Over Four Decades of Design Optimization

An Interview with the founder of VR&D,

Dr. Garret N. (Gary) Vanderplaats

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Introductory Remarks by Professor Lucien Schmit,* July 20, 2013

I have known Gary Vanderplaats for 45 years. He is an extraordinary engineer and a wonderful friend. During his career he has done more than any other individual to make the original structural synthesis concept into a practical commercially successful set of design optimization tools. His leadership in developing well documented commercial codes is legendary. Gary has also done a great deal to advance multidisciplinary design and analysis concepts.

Gary is what I call a "go-to man," the sort of person you can take your problem to with good expectations for a solution. If ever I was stuck on a desert island, Gary would be my first choice as a savior. Many of you may not know it but Gary is an extraordinarily versatile individual. Early in his career he felt the need for a computer at home so he built one from a kit on his own. He can take most cars apart, fix them, and put them back together in working order. He can probably out walk most people half his age. He is also very facile with tools of all kinds. Fixing up an old house or building a new one are well within his ken.

In closing these brief remarks I want to offer my earnest congratulations to Gary Vanderplaats on a life well lived----it is indeed my honor to know Gary Vanderplaats as a closely held friend and a distinguished colleague.

*Professor Schmit is the originator of modern structural synthesis. His original paper is available here: Structural Design by Systematic Synthesis

Garret N. (Gary) Vanderplaats was born in Modesto California in 1944, and a year later moved to Groveland, less than fifty miles from Yosemite National Park. His father was a logger and Gary spent summers falling timber and driving a 'Cat.' He began working on cars at age 12 and continues that as a hobby to this day. Growing up, Gary spent a lot of time in the mountains and every fall he still sets aside a week or two for backpacking/fishing trips in the High Sierras. Throughout his career Gary has been recognized as one of the major innovators of design optimization technology, and many of his technological breakthroughs have occurred to him in the mountain solitude. He even has a patent on a collapsible fishing net he designed for backpackers.

At 18 Gary went to Junior College in California and, at 20, went to Arizona State University where he studied engineering. While there, he earned Bachelors and Masters Degrees in Civil Engineering. Gary received his Ph.D. from Case Western Reserve University in Structural Mechanics. While attending Case, under the tutelage of Professor Lucien Schmit (who was the originator of structural synthesis in 1960) he developed a fascination with design optimization and has made it his lifelong pursuit.

Gary has been a research scientist and conceptual aircraft designer for NASA, Engineering Professor at two universities, a design optimization consultant, and Founder/CEO of Vanderplaats Research and Development, Inc. (VR&D). Over 100 universities use VR&D design optimization software and many of those use Gary's textbook, *Multidiscipline Design Optimization*, as well. Gary has published numerous papers, given many keynote addresses, and received a number of honors, all related to design optimization.

Whenever asked if some day he'll retire and quit working so hard, Gary always replies "When you love what you're doing, you never work a day in your life."

The following interview with Gary Vanderplaats took place on July 10th, 2013 at the Colorado Springs office.

Interviewer: Gary, what inspired or prompted you to study numerical optimization?

Gary Vanderplaats: Well, when I first encountered it, I was completely uninspired. When I was getting my Bachelor's degree, Professor Louis Hill at Arizona State University, was encouraging me to get a Master's degree. He stopped me on the sidewalk just before graduation and said "I have a fellowship for you, now get a Master's degree." He gave me Lucien Schmit's classic 1960 paper as well as his own, and several others. He'd gotten a PhD in optimization at Case. I confess I didn't read them in detail, I browsed them and I said "This is mathematical gibberish." I politely took his fellowship and did my Masters in finite elements with another professor (laughs).

The next year, same time of day, same place on the sidewalk, possibly same day of the month, I don't know, he stops me and says "I've got you a three year NSF fellowship. Now go to Case and get a PhD." So I went to Case, met Professor Schmit; he said he was delighted I came to study optimization with him. I didn't disillusion him, not wanting to give up my fellowship. As soon as I had taken a class from him on optimization I was hooked, and so the rest is history. I'm the only student of that time period that's spent his entire career in optimization. The rest of them had to get honest jobs.

