**Introduction to Research**
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**Lecture - 42**
**Research in Aerospace Engineering**

Prof. Prathap Haridoss: Welcome. We have it's our pleasure to have with us Prof. Satyanarayanan Chakravarthy, who is a professor in the Department of Aerospace Engineering here at IIT, Madras. He is basically a B. Tech from IIT, Madras and he has got a PhD from the Georgia Institute of Technology also called Georgia Tech, I guess. He is been a faculty in IIT, Madras for 20 years. His areas of research are Propulsion and Combustion. In fact, I mean he is recognized expert in both these area. So, he heads the, he is the coordinator for the National Center for Combustion Research and Development, which is housed here in IIT, Madras. He is also the coordinator for the center for propulsion technologies. So, he has a lot of you know experience, worked with a lot of students and so we feel he is ideally suited to discuss research aspects associated with Aerospace Engineering. So, welcome.

Prof. S.R. Chakravarthy: Thanks a lot, Prathap.

Prof. Prathap Haridoss: So, Aerospace Engineering. Generally, so this is the camera that would be easier for you. So, if you look at Aerospace Engineering in general, what you would consider as you know traditional areas of research in Aerospace Engineering which may be you know people may have been working on for a long time. So, there's a lot of literature available in these areas, but still these are areas that you know continued to be looked at.

Prof. S.R. Chakravarthy: Yeah, broadly across the world and most universities, if you look at vehicle Aerospace Engineering Department, there are 3 broad areas. So, the first broadest area is probably aerodynamics, which in many places also includes flight mechanics but, in some places there are specialized faculty researche intense in flight mechanics, so they tried to treat it little separately but normally aerodynamics includes flight mechanics as well.

And then, the second large area is structures, which involves which also a course includes some materials, smart materials, those kinds of areas. But, typically dealing with the shapes in which materials are formed to get air craft, another space craft components and retreading the loads and all those things. And, the third one is propulsion which portents to engines, the once that propel the air craft or the space craft. So, engines would also include things like rockets and so on. So, these are the 3 broad areas we can say that most Aerospace Engineering gets itself slotted into.

Prof. Prathap Haridoss: In addition to these, are there certain areas that are considered you know modern areas of or very recently started areas, initiated areas in Aerospace Engineering.

Prof. S.R. Chakravarthy: Yeah, very much, very much because see for example, as we speak we are now beginning to see emergence of for example, unmanned aerial vehicles, micro air vehicles and so on. So, there is a lot of buzz in the society about these things. So, that's an area that requires a lot of specialized attention and so it is kind of grooming itself into area by itself. But, if you now look at like it is aerodynamics like for example, if you want to mimic insect flight or some such thing, the aerodynamics is horrendously complicated.

So, that gets to be a specialized area there and similarly, the structures of flopping wings and aero-elasticity is like a specialized area that is coming out to be there and of course, these areas have been applied in the past as well, but they are actually getting more specialized in and focus for let say, UAV kind of application, similarly, micro thrusters for propelling these devices. So, in all these traditional areas you are now beginning to see like deeper focus. Similarly, things like Controls, for modern aircraft as well as these newer aircraft that we are talking about, space technology going forward into deep space machines and so on. So, these are all some sort of newer areas that are emerging.

Prof. Prathap Haridoss: OK, and see if you look at say what industry is interested in of course, aerospace industry - I mean yes, directly interested in much of what you are doing. Other industries also which you know, which are may be peripheral not directly aerospace industries are they also interested in some of the kinds of research activities that go on in Aerospace Engineering?

Prof. S.R. Chakravarthy: A lot, actually. So in fact, because aerospace is somewhat exotic, so there is a lot of pioneering research that happens in this field. So, just to give as an aside as an example: For example, the personal computer actually started with the space shuttle, so that was in the 1960's that they were trying to develop and then. So, now it is so ubiquitous. So, likewise lot of things that the automobile people actually adopt like, even things like head-up displays or the driverless cars that we are talking about have been pioneered in aerospace.

So, that way there is a lot of applications that aerospace people can do like, development of new materials, smart structures these things have a lot of applications. On the engine side for example, engines go along with not only propulsion, but also power. So, things like power generation devices electricity generation can be done with things like gas turbines, which are also the same kind of cycles that are adopted in air craft propulsion and there are many such examples that we can give of terrestrial, what we call as terrestrial applications actually.

Prof. Prathap Haridoss: And In fact, in an associated context see we have typically, when we look.

Prof. S.R. Chakravarthy: Wind turbines, I am sorry.

