Blues Skies Podcast
Season 1, Episode 48

Navy LCA - with Cmde Jaideep Maolankar

PR Ganapathy:
Hello and welcome to the Blue Skies Podcast. I'm PR Ganapathy, your host.

We continue our interview with Commodore Maolankar. Welcome back, sir. And maybe we'll shift gears now to the Navy LCA. I know you were involved with some of those initial concept development when you were on the ship, but tell us about what are the differences that Navy LCA required and what are the design changes that were made and what are some of the practical examples of differences that you encountered as a result of those changed requirements.

Cmde. Maolankar:
So, like I had said earlier, my first encounter with the LCA was the project definition phase, but then pretty much thereafter, I didn't have any contact with the program, et cetera, till I joined NFTC. And that is when I got back to figuring out what all has been done. So the bulk of the aircraft, major elements, which I'm going to kind of talk about moving forward, those had already been done and defined and whatever was left with the other aspects, which I'll again talk about in detail.

So the basic concept of the LCA Navy program was that piggybacking on the efforts and the investments that have been made in the Air Force Tejas, they would attempt to build a carrier-borne aircraft. Now, when I'm saying it like this now, it does sound, you can straight away, see everybody rolling their eyes. Not possible.

Because as it is, the LCA program by itself was an extremely ambitious program. From nothing, you are straight away jumping to a Fourth Gen aircraft in the package of a final finished product. That was the promise. The promise of the program was to create a complete product, not just an experimental demonstration of one or two, Fourth Gen technologies, Four completely brand new Fourth Gen technologies, and packaged together in an aircraft which can be used in frontline service.

So as it is, very ambitious. Second layer of ambition, smallest aircraft, but full multi-role. So that itself is hugely ramping up the complexity. Because it's like if you decide to become a weightlifter, a few extra kgs won't harm you. That means if you're inefficient in your design and you end up with a few Kgs heavier than you want it to be, it's not going to affect your primary purpose, which is what weight you are going to lift. But that's a single-role aircraft.

Whereas if you're talking about a multi-role aircraft, you're talking about a gymnast. Every extra kg or muscle that you put on is going to have to fly through the air, pick up momentum and also land on the leg. So it's not something to be done. Multi-role aircraft are much harder to get right and then you try and do it in the lightest possible program. Remember, everything doesn't scale downwards with size. The pilot remains the same weight, whether he's a large bomber or small single seat fighter, and associated with him, a lot of such systems, the number of sensors. For example, the expectation of number of sensors doesn't go down when you scale down the size of an aircraft. In fact, if you retain the multi-role tag, the number of sensors remains exactly the same.

So it's already ambitious. Now, on top of that, you add carrier-borne to it and actually it is a recipe for failure. That is, you will not achieve the end product that you are looking for. On top of that now, because it was defined as a piggyback program, there was a need to minimise the extent of changes. So typically even when you take a land based aircraft and make it carrier based, you typically end up with bigger wings because you're trying to cut down the approach speed. Now here the wing itself was a very significant investment in design and all the wind tunnel work and all the data that had been created, et cetera, the carbon fibre layup work, the structural work that is associated with the wing. So you couldn't touch the wing, for example.

Now as far as the fuselage is concerned, it was decided that all changes would be restricted to the centre fuselage, right? When you say that, it means now the undercarriage has to remain attached to the centre fuselage as opposed to being allowed to migrate out into the wings. And typically one would expect that one has to have the undercarriage that is much stronger for a carrier based aircraft. So you can see how we are very rapidly piling on the constraints and still retaining an expectation of lightest in the world, multi-role, carrier-borne fighter. Ambitious, clearly, clearly, very ambitious.

So at that stage they thought they could get away with just centre fuselage changes. So in fact, the front fuselage, rear fuselage, wings are common with the Air Force program.

Then they also decided that the front fuselage would be made common with one of the programs. So it was to be made common with the trainer program because some changes were mandatory in the front fuselage, for example, for enhanced over-the-nose vision. So rather than creating a third aircraft, that is single-seater land-based, two-seater land-based and then carrier-based aircraft and then potentially two-seater carrier-based, which is yet another fourth variant. So they chose, it appeared seductive that the two-seater variant, that is the two seater configuration which has got the Navy vision and use that also for the trainer land-based as well as for the single seater carrier based.

Again, it's a constraint because one must remember when you are designing multi-role aircraft, they have to be designed to the minimum number of compromises and not the maximum number of compromises. Everybody, when you're writing specs, tries to pile on as many specs as possible. Whereas if you truly want excellence in any key specs, you have to have as few other specs as possible. Optimization. That F-15 slogan of “not a pound for air to ground”. Imagine the ultimate strike aircraft going around now, which is the Strike Eagle is the descendant of an aircraft which was designed as “not a pound for air to ground”.

[08:37]
So you have to understand these things before you define the program. I'm just describing what are the constraints? And they thought they could get away with just a revised undercarriage attaching to the same centre fuselage, a hook, obviously, an arrestor hook. Again, attaching this primarily into the centre fuselage. That means dissipating its load primarily into the centre fuselage. And the only real concession that was made was an aerodynamic surface called the LevCon, which promised to reduce the approach speed. Right. By further destabilising the aircraft. And then as a result of destabilising it, the elephants would end up drooping. To compensate that destabilisation, you effectively get a more cambered surface in the landing configuration, which would give you lower speeds. That's the theory for the audience.

PR Ganapathy:
And for the audience who are not familiar with this, in a photograph of the Naval LCA landing, you can see the levcons right next to the cockpit.

