Zen and the Art of Airbus Failure Handling

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1 Mental Model

Picture a small stream emanating from a mountain spring. Sitting by it are five bowls. They are labeled:

1. Diagnosis
2. Containment
3. Strategy
4. Tactics
5. Review

You have a ladle which allows you to transfer water from the stream to the bowls.

Slightly downstream, the water runs into a bamboo channel containing fish. The bottom of the channel has a number of small drainage holes, so some water from the stream must continually feed it.

Usually, there is more than enough water flowing from the spring and it overflows the channel into the stream bed, but when you start using the ladle you must take care else it will run dry and the fish will die.

2 Model components

2.1 Spring

The spring represents your cognitive flow rate. There seems to be little you can do to increase this. Tiredness and illness definitely decrease it.

2.2 Channel

The channel represents the continual cognitive drain of the flying and navigational tasks.

History has shown that it is perfectly possible to get so involved in failure handling that the flight path is fatally disregarded, the situation represented by the fish dying. Sufficient cognitive capacity must always

be devoted to the flying task by PF and to the monitoring task by PM. Active awareness of how difficult it is to do this in the face of a complex failure is the only real defence.

Unlike the flow rate from the spring, the flow rate out of the channel can be changed – some of the holes can be plugged.

In the short term there are two major opportunities to reduce cognitive drain:

- If you can get the autopilot to do the flying, much less capacity is used for the flying task.
- If you can get above MSA and fly a holding pattern somewhere sensible, much less capacity is used for the navigational task. This is particularly true if you can maintain VMC.

Over the longer term, training manual handling skills will permanently reduce the size of the holes. The more severe a failure is, the more chance there is that you will be flying the aircraft manually, possibly with degraded handling characteristics. If you have been regularly honing your skills on fine sunny days, the cognitive drain on the dark stormy night when it's all going wrong will be much lower.

There is often a significant asymmetry between the capacity drain for flying and the capacity drain for monitoring. This can easily lead to PF not properly monitor PM's actions or being able to absorb the intricacies of the failure. Temporarily swapping control is useful in these circumstances, giving PF the capacity to review what has been done and expand their situational awareness, giving an overall increase in cognitive capacity on the flight deck.

2.3 Ladle

The ladle represents the triage process. This is related to the concept of chunking of cognitive capacity in the face of a requirement to simultaneously carry out multiple novel tasks.

Human beings are not particularly good at real multi-tasking; we actually rely on motor programs and rapid task switching. If a task is

novel, we will not have a suitable motor program unless we can re-task something that is not novel.[1]

Interrupting a task before it is complete will often lead to errors, particularly errors of omission. Focusing on a single task, however, may leave other critical tasks unresolved for too long.

The trick is to methodically break workflow down into short, focused, completable chunks. The best chunks are those that come from a suitably stocked "bag of tricks". Stocking the bag requires systematic study of the abnormal procedures and techniques set down by Airbus with the aim of identifying common chunks.

Triage is the art of selecting the right chunk at the right moment.

2.4 Bowls

Filling the bowls represents completing the tasks required for a successful outcome. The size of the bowls and the rate each needs to be filled is dependent on the specific failure that is being handled.

2.4.1 Diagnosis

Diagnosis is the foundation on which all else is built. It is often a multi-level process rather than a single task, with each level of diagnosis triggering containment, strategic and tactical tasks that are completed before returning for a more detailed diagnosis.

Good technical knowledge is at the heart of accurate diagnosis. It is important to remember that, at best, the ECAM provides a data point for a diagnosis, not the diagnosis itself. All relevant information must be sought out.

Diagnosis in the sim is usually much simpler than diagnosis in the wild. It is quite possible that a proper explanation for what is happening will not be available until the aircraft is stripped down in a hangar, and

[1] Re-tasking motor programs is often a good technique. For example, for a go-around everything after reading the FMAs is the same as a flap 3 takeoff; it is worth practising a flap 3 takeoff from time to time so you can have the motor program available for the go-around.

you will have to satisfy yourself with treating the symptoms. This is a deeply uncomfortable position.

A particularly good way to improve your diagnostic skills is to read incident reports. It is always better to benefit from someone else's bad day out than from your own.

2.4.2 Containment

Containment is generally either about recovering a failed system or about stopping things getting any worse. It is usually driven by ECAM or QRH procedures. It is essential to understand what each step of a procedure you are running is supposed to achieve.

Airbus procedures are sometimes not a model of clarity. The chance of making an error increases dramatically if you are encountering a checklist for the very first time during failure handling. Studying these procedures in advance pays dividends.