Interviewer: What year was that?

Gary Vanderplaats: The first encounter was 1967. I was getting my Bachelor's degree in Civil Engineering. I got the Masters in '68 so I went to Case in the fall of '68. It happens that when I was about to start on the actual research on the thesis Lucien called me in and said "I know you came to study with me, but I'm going to UCLA." We looked at me going with him but I would have had to take the qualifiers over and he said "Stay and finish with Fred Moses," which I did. A year later he was instrumental in getting me a job at NASA.

I might note that there's a more extensive discussion of this in the paper Fifty Years of Structural Synthesis.

Interviewer: When, and what made you decide to start your own company?

Gary Vanderplaats: Well, to back up, I worked for NASA doing conceptual aircraft design for eight years. Started in 1971, in '72 I released a program called CONMIN which became fairly widely used and even today is sold by our competitors. It was a research code that followed some years later with ADS in 1984, again a research code. To back up, in ’79 I left NASA and went to the Navel post-graduate school as an associate professor. In ’84 I went to UC Santa Barbara as a full professor. Then in ’87 I decided to leave and devote full time to the company. At that time I had CONMIN and ADS; both research optimization codes, both pretty widely used, both today sold by our competitors. I never sold them. I worked for the government. I didn’t think it was appropriate to make money off what I did for my job.

During that time I was doing a lot of consulting and several companies I consulted with were saying “You need to leave the university and commercialize this.” Well, about that time I was getting bored with teaching. It seemed rather repetitive to me and I kind of proved everything I wanted to prove, at least to myself. I’d written a book, got some teaching awards, all the stuff teachers and professors are supposed to do. So in ’87 I left UCSB and also, about that time, we were hired by the MacNeal-Schwendler Corporation to add optimization to MSC/NASTRAN. That provided funding for the company for about three years. That three-year project led to Solution 200 in MSC/NASTRAN.

Also at that time I said since I’m going to have a commercial organization I need commercial grade software and I wrote DOT; actually started on it somewhat earlier. Basically the idea was DOT would have the best of everything I’d learned in fifteen years. It was commercial grade, and maintainable. Today it’s, I think, version six or seven, and it has three basic algorithms. The combination of people encouraging me to go commercial, and me looking for change led to leaving the university with my ocean view office and tenure, and start the company. Coincidentally, as soon as I did that, many of the people who encouraged me to start the company decided to not answer their phones. So we had a few rough years (laughs), but have survived.

Interviewer: What does DOT stand for?

Gary Vanderplaats: Design Optimization Tools (DOT).

Interviewer: What was the state-of-the-art of design optimization at the time you started VR&D?

Gary Vanderplaats: At that time we had the optimizers, both research and now commercial, that were in pretty good shape. We could solve, reliably, one hundred design variable problems. Understand, most of the state-of-the-art optimization work was in structures up to that point, although I’d done conceptual aircraft design and airfoil optimization in the seventies. I had applied, by then, optimization to everything from conceptual aircraft design to windmills to gas dynamic lasers, but with relatively few variables. The software was batch software; we didn’t have any graphical interfaces, or anything. So, people who used optimization had to do a lot of coding themselves. We were still going to conferences solving the three-bar truss. In the mid-seventies we got up to the ten-bar truss. We had a program called ADS/NASTRAN which we marketed, and sold a few copies. We had externally coupled the ADS optimizer with

NASTRAN, and were able to do 1500 variable structural optimization problems. Not widely used, not widely understood, optimization even today is seldom taught at the undergraduate level.

Interviewer: What year was ADS/NASTRAN made available?

Gary Vanderplaats: ADS/NASTRAN was probably 1985. I'd have to go back and look and see when we first published that.

Interviewer: Can you give an example of a common type of optimization problem that is done today?