Cmde. Maolankar: [09:33]
Yeah, they're like two flat plates which have been deflected upwards, but they are also present even when you deflect them back to zero, they still change the planform of the wing. They don't disappear. So this is what is the scope of the LCA Navy program as was originally envisaged.

PR Ganapathy:
Now, from a take off perspective, the Indian Navy carriers don't have a catapult, and therefore they need to, with full load, generate necessary thrust to be able to accelerate and get off the ski jump - that was considered within its capability is it? That wasn't an area of concern?

Cmde. Maolankar: [10:14]
At that time, ski jump was probably not considered to be a major risk area. In theory, if you look at it, very simplistic thinking, it really is not a problem. Ski jump can add performance to any aircraft, frankly. The complexity that would arise from digital flight controls, that was not, I think, fully understood at that stage. But it's okay. It was not a foolish risk to take. In a sense, in a ski jump, you are exchanging… or you're buying performance at the expense of controllability. You're getting airborne at a speed where you normally don't fly, and therefore, you're not assured controllability at those low speeds, but you just ballistically throw the aircraft up and give it, therefore, time to create the speed. And that means you're buying performance by encashing controllability.

PR Ganapathy:
That's right. In that distance, to be able to generate enough acceleration to reach sufficient speed, that was considered enough.

Cmde. Maolankar: [11:38]
See, the hope was that we would be able to achieve all these changes that we spoke of within a reasonable weight budget. Right? So it's really what other changes got thrust upon

the program which have made the difference in the end? So what was not envisaged, for example, was, if in the same centre fuselage, the same outer contour of centre fuselage, you're going to house a much significantly bigger undercarriage. I mean, if you're talking about Air Force aircraft normally landing at half a metre per second, that means the flared landing. Occasionally in a really bad near-accident case, being able to survive one-off 3 metres/second. It means the bulk of its time, half metre per second touchdown, whereas on one odd occasion of 3 metres/second touchdown. You are jumping straight to where every landing is going to be four and a half metres per second with an occasional 7 metres/second. So it's almost ten times the energy that you're talking about because this rate, it's a V-squared relationship. So 0.5 metres to 4.5 metres/second is a massive jump and even 3 metres to 7 metres/second is a massive jump. So being able to house it in the same centre fuselage is not going to happen in the same volume, which means you're going to have much less volume for everything else in the centre fuselage. Now, where does that go? Where does the fuel tankage go? Where do the LRUs that were housed in the centre fuselage go? When they migrate to other parts of the aircraft. So obviously you start running out of internal volume.

Next is, all these structural members have to be that much stronger, so they are again growing. For example, if the floor of the fuel tank is also where your undercarriage is attached, then it is no longer going to be just thin skin which has to withstand pressurisation. It's going to be a full fledged machined, massive structure which absorbs landing loads.

Okay, so the aircraft has obviously ended up putting on a lot more weight than was envisaged. Of course, the arrestor hook was another very, very, major undertaking. You need to have the arrestor hook shoe significantly far behind the main wheel so that it can satisfactorily pick up the wire. And yet we were planning to dissipate the loads into the centre fuselage, which is midway up the length of the aircraft.

So what about all the structure in the middle? It's all hanging. It's all going to be made to hang from the aircraft and it's not going to leave those parts of the aircraft untouched. It's definitely going to require strengthening in all those places. So the aircraft actually turned out to be a lot heavier than what was planned because these aspects were not factored in when the original concept of the program was fleshed out, which is why they always say, start with a clean sheet for carrier based aircraft, make your design for that. It's always easier to make an aircraft lighter, by saying I don't need as much strength. It's easy to drill holes and make it lighter than to strengthen something and arrive at a decent thing.

Okay, LCA Navy was kind of locked into planned failure, I would say that is as compared to a goal of entering service. Right? However, if you Zoom out and if you put that aside for the moment and just look at it as where we were in terms of development. And that means you're already ambitious on the LCA program itself, already ambitious in terms of hoping to turn that into a product. Now you added one more layer of ambition in terms of the carrier-borne variant. And you're not recycling technology, you're recycling direct parts. Like I said, it's a combination of all the very elevated expectations that we had piled on, which basically decided that the technical risk is just too much and you're not going to succeed. The failure as a product was kind of built into the definition of the program in the first place.

But that does not mean that it would not succeed as a technology exploration program, because if we had zoomed out and looked at this whole scenario, we would have realised that even just technology exploration for carrier launch and recovery is itself ambitious enough. It's a big enough leap by itself. This whole field of carrier suitability and compatibility with a ship, there is a huge number of disciplines. A lot of extension of knowledge would be needed, which was, I think, not anticipated at that stage. What is the size of the mountain that you're trying to climb? It would have actually been a very wise thing to have pitched it as a technology exploration program right from the very beginning.

Unfortunately, that is not how we fund programs. We fund programs only when they promise to result in an end product. Now that itself is a flaw because you can only do that with technology which are already mature. If you are trying to catch up in technologies, that means you are talking about outdated technologies, because by the time you put the thing together into a product, those technologies are no longer going to be sufficient to meet your expectations. So we really need to sort out our thinking on these basic things.

If we expect cutting edge products, then you have to invest in experimentation. You have to not just tolerate failure, but celebrate failure, because what is deemed a failure in one way, from one perspective, can actually be the foundation of all the stories of all the materials and products which were created by accident as a failure in some other program and have been a major success in some other form. We are going to lose out on all that unless we celebrate failure, deliberately spend a lot of energy and experimentation, and then when certain technologies show promise, put those together into products.