Prof. Prathap Haridoss: Yeah, yeah.

Prof. S.R. Chakravarthy: Wind turbines is something that like, is also because trust is on renewable energy, yeah.

Prof. Prathap Haridoss: Right, in that context if you look at, say again industry expectations of the people that they absorb into the industry generally, there is this impression that if you do a MS or PhD or a specialist and so, there is little narrower area where you may get absorbed. In that context, where do you see you know, let's say the recently graduating MS PhD students, what sort of positions are they getting say in industry or anywhere else? What sort of positions do they end up looking?

Prof. S.R. Chakravarthy: So, I think this answer I would like to actually take a step back and do a little bit broader outlook.

Prof. Prathap Haridoss: Sure.

Prof. S.R. Chakravarthy: So, if somebody is doing research there are about 3 different facets to it. So, one is looking at the phenomena, looking at the process that they are trying to research. The second one is where it is being applied; and the third is what are the skills sets, we are acquiring in order be able to do the research that we are doing on the phenomena that is applied to something right. So, if you are like a phenomena kind of person, you are probably cut out for academic perceives.

If you are the application kind of person, you probably you are looking at what traditionally we call as core jobs that means like I am. Obviously, when you come to Aerospace Engineering it is very unlikely that you will be actually doing sports medicine in Aerospace Engineering, although it is related okay. So, there is lot of aerodynamics you know and structures of muscles and stuff that there are faculty members in some universities that do those things. So, that is an application area, your core area may be sports medicine or something, but you can always associate a core engineering job, social with applications of what your research is.

Outside of that, that the larger area is the skill sets thing. If you are not this phenomena type of person right, you can now try to leverage the skills that you are learning, right. So, the skills typically broadly again fit into 2 or 3 categories, Experimental skill sets, Computational skill sets and may be Analytical skill sets. So, all these 3 things are there.

So, for example, we do very advanced laser diagnostics which can be applied to let's say, flow pass automotive vehicles in trying to making them more streamline and so on. Or do things like FEM or CFD and analysis which are computational tools that are ubiquitously adopted in lots of different applications. So, the question is which one do you want to leverage? What tickles you? What fascinates you? Are you trying to actually unreliable physics, then you probably want to be an independent researcher all the time in your life and that is one kind of job profile that you will try to attack. If you are applications kind of person you will look for core jobs, but if you are trying to leverage your skills then the world is open for lots of options.

Prof. Prathap Haridoss: Okay so, let me step back a bit now, we spoke about your students are leaving the program and where they may end up going. Let's look at the people who come in, I mean presumably you may have in fact students from different backgrounds coming in.

Prof. S.R. Chakravarthy: Yes, that is correct.

Prof. Prathap Haridoss: And also some coming from Aerospace Engineering, itself from may be different universities and so on. They are also transitioning from you know course based education to a research based education when they go for an MS and PhD degree. Are there specific issues that you see them encountering as they settle into this phase of their educational existence? Is there some other, any things that the challenges that they face or and if so, what should be done for them to you know be prepared?

Prof. S.R. Chakravarthy: This is again a general question that is not necessarily aerospace specific okay. So, I am going to answer it in that way to start with and see where aerospace fits in, if required. But, fundamentally what I see is that, right from kinder garden to let's say undergrad or let's say a course based masters like an M. Tech program, each child to start with and ultimately going to being an adult, is actually programmed. So, we have a time table that is given at the beginning of the semester or a year. So, we know exactly where we need to be sitting in, which room, in which seat, perhaps at which time and so on. So, we are not really trained to think independently on, how we want to spend our time?

And, when you now become a researcher so if you really think about it, even when you are doing course work right, to start with you are doing like lot less number of courses when compared to a typical M. Tech or a B. Tech and lot less when compare to what yourself did when you were a B. Tech or the M. Tech, right. So, you probably did like about 6 courses and then a couple of labs that kept you busy, pretty much all week. With all the home works and assignments to boot. But, now you probably doing like about 2 courses, what you do with the rest of the time?

So, typically I think this hurts the master students more when compared to the others, the PhD's because they have this mindset that I am doing courses so, let me not do any research and that is actually a bad strategy, because they are just wasting a lot of time saying that they doing courses and that chunk of time is like an appreciable part of like let's say, a Masters. So, masters are supposed to be like about 2 to 3 years, but typically everybody thinks it is a 3 year thing rather than 2 year thing which does'nt have to be actually, right. But, they pushed it that way because they had this you know, taking it easy during courses.

