Transcript of interview with Pilot

R: Interviewer

M: Pilot

R: Firstly, before we begin with the model proper could you tell us a wee bit about your background and experience in aviation, your career and so on?

M: Sure. I came through on a cadet programme with Flybe, that was in 2001 so I've been flying commercially for fifteen years - that's been nearly 12 years flying around Europe based out of the UK and for the last three years I've been with FlyDubai on the 737 flying pretty much everywhere within six hours of Dubai, so I've been all over the place. So that's the nutshell - I'm a captain on the 737, I used to be a training captain, I used to be a sim instructor so I've seen TCAS in action from behind the scenes as well as at the front on the controls so hopefully I'll be of some use.

R: So you've covered it from both angles - that's useful.

OK, we'll start in a moment with this sample model that we have here - can you see that OK, is it legible?

[brings up sample - restaurant model]

I'll just give you my little spiel to start with, then we can look at this model. So we have based on some previous work done at St. Andrews University we are working on this notation for modelling these types of large, complex systems called responsibility modelling and the trick there is to have a single modelling framework, a notation like the one you see here that can cover human elements of systems, it can cover organisations and it can also handle technical elements, equipment and so on. It's an overarching technique, fairly abstract so it doesn't have that high technical detail you may see in other modelling or safety analysis techniques; the tradeoff there is that by not being so technical we can try and cover more ground with more breadth.

So I'll now tell you a little bit about the technique itself. So in this notation we have three types of entity, of object and you can see three of all three of them in this model on the screen. Firstly we have the idea of responsibilities, and they are basically the core concept in this technique. And a responsibility is a duty, an obligation to do something or to ensure something occurs and in that in regard it is a little more abstract than for example goals, processes, tasks that are often used in other modelling techniques. The idea is that is that as they are more abstract they can cover more ground, can be more flexible and can be more intuitive; there are times when you can feel you have a responsibility to do something, but you cannot necessarily express it as a process, but it is still something that you have to do.

And then we have our other two entities; they [responsibilities] are indicated in the model by these rectangles - so you can see there are responsibilities - for the chef to cook meals, and for the managers to be sure that people in their restaurant have a nice meal. We then have as you can see with the stickmen figures we have actors. They are our second kind of entity. Actors can represent individuals; they generally represent some kind of role so we talk about a waiter and a chef and a restaurant manager not meaning an individual person that is a waiter, but meaning the general role of being a waiter. They can be roles that are filled by individuals, as the ones in this model mainly are; but they can also be roles that are filled by organisations - for example, if we extended this model to add a supplier of food, of ingredients that could be a company rather than an individual person; and these can also be computer systems, pieces of hardware, technical elements and so on. So we could in some case of the model have an oven as an actor, some device that provides heat and provides cooking would be relevant in this example.

And the third entity are resources, as you can see here we have the Order and the actual Food being served as a resource. Resources can be basically be of two kinds - they can be a physical thing, for example a meal, a physical piece of food for example or it can be a piece of information, like the Order. We don't, the Order does not represent the order written down on a piece of paper on a waiter's notepad; it represent the information more generally that there is an order that is to be placed. So we will see later on in the TCAS model that for example a resource can represent an alert, a piece of communication is treated as a resource.

So those are the three basic types in the system. Any questions about those before I go on to talk about how they interact?

M: No, that's fine.

R: Excellent, thanks very much.

So the overall aim of one these systems, modelled in this way is to make sure that all the responsibilities are completed, that they are all discharged. That is the core task of the system and we consider this example meal system to succeed if the orders are take and the meal is cooked and the customer enjoys their meal. We consider the system to have failed in some way if either of those don't happen. So that's the general concept of the model. In order to understand this in detail we need to look at how they interact. We have four or five different kinds of relation between these objects, so we'll go through some of them now.

Firstly, we look at resources; they're relatively straightforward. You can see that a responsibility can produce a resource - for example, cooking a meal produces the food; that's a fairly straightforward relationship that you can see here with the arrow between them; and that the meal, the resource can then be consumed by some other responsibility, for example in order to enjoy the meal you have to eat the food and therefore the resource is consumed by the next responsibility, like a production line. We can also say that certain responsibilities depend on each other or rely on each other - for example, you can see that for a meal to be enjoyed we must first have taken the order and cooked the meal - you can see the relationship between two responsibilities like that. Just to check - if this one is not completed then it is impossible to complete the next one. And that covers responsibilities.

And perhaps the more subtle relationships are between the actors and their responsibilities. Because there are two kinds of interactions that can occur there. Firstly we can say that in order to complete some responsibility they must involve some actor. So we can say for example that it is not possible to take an order unless you have a customer to take the order from, and you can see we have indicated that with this normal sort of grey arrow at the bottom of the diagram, and you can see the chef is required to cook the meal. Then we have a more abstract concept, which is the concept of holding a responsibility. That indicates not that the actor is required necessarily to perform it, but they have some level of control or accountability over that. This is perhaps best demonstrated by the example of the manager of the restaurant. The manager (this is indicated on the diagram by the open arrow head - you can see there is open arrow head between Enjoy Meal and Restaurant Manager rather than a closed one). This is an important example, because we say here that the restaurant manager holds the responsibility Enjoy Meal for the customers - but the elements required to complete this are thing like the order must must be taken, the meal must be cooked and the food must be made. And the restaurant manager does not do those - as you can see, they are done by other people. But they still hold the duty to ensure this happens, a sort of managerial responsibility. And that's more interesting because we make inferences from this - that for example the manager should wield some control over these other actors, because if the customer does not enjoy the meal they will blame the manager even though the manager was not directly involved in cooking the food, for example. So we have this sort of hierarchy where you can depend on other actors that you do not directly control, so the idea is that managerial responsibility comes in.

M: The lack of direct control?

R: Exactly. Sometimes you are responsible for things you don't directly control and that can lead to

interesting systematic vulnerabilities if you are not careful.

So just before we move onto TCAS itself can I ask you to just talk me through this model, describe it for me so we've got a common language about what we're seeing.

M: OK, so we've basically got three main aspects - we've got the tasks such as taking the order, we've got the actors who the people who are involved in the tasks and we've got the actual resources. And then we have some of the actors don't have direct involvement, some of them have then overall control over the aspects of the process, however by not having direct control they are relying on others to action their resources, the tasks. They all interact, a lot of the tasks require multiple inputs for them to be in effect and it's kind of a process - if one process breaks down then the whole system doesn't work. That's kind of my interpretation.

R: That's excellent - just checking we're on the same path otherwise it gets tricky later on. I'll just check that I've covered everything that I want to go over. We have.

So now we'll jump on and we'll look at our models of TCAS proper. Just give me a minute to switch over the views.

[Loads "Pilots" TCAS sub-model]

OK, let me expand the window so this is easier to see.