You cannot hope to fund basic R & D in the form of a product because a product management team has timeline as its primary goal, cost as another primary goal. And as far as performance is concerned, they are always hoping to get away with the minimum mandated performance. Rather than actually trying to create the maximum performance. They're trying to get by with the minimum mandated spec performance. So if you feel you can renegotiate the spec, you're going to put your energy there, other than putting the same amount of energy into enhancing the performance. Do you get my point?

So we need to have these kind of conversations about defence R and D and technology and funding and Indigenous products, and the conversation needs to include these kinds of perspectives rather than just the usual meets the spec doesn't meet the spec. That's very stunted. It's a half conversation. It doesn't cover the full spectrum of things.

Yeah. So the LCA Navy is the tip of the sphere carrying all these burdens.

PR Ganapathy: [20:00]
Would you say that one has substantially overcome a lot of those challenges now, and at least now it seems to be on its way towards becoming something that can be used.

Cmde. Maolankar:
See, the LCA Navy as it exists, there is a Mark one as compared to the originally mandated

specs. It will not achieve those for sure. Right. Because she is substantially heavier, she has substantially had to shed several systems in order to remain within the same volume, et cetera, et cetera. Right. So there's no way that she can meet the originally mandated specs.

Can you still make a useful platform out of it, considering that it has within it, what it is capable of, what we should have been expecting from it, which is, let's say, a good training platform. Have we done enough to actually be able to use it? That is a very interesting question. And frankly, you can see the answer in the fact that HAL actually wanted to bid it as a candidate for one of those US Navy RFIs that was put out. Of course, that was just an RFI, but nevertheless, it shows you that there is sufficient, sufficient things. We have succeeded in sufficient number of things.

Has it succeeded in… Have we learnt what we need to learn from it? That is the key. Right. Have we learned enough from this platform to guarantee that the next platform, let's say the TEDBF, to make sure that that is going to be a success? Now, that is a work in progress, I would say, because you really need to ring out this platform. So currently we have done a certain amount, we've taken out of the [shifts], but there is still a lot more to be done to truly understand everything. And remember, this aircraft does not have everything right in it. So you can't learn everything by succeeding.

It's like what they teach in these academies. They're trying to teach you things. You have a black demo and a white demo. The black demo has everything wrong in it and the white demo has everything right in it. Now you can't learn everything only from the black demo, only what not to do. Your learning will still be a little restricted. And you can't have the white demo because you can't hope to have the white demo the first time around where everything is right. So it's a grey demo how much we are able to, but there is still work to be done, I would say on the Mark 1 to truly learn and thereby guarantee actual success on the TEDBF.

PR Ganapathy: [22:57]
If you can just speak about carrier suitability testing, I know you did a lot in terms of working with the US Navy to get trained on some of these concepts. There was that shore-based testing facility. What are some of the work that went into the unique testing that the Naval LCA required? And also examples of the critical sorties – first flight of the Naval LCA, first ski lump launch, first arrested landing on a carrier. What are some of those like?

Cmde. Maolankar:
I think we'll put that last bit out of the way first because the carrier suit is a bigger kind of a topic. The LCA Navy has now developed by a set of people who spent a lot of effort on developing a land based aircraft, and then they were told that piggyback on top of that and create a naval aircraft.

Now, I think in the beginning, when you've spoken about differences between flying at sea and naval flying and land based flying, unless you spend enough time on that, you cannot be sure that all technologies can piggyback. You can end up building in huge threats or risk areas simply because of the assumptions that are made, typically software failures. A lot of the failures originate from incorrect assumptions. So, for example, when a brake computer is booting up for it to expect that the INS [Inertial Navigation System] would be showing zero ground speed is a pretty reasonable assumption on a land based aircraft. But when that same brake computer, you put it up on a carrier and the carrier is doing 25 knots, and when it looks at the wheel speed, if the wheel speed sensor is showing 1 metre/second, it looks at the ground speed and says, but hello, what's happening? So it can exhibit very strange behaviour because of incorrect assumptions itself to start with.

So this understanding of the naval environment has to be a very deep seated, deep rooted, well understood aspect before you can even say that I will reuse the same software. Now it was deemed in fact, it's ironic because these are the things which were done in the name of safety or accepted in the name of “these are safer”. This is one of the biggest learnings I've had personally from. There is no such thing as “safer” in an aircraft program. There is “safe”. And for that you have to work on first principles. Is it safe or not? And taking something and saying this can only become safer by this. Those are always famous last words.

One of the things that was done when the LCA Navy first flew, for example, was that all the software in it was the same Air Force software. It was the same Air Force trainer flight control software, same fuel software, same brake software, there were no changes at all in it. And that was a source of comfort for everybody. Whereas actually when we started testing, it is when we realised that, no, that is a source of potential trouble.

So, for example, if the wheels have changed, the undercarriage has changed, but your anti-skid braking software is the same, or your wheelbase has changed and you've gone from a twin wheel nose wheel steering to a single wheel nose wheel steering with a planetary gearbox in the train, simple rack and pinion. The same nose wheel steering software is a threat. It's not a source of comfort.

That is probably what characterised the whole initial phase of flying on the LCA Navy to come to grips with this idea, to understand what are the kind of risks that we have actually ended up ramping up on this aircraft, simply because we have inherited a whole host of software. So you can imagine the same flight control software, but with an additional aerodynamic destabilising surface. If you just compare the two planforms, you'll see the difference. And this is on an aircraft where already you have made it as unstable as you think you can afford to. Now you've got a further destabilising surface on top of that. But the software is the same. So is it a source of comfort or is it a source of risk? Similarly, like I described to you about your anti-skid braking logic, you've gone from wheels, which are pretty much vertical zero camber to wheels, which are significantly cambered, visibly cambered. They are angled inwards, which are, instead of normal 200 PSI, you're going to 450 PSI. It's like a rock. It's like rolling on steel wheels. Brake control software can't be the same.