Gary Vanderplaats: Well, today probably the most common is of automotive applications where vehicles are optimized for ride quality, or for crashworthiness. Probably ride quality is the thing that really got us going in the auto industry. Just the ability to increase the first couple of structural frequencies of the car while adding hardly any mass has a major impact on the ride quality. So, that's a very common one. Also, our client Aisin AW in Japan designs automatic transmissions and they've made extensive use of optimization. They are now the largest automatic transmission manufacturer in the world, and use optimization as a pretty standard practice.

Interviewer: In your career, what was the most unique or intriguing applications of design optimization you've done or seen others do?

Gary Vanderplaats: That's a good question….probably Alcoa Aluminum. In the seventies I made a comment that you don't have to get function values from a computer. You could use experimental results. In a short course I was teaching a man named J. O. Song of Pratt and Whitney in Florida went back home and said "This was possible." At that time when they designed jet engines they would adjust the pitch of the fan blades to maximize adiabatic efficiency, and they called it test stand optimization. Well they said "OK, we'll try. We'll tell you where we started, but we won't tell you the answer." He got a better solution with forty percent less experimental tests on a test stand that, at that time, cost thirty five thousand dollars an hour. That was published, I think, in 1982 by Garberoglio, and Song.

That was interesting, but somewhat more interesting to me was about that time Alcoa Aluminum got the program. This is a program called COPES that I wrote at NASA which eventually became VisualDOC many years later. You were able to input the X vector and the function values, and it would fit curves to that data to optimize. Then it would try to call your analysis and the analysis didn't exist so the program would crash, but not before it printed the new proposed design. So Alcoa Aluminum got this and I didn't hear from them for probably six months. A guy called and said "Good news. We used this to improve our production rate of rolling sheets of aluminum, and the variables are: feed rate, pressure, temperature…." and one or two more. He said "We've improved our production by one tenth of one percent." And I said "I thought you might do a lot better than that." And he said "No you don't understand. We've been doing this for a hundred years, and we're a multi-multi-million dollar company so you can imagine what one tenth of one percent productivity improvement is. To prove it to you, you are invited to come to our 100th anniversary at Hilton Head South Carolina for a week, and give a talk, all-expense paid." Which I did, and a few days after I got home there was an air express box on my front door with a custom designed chess set made out of aluminum. I think they only made a hundred or so of those. They couldn't tell me the details of course it was very proprietary. I think that's the first commercial application that was really big money.

Interviewer: Well, speaking of interesting applications, you mentioned Aisin AW and automatic transmissions before. What kind of optimization do they do?

Gary Vanderplaats: Mainly structural, but the fluids guys are doing it too. If you ever take apart an automatic transmission, you see fluid channels EVERYWHERE! In fact, I've overhauled more than 150 engines and probably 50 stick-shift transmissions, but I will not touch an automatic (laughter). I've taken them apart and thrown up my hands and said "I can't even imagine how the guy decides where all these channels of fluid go." But a key thing in automatic transmissions is also noise. Aisin AW at one point collaborated with us to incorporate noise into GENESIS by coupling with another code and reducing the radiated noise. We got the program working and Iku Kosaka and I went to Japan to talk about it. He was having a lot of trouble making it work, but he found the problem. It was actually modeling in the noise program. He started a run before he got on the airplane. When he got to Japan the run was finished, and he was able to present the results. It was a significant reduction in radiated noise. At that point an Aisin AW executive turned to one of his engineers and asked him to bring something in. They brought in a composite part that they had covered the transmissions with to reduce the radiated noise. It was a very complicated part. He says "Now we can throw this away because we've reduced the noise to acceptable levels." I think that was a major advance and a big money saver for them.

Aisin AW had another example of just a simple arm. It was a little mechanical arm that goes in the transmission to hold the lever in place when you shift. The tactile feel is very important; it should have just the right stiffness. That piece used to be made up of an arm, a roller, a connector for the arm and the roller, and two rivets. They were able to replace all that with an arm wrapped around the roller with no rivets. Manufacturing costs for the part dropped very dramatically. They just look for every little piece where they can do optimization, and that's the first corporation that I've seen that says optimization will be standard practice.

Interviewer: What has surprised you the most about the success of optimization, or lack of success?