OK, so the text here is rather small - can you read that?

M: Yeah, I can see that.

R: So what we have here; we made a large model of TCAS and then for ease of understanding at first glance we divided it up - this is a series of responsibilities, resources and so on that directly involve the pilots in the event of a TCAS incident. I should say at this point that our model is focusing on pretty much the events just before a TCAS alert, the events during a TCAS alert and then the events immediately afterwards as the situation is resolved. It's not trying to be a general model of aviation or air traffic control or things like that; that's the sort of scope of the model. So please take a minute or two to look at that and then if I could ask you, based on what we said in the example if you could briefly describe what the model says.

[quickly]

M: It's basically the pilot flying has a number of duties to action, to follow in accordance with the operational procedures such as; we have the TA notification we got through the process, we have direct control over that; basically it's just seeing how everything is co-ordinated; we also have as an operator you have that additional responsibility of having to train your pilots to follow the TCAS correctly.

So as pilot every time I'm in the simulator, every six months I go through the TCAS RA responses, and again it's just making sure the pilot flying is the central element of the TCAS system - it requires the pilot to actually do something to make TCAS operate, and it also involves a number of requirements for the pilot to be aware of such as response time, ensuring safe flight. I can see a number of the actual responses have two arrows, one with a direct control and one with a direct control, so again that's kind of what I'm picking up. Anything else? That's it for me.

R: OK, so now I'm going to ask a couple of questions about usability.. - it sounded to me that you could follow the structure of this quite well, does that seem a fair point?

M: Yeah, yeah. It's quite easy to interpret and it's very familiar language to a pilot - when I read the boxes I'm recognising them and I know what the object of the box is.

R: That's good to hear. I'll just briefly flick this on to show it...

[Activates Sourcing mode]

We took all these, the wording from various parts of the ICAO ACAS manuals and that's where we

got our details out of.

[Disables Sourcing]

So you seemed to get this quite well - are there any parts of this model that you find confusing or can't quite follow what the model or the notation's saying?

M: Just the open arrow heads, in terms of not in direct control. When you have Pilot Flying not having control of safe flight - describe how that...

R: OK, the reason took that particular responsibility was that from reading the various standards documents we very much got the idea that the pilot has this quasi-legal responsibility to ensure safe flight, a sort of moral and legal duty to be safe, but at the same time at no point is it ever described how we can do that; it seems like a very multifaceted thing-

M: It's a real overall picture thing - you are in charge of safe flight.

R: So it's OK to think of things that mean you are failing to do this, but it's hard to think of; you can't really say that if you follow all these steps safe flight is guaranteed; there's always a bit of uncertainty in it.

Because we couldn't think of, find a concrete way of doing this we left in as the pilot is responsible for this absolutely, in the abstract indirect way but they are not required to do it because this is not a responsibility we can directly complete; you can't tick a box and say "Well I've ensured safe flight", and that was our; we felt it had to be in there because it's an important aspect, and perhaps there are some interesting scenarios where for example the pilot might feel that doing one of these other tasks might, other responsibilities might cause them to be not ensuring a safe flight. They might want to overrule something for some reason, so it's an interesting thing to have in the model but you can't directly complete it, because know how that can be done.

M: Gives you a bit more leeway.

R: Does that sort of-?

M: Yeah, that's sounds about right. Sometimes we, in the interests of flight safety are allowed to violate certain SOPs, procedures, there might be a reason why we don't follow one of those instructions. That makes sense.

R: I was going to ask - in cases where doing it by the book would potentially be-

M: Not always the best way.

R: That's reassuring for us that these things we put in the model actually represent some kind of actual real scenario. OK.

So I suppose the next thing to ask in this case is are there; this model broadly fits with the kind of [unintelligible] and actions that you would carry out when flying? So I suppose the question there is are there any bits of this part of the model that seem inaccurate or miss the point - that don't represent the real-world behaviour as you see it?

M: The only thing I would say is that Pilot Not Flying would have more involvement as well as updating location, monitoring RA he is also in charge of ensuring safe flight, he's also in charge of making sure the RA is adhered to; if the Pilot Flying is not following the procedure the Pilot Not Flying will take over - so that's the only thing I would really say, otherwise it's good, yeah.

R: That's a point we had raised also in a previous interview we had with an air traffic controller that was saying that these roles are perhaps more flexible that the model suggests. From our interpretation of these ICAO documents they seemed quite clear that the Pilot Flying did this, and this and this, rather than the pilots as a group, a team; but is it a case that you almost flip roles, if the Pilot Flying is not handling it then the other one jumps in, or is it just that they are more flexible with how things are distributed in general.

M: It's usually fairly strict as to who is Pilot Flying and Pilot Not Flying to avoid confusion, however if there is an event where the Pilot Not Flying would do better as the Pilot Flying we do swap over very quickly - I'm a captain, so if I'm flying with a first officer who gets out of his depth at any time I will take over; I'll take over either for the rest of the flight or for a short period and then hand control back to him, so yeah there can be a bit more flexibility but in that case you probably could argue that the Pilot Flying becomes Pilot Not Flying and vice-versa. And then the Pilot Not Flying, who is now Pilot Flying takes over the roles. It could be quite confusing.

R: It's a good point - we don't have anything in our model that suggests that flip could happen, which is perhaps something for us to think about - the observing each other and checking that you're--

M: That's why there's two of use there - we cross-check everything, we're monitoring everything and we are ready to swap over roles if that's the safest course of action.

R: Are there any, any of these entities in the model that you would say are missing - important aspects of that interaction around the TCAS events that are not in this model, from the pilots' side of things?

M: I can't think of anything missing, no - certain aspects are covered by, ensuring safe flight is a fairly broad spectrum, but when you flying, following a TCAS you'll find you get a TCAS at the very edge of our enve-, our performance and you have to be very careful not to either stall the aircraft or overspeed it so that ensure safe flight does cover a lot.

R: That's an interesting point - the TCAS system isn't clever enough to realise that you aren't going to exceed your ceiling or whatever when it gives you instructions?

M: No, it's basically just a box talking to another box, making certain we avoid collisions. It doesn't actually take into account performance of the aircraft - we have some restrictions such that at low altitude we won't get descents, but that's the only inhibits we have - at high altitude there's nothing so it will absolutely put you in a bad situation if you are not careful.

R: So it could tell you to keep climbing until you are no longer capable of-

M: Yeah, we call it the "coffin corner" where your high speed and low speed gets closer and closer and then it will actually put you right into, well beyond the envelope of the aircraft.

R: So in that case again the documents we have looked say, there is almost this obligation on the pilots to follow the instructions of the TCAS system, but at the same time you are saying that if you are not careful and follow them too closely, too blindly you could put yourself in danger.