Same thing with almost every system on the aircraft. So the aircraft, when it first flew, LCA Navy, when it first flew, had to fly [with] very severe limitations. In fact, because of the things that we had, problems that we had in the fuel system, the aircraft could fly only a prefixed pattern. We were not sure, basically for almost the first 50 odd sorties, till we did a significant mod on the fuel tank, we really did not have any great idea about how much fuel is there in the aircraft. The fuel gauging was all over the place because the tank was such that there were huge pockets of fuel which would not feed, because certain those bleed lines, cross feed lines had to be deleted because of all the extra strengthening, extra structure those had got deleted. So those are not trivial elements. So now, if you slow down to your landing Alpha, which would be 14-15 [degrees], that kind of zones, the whole back end of the tank, the fuel would get cut off because that bleed pipe at the back end of the tank had got deleted. So until we segmented the tank, put pumps in the back end of the tank. Only then could we be sure that all fuel that is being registered. I mean, the fuel gauges were resisting fuel, [but it wasn't feeding]. You can't guarantee that it will feed.

So this was the major risk associated with the initial part of the LCA Navy flight test program, getting to understand the aircraft enough on this. And because by that stage, it had been decided that it's not going to be a final end product, it's only going to be a technology program. So what also tends to happen is that you don't get the kind of effort – design effort, software effort to solve every problem until, unless that problem is a show stopper towards your primary objective, which is demonstrating carrier capabilities. So you have to then do a lot of workarounds, which means deep understanding of the aircraft, and only the people who have the full picture can safely operate the aircraft. So it remains simple to fly. There's no doubt about that. But it remains very easy to get into trouble because you have not covered up all the open manholes. You only marked all the open manholes, and you know exactly where they are. And you're saying, “I'm going to guarantee that whatever I do, I'm going to avoid all those open manholes”. That's the kind of scenario in which the LCA Navy program had to be flown.

So today, for example, we have not really pushed the brakes very hard. We have cured, for example, to a certain extent, the uneven wear that was occurring because of the camber and extra tire pressure and stuff like that. But we've learned how to manage the tires, something like the Formula One. How do you do a lot of tire management? We've figured out a way in which we can efficiently operate from a runway without significantly consuming our tires. But we haven't pushed the limits of the brakes, the braking, or how to tune the anti-skid braking for the extra rigid tire when it is pumped up to higher pressure to withstand carrier landing. So you know for sure that's an area to avoid – unexplored terrain: avoid. So while the LCA Air Force was happily doing, you can smash around, you can smash down on the brakes and run through puddles and be sure that everything will work properly. This aircraft has, even after some adaptations, even after we've done some iteration on the software, there are still many areas like this which have got left out. So even right now, if you want to turn into a product, there will still be many such things to be finished, even within the existing capability, if you decide that I want to use it as a trainer, there are many of these areas, we have sidestepped, which would need to be finished. So that's pretty much the LCA Navy as an aircraft by itself.

Now, the big area where the big chunk where problems cropped up and affected our carrier suitability were in the way the aerodynamics of the aircraft and the flight controls were built. So we have significantly guttled and rewritten the flight control software for sure. Major work has been done in that zone. But like I said, since the aerodynamics were different, even the way the aerodynamic data was acquired itself had to be gone into. So the most extensively mapped and studied aircraft is the basic Air Force single-seater. The Air Force two seater, which is with the droop and the bigger front fuselage, is a Delta on top of the add on. That means a limited set of tests which are added on to the database that is created from the basic single seater. You say that okay, these things are not expected to change. So therefore I will not explore that in order to save internal time. And you do only the areas where you expect the change to be. So the Air Force two seater is an add on, and then the Air Force two seater with the Navy lecon is the second layer of add on. So it's two layers of add on away from a full fledged, properly deeply investigated, wind tunnel. In fact, I keep pulling their legs because we found so many aerodynamic phenomena on the aircraft in flights which were not predicted by the simulation, flight controls and the aerodynamic data sets and all that. So I used to keep threatening them that I'm going to make a patch saying: “Wind tunnel in the air” and fly around with it, walk around with it.

This was one significant area of threat and therefore we have had to invest a fair amount of flying on actually mapping out the LCA Navy in flight. I mean, “wind tunnel in the air” is not entirely completely wrong.

So this was all just to come to grips with the basic aircraft. Now is the real bear, which is carrier suit. Carrier suit, like I described to you, carrier landing is a huge big affair. Carrier suitability testing brings with it some additional issues. Okay, a land based aircraft for landing. Let's talk about the arrested landing. That's the big one. So a flared aircraft aircraft which does a flared landing is designed for the bulk of the landing. 99.9% of the landings are going to be within half metre to 1 metre/second, sink rate at touchdown. Right. That's the kind of load that's going to come on the landing gear structures, et cetera, et cetera. And the occasional bad landing is going to be 3 metres/second. Right. There are certain other design specs wherein they force you to design for a three point landing, that is a simultaneous landing on all three wheels. These are all things which they sound like it's a reasonable spec to demand on paper. But when you look at it, is it truly applicable to a Delta wing aircraft which is landing? Even the Air Force aircraft is landing at 12-13 Degrees Alpha. It would be twelve degrees away from your intended attitude. It's a pretty drastic error to be asked to tolerate. So that itself starts becoming an absurd requirement on the Air Force aircraft itself. Now when you go to 15 Alpha on the Navy aircraft it becomes and that too, with a change of technique – that is not moving the nose around like I spoke about earlier. Then to be 15 degrees away from your intended thing is that much more absurd and still expect to walk away with it? See, the point is not that can you crash the aircraft? You can crash the aircraft any which way you wish to, but are you allowed to still expect to walk away from it? Is it reasonable to expect to walk away from it? Is what we're talking about.