Gary Vanderplaats: Actually what surprises me is the lack of success. I think it was 1978 when I was invited to give my first keynote address, and I very pompously and confidently declared “By 1985 optimization will be standard practice.” I feel a little bit like Bill Gates saying we’ll never need more than 380K of RAM in a computer (laughter). That of course never happened. When you look at the power of optimization and the versatility; I mean if you have any program with input and output, optimization can be used to improve the output by changing the input. So you would think that it would have become very widespread a very long time ago. I don’t know why it hasn’t. I think largely because it’s not taught. You can approach an engineer who’s been doing trade off studies for twenty years, and say “I can help you do that in minutes what you’re taking weeks to do.” Sometimes he’s threatened because he’s afraid to lose his job if it’s so simple, but mainly he just doesn’t believe it’s possible. In my experience optimization’s never cost anybody their job. It’s a little bit like word processors. When they came on the market a lot of people said “Well, we don’t need secretaries anymore.” Well, we have just as many secretaries as ever; they just do a lot more than they did in the past. It’s an efficiency improvement. With optimization for many years when it was becoming used, engineers just got better designs but they never took less time. I used to present it as a time saver, but then I learned that if you’re given six months to design something you’re going to take six months to design it. If you’re using optimization you’ll just look at ten times or a hundred times more possible design concepts and come up with a much better design, but you’ll use all the time you’re given. More recently management has realized that you can design faster, and so they shorten the design cycle. There’s international competition that’s driving the use of optimization because when people have to get a car out in one year instead of five, they need these tools to make it happen.

Interviewer: Do you think that the power of computers has helped with optimization? For instance, how many independent design variables can be used in an optimization now?

Gary Vanderplaats: Well. Yeah it’s the combination, I think, of two things. One is the power of computers has been essential. When Professor Schmit solved the three-bar truss in 1960 he took half an hour on an IBM….I think it was 650….whatever that machine was in those days. Well, that problem now takes a millisecond or so on a laptop. So the speed has been a very important factor. The other factor is now with tools like GENESIS, the pre-processor for finite elements as well as Design Studio which now sets up the optimization task, has been essential. Likewise, for VisualDOC. Where you used to have to couple your program with DOT, now it’s all interactive, and it’s all very fast. You can set up an optimization problem in minutes. You can couple optimization with your analysis in minutes. The problem size now with our BIGDOT code is in the millions of design variables and millions of constraints. Just imagine editing a finite element model and going line by line saying “This is design variable one, this is design variable two…” up to a million. You’ll be there forever, but with Design Studio you do that with a push of a button. So, it's a little bit of both. It's the dramatic speed increase in computers and a dramatic improvement in the theory, the optimizers, and the tools we have to do optimization.

Interviewer: What is your experience with the application of classical MDO methods to industrial optimization problems?

Gary Vanderplaats: I'm not sure what you mean by 'classical MDO methods'. My view is I thought that we were doing MDO in the seventies when we did conceptual aircraft design and we included geometry, aerodynamics, propulsion, trajectory, mass properties, everything at once. We had all the disciplines together. In 1980 Jarek Sobieski at NASA Langley published a paper, *Blueprint for Development*, and that's what many people now tag as the beginning of MDO. I kind of disagree with that perhaps for selfish reasons. That led to a lot of research of very sophisticated analytic methods, none of which I think are used today in commercial software. And the reason is that there are various methods that use very elegant mathematical formulations, decomposition and so on, but what they don't recognize is engineering design is not so elegant. When you put this on a digital computer, and you interface several different disciplines at one time, you're dealing with software that very often fails, is noisy and you can't use precise mathematics. You have to understand it's a digital world.

