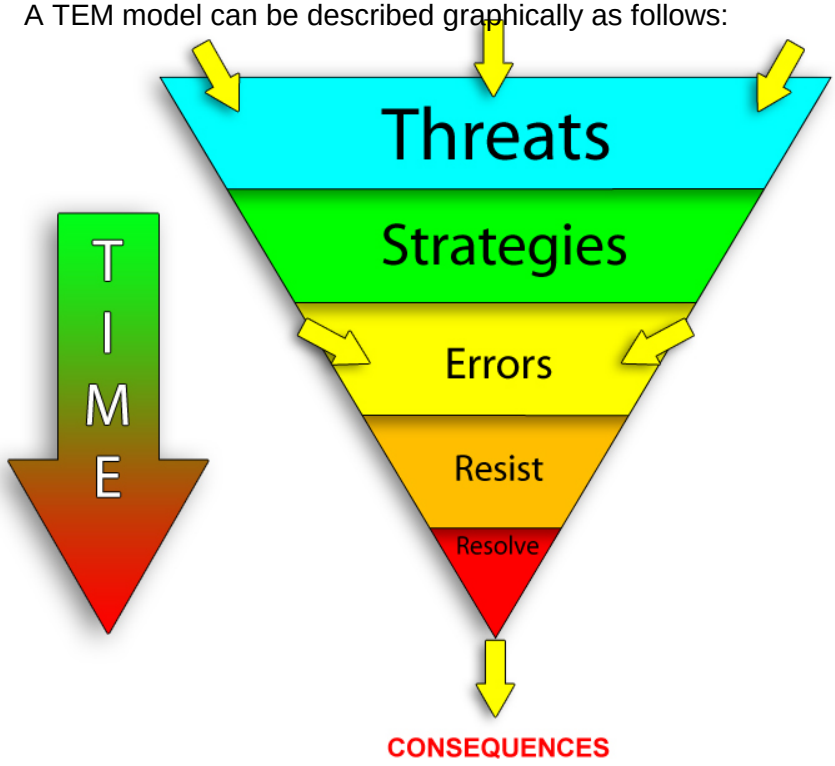
In the past, accident investigators often published the reasons for aircraft accidents as being 'pilot error'. This was a trite and unhelpful term that did little to reduce the future likelihood of a similar error recurring. This term is now rarely used in accident investigations, the reasons for aircraft accidents are now described in much more detail – often in a non-accusatory manner.

Error results from physiological and psychological limitations of humans. Causes of error include poor technical knowledge, fatigue, workload, and fear as well as cognitive overload, poor interpersonal communications, imperfect information processing, and flawed decision making. In aviation, teamwork is essential, and team error can be defined as action or inaction leading to deviation from team or organisational intentions.

Error management is based on understanding the nature and extent of error, changing the conditions that induce error, determining behaviours that prevent or mitigate error, and training aircrew in the use of these tools.

Some excellent work has been done jointly by the University of Texas and Continental Airlines on the development of a threat and error management system.

A TEM model can be described graphically as follows:



Acknowledgement: Cathay Pacific Airways Ltd.

Threat is defined as a problem, or potential for problem that arises outside of the cockpit. This would include such factors as:

- Adverse Weather (72%)
- ATC (60%)
- Aircraft Malfunctions (49%)
- Cabin/Ground Crew distractions (40%)
- Operational pressures (39%)
- Terrain
- Heavy traffic
- Unfamiliar airport
- Missed approach
- Time pressures
- Diversions
- Similar call signs

(The above percentage factors represent the frequency that various threats have occurred in the operations of a major international carrier.)

Strategies are procedures put in place to recognise and combat the threats. This might include consideration of alternate airports, actions in the event of a late runway change, continually updating divert procedures in the case of system failure, etc.

Errors are problems that arise inside of the cockpit.

Resist is the hardware and/or software that exists to counter the threat or problem, before the pilot necessarily becomes aware that there is a threat.

Resolve is the skills that the pilot brings to the system i.e. the above eight core competencies.

20.16 Threat and Error Management in Australia

20.16.1 Introduction

In Australia you are 20 times more likely to be fatally injured riding a motorcycle than driving a car. To help protect yourself from harm as a motorcyclist you might purchase a good quality helmet, body armour protection and protective boots. However, your safety on the bike will be heavily dependent on how well you manage the hazards, such as other vehicles, road surface conditions and pedestrians, you encounter on the road.

Consequently, many motorcycle riding courses do not just teach you how to ride the bike (e.g. cornering technique and gear selection), but also focus on identifying and anticipating potential hazards.