M: And again, the TCAS, other systems such as stall warnings and GPWS overrides TCAS, so again it says TCAS there is a problem here which you have to fix, but if you then stall the aircraft then you have deal with the stall first and then the TCAS. There is some logic, but you do have to be careful with TCAS and be aware.

R: Again, that's something from reading, doing it by the book that should never happen but it clearly it's not as simple as it sounds.

I suppose the flip side of that previous question is was there any parts of the model here that seem irrelevant or of minimal importance?

M: No, they're all aspects you have to consider; I'd say every one of those is good.

R: Excellent, that's very reassuring from our point of view that we've got a reasonable match. Let me check if my notes to see if I have anything else to ask...

Let's move on to the next one. What I'm going to show now is a model of the air traffic control side of this; first-order interactions that the air traffic controllers are involved with, and from your experience of interacting with them if this seems like a fairly accurate view of how they would operate.

[Switches to ATC submodel]

R: OK, let me turn off again these sourcing labels.

[turns off Sourcing mode]

R: So I apologise for the slightly overlapping arrows; it's very hard to lay it out in a particularly nice manner. So again, just take a moment to have a scan through this and if you briefly described what interactions that it's telling you about.

M: OK, so in my interpretation I'm reading the pilot's interaction with ATC basically to advise of the RA then ATC is to acknowledge the RA and await for confirmation that the RA has been resumed, has been completed and then they start to run the aircraft again and to try and avoid any future conflicts. And then with the future look to feedback to address what happened and avoid in the future. That's what I sort of see from there.

R: Excellent, thank you for that.

Can I just say here a little bit of notation I didn't introduce - you see this bit with TCAS and Report RA in the top corner which is greyed out and the arrow is dotted rather than straight, and that's just to represent that part of the model of disabled; we've modelled it but it's not functional. And this basically came from us reading in one part of the documentation that there was this idea at least that the TCAS should automatically report when it generates alert back down to air traffic control by some sort of datalink system, which I understand never happens.

M: No, it's not part of our monitoring system yet.

R: In theory at least, someone thought this was a good idea and wrote it into the standards and said that it was an implementation detail to be worked out but it will be dealt with later and twenty years late it appears nothing has happened.

M: I think they're probably just planning ahead. The way we're going we're getting more sharing of information between the aircraft and ATC, but it's just happening slowly. So I would have thought that in the future that kind of information will be shared. As you say, not yet.

R: OK, so again did you find this particular bit easy enough to follow?

M: Yeah, as pilot anyway my aspect is looking at, how we interpret working with ATC in the system; the rest of it - the STCA, the ANSP maybe it's, I probably won't follow it quite as closely - I can understand what's it's trying to say, it's looking at the feedback and the reporting of the incident but from a pilot the actual PF duties look fine. What I've been trained and my understand of how ATC would respond to my RA call.

R: So your direct interaction with certain parts of this is fairly minimal given that your only about one half of this, but do the bits you interact with yourself match your experience and seem to broadly correspond to real-world behaviour?

M: Very much so, yes.

R: Good. So I ask basically the same questions again: where there any parts of the interaction with ATC that you think are missing from this subset of the model?

M: No, it's very basic but if we have an RA we advise ATC that we have an RA and they are trained to wait until we've told them to resume their control, so in that respect it's fine.

R: So in that case could I ask you - we did an interview a week or two ago with an air traffic controller and he said that it's not as simple as this, in that when he is informed by the pilot of an RA he stops trying to control them but he sometimes gives them guidance; says there is a plane so many thousand feet above you, or gives you an idea of local traffic and that pilots sometimes use that to decide how they respond. Have you encountered that kind of thing?

M: Not really. If it's got to the stage where we have an RA we're going to follow the RA; it could be

useful information he's telling us, because it could be an aircraft we weren't considering that caused the actually RA so any information is useful but it's a busy time, it's very stressful and if we weren't expecting it it's the surprise of it; as a pilot I can say if ATC is talking to us we're probably not really hearing them - at busy times, coming into busy airports where we expect traffic to be around we're almost waiting for a RA where we have more capacity then yeah, we would use their guidance a bit more but reality is we're following the RA, we're listening to TCAS.

R: So you're pretty focused on following-

M: Yeah, again especially in busy airspace we don't want to overreact to TCAS; first of all we don't want anyone in the cabin to hurt themselves but also we don't want to put ourself close to another aircraft if we don't have to. So we're trying to fly this aircraft, this TCAS resolution as accurately as we can and we do have manually fly them - I think it's only the latest Airbuses where the autopilot will actually follow the TCAS - so we are actually quite busy trying to fly as accurately we can in the situation.

R: We read now and then of these cases where if you are overly enthusiastic in your response that can bring you into conflict with another aircraft and the whole thing dominoes.

M: That's the danger, yeah.

R: So, OK that seems straightforward and useful. Now we have one final more submodel to look at before we look at the whole thing, which is just some of the internal details of TCAS itself.

[Switches to TCAS submodel]

OK, this is our little model of what TCAS does and some of it's interactions with others. And again you could have a look at that and give us a brief description of it.

M: OK, TCAS is the central aspect and we're just looking at what elements influence TCAS, such as the manufacturer, how the authorities write up the regulations about TCAS and then the actual process of TCAS working, in that it looks for an intruder, it has look at the intruder to see if they are a potential conflict, it generates the Traffic and then the Resolution if we need it and possible subsequent Reversal Resolution if we need further guidance and then again the potential to advise ATC in the future maybe with the dotted lines; so yeah it's just all the inputs as to how TCAS is designed and what actually TCAS does on the aircraft.

R: One thing that I will briefly ask about because we've encountered this before is we've got the idea that TCAS alerts are always right, in that they are useful instructions and we read occasionally of cases where TCAS fails in interesting ways and gives inaccurate or unhelpful alerts. Is that something you've ever encountered?

M: I've never found a TCAS alert to be in the wrong; sometimes they can be confusing - we have certain aspects where if there is a no bearing message it can be quite confusing because we get used to seeing TCAS traffic exactly where, we can look out of the window and take a look at a particular area of airspace and expect to seen an aircraft there; occasionally there'll be a input with no bearing so we simply get a digital readout of an aircraft is somewhere around us, gives us a distance and an altitude - so that can be quite difficult if you're not, if you haven't experienced that and you suddenly see this is writing - TCAS is suddenly yelling at you there's an aircraft around and all you can see is a distance and an altitude so where am I supposed to look? And if you went - some people probably don't even know that that is one of the displays you can get on TCAS - so you do have to be careful in that respect. I've never had a TCAS advisory or a Traffic advisory in any way that has been incorrect, and I've also found it very useful. Occasionally we get, if a ship for instance has a transponder we will get a return; we won't get a Traffic Advisory or a Resolution from it but we will get a traffic information saying there is something in front of us with no altitude and that can be a bit disconcerting and then you think - maybe it's that ship down there, or maybe it's a small aircraft that we haven't seen, so you've got to be careful. That's the only time that I've really encountered any kind of TCAS not being helpful.