I think this we have to inculcate in our students to do a much better time management. They need to understand that there are 24 hours a day, there are 7 days a week, 168 hours a week. If the moment you say like there is 168 hours in a week because somebody they don't even know that because they have not done that little arithmetic, right and they don't know that, how to use those hours and this is something that I find most students are not really cut out managing very well. They get into some kinds of a certain expansion of a lot of freedom where they are not being monitored, they are not being required to be in a particular place doing particular thing, anymore and they are on their own doing things which is very, very hard to sharpen and say at the end of 1 year what have you achieved may be a lot less than, what would have if you have been lot more conscious of your time.

Prof. Prathap Haridoss: Okay great, and also in terms you know preparation for let's say, the kind of detail and regard we have for our course work here and so on. Do you find generally students coming in; are they well prepared enough that once they come through our selection process they are able to handle all what we require of them here? or do you feel they are may be, is there any challenge they face let's say with respect to the math involved in our courses, any other analytical skills are there things they need to be more aware of?

Prof. S.R. Chakravarthy: It's an evolving thing. So, one is maybe they are not really prepared for it may be, but may be they are, so that is a spectrum. But, many of them adapt. So, when they come in they know what is expected and therefore, they try to adapt, they try to pitch at themselves at a higher plane that is required of them and so on. And, progressively I am seeing in the last 20 years that I have been around, our expectations are also getting elevated. So we are, for example, if you see that, there are lots of advance level electives that have being offered with more faculties coming in and with greater levels of specializations and new areas that are being filled in interdisciplinary courses and so on.

So, the level of expertise, expected of the student is increased and if you increase your expectation many times the students rise to the occasion and meet it. So, that the most important thing is actually keep our expectations at the level that is appropriate and not necessarily water it down. Of course, don't make it too higher as well, that gets a bit

unrealistic. But, I think it's important to not let down the expectations and hold it at a certain level and get the students to rise up to attend and they would do it.

Prof. Prathap Haridoss: Okay great.

Prof. S.R. Chakravarthy: Yeah.

( 13.47 ) Prof. Prathap Haridoss: And, okay maybe I have a sort of mundane question related to this kind of you know the life that students have, yes there, doing their research activities here. There is always this idea that you know lot of learning happens when they interact with fellow students, with their faculty, with their guide and so on. What do you feel is a good frequency with which students should be meeting their guide?

Prof. S.R. Chakravarthy: Well, I have been on an average doing like once a week or so and once a week or may be sometimes because of travels and conferences and all that steps may be like once in two weeks. But, I think we need to give some. So, if you are particularly talking about guides versus students that's a different equation, when compare to students meeting fellow students. So, I think that students meeting fellow students has to be happening all the time. I mean they must be in the lab and the lab has to have like a bunch of students working on things, may be some times 1 experiment or whatever it is, it may not be possible to actually be done by 1 student, but it does'nt mean that every student gets a helper to help him something, it dose'nt made sense at all.

So, therefore, like students will have to actually combine the resource and they may be also sharing equipment and so on. So, if so one person is doing his experiment the equipment gets tied to that experiment which means, like it's not available for the next student who is sharing that equipment. So that means, like they have to have a very good helping tendency and they are not really helping for nothing, I mean it is like when I am helping my friend in the lab he is going to help me when I am doing my experiment.

Prof. Prathap Haridoss: So it's a learning experience about.

Prof. S.R. Chakravarthy: So, typically what is happening across the world in many places and you might find this actually, the number of authors is kind of proliferating in many general publications for and there is reason for this. So, many labs are actually getting on a campaign mode. So, they now say OK, now I am going to actually work on a student

axis experiment that means, the entire lab works on student axis experiment on a campaign mode. So that means they finish the experiment in about a week, get that student text to actually process all the data because there is just many times these days we are getting a lot of data, whether it is numerical work or experimental work. It's easy to get the data, lot harder to understand process and there is too must post processing that we need to do, to squeeze physics out of it and all that. So so, let him do the post processing, but he should be available to actually get into the next campaign during the day time or something like that, with the other students and so on. So then, it turns out that many of these people actually get on.

Prof. Prathap Haridoss: Each other's.

Prof. S.R. Chakravarthy: Each other's publications and so on. It's not a bad deal, actually and they learn about each other's experiments, (Refer Time: 16:18) of the problems that they are working on. So, I think that kind of time sharing and time management among students is very important.