So there are many such specs which we had to understand that are actually absurd. Coming back to carrier suit testing. So the runway based landing, there is a significant margin between its one time capability of the structure. The structure can one time withstand 3 metres / second sink rate, but it has got to basically withstand regular 1 metre/second or less. So structures tend to get defined by both of these. Sometimes the one time overload requirement may not be the main one. The repeated landing requirement may be the most stringent requirement. You have to operate at a lower percentage of your actual capability. With a carrier-borne aircraft, you don't have the luxury of three times the structural capability exists. 1 metre/second to 3 metres a second is a three times margin, whereas in the carrier landing, if the nominal is going to be four and a half, that means your one time goes to 13, which is impossible. Your aircraft will just be one big landing gear. It will not have any capability. So you can't afford that, which means you have to shave off massively. So four and a half is designed for a one time capability of seven. It means what? It means you are operating closer to the absolute limits and therefore you have to deal with you, are going to encounter many more uncertainties.

Structural design is another area where I won't say inexact science, but definitely there are always adaptations to be made when you actually practically see how it manifests on the aircraft. So you're operating much closer to the… nominal operating is much closer to the ultimate tolerance capability of that aircraft, which then demands that practical testing and demonstration becomes mandatory.

So the land based aircraft does not, because it's so far away from the normal landing is so far away from its capability. It does not need to demonstrate a three metre per second practical flight test. Demonstration of a three metre per second landing on the land based aircraft is not considered necessary and has not been done, whereas only parts, the undercarriage was dropped by itself and proven that it can take the load, et cetera, et cetera. But overall doing it in flight test, putting it together and doing it: not necessary and not done.

In carrier suit testing because you are that much closer to the limits the philosophy is no, nothing doing. You have to demonstrate. You have to demonstrate practically three repetitions at more than 80% of the final capability or at least once to 100% of the capability. Which means if I say that she will not break till 7 meters second and after that, I don't know, I have to demonstrate at least once, exactly 7 meters / second, or three times more than 5.6. 3 times, I have to demonstrate more than 5.6%.

Now that means you are significantly enhancing the risk in flight test. Because now this is a deliberate mis-landing. Right. Now, how do you do a deliberate misleading and I'm aiming therefore for the three times 80% and not for the one time, 100%. Because if I aim for the one time, if I sneeze, I'll end up at 110% and actually break the aircraft. And that is the most foolish way of demonstrating the limits of an aircraft by breaking it. Any fool can demonstrate when it breaks. It's only a test pilot who can demonstrate how much it can take without breaking and do it in a way which is convincing enough or repeatable enough so that you can actually extract some worthwhile data from it. So this is the crux of carrier suit testing.

Now, in addition to this, you have to look at all these adverse cases, all the possible mis-landings, because the ship is going to be moving. So now to say that she will land in some funny attitudes, that means attitude variations landing on one wheel, landing while I'm still flying. That means landing at very low sink rate and the hook picking up the wire while the aircraft is still trying to fly. These are all the kind of there are some 17 such mis-landings, defined mis-landings, all of which need to be demonstrated. So this is the essence of the problem of carrier suitability testing, being able to in a controlled manner, repeatable manner, demonstrate these so called mis-landing, which are very close to the limits of the aircraft. And if you go over, you're going to break the aircraft. So everything is designed around this.

And the basic concept is you try and do everything in a slow build up. So change only one parameter at a time, keep everything else constant, change only one parameter, the one that you want to explore. So if you want to explore, just sink rate, keep everything else constant and just keep steepening the glide slope on which you are attempting a landing. So you keep dialling up even the approach slope indicator that you have, you keep increasing and angling it further and further upwards and you calculate what increments literally you're talking about quarter degree or one eighth of a degree increments, you're adding it up, which obviously means that you have to consistently fly the same techniques. So if a certain technique is giving you a certain sink rate, now I have to guarantee that I will fly it the same way, only that I can put in an increment in the thing. If I change my technique and fly it with a different technique, the next approach with a different technique, I will end up with some other unanticipated number. So this business of the same set of people using a consistent technique and doing a slow build up is the heart of carrier suit testing.

PR Ganapathy: [43:42]
You've almost resisting your training and instincts, and all of that just calls for a tremendous amount of discipline.

Cmde. Maolankar:
Way beyond your comfort zone, because the approaches start looking frightening, doing a four and a half degree slope, or maybe even five and a half, six if the winds are not favourable. Because when the winds, when the head wind picks up ashore, it cuts down your sink rate. So you need to go steeper because the wind happens to be stronger that day. But what you can see in front of you is that much steeper. It genuinely looks frightening at times. And now you are adding, you've got these cases of where you have to fly with roll and yaw. So you have to touch down with certain amounts of roll and yaw and still pick up the wire at the same time. Or you have to guarantee that you land on top of the wire. That means your tire lands on top of the wire with a certain amount of load. So these become even more accurate landings than the basic carrier landing, which still has a certain amount of margin of tolerance. These become even more accurate than that.