The same principle applies to TEM training (threat and error management) for pilots. TEM does not teach pilots how to fly an aeroplane. Instead, it provides practical techniques for maximising safety margins and promotes anticipation or 'thinking ahead' in the constantly-changing environment of flight operations. TEM is similar to 'stay upright' training for motorcyclists.

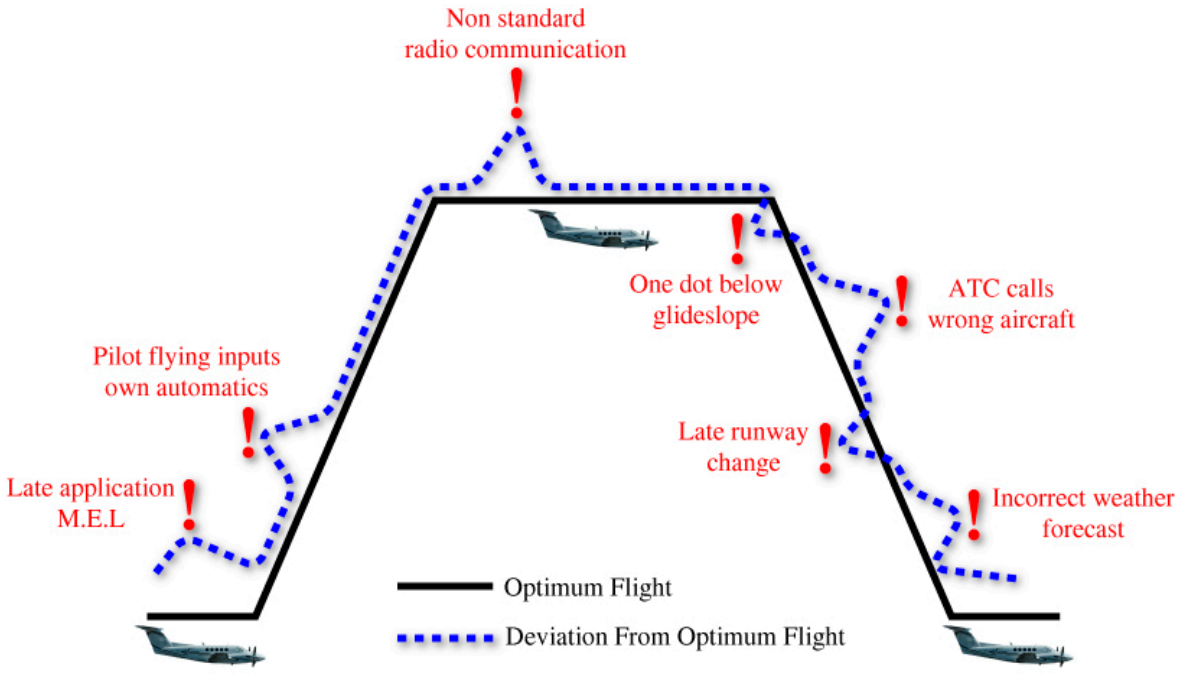
There are three basic components to the TEM model:

- Threats
- Errors
- Undesired aircraft states.

The best way to illustrate the TEM model is to think about your last flight as an operating crew member. Ask yourself the following questions:

- Was it the perfect flight?
- Did anything not go as planned?
- Did you experience any pressures or stressors that took your attention i.e. did these events require some sort of response?

Most probably, you can recall something in your flight that required you or your crew members' attention. Consider the following figure showing possible deviations from an optimum flight. The difference between the perfect flight, where nothing goes wrong (has this ever happened?) to something or everything going wrong is the threat.