R: That's an interesting example I had not considered - the shipping lanes below you causing interference. Can I ask more about the example of the TCAS no bearing information - is that because of some sort of limitation to a transponder that means it can't accurately determine the location?

M: I believe it's if the other aircraft has a limited transponder - it is giving you information as to roughly where the aircraft is - if it can't work out what bearing it will just give you as much information as it knows, which is usually distance and altitude. And so it actually it will just give you a digital readout rather than a nice little picture of where the aircraft should be. So again I've only had this a few times in a simulator and it is - it throws you off guard if you are not expecting it.

R: So you look around and can't see it and get concerned as to where it might be?

M: Yeah, because it's a simulator you'll get the resolution which I follow.

R: Thanks - that's one of the areas we're trying to do with this modelling is work out how abstract to be, and we think TCAS, the mechanics of TCAS seem relatively straightforward and therefore we don't need very much detail and can be abstract there; we're trying to work out if these interesting subtleties are problematic...

M: Yeah, these are a real minority. The majority of TCAS is as you depict - very simple, very straightforward and as a pilot we do keep it as simple as possible, which is great. The actual chart there is very accurate.

R: OK. So does this still hold true in congested airspace where you have potential interactions with multiple aircraft simultaneously?

M: Yes, it does. We actually - in busy airspace - we use the basic transponder and TCAS displays without relying to the TCAS TAs and RAs; we'll use - if there is a depiction of where an aircraft is - we'll change the way we are ascending or descending to avoid the potential of becoming a TA or an RA so again we're looking at what traffic is around on the TCAS, using the way it is depicted to try and prevent something before it becomes an event.

R: So you're effectively interacting with the TCAS despite it not having generated an RA or a TA: you're using it as a screen that tells you about nearby aircraft?

M: Using it purely for information, because again awareness, situational awareness is a big thing for pilots - we use all the inputs, all the information we can to try and see the big picture and we'll reduce our rate of climb if we see a aircraft above us, likewise in the decent; other aspects like if we're going through a holding pattern and see lots of aircraft below us we know there is a lot of holding, so we'll slow down - so there are many useful things for transponders and TCAS other than just a TA or a RA; but in terms of following a RA it's exactly the same whether it's busy airspace or empty.

R: That's very interesting - something for us to think about in our modelling is this non-reactive use of it. It's again something that from reading the documentation you would get the impression that it is a purely reactive thing that has all this internal logic and gives you warnings and that's it and it's a little more subtle than that.

Again, I'm just going to look through my notes here...

Once again, are there any parts here that either seem completely irrelevant or are there any important parts (other than what we just said about keeping track / spacial awareness) that are missing from this TCAS side of the model?

M: You could, just in terms of the traffic information you could have another box depicting that - at the moment you've got the TA and the RA but we also get traffic information from TCAS - that could be useful, at least for spacial awareness.

R: You mean traffic information as in looking at the display, rather than-

M: Yeah, saying there's an aircraft 2000 feet above us. We'll use that in terms of how we decide to climb or descend the aircraft. It's a very useful tool to a pilot, just the information it's displaying to us, without it necessarily being reactive, the TA and the RA.

R: You're hopeful that by using this extra spacial information you can avoid getting to the stage where you are getting a TA or a RA?

M: Yeah, absolutely. Saves the paperwork.

R: If you've got this sort of traffic information which you are able to read off the TCAS, how does that interact with the fact you are being guided and instructed by air traffic control?

M: Our basic requirements from air traffic control are fairly simple, and it's not hard to keep ATC happy while preventing these TAs and RAs. Often if we do have an aircraft 1000 above our cleared altitude if we are climbing for instance ATC will actually advise us that there is an aircraft 1000 feet above our cleared level and they will expect us to then do then, as I said reduce our rate of climb to prevent a TCAS RA and again it's a secondary backup - we have the information in front of us on TCAS hopefully but ATC will also co-ordinate us and make us aware - again helping us with our spacial awareness, where we are in the scheme of things. So with the TAs and RAs ATC don't, it's not a problem for us to show our awareness of what's around us and fly the aircraft in accordance with that and ATC shouldn't really be bothered. Occasionally I'll tell them expedite climbs, expedite descents but otherwise our only restriction is a climb of rate of about 500 feet per minute or a descent rate more than that and that is very easy to achieve.

R: So if you are told - say you are using the traffic information on take-off or landing then you have some flexibility from ATC in the rate you take that at, the speed and you can vary that based on the traffic information you see?

M: We're talking about altitudes, we've been cleared to an altitude - as long as we are climbing or descending more than 500 feet per minute (which is quite a small number for a modern aircraft) ATC don't have a problem with it. Occasionally if they want us to climb quicker they will tell us; they'll tell us to expedite but otherwise they kind of leave it to us. More importantly if they do give us something like speed control they're using that to control the separations so we have to follow that very closely, likewise routings, headings - they're using lateral navigation and vertical navigation is more up to us. Cos all aircraft are different - we can control our speed quite easily but if we're trying to fly a particular speed profile for ATC it will affect our performance so again as long as we can adhere to the basic requirement ATC should leave us alone.

R: So there's that flexibility for you to adapt based on the conditions?

M: Yes, yes.

R: Excellent.

So the next thing we'll look at is the model as a whole - if you'd like to take a five minute break here and have a glass of water or we can keep cracking on - it's up to you.

M: No I'm fine, let's carry on.

[Switches to full model]

R: I'll need to zoom this one out.

So this is our full model and you can see the various parts that we looked at earlier divided up. And it's obvious the most interesting part here is the interactions between the various subsections.

Once again, could you take a look at that for a moment or two and then describe for us what you see, particularly in regard to these interactions.

M: It's a combination of three slides, so again Pilot Flying is one central aspect with lots of responsibilities, ATC also has a lot of responsibilities; again it's how they all work together to

achieve the safe flight. Again we've got the TCAS, the manufacturers input and also ATC's input and then Pilot Flying how they actually respond to an RA to make sure safety is maintained. There's a lot of subtle connections which you probably wouldn't consider at the time such as the Pilot Flying addressing potential conflicts so that's probably along with what I was saying early about how we use the basic TCAS display to prevent an RA from developing. At first glance it looks very cluttered but when you break it down it's quite straightforward-

R: That's why we went for displaying it in thirds first - trying to lay this sort of model out in a nice way where none of the arrows overlap and it's all very clear is a whole PHD in itself.