So there's only one way to do it, which is the same set of people. Even if you follow the same process, it's like climbing a mountain. Now you can say, okay, I'll climb Mount Everest in stages. But if you say, I'll climb up to base camp and back, and next time I will helicopter to base camp and start from base camp and go up, it doesn't work that way. So you have to finally climb the mountain from the bottom to the top in one go. In one continuous stretch. So how do you do that when your actual test case that you're doing is landing at a fixed weight +/- 100 kg? So how do I do this? Because each landing like this at one, I can be at that weight only once in a sortie. After that, my fuel is consumed and below that weight. So how do I do that? Because now if I switch off and I go back and have lunch and come back, it's like going back to the base of the mountain and saying I had climbed halfway up. Now I'll start from halfway up. The risk is too much.

So the only recourse is if you do what is called hot refuelling, which is at each stage you do a landing, you taxi off, get yourself refuelled, debrief the landing, look at the data. That means offline while the pilot is still in the aircraft, have a quick discussion on what worked, what didn't work. Maybe a repeat is required, or maybe it's good to go for the next one, or he wants to make some slight alteration to the next attempt that you do and then go to the next one. So pretty much every 20 minutes or so, you're doing 20-25 minutes, you're doing the next incremental test point, so you get a certain amount of fuel. You again, you do one or two practice approaches at this new setting and then get yourself down to the correct weight and then attempt a landing on that new setting. So that's about ten to 15 minutes of flying. If you succeed or don't succeed, you taxi off and get yourself refuelled. Another ten to 15 minutes fueling and looking at the data and then get up again. So it's a long duration kind of cycle. And every 20 minutes you're doing a short burst of activity and climbing up the mountain progressively. It's like sitting at base camp and somebody comes and gives you a plug of ration and then you go to the next one and then somebody comes and gives you another set of oxygen cylinders and it's like climbing the mountain that way. That way, what happens is in one session, you are expecting, hoping, and it's a reasonable hope to build up your skill.

Your skill is progressively building up. Your familiarity with the conditions is building. How is everything working out today? Is building up as you are approaching the actual limit, you are safest when you are right at the beginning of the base of the mountain and as you are approaching the actual summit is when you have also given yourself this maximum continuity. So this hot refuelling is not simply a matter of just somehow pushing and fuel while the engine is running. It's this whole business of being able to analyse what you have done in the previous point while the engine is running the compressed time frame. What would normally be one week's worth of analysis, you have to do it with real time data in a real time scenario, with limited analysis tools, deployment of tools, you have to do it and give a good enough assurance that it's good to go for the next one or not. You first validate whether you did what you intended to do. Then you figure out how did it behave. So what loads were measured, where all.

Sometimes sensors break, sensors fall off. Sometimes the thing that is being measured, that itself actually breaks. So you have to inspect the aircraft. What are the hotspots where things are expected to break? So, like you say, it's a whole ship activity. Even the ground crew are at significantly enhanced risk. They are having to deeply inspect the aircraft while the engine is running. I mean, he's looking for hydraulic leaks because he's looking for which are the hotspots, where hydraulic pipelines are closest to each other, which are the internal components which tend to move relative to each other internally. When you do these heavy, hard landings, what is the location to look for a telltale leak from that zone. So you have to have studied the aircraft very intimately. It's like the way a gymnast knows his own body. He knows his own joints and he knows his own muscles really well. Only he can tell you when he's beginning to tear a muscle. But this has to now be distributed over a team of people.

The designers looking at the data, the flight test instrumentation guys, making sure that the people are not working on corrupted data because the sensor has worked loose. A sensor which has worked loose will show some crazy spikes the ground crew are inspecting. It's a very subjective call. Have you smashed up your tires enough? Are they good enough to withstand another one of those? Or have you the only thing you can't replenish on the aircraft is the tire while this is running, so you can change the hook shoe, you can do all kinds of things on the aircraft while it is running. But tires are not something that… we have perfected in the art right now. Doing so this hot refuelling actually is not trivial like I described you earlier, air to air refuelling for flight test and hot refuelling for flight tests. These are not nice to have things. These are the way in which the rest of the world does what we have taken say ten years to do. They do it inside of one year. It is because of this. It is not just faster, it is actually safer. So you need to build these capabilities from day one. It's not good enough for the aircraft to finally become all weather and be capable of air to air fueling just before it is delivered to the customer. It needs to be rain proof so that you can wait out a small passing squall in Goa. Even the first prototype needs to be rainproof. The first prototype needs to be capable of air to air refuelling or hot refuelling. Not the last project. It's a way of thinking.

PR Ganapathy: [51:56]
I've taken so much time. But autonomous flight is one area that is one of the interesting ones. Automatic take off, auto landing, completely new ground. It's mind boggling to think of an automatic landing on the ship.

Cmde. Maolankar:
Yup. This is what actually currently excites me, because I am getting old. Finally retired from the Navy. Yeah, because it's the new flavour of the month and everybody is promising all kinds of over-promising all kinds of stuff with automatics and autonomy. And unmanned, actually, if you just look at the vocabulary that has been thrown around itself tells you that most people actually don't know what they're talking about or even what they want as a result of it.

Unmanned doesn't mean that there are no humans in the loop. In fact, unmanned platforms typically end up with more humans in the loop than manned platforms. When a manned platform can truly be completely self contained with just one human being, the one who's inside that platform. Whereas an unmanned platform would almost by definition have two, three or four people in the whole command that control chain. What I'm saying is the whole chain from planning to mission assignment to. Whereas a single pilot, you put a single pilot on a deserted airfield and he can actually give himself a mission on the basis of his understanding of what the situation was and actually go ahead, plan, execute the whole mission. Whereas that is not possible with an unmanned thing.