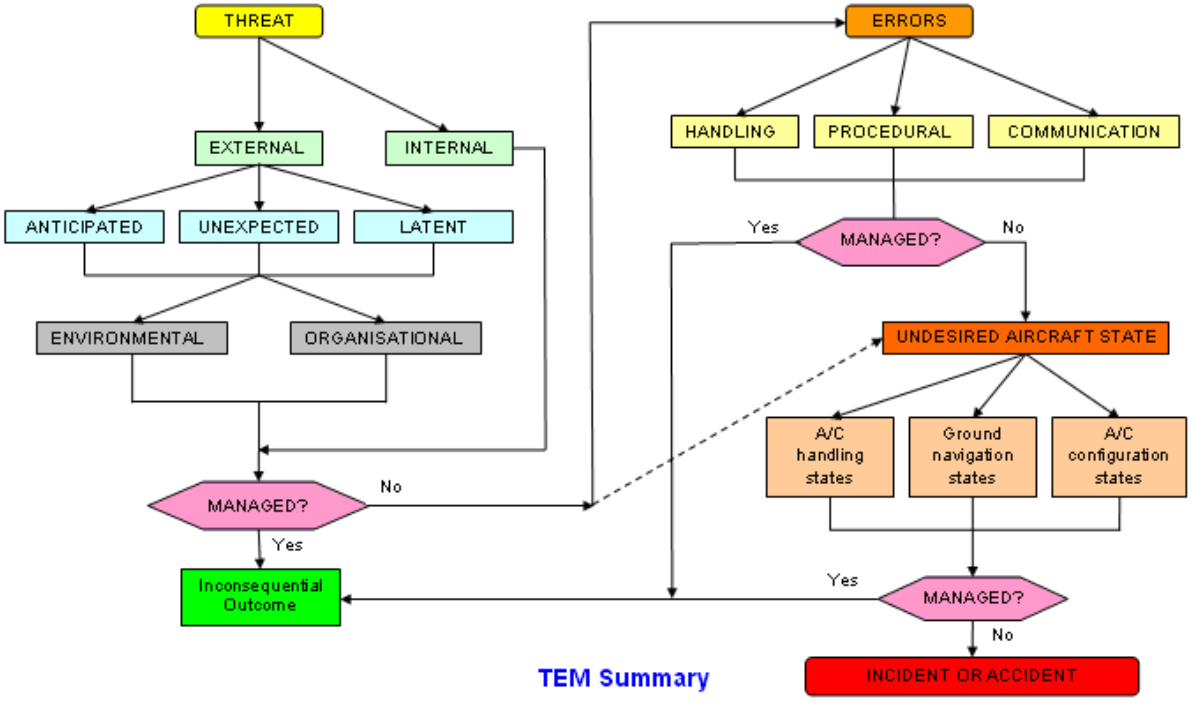


In this model, threats and errors are part of everyday aviation operations that must be managed by flight crews, since both threats and errors carry the potential to generate undesired aircraft states.

Flight crews must also manage undesired aircraft states, since they carry the potential for unsafe outcomes. Undesired aircraft state management largely represents the last opportunity to avoid an unsafe outcome and thus maintain safety margins in flight operations.

Another way of looking at this is to think about what you must do as a flight crew member of a 'normal' flight. The figure below suggests that to manage operational goals while maintaining flight safety, flight crew must:

- Manage 'normal' everyday operational difficulties and problems, referred to as 'threat management'.
- Manage their own errors or those made by other people they are working with, known as 'error management'.
- Manage 'bad' or unsafe situations they find themselves in, called 'undesired aircraft states' (UAS).



Firstly, on any given flight, flight crew will encounter a number of threats or 'red flags', which may or may not require a response to maintain safety.

> Examples of threats include poor weather, clear air turbulence, maintenance unserviceability, non-standard phraseology, fatigue and hazardous attitudes (complacency or over-confidence).

As individuals and as a team, flight crew will have a number of strategies to manage these threats. Some of these strategies will be well-practised standard operating procedures (SOPs) but some will require crews to use their critical decision-making and to find solutions.

The model implies that if the strategies used to deal with the threats are inadequate, then errors may occur. Examples of errors include not confirming ATC clearance, setting incorrect altitude, failing to make a safety announcement e.g. ‘crew to be seated for landing’.

20.16.2 Coping with Errors

Even if errors occur, the aviation system contains many defences that will resist and resolve these errors. The ‘resist’ part of the aviation system is the hardware and software that exist even before human responses kick in, such as:

- Ground proximity warning systems (GPWS).
- Traffic collision avoidance systems (TCAS).
- Checklists
- Automation
- Air traffic control (ATC).
- Standard operational procedures (SOPs).

Resolve:

- Decision-making
- Leadership
- Situational awareness
- Vigilance
- Assertiveness
- Monitoring and cross-checking.

20.16.3 TEM Basic Philosophy

- Anticipation:
  - Accepting that while something is likely to go wrong, you can't know exactly what it will be or when it will happen.
  - This is the vigilance factor that is necessary in all safety-critical professions.
  - Anticipation builds vigilance, and vigilance is the key to recognising adverse events and error.
- Recognition
- Recovery.

20.16.4 Threats

Threat can be defined as a situation or event that has the potential to impact negatively on the safety of a flight, or any influence that promotes opportunity for pilot error(s).

Threats can be:

- External to the flight crew
- Internal—those the flight crew brings to the operation.

20.16.4.1 External Threats

- Distractions
- Cabin crew
- Weather
- Maintenance
- Ground crew
- Heavy traffic
- Unfamiliar aerodrome
- Automation
- Missed approach
- System malfunction/failure
- Flight diversion
- Time pressures
- Similar call sign
- Terrain
- Air traffic control
- Passengers.