OK, perhaps what we should do is with this one is walk through some of these interactions between the sections which might be the most interesting part of this. So let's have a look:

Perhaps the most obvious place to start is the interactions between the pilots and air traffic control. Perhaps we should briefly talk through the idea of to what extent does the TCAS alert completely override the instructions from air traffic control. Is it a matter of "I've got an RA, I'm going ignore everything else that I have been told before for the next ten seconds" -

M: We follow the RA. Basically that takes precedence, takes priority no matter what ATC has told us in the run-up to this, no matter what ATC tells us as the RA happens we follow the RA because we're following the RA, the other aircraft should be following if they got an RA too they'll be following their RA and the TCAS units will keep us with the best avoidance; while ATC we just tell them we've got an RA - we don't even tell them if we are climbing or descending because we don't want to risk them trying to control us so we just tell them we have an RA and we will tell them when the RA is over.

R: So you are very clear that it's a hands-off; we've got the next thirty seconds or whatever-

M: Yes, it literally is "leave us alone - we've got an RA and we'll tell you when we're done". And you can carry on controlling us. It's fairly black and white. Again, it became black and white after we had an incident over Switzerland where one aircraft followed the RA and the other followed the ATC and they collided. Every since then it's been drilled into all pilots that you follow the RA.

R: So one thing we've seen a little uncertainty about is at what point do you inform the ATC that you are doing this - do you-

M: We're trying to tell them as soon as possible - we will ensue that we are following the RA - we make the manoeuvre, we get the aircraft following the RA and then Pilot Not Flying will tell ATC as soon as we can, workflow permitting.

R: "Aviate, Navigate, Communicate"?

M: That's right.

R: You said here that it would be the Pilot Not Flying doing the communication with the ATC - is that the general case?

M: Pilot Flying is always flying the aircraft, monitoring the aircraft profile while the Pilot Not Flying does the paperwork, the radios so in that case the Pilot Not Flying will advise ATC. He'll just make sure the Pilot Flying is following the RA and when he's satisfied the aircraft is under control he'll tell ATC.

R: Again, that's in our contrast to our model where we have the Inform ATC responsibility lying with the Pilot Flying, which is something we're going to have to go away and look at and reread that part of the manual.

M: Technically you could say the pilot flying - it is there responsibility but it is just done by the Pilot Not Flying but again it is something that will be done by the Pilot Not Flying.

R: That's the kind of the subtlety we would like to be able to capture - the Pilot Flying has overall charge in a sense but; actually, another important subtlety there is that in the model the idea of the

Pilot Flying is the big boss in charge, but at the same time you have the Captain / First Officer thing-

M: The complicated is thing is you'll have Pilot Flying / Pilot Not Flying but you also have Pilot in Command. The Pilot in Command is the captain. Whoever's actually flying Pilot Flying or Pilot Not Flying the captain is still the person who is in charge. So again it's technically the Pilot in Command's responsibility for the radios so we; it's very difficult - we almost assume that the Pilot Flying is the captain.

R: So we've got the subtleties for us to capture - they're not separate roles as such; it's no as if there are four people on the deck - the Pilot Flying, the Pilot Not Flying, the Pilot in Command, the Pilot Not in Command; they are different expressions of the same rules...

M: There is always a nominated Pilot in Command on every flight so they have the ultimate responsibility no-matter who is flying the aircraft; when I am Pilot Not Flying the first officer is flying the aircraft I'll try and let him or her make all the actual decisions - however if they make a wrong decision it's my responsibility to correct them. That's the way it works legally but it's quite a technicality - the slide itself - again, you don't want to make it too complicated.

R: This gives us some things to write about and think about - should we model that, does it make it too complicated; are there important subtleties in this? For example, sometimes I read cases where perhaps the senior officer, the captain with many years experience makes the wrong call and the first officer, the second officer knows this but because of hierarchical structures doesn't intervene and then some nasty accident occurs.

M: They way we are trained is if you see the person next to you - it doesn't matter how; they could be the Chief Pilot; if they are doing the wrong thing then first of all you try to advise them and if they don't responded you take over; that's how we're trained.

Even the fresh-faced guy fresh out of training on the right-hand seat will override the captain on the left-hand seat if they are making the wrong decision; that's the theory and that's what we try to teach. Certainly different cultures will respond differently, but in a western airline the first officer can quite happily take over and the captain will let him, hopefully.

R: And you're out in the Middle East with these relatively new airlines - are they following the same sort of Western structure?

M: Yeah, especially in the Middle East they are following the Western, the European of way doing things and the American way of doing this very much so; I'd say the problem areas are probably Africa and possibly even certain parts of Asia; I know some of the Korean airlines had difficulty with CRM in the past but the Middle Eastern ones in my experience here in Dubai is very similar to flying for a European airline in that respect.

R: OK, let's look have a look at the TCAS - Pilot interactions. I think the main thing to look at there is that they have these very strict time limits - you must respond within five seconds, two and a half seconds - are these time limits met in practice?

M: Easily. They're actually quite long time frames - the real dangerous with TCAS is people over-controlling and jumping in too quickly. If you think about it we have to respond within five seconds of an RA - that's actually quite a long time when you think about it through your head. Respond to a reversal within two and a half seconds - by the stage we're flying the aircraft, we're hands on, hopefully the adrenaline is kicking in, thinking quickly; and two and a half seconds for a reversal is not a long time, so it's not a particularly difficult time to achieve. The real dangerous is people over-stressing the aircraft - the key is to do it very smoothly. It's a very 1G manoeuvre, effectively.

R: So because you are alert and fired-up these timescales are not a problem?

M: When we're going into busy airspace and expecting these things it's much easier to deal with; however when we're flying around in the cruise during a four-hour cruise, if something happens

then we have what's called a `startle factor' and that's why people are in danger of over-controlling and putting the aircraft in a more dangerous situation. So the five seconds and the two and a half seconds are fairly relaxed time frames to achieve.

R: So your main concern is that you don't overstress the airframe or fall out of the seats by being too aggressive in your manoeuvre?

M: If it's a surprise - if it's goes from nothing to a RA, it skips the TA, the conflict is that bad then there's a lot of adrenaline kicks in and it can be easy to over-control the aircraft and again if we are at high altitude (we're usually trying to fly at as a high an altitude as we can because it's the most efficient place to be) then you're at real danger of over-control and doing something the aircraft does not want to be doing.

R: So you're sitting in the cruise and everything seems straightforward; suddenly you get a blaring RA, you pull up on the controls and suddenly you're hitting your height limit?

M: You stall the aircraft, you could run out of performance space. The TCAS is just giving you an avoidance; it's not taking anything into account like your performance, where you are in your envelopes so if you follow the RA as subtly and smoothly as possible you are still in danger of putting the aircraft beyond it's envelope and you do have to be very aware.

R: So again now that you can see the whole thing - are there bits of relevance that you would say are missing from this view around the TCAS alert?