As far as the guide is concerned, I think once a week either in individual meeting or least a group meeting is pretty good. Particularly, in the Indian setting I think when compared to let's say Germany or somewhere else where students do not meet the guides for very long time and still on their own because they know how to work with their canes and they know how to craft things and so on. Whereas, I think our students are not very well prepared to do things. So, we have to actually shed our ideas with them and we don't really have a very extensive post doc culture so that means, like all the integrities say something that people gets stuck on and we do end up doing some quite of like a repetitive teaching of these little skills.

So, I think skills development, both moved and for example, teaching and interaction. I think skills development of students has to be focused upon. So, if there is way by which we can actually develop lot of skills for example, things like if somebody wants to learn Fourier transform right, he needs to go to some place and learn it. So that, there could be like some sort of YouTube video, lecture of about an hour with lots of equations or like let's say mat lab programs and so on. That are all available in post free, like an NPTEL things. So, it does not had to be like a formal course for 50 hours or something, can I just learn something quickly, right.

Those kinds of skill development is something that if we have a very good base of it the faculty involvement could be a little lesser, but one of the problems that we have in having to have an involvement is we are not really making a lot of progress, on what our original research goals are in these frequent interactions that seem to be a must right now, simply because we are actually providing through developing skills of each and every student every all over again every time.

Prof. Prathap Haridoss: Okay I think it's a very, very pertinent observation, where we are doing it? How we are approaching things to it? In terms of you know okay, again one of the things you mentioned you know this multiple author publications and so on. And of course, generally we tend to look at publications as one measure of, how progress is happening in the a research scholars' activities? Is there any other way that you feel you know in a more philosophical sense that you feel you need to look at a student or students need to look at himself or herself to understand that they are actually making progress in to research?

Prof. S.R. Chakravarthy: This is a very difficult question and this is sort of highly personnel, as in every researcher and this doesn't have to be a necessarily a faculty member, it also portents to a student researcher. So, every researcher has to actually make up his mind, what is going to make him sleep well that night that he has a sense of accomplishment and of course, as a researcher sometimes I spend sleepless nights thinking about my research so and that doesn't count. So, if I am doing that I am quite excited about my work and so on and that is OK.

But, I think the sense of accomplishment or achievement is highly personal and there are lots of ways by which this can be done. We can measure in terms of matrix like number of publications or the impact factors of the journals, h-index, whatever it is that you want to talk about. And, you may claim that you are bringing in some quality and citation index and all those things into picture in all that stuff. But, I don't know if that's what is going to make you happy, right. So, keep in mind, in the Indian academic context I think most of the academics in India or actually on this job because they wanted to derive satisfaction out of the job that they doing. And, job satisfaction on the whole in most industry is the oxymoron, I mean you either do, you either have a job or you have a satisfaction, so it is one of the, OK.

So, here I think we are trying to do this. So, and we have to actually ask ourselves what satisfies me. So, there are people who want to see what they are doing actually be applied in the industry. There are some people who want actually look the most scholarly and like for example, if you look at what, if you look at G H Hardy's book, an apology of a mathematician, he actually loads his number theory being applied to let's say chess games or something like that. So, there are these pure, experimentalists who do not want any application.

Prof. Prathap Haridoss: Yeah, yeah.

Prof. S.R. Chakravarthy: So, you have to respect them for what they are.

Prof. Prathap Haridoss: You feel you are lowering the.

Prof. S.R. Chakravarthy: Exactly. So, you have to respect them for what they are.

Prof. Prathap Haridoss: Yeah, yeah okay may be to close actually, I just wanted to get your opinion or actually your words of advice, what words of advice would you have for students who are aspiring to join an MS or a PhD program in Aerospace Engineering?

Prof. S.R. Chakravarthy: Simple, 3 words answer is follow your heart.

Prof. Prathap Haridoss: Ok.

Prof. S.R. Chakravarthy: So, I think this is true for anything. So, whatever you want to do, we have a lot of societal pressure unfortunately because we are still a developing country. So, there is like lot of pulls and pressures, family, lots of things. So, I think at the end of the day we need to make up our minds what we want to do and we have to follow our heart. So, if we want to do research and we want to do a particular kind of research, we want to do a particular topic of research, we want to work at the particular guide in a particular department, discipline, whatever it is, just do what you think is a right thing. Don't worry about anything else; everything else will work out for you. I think you can have this attitude like the universe was created for your sake okay, just go on and everybody will follow, not a problem.

Prof. Prathap Haridoss: Great. Thank you very much for joining us, it was a pleasure.

Prof. S.R. Chakravarthy: Thank you.

Prof. Prathap Haridoss: I think very nice insight into what students should look at.