20.16.4.2 Sub-Division of External Threats

Anticipated threats:

- Some threats can be anticipated, since they are expected or known to the flight crew.
- Thunderstorm briefing their response in advance.
- Heavy traffic—keep a watchful eye.
- Unfamiliar aerodromes.

Unexpected threats:

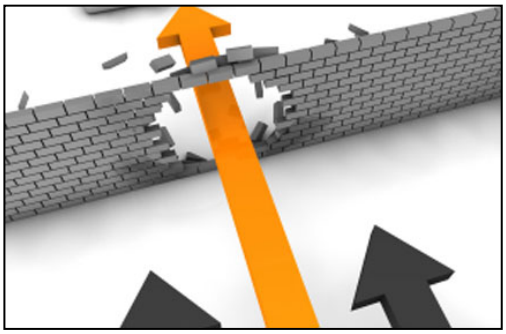
- Threats that occur unexpectedly and sudden during flight.
- Crew need to use their knowledge and experience to cope with these threats
- Missed approaches or In-flight diversions
- Distractions from passengers.

Latent threats:

- Things that are not obvious and need safety analyses to be uncovered
- Equipment design, optical illusions, etc.

20.16.4.3 Internal Threats

- Fatigue
- Team familiarity
- Language and culture
- Health and fitness
- Lack of experience in a role
- Operational recency and proficiency
- Pilot personality.



20.16.4.4 Threats Management

Threat management can be broadly defined as how crews anticipate and/or respond to threats.

A mismanaged threat is defined as a threat that is linked to, or induces flight crew error:

- Reading weather advisories
- Turning weather radar on early
- Thorough walk-arounds during pre-departure
- Correct use of procedures to diagnose unexpected aircraft malfunctions
- Briefing on an alternate runway in case of a late runway change
- Briefing cabin crew on acceptable times and reasons for interruptions
- Loading extra fuel when the destination airport is in question due to poor weather or restricted access
- Changing mindset in the pre-flight planning phase e.g. 'I know I'm predisposed to rush the walk around and checks when I'm running late, I will deliberately slow down these cycles to minimise the chances of further error'.

20.16.5 Errors

Errors are defined as flight crew actions or inactions that lead to a deviation from crew or organisational intentions or expectations; reduce safety margins; and increase the probability of adverse operational events on the ground and during flight:

- Minor errors—setting of wrong altitude but correcting it immediately.
- Severe errors—failing to set the flaps before take off.

20.16.5.1 Types of Aviation Errors

Handling errors (rate decreases as experience increases):

- Flight controls
- Automation.

Procedural errors (may occur across the whole spectrum of pilot experience):

- Checklist
- Briefings
- Callouts.

Communication errors:

- With ATC
- Ground
- Pilot to pilot.

20.16.5.2 Reasons for Errors

- Slip—diverting attention
- Lapse—memory failure
- Non-compliance—intentional act (shortcuts by flight crews).

Errors occur in three distinct ways:

- Spontaneous: These errors are independent of threats, e.g. incorrect setting of altitude.
- Induced: These errors are as a result of threats, e.g. missing a checklist item due to radio call interruption.
- Linked: These errors are part of a chain, each compounding the problem, e.g. iced pitot leading to airspeed error leading to incorrect pilot action leading to extreme attitude.

20.16.5.3 Handling Errors

Handling errors	Examples
Automation	Incorrect altitude, speed, heading, autothrottle settings, mode executed or entries
Flight control	Incorrect flaps, speed brake, thrust reverser or power settings
Ground navigation	Attempting to turn down wrong taxiway/runway, missed taxiway/runway/gate
Manual flying	Hand flying vertical, lateral, or speed deviations, missed runway/taxiway, failure to hold short or taxi above speed limit
Systems/radio/instruments	Incorrect pack, altimeter, fuel switch or radio frequency settings

20.16.5.4 Sub-division of Handling Errors

- **Systemic error:** errors with a definite pattern
- **Random error:** errors without any specific pattern
- **Sporadic error:** occasional and serious error after satisfactory performance for a period of time. The most difficult error to remedy.