M: Again, unless you put another box in using the TCAS information to try and pre-empt any possible TAs even which would then leave the RAs; that's about the only thing that I can see that I would put in, otherwise it's all very through and everything is covered as I can see.

R: OK. Do you see any inaccurate relationships, other than the ones we've previously mention; any bits that aren't quite right?

M: No, I think they all look spot on.

I suppose the only thing you could add is another responsibility of the operators to ensure the TCAS serviceability. We have had some instances where we have had TCASs; they are an item where if they don't work we can still dispatch, so we can still go flying without a TCAS and I think we have to advise ATC on our flightplan - that's the main restriction. Some places we wouldn't be allowed to go, particularly in the UK - outside controlled airspace if we weren't operating TCAS we weren't allowed to go there; because again we use for co-ordination around civil aircraft.

R: So how do you feel when you are given an aircraft to fly and the TCAS isn't working at the time? Is that an annoyance to you?

M: Yeah, it is and it's a huge gap in your awareness. You realise how much you use the TCAS when it's suddenly not there; for instance. we'll use it when we line up on the runway - we'll put the TCAS on and make sure there's nothing imminently on approach; busy airspace we'll have a look to see where the aircraft are so the gap is sufficient and make sure air traffic control haven't missed something. So it's a huge source of information for us as pilots, and if we do dispatch we almost feel like there is something missing. It's a not nice thing to dispatch without, and during my time in the Middle East I haven't actually had that but in my previous airline around the UK and Europe we did a few times.

R: This all fits with the idea of TCAS as a information system which is something we had not at all got out of the things we have read, so it's important for us to work out these gaps between "by-the-book", rule-based activity and what actually happens - that's one of the most interesting things in this kind of work.

M: Yeah, legislation will probably be written with TCAS purely used for TAs and RAs, but we use it for a lot more than just that.

R: That's exactly why we carry out these interviews and ask people, because we wouldn't get this from a document based analysis.

So now we'll move on to the last section of this, which is that based on this model the toolkit you can see here generates some warnings and notifications as to where there might be systematic vulnerabilities.

And we'll talk through the – what they say and whether or not they represent potential, real-world vulnerabilities or if they a sort of artefact of the modelling process. So I'll bring up the warnings panel…

[Resizes the "Problems" window]

So you can see here all these various warnings and alerts, so where will we start…

OK, let's start with reliance. So what we have – I said at the very start we have this idea that an actor might be responsible, hold some responsibility that they don't directly influence and therefore they depend on others. So one of the things this toolkit can do is it can give us these lists of who depends on who else – you can see the text here that says that.

[indicates "Relies on" warning]

So if we go through one or two of these and talk a little about how these interactions work out. Let's start with the Pilot Flying - a nice obvious example. And our vulnerability analyser tells us the pilot flying relies on air traffic control, they rely on the TCAS and by extension the manufacturer of the TCAS and they rely on their colleague the Pilot Not Flying. Does that seem a reasonable definition of who they rely on in this model?

M: Yeah, absolutely. They're all the inputs; I suppose you can add to that the engineers that maintain the TCAS, the trainers who train your colleague to make sure that they know their stuff, but yeah, that's good.

R: So, yes, one of the things we haven't really got in this model is the idea that the aircraft has to be maintained; presumably when you are flying you are relying on your engineers having put the plane together in a working way that won't have various failures when it's in the air.

M: And you're also relying on the other aircraft to have the equipment as well.

R: Is that a problem you've encountered – you said you're anywhere within six hours of the Middle East – there must be places where the standard of aviation, of ATC is not of a Western standard.

M: Yeah, we fly over the Indian Ocean and you have no air traffic control, it's all done on procedures – so the theory is that we shouldn't have an interaction with other aircraft because we're spaced out by slot times, by altitudes but if things go wrong we kind of rely on ourselves out there – if we have an engine failure we have to descend so what we try to do is exit the airway before; minimise our rate of descent until we've exited the airway, so we do rely on TCAS and other traffic information to actually work our way round these problems and that's part of our procedures.

R: So we sort of made the assumption with the model that you are flying in controlled airspace and therefore ATC exists; of course there is the other side that perhaps you are under procedural control or even in visual rules only.

M: Yeah, we go into uncontrolled airspace, uncontrolled airfields where we rely on TCAS to work out where we are with other traffic; we'll be talking with other traffic to organise our own air traffic control effectively, because the guys on the ground are literally there to tell us what the weather is.

R: So you're flying to actual commercial airports that don't have any traffic control at all?

M: Yeah. It happens a lot in Australia, we go to places in Saudi Arabia which are just huge long runways in the middle of nowhere; we have a guy on the ground telling us what the weather is and we have to then co-ordinate with other aircraft – we have specific frequencies to reach them on; we

use TCAS, the transponder a lot to work out where they are and who might be in front, where they are in the procedure, whether we have to slow down; yeah, it's a really useful tool.

R: That's really interesting – I would have thought that kind of uncontrolled airfields would be for small prop aircraft, not you in full-sized jets.

M: In Africa you'll be flying; there's very little air traffic control over anywhere once you get over the middle part of Africa; you can't reach anybody on the radio, so again you're relying on your TCAS, you're speaking to other people, position reports – it's like being back in the 40s and 50s – you're relying on very basic procedures to maintain safe flight.

I don't want to put you off flying. [laughter]

R: I suspect I'm not likely to be flying into random second-tier strips in Saudi Arabia; it's not my…

M: It's beautiful this time of year [laughter]

R: So again we say that the operator relies on the pilots they employ; that seems fairly straightforward. Perhaps we could explore this a little bit since you were previously a training captain on how training for TCAS events was organised and structured?

M: Again, we basically teach them the process you have there - if we give you a TA you start looking for the aircraft, so that is your priority; one of you will always be flying the aircraft but you'll both be looking out the window to see if you can identify the intruder; then if you have an RA then you respond, Pilot Flying responds, Pilot Not Flying informs ATC and we teach them the strict response, the strict radio call which is just your callsign, TCAS RA with no further involvement. That's basically all we do, it's all you can do. And we give them the more complicated RAs, we give them the reversals so we teach them how to, again not overstress the aircraft, not overreacted; we teach them five seconds is quite a long time to get your head back into flying the aircraft and two and half seconds is quite a long time to reverse your manoeuvre and again it's just a gentle input. You follow that up - after you've done an RA check with the cabin crew, see if anyone in the back's injured, anybody fell over - things like that. So that's kind of the structured program we have for training, and every time you go into the simulator, every six months for our check you always have TCAS RAs which we then follow up with a jet upset so we simulate the fact that you've just had a response, you've narrowly avoided another aircraft and then you hit wake turbulence which puts you on a wing drop or something.

R: So you make all the bad things happen at once?

M: Hopefully if this does happen to you in the six months between simulator events you're slightly more prepared.