So unmanned doesn't mean no humans. Automatic does not mean intelligent. I mean, our toaster is also automatic. And yet we know that the second toast is, on most toasters, the second toast is darker than the first toast. And by the 10th cycle you have dialled that browning setting down to significantly lower, otherwise you're going to burn the toast. Now imagine that is where actual weapons are being released and something is going to happen, something dramatic is going to happen at the end of it. So your burnt toast means somebody gets killed when he should not be getting killed. So automatics is very easy to do, but very dangerous to do if you pile on too many complexities.

Autonomous: again, what do we expect? Do we expect full fledged general intelligence? That means it can give itself a mission. That is the stuff of all the Sci-Fi horror movies. So what is it that we really want? Actually, that is the real debate that we need to have right now, since we are not working with specifics as yet. People have not got to grips with this and therefore I think we need to experiment with many such toys and tools and then figure out for ourselves, what do we really want? Because what we want is then what we are going to work towards and what we can hope to get at the end of it. It's a very exciting field right now because right from this philosophical kind of understanding. In fact, some of the books I'm reading are about Rationalism versus Empiricism and Plato versus Aristotle and stuff like that. It's a very fascinating thing because it gets to the heart of when you want to replace human intelligence or human capabilities with non-human devices, then you have to have a very deep understanding of what was the human doing in the first place in that whole platform. What is the pilot doing inside an aircraft has to be understood completely before you attempt to replace many of his functions with something else.

Because don't forget, there is this paradox that the more automatic that you make flight, flying or flying operations, it means that pilots do less and less when everything is going well, right? And when, therefore, they get less and less skilled, they are not building up skill even though they are sitting in the aircraft, right? Even if you have 10,000 hours of airline ops, for example, because that whole structure, that whole concept of operations is built around automating as much as you can. Therefore, when things and pilots are flying routinely, they're not being allowed to, they are being actively discouraged from hand flying and therefore developing skills. Yet why is the pilot being retained? Because when the automatics give up and the automatics are not able to handle the aircraft is when you are telling the pilot: now handle it, it means you are expecting that when the aircraft is degraded, you want the pilot to be able to intervene and handle. Now how is he going to have that skill if you're not allowed him to build up and retain that skill?

So these are the paradoxes which actually lead you into very differently… that led me personally into very different conclusions as to what should be the role of autonomy and automatics in flying. And therefore, actually what currently we are hoping to steer our efforts into is: which are the elements of flying, which there is no way that a human can do as well as a computer can. And the converse of it, which is what are the elements of the whole business of flying, which is right from situational awareness to strategizing decision making, etcetera. All those elements which are the elements which you can never really hope in a reasonable time frame to replace a human. A human will necessarily be required because a human can handle that level of complexity and subtlety. So you have to understand both of these and target your energies in the right places. That means in the parts which can be done automatically better, you provide that necessary assist and at the same time in the parts which you can never hope to do better, you make sure that you only enhance the pilot's natural capabilities rather than try and replace them.

So, for example, that Airshow roll inverted, pull downwards towards the ground. Now I can do it in an air show because I know exactly what speed to start with. What is the speed window to start with? My preceding manoeuvres have been designed in such a way that they put me very close to that speed band. And therefore I know with a very high degree of certainty that if I roll inverted and pull, I can hack that manoeuvre without hitting the ground. And not just that, even with certain expected failures, how I'm going to be able to do it and still hack it. I have been able to do this, but the same capability now becomes useful only if I can see a target flying past me at ultra low level and I can roll inverted. That means from an uncontrolled initial condition, I should still be able to do the same thing. If I can't do that, then all this nine G capability on my aircraft is of no use because going into the ground in an F-16 or going into the ground in AMCA, there is no greater glory in either one of them. So does my aircraft offer me the protection that I can say: I want to do this, but the aircraft can calculate because the aircraft can work with the precision of the computer and say that no, you can't do this manoeuvre and therefore prevent me from doing it. That is the minimum I would expect. The best case that I can expect is “Okay, so if the computer tells me you can't do it”, then my next expectation from the computer would be “Okay, then what can I do? What is the closest I can do?” That means what is the steepest downward oblique that I can handle right now? Again, these are highly amenable to powerful number crunching. And therefore this is an area which definitely the computer must develop some autonomy and automatics to maybe override me if need be, right.

At the same time when it comes to deciding, for example, whether to divert or not. Now that is something which is far too abstract a decision. It's a strategic decision. It cannot be or even whether this blip that I'm seeing in front of me is a target or not. Now just imagine a scenario where you are totally gung-ho only on your sensors and non cooperative target recognition and the works you've got going in front of you. It still doesn't tell you intention of the enemy. So imagine that scenario where during the second Gulf War where the Iraqi Migs are all being flown to Iran. Now imagine the Iranian air defence, fully automated, with all the fancy sensors it picks up MiG 29 classic signature flying straight towards it. Therefore it's a valid shot. They should have shot down all of them, but they obviously must have been given some Int feedback. Last minute feedback saying no, nothing doing. These guys are defecting. Let them come in. Now how do you sit and disable all the lines of code in your highly automated software to make sure that they don't shoot it down at the last minute, five minutes before a guy calls up from there and says, don't shoot these guys, At the same time.