Airbus often mix in strategic and tactical recommendations with their containment checklists. It is easy to get drawn into detailed planning at inopportune times as a result. A good example is Flaps/Slats faults. The basic containment is utterly trivial – fly at a speed that doesn't overspeed the locked device. As soon as you call for the QRH procedure, however, you will be drawn into a whole bunch of techniques, notes, tables and conditional subsections that are going to do nothing to improve your immediate situation. It is often useful to simply acknowledge the existence of such recommendations and agree to defer detailed examination of them for a later planning phase when more capacity is available.

2.4.3 Strategy

Strategy refers to the "big picture". Strategic planning generally rises through three levels, with increasing amount of cognitive capacity required for each:

1. Establish a safe flight path
2. Head in a sensible direction
3. Specify destination and fallback position

Each stage of strategic planning can be broken down into four necessarily sequential steps:

1. Declare requirements and preferences
2. Generate options
3. Declare the plan, preferably including a fallback option
4. Communicate the plan

If you like acronyms, **R**equirements, **O**ptions, **P**lan, **S**ay (ROPS) works for me.

A discussion and clear declaration of requirements and preferences is a great barrier to rushed and faulty strategic decision making.

The usefulness of the MEL in requirement generation should not be underestimated. If Airbus allow you to dispatch with something, then, provided you have the fuel and any MEL conditions for that dispatch are met, continuing to scheduled destination is probably the right move. The MEL can also generate ideas for additional containment and tactical procedures.

On the flip side, if the MEL forbids dispatch with a failure, a decision to divert should be strongly considered. An example of this is the relatively common Blue System Electric Pump failure which feels fairly minor (mainly just loss of a spoiler per side and slow slats, with the RAT available if another hydraulic system is lost), yet Airbus won't let you dispatch with it. This is an indication that the redundancy provided by that pump is designated critical by Airbus and thus pushing on to a distant destination might be considered overly brave.

There are usually three sets of people outside the cockpit that need to know your plans: ATC, the cabin crew and the passengers. Under stress, non-standard communication can easily become muddled. A good tool to ensure structure is the NITS brief, which can be used to clearly disseminate the plan to all three groups:

- **N**ature of failure
- **I**ntentions

- **T**ime
- **S**pecial requirements

2.4.4 Tactics

Tactics are the detailed implementation required to achieve your strategic goals. They are a "bag of tricks" containing supplementary flying, automation and systems handling techniques.

A tactic is most effective when it is constructed as a rapidly completable block of simple, logically connected actions that can be considered as a single unit.

For example, if you have a well rehearsed "asymmetric take-off" tactic[2] that you can reliably execute as a unit, the initial part of an EFATO becomes trivial. Similarly you can break down the RTO into an "RTO initiation" tactic and an "RTO cleanup" tactic, with a consideration of fire versus wind between them.

When you start breaking things down in this way, even complex failures such as dual hydraulic failures end up boiling down to a short unthreatening list of common tactical units. Furthermore, you end up with a flexible toolkit for dealing with failures and combinations of failures that Airbus has not planned for.

From a tactical point of view, failure scenarios tend to be made up of two phases, starting with a "catch up" phase where tactics are inserted individually on an ad hoc basis to meet immediate challenges and evolving into a "tactical stack" phase where a pre-planned series of tactics are interleaved with the standard operation. For the latter it can be very helpful to write out a bulletted list of the tactics you intend to deploy so that you can easily check they have been actioned once the workload starts to build.

2.4.5 Review

Review needs to be methodical to be useful. I find the best way to go about it is to examine each of the other bowls in turn.

[2]Mine is slower rotation, $12\frac{1}{2}^\circ$ pitch target becoming a V_2–V_2 + 15 airspeed target, max bank angle 15°, TOGA when flight mode blended

To review Diagnosis, you review the systems pages and panels looking for contradictory evidence.

To review Containment you use the RCL button to check through the cleared ECAM procedures, check through QRH procedures for errors and omissions (particularly if you were not the one doing them), consider any available resets that may not have been tried and refer to extended checklists and the MEL as appropriate.

To review Strategy consider whether your requirements and preferences remain the same and whether the chosen option and fallback position remain optimum.

To review Tactics you check through the tactical stack with an eye for omissions.

The optimum quantity and timing of reviews is a non-trivial question that needs to be adapted to the situation. It is easy to end up burning time and capacity pointlessly re-reviewing.

My default is to carry out a full review once the final stage of strategic planning is in place and being actioned, then to assume that unless something drastic happens, those areas are solid.

Then, at a suitably low work-load time on the approach I will use the bulletted list of tactical units I created to ensure that everything that was planned to have been done up to that point has been completed and any remaining items are at the forefront of my mind.