R: The other interesting part in terms of this reliance is that we basically seen again that the both the pilots and the air traffic controllers rely on basically everyone else in the entire system; it's a very tightly coupled interaction and that; neither of you have a good day at work unless you are talking to each other - does that seem... ?

M: Yeah, that's right. We have to work together - as you say we rely on a lot of other aspects; that is aviation - you're relying on a lot of pieces of the puzzle for the safe flight, yeah. You can see how many interactions we have in just one aspect of our aircraft, TCAS.

R: But at the same time in some cases, some geographic areas you have a lot of this taken away from you at some points?

M: Yeah, it does become a lot simpler in some places. It becomes simpler with some aspects taken away, but we need to add our own aspects to give us the protection we need, such as: although we lose air traffic control we have to become our own air traffic control, we have to put out our own position reports, liaise with other aircraft, we have to give our estimates and if someone else is estimating we'll have to co-ordinate our own separation.

R: That conveniently gives a link to the next analysis technique. So basically in that case when you don't have these things to support you that places you under greater load-

M: Yes.

R - so it's a more tiring and stressful flight if you have to do all this yourself rather than have it handled for you.

M: Absolutely. And the responsibility is another burden we have to deal with rather than being able to rely on air traffic control we have to rely on ourselves.

R: So would you prefer flying in the controlled airspace where it is handled for you or would prefer the control of doing it all yourself?

M: I think you always prefer air traffic control, because we have still have TCAS, so even if air traffic control get it wrong we'll still have our capabilities of saving ourselves; however, we just have another pair of eyes looking after us, so we'd always rather have air traffic control.

R: Again, this very much sounds like the Swiss Cheese model where if air traffic control get it wrong then TCAS will help you out, and even if TCAS doesn't you might by your professional skill get out of it.

M: Yeah, absolutely.

R: OK. The next thing that our toolkit generates for us is the idea of effort, overload that might generate some systematic problem where actors have to do too much at once; basically it tells us that there three of these actors have load on them that could be problematic. So the first one it points out is that the Pilot Flying has more responsibilities to cope with than anyone else. So do you... when you respond to a TCAS event, do you feel that as a pilot you have enough energy and focus to cover all these things at once or do you sometimes feel that you have to juggle too many balls?

M: I think when actually get a TCAS RA it becomes very simple - we're just following the RA, doing whatever we need to do to achieve that. So, no I think when we get a response to a RA it simplifies things - TAs can be a different matter; TAs can make life a lot more interesting because you're still having to follow your ATC instruction, you don't have the ability to disregard air traffic control and at the same time you're still supposed to be looking out for traffic and possibly about to pre-empt and get ready for a RA, which for me would be turning the seatbelt signs on. So yeah it's an interesting one - it's a sort of a subtle difference between a TA and a RA - the RA is actually when things get worse, life gets slightly simpler - it's like having a big problem instead of a small problem.

R: Again, that's something we don't really capture here. The TA is on top of everything else, while the RA is a singular focus.

M: That's right - the TA is an additional workload factor while the RA is basically the follow the RA; it almost cuts down on a lot of things you're trying to achieve.

R: So what kind of things do you through out of your mind when you get the RA - what things do you no longer worry about when you're too preoccupied?

M: Well I'm not going to worry too much about my navigation; it's going to be a case of disconnect the autopilot and fly the RA until the RA tells you we're clear of the conflict and so if that involves a departure over an airfield you're going to ignore it as long as terrain is not an issue, of course. That's one of the big things; again, you're trying to keep it smooth, not particularly for passenger comfort but you don't want anyone hurting themselves and you don't want to overstress the aircraft so you try to keep it smooth for those two reasons alone. That's probably it, really.

R: That's useful to get a feel for some of the counter-intuitive stuff around load. What else do we have...

So the toolkit also tells us the air traffic control may be overloaded, and I suppose the subtlety here

is that you as a pilot are only flying one aircraft, while the controller is co-ordinating ten, fifteen, whatever aircraft in their sector. So do you in your experience, your interaction with air traffic controllers do you ever get the feeling that they are stressed or finding it difficult to handle?

M: Particularly around London, particularly during something like bad weather London air traffic controls are already very busy, so throw in something like someone trying to avoid weather and it just really makes thing difficult; we listening to them and we're spending like five minutes just to check in and tell them you're speaking to them, and that's just the way it is. One call to next call to next call and you just look at the first officer and say at least we're only dealing with this guy for ten minutes, imagine he's got one hour of this. Sometimes you do talk to the guy and they are busy, usually the approach controls they are very busy at the busier fields, but once we get into the cruise, once we get into the high altitude stuff it normally does get a bit quieter.

R: So you can directly see the impaired performance from the load - that they're taking longer to respond to you than they would do if it was all clear?

M: Yeah, totally. When they get busy you can hear it in their voices, you can tell when they get stressed - you can tell when things are getting out of hand for them when they are maybe a bit maxed out and occasionally you hear a TCAS RA or another pilot and then you usually get a different voice on the air traffic control...

R: That's very interesting, because I think if I remember correctly when we interviewed the air traffic controller he was of the view that pilots get overloaded but air traffic controllers never get overloaded - the exact opposite.

M: Well, we're flying one aircraft - if we can't get a call in because we need to avoid some weather then that's a stressful situation; sometimes if air traffic control are really busy we can't get the requests we need or something we need then it gets busy, gets stressful and our life gets very difficult, but if the controller's busy we usually just feel sorry for the guy. We've all got the same goal here and I wouldn't want to be an air traffic controller.

R: So the last warning about overload is indicating that the TCAS itself might be overloaded. I suppose the question there is do you ever encounter issues when you are in very busy airspace that you get perhaps too many alerts and the system can't quite perhaps cope with the volume of traffic?

M: You can get a very cluttered display when there is a lot of traffic such as when we're in a holding facility; if you have a busy stack we can have like seven or eight aircraft on our display at any one time, so then we have different range scales so we can zoom in and pick and choose ourselves. The actually TCAS itself, the system has a huge ability - I believe it can co-ordinate fifteen different RAs and something like thirty different TAs and the same time so in terms of; I've never doubted that TCAS can cope and it's interesting, going back to the previous point, it might not just be two aircraft having a TCAS RA - it could be three or four, or two which then becomes three and then becomes four as you said earlier it can snowball; a lot of pilots will try to put in a TCAS RA and the ATC's just trying to work out what's going on and try to stop it getting worse. So the actually TCAS system itself no, I've never found it to be not useful; occasionally it will give you, if there's an aircraft without an altitude without a transponder it will give you a traffic call; also if you've going into busy uncontrolled airspace with a lot of GA, circuit traffic - I was based down in Exeter for a couple of years and that's got a lot of flight training going so you'd come into the circuit and there would be like seven or eight aircraft buzzing around - they'd all get moved away from you to let you in but the transponder will often be shouting at you - Traffic!, Traffic! and so you try and look for it and can't see it...