Procedural errors	Examples
Briefings	Missed items in the brief, omitted departure, takeoff, approach, or handover briefing
Callouts	Omitted take off, descent, or approach callouts
Checklist	Performed checklist from memory or omitted checklist, missed items, wrong challenge and response, performed late or at wrong time
Documentation	Wrong weight and balance, fuel information, ATIS, or clearance recorded misinterpreted items on paperwork
Pilot flying (PF) / pilot not flying (PNF) duty	PF makes own automation changes, PNF doing PF duties, PF doing PNF duties
SOP cross-verification	Intentional and unintentional failure to cross-verify automation inputs
Other procedural	Other deviations from government regulations, flight manual requirements or standard operating procedures

Communication errors	Examples
Crew to external	Missed calls, misinterpretation of instructions, or incorrect read-backs to ATC, wrong clearance, taxiway, gate or runway communicated
Pilot to Pilot	Internal crew miscommunication or misinterpretation

- **Vigilance decrement:** A pilot monitoring the instruments while flying with autopilot is highly likely to miss malfunctions or deviations after about 30 minutes. It takes even longer for the pilots to recognise problems while flying manually in IMC.

20.16.6 Undesired Aircraft States

An undesired aircraft state (UAS) is defined as a position, condition or attitude of an aircraft that clearly reduces safety margins and is a result of actions by the flight crew. It is a safety compromising state that results from ineffective error management.

Undesired aircraft state	Examples
Aircraft handling	Vertical, lateral or speed deviations Unnecessary weather penetration Unstable approach Long, floated, firm or off-centreline landings
Ground navigation	Runway / taxiway incursions Wrong taxiway, ramp, gate, or hold spot Taxi above speed limit
Incorrect aircraft configuration	Automation, engine, flight controls, systems, or weight / balance events

An important learning and training point for flight crews is the timely switch from error management to undesired aircraft state management.

A flight crew select a wrong approach in the flight management computer (FMC). The flight crew subsequently identify the error during a crosscheck prior to the final approach fix (FAF). However, instead of using a basic mode (e.g. heading) or manually flying the desired track, both flight crews become involved in attempting to reprogram the correct approach prior to reaching the FAF. As a result, the aircraft 'stitches' through the localiser, descends late, and goes into an unstable approach.

Undesired aircraft states are transitional states between a normal operational state (i.e. a stabilised approach) and an outcome.

Outcomes, on the other hand, are end states, most notably, reportable occurrences (i.e. incidents and accidents).

While at the stage of undesired aircraft state, the flight crew have the opportunity, through appropriate TEM, of recovering the situation and returning to a normal operational state, thus restoring margins of safety.

Once the undesired aircraft state becomes an outcome, recovery of the situation, return to a normal operational state, and restoration of margins of safety is not possible.

20.16.7 Countermeasures

According to Merritt and Klinect (2006), flight crews who develop contingency management plans, such as:

- Proactively discussing strategies for anticipated threats, tend to have fewer mismanaged threats.
- Crews that exhibit good monitoring and cross-checking usually commit fewer errors and have fewer mismanaged errors.
- And finally, crews that exhibit strong leadership, enquiry and workload management are typically observed to have fewer mismanaged errors and undesired aircraft states than other crews.

20.16.8 CRM vs. TEM

Many of the best practices advocated by crew resource management (CRM) can be considered TEM countermeasures:

- Planning countermeasures
- Execution countermeasures
- Review/modify countermeasures.

20.16.9 Planning Countermeasures (before departure)

SOP briefing	The required briefing was interactive and operationally thorough	Concise, not rushed, and met SOP requirements Bottom lines were established
Plans stated	Operational plans and decisions were communicated and acknowledged	Shared understanding about plans Everybody on the same page
Workload assignment	Roles and responsibilities were defined for normal and non-normal situations	Workload assignments were communicated and acknowledged
Contingency management	Crew members developed effective strategies to manage threats to safety	Threats and their consequences were anticipated Used all available resources to manage threats

20.16.10 Execution Countermeasures (during flight)

Monitor/cross-check	Crew members actively monitored and cross-checked systems and other crew members	Aircraft positions, settings, and crew actions were verified
Systems and workload management	Operational tasks were prioritised and properly managed to handle primary flight duties	Situational awareness is maintained
Automation management	Automation was properly managed to balance situational and/or workload requirements	Automation setup was briefed to other members Effective recovery techniques from automation anomalies

20.16.11 Review Countermeasures

Cope with unexpected contingencies during flight

Evaluation/modification of plans	Existing plans were reviewed and modified when necessary	Crew decisions and actions were openly analysed to make sure the existing plan was the best plan
Enquiry	Crew members asked questions to investigate and/or clarify current plans of action	Crew members not afraid to express a lack of knowledge 'Nothing taken for granted' attitude
Assertiveness, remain alert	Crew members stated critical information and/or solutions with appropriate persistence	Crew members spoke up without hesitation

20.16.12 Systemic Based Countermeasures

Mechanical/electronic devices	Appropriate pilot actions
Ground proximity warning system/ airborne collision avoidance system	Checklists Briefing
Stall warning devices	Standard operating procedures
System failure warnings	Training