It's not just a simple matter of powering off this power of your defence system and say, okay, let them come in. Because out of those hundred aircraft which were forced to defect, there'll be two guys who are reluctant. And therefore they'll say, okay, I'll go along and I'll create chaos in that system. That means within that thing there is also a place where you need to deviate from your own briefing. Now, this level of complexity cannot be handled so easily by predetermined logics or even machine learning is the current flavour of the month. If it has not seen the scenario. And the nature of combat is this that every time a new capability develops which overwhelms the opponent, the opponent changes the game. So you start playing damn good cricket. He brings a football the next day to the field. When you start playing the tennis ball, one day turns up with a hard ball and people start getting hurt. Next day the opposing team brings the football saying let's, okay, great, let's equalise it. Then one team starts wearing football shoes, the other team starts, okay, let's play a third different game. Let's start running. So the essential nature of combat is to prevent you from bringing to bare predefined overwhelming technology which will keep you safe forever and ever. And you don't need to worry about your defence.

So this is the milieu within which we're trying to work at. We need to invest in this. It's a

Greenfield area. What people expect right now is too crude and simplistic definitions. They will be horrified with the results if you just go and simply make everything automatic. It’s simple, for example when the Aadhaar fingerprint reader couldn't read the old folks fingerprints and can't refer to the other database and you start denying them rations at the shop, imagine if that's happening with weapons. Imagine if they start getting shot as a result of that. It's simply untenable.

So I think there is a lot of need for exploration, brainstorming and experimentation in this area. Simply automation is not the answer because automatic landing was done in 1965, 1st if I'm not wrong, it's a very old technology, but automatic recovery of an aircraft, when the scenario decides that the aircraft should be recovered now rather than creating a panic situation later, that is something which I don't think is going to be there for another 50 years and maybe never. You get my point. This is a field which needs to be opened up and it needs a lot of gray hair, bald heads.

You need AI skeptics to work on AI to generate robust AI. The biggest interface, the biggest challenge I think is going to be explainability. It's very fashionable to say AI produces these totally out of the box solutions, but if the solution has the potential to dramatically have drastic effects, then you will demand explainability of that solution before you permit it.

If I can say, okay, the final trigger will be in the human hand. But if the human cannot understand why it has suggested a certain thing, how is he going to decide to pull the trigger unless you explain to him now you have taken a problem saying it's too complex for the human to handle. Only the computer can handle it and come up with a solution and the computer gives you a final yes / no answer. You might as well let the computer shoot because you have to get the computer to explain this complex solution to you and therefore the limitations of your current 2D display surfaces. How do you display these very complex abstract ideas to the person? What all senses do you use to convey abstract. You have to convey an abstract chain of logic in a very compressed time frame because it's all being done under pressure, under combat pressure.

I said it's no wonder that a lot of the Sci-Fi movies have these very phenomenal out of the world kind of interfaces, these 3D holograms. And this is another area which actually needs a lot of first principles kind of thinking and disruptive kind of solutions before we have what we… I feel we should invest in this because this is a path which offers us a chance to catch up with the rest of the world. So that's six Gen. When you're saying four plus Gen or five plus Gen, it's not a linear little more than four Gen is not fifth Gen or four plus each. When you say Gen, it means specific capabilities. You have to add on some fifth Gen capabilities or even beyond. Fifth Gen capabilities, which you add to a fourth Gen aircraft is what makes it four plus. Not a little bit of reduction in the RCS doesn't make it to four plus.

PR Ganapathy:
I've taken so much of your time. I want to thank you for all that, but I want to leave you or ask you a question. One last question. When you take an aircraft into combat, obviously, a lot of it depends on the pilot and the training and how that fighter controller vectored him onto the target and so on and so forth. But given all things being equal in the threat environment in

the subcontinent, where do you think, how confident are you that the Tejas will give up a well trained pilot, reasonably trained pilot, a fair fighting chance in combat, which is where the rubber hits the road.

Cmde. Maolankar: [1:08:52]
You are in with a fighting chance. You're definitely better than many of the several of the current platforms which are in service, which we are putting in, which are still fielding in front line service. There is no doubt that it is a big step up from there. Does it give you sufficient capability to make tactics and training the deciding factors? Definitely. That there should be absolutely no doubt about the best part of the whole thing is if you identify a weakness in it, you have all the tools and resources at hand to be able to overcome that, maybe even within days, if need be, during a conflict itself. You have the potential to be able to overcome a deficiency if you feel the need, which is not true with.

PR Ganapathy:
Amazing. Thank you so much, sir. This has been just a wonderful conversation, and we've covered so much ground. I want to thank you for your service. I want to thank you for taking the time to speak to me. It's just been wonderful.

Cmde. Maolankar:
I just don’t know how you’re going to edit it.

PR Ganapathy:
My style is to just leave most of it in there because I think the audience enjoys it. It's been great.

Cmde. Maolankar:
But honestly, frankly, just check out the IWM archives. I think I mentioned them to you about because some of the most interesting conversations are like 8 hours, 10 hours long. So just do iwm.org and look at these oral histories. Bill Bedford all the test pilots and they speak and they've got like half an hour episode, 8 hours and maybe even a transcript so people can or maybe with a summary of eight sections with a small summary of the topics or the issues covered in each section, then people can pick and choose. I can't see people who know me sitting through 8 hours. They could jump to your views on a specific topic.

PR Ganapathy:
That's right. On a specific topic. Yeah, maybe that is something.

Cmde. Maolankar:
I've seen you do it for some of the two episode things, but this threatens to spill over more than two episodes.