R: So the challenge is not that TCAS can't cope with it, it's how you can accurately interpret this large amount of information that's coming from it?

M: Filtering out what's not useful and making sure you follow what is useful; it's pretty much our job day-to-day as a pilot - you're always trying to extract information that is useful to you.

R: OK, so let's look at our next - the next technique it has is the idea of criticality analysis, to locate the most serious points of failure, which would have the greatest knock-on effect. What it has basically calculated, and this is perhaps a truism, is that for a model of TCAS events the most critical part is the TCAS which perhaps not especially insightful in that regard. However, perhaps the interesting question to ask there is (you've already mentioned a bit) is what you do when you don't have TCAS, you are missing out on some information. And we've mentioned that, so we've also already mentioned what happens when you don't have air traffic control guidance - it's more effort for the pilot. Are there any other parts of this model that you think if they were not there for some reason that would have a serious affect on your ability to easily manage the flight?

M: Eh... Again there are times where we'll be the only pilot on the flight deck, especially in the cruise - one of us will go back for a rest break, whatever and so there is a potential for you to be the only pilot in the flightdeck when a RA happens, which would really put your workload up. That's the only thing I can think of really, but that's a fairly unlikely statistical chance, but it's there.

R: That's an interesting example - so in that case you're basically merging the two actors into one - everything that you have to; you have to do all the responsibilities that both of them have... Clearly that would be quite a stressful event.

M: It would be yeah, mostly because potentially it could be quite an inexperienced person at the controls with the captain at the back; yeah, it would be quite a nasty situation to be in.

R: You're saying it's statistically unlikely - it's not something you've ever encountered personally?

M: No, never. But it's a possibility, but it is very statistically small, because that's probably about five minutes on a three-hour flight.

R: And I understand that on long-haul flights they have more than two pilots and structure it so this doesn't happen?

M: Yes, on the long haul sectors with additional crew you'll always have two pilots in the flightdeck but on the six-hour legs, the eight-hour medium haul you only need two pilots legally, so at some point we're going to leave the flight deck.

R: Is this a sort of you can only be on duty for eight hours, ten hours, something like that so therefore the long flights aren't physically possible?

M: Yeah, but we can twelve to fourteen hours days with two pilots without the need for additional crew, so yeah we can do long days with just the two of us so it's impossible for you to be on the flightdeck of a seven hour flight for the whole time, but we only leave the flightdeck to go to the toilet, stretch our legs and come back. So it's a pretty small time-frame, but it's a possibility.

R: Presumably because you are doing that in the cruise it's the least likely time for anything interesting to happen?

M: Absolutely - we make sure it's a time where the workload will be low, where we don't expect to have to do any co-ordination and some of our sectors, despite being a long cruise are periods where it is busy and where it is quiet, so we try and make sure it's when we're quiet.

I don't see anything else missing.

R: There's one or two more alerts then we're basically finished. So we mentioned earlier that "Ensure Safe Flight" is this fuzzy, overarching duty that we couldn't quite pin down in terms of what it meant - do you have any general comments, things that you do thinking because this is the safe thing to do that aren't reflected directly in this model?

M: Ensuring Safe Flight is basically the overall goal for a pilot, basically. What I'll do is I'll be conservative when I need to - if it's going to be turbulent then I'll not cruise at our very limiting altitude so we have excess performance, which again if we do get a TCAS will give us that extra bit of buffer; it's just, everything we do day-to-day is ultimately trying to achieve this safe flight - we

take extra fuel so we don't have to get stressed about manoeuvring and so we can avoid weather - we don't have to worry about going through a thunderstorm because we don't have the fuel to go around it. Yeah, the way we respond to a TCAS would just be another aspect of that, of our thinking, the way we brief; if we're coming out of a busy airport we can talk about potential traffic advisories, how we'll manage it, who'll do what - apart from anything else specific about ensuring safe flight we always have to bear in mind that we have a cabin behind us with passengers and cabin crew so we want to always have a bit of consideration for those guys - we don't want to overreact to an RA and end up breaking one of their legs, so again it's the more experience you have the bigger the picture you have mentally of what's going on around you. That's it really - controlling rates of descent and climb before levelling off - all these things help ensure you've got the safe flight but also reducing the chance of react to an RA or TA.

R: So in a sense almost everything in this model contributes to this in some extent?

M: Yeah, everything in aviation is about ensuring safe flight, because if it's not then there's no need for it.

R: So I think I've covered my list - ah. I've gone through this list of warnings of common vulnerabilities that our bit in rules considered - are there any interesting, systematic problems or vulnerabilities in the TCAS operation that I haven't gone through that you've encountered in your own personal experience?

M: Umm - you mean like shortcomings of the TCAS system?

R: Yes - basically just any shortcomings, things that have not performed as expected, etc. etc.

M: As I mentioned earlier the "No Bearing" information - that's probably one of the biggest things that's thrown me; we also have as I mentioned earlier different ranges we can set on our displays and we get a Traffic Advisory that's beyond the range we've set then we get an off-scale advisory - so it won't actually tell.. we won't have access to where the intruder should be unless we zoom out; it's not really a shortcoming - if we get an RA it's still going to have the RA and we'll following the RA; but in terms of the TA it might be something - some displays on some aircraft automatically go to a bigger scale so you will see the intruder; I fly the Boeing which is a fairly basic aircraft so you just get an advisory off-scale.

R: So you get an advisory but can't see immediately where it's coming from?

M: Yeah, you'll get a "Traffic!, Traffic!" you'll look on your display and it will say Off-Scale, so unless you zoom out you won't see where the aircraft is.

R: So it's just taking you a little longer to work it out because you have fiddle with dials?

M: That's right - again the startle factor, it might take you a moment to find the right switch - hopefully by the time you've zoomed out it's still a TA and hasn't become an RA, because if it becomes a RA then you're busy responding to the RA and won't know where the intruder aircraft is. So again it's fairly good SOPs that one of our displays will be on a bigger range, a more sensible range for the area where we are - some aircraft we only get TCAS information out to about 40 miles because there's no point having it out further than that, it'll only clutter the display. So yeah, the No Bearing Message and the Off-Scale are the only two shortcomings that I can think of when it's not intuitively obvious to you what the problem is. Otherwise TCAS is a great system, it's fantastic for our spacial awareness as well as the safety aspect - as we were saying earlier it's so much more than the RAs; it's just good for our situational awareness, planning, how we actually conduct the flight.

R: Excellent. I've come to the end of my list of questions. So, I've think this is basically coming to the end of the experiment here, so first of all I will cut, close-off the recording.

[ENDS]