In fact, to back up, I think that's the reason my optimizers are successful. I try to model how engineers think. And so I don't look for a six significant figure answer. I look for a good design very fast. So, my approach to MDO is just use optimization at every opportunity. With a program like VisualDOC you can interface a dozen different disciplines simultaneously. We can handle very large numbers of variables; we have the computer power to do it; we can do parallel processing; we can do all these things to solve the multidiscipline problem. Having said that, the example that's always used for the need for the theoretically elegant methods, is an aircraft wing. They'll say if the structures guy designs it, it's going to be short and stubby, and thick. The aerodynamicist will make a long slender wing. The argument is that the true optimum is not the combination of the individual optimums. Well, the point is that neither of those people gets to design the planform of the wing. That's done at the system level by the chief engineer. They can modify the structure internally. They can modify the airfoil shape a bit. They can give their best results if the chief designer changes the aspect ratio, or sweep, or whatever, but they don't get to make those system level decisions. So, once you understand that, then the system variables are handled at the system level. You change the definition or the shape of the wing. You call the aerodynamicists, and tell them to improve the airfoil shape as best they can. You call the structures guys and say minimize the weight of the structure. The aerodynamicist provides loads for the structure…that's fine. Now just put it all in a program and out comes the optimum. So, the statement that the sum of individual optimums is not the true optimum is true, but if you formulate the problem the way engineers do you invariably get the true optimum, (pause) and you do it very efficiently.

Interviewer: What theoretical contributions have you personally made to optimization?

Gary Vanderplaats: I think, ultimately, that's judged by others. From my perspective, I think the first one was what generated CONMIN. While working on my thesis I fell in love with Zoutendijk's method of feasible directions. Once you understand how it does optimization, it's very physical, very easy to understand, and it does what engineers do. It says if I take a little step, how does it change the objective and constraints, and how can I find a search direction that will improve the objective and stay feasible. In other words, satisfy the design requirements. That method had a bad reputation. They said it would zig-zag. A constraint would become active on one iteration then inactive then active. Well, that's because people said a constraint is active if its value is within some very small tolerance of zero. The contribution at the time was very simply saying if I get within ten percent of active, as an engineer, I start worrying about that. And so I'll push away from the constraint very modestly. As it becomes more active I'll push harder and harder. That added a lot of stability to the method and eventually became CONMIN. That method actually will push away from the constraint instead of trying to follow it if you imagine a constraint looks like a fence on a hill.

A later contribution became the modified method of feasible direction (MMFD) that I published, I think, in '84 where I learned that there's a way I can actually follow the constraints. That gives a more precise constraint satisfaction. It's similar to a method called generalized reduced gradient, and when I was studying that method I realized that the mathematics there are mathematics that are contained already in the method of feasible directions. The generalized reduced gradient method required that people define a subset of dependent and independent variables. The modified method of feasible directions is able to avoid that. So, the algorithm for MMFD became the primary method in DOT.

In the eighties sequential quadratic programming came along. Professor Yoshida, who was visiting me at the time, and I modified that method and it became method two. Sequential linear programming became method three in DOT. I think those are the theoretical things that I've done in optimizers.

In the mid-seventies the thing that made structural optimization possible today was Lucien Schmit and his student [Behrooz] Farshi (pause), I'm sorry I forget his first name. They developed approximation methods in structures, where they used reciprocal variables to approximate stresses. By that time Lucien and I were very close friends and I followed his work, and he followed mine. It made good sense to me. At the time I was dabbling in aerodynamic optimization with two colleagues at Ames, Hicks and Murman; It kind of made sense that approximations could work. We had very expensive function values, and so I said well why don't I just take that idea, take several candidate designs, fit a curve to them, and optimize the curve.

The other thing that was published in the seventies was called reduced basis where people would have several candidate designs and they'd ask "What's the best combination of those?" Well, in aerodynamics we were treating the airfoil as a polynomial which is not a good way to design airfoils. It's not well conditioned or anything. So, I went into the old NACA books and I got four airfoils and said "What's the best combination?" Lo and behold the combination of four low speed airfoils designed a supercritical airfoil that almost exactly matched Whitcom's supercritical airfoil that was all the rage at the time. So the combination of reduced basis and approximations worked. I called it curve fits when I published it, today we call it response surface approximations. That allowed us to solve problems where the analysis was very expensive, and there were not too many design variables. It would get a very good answer very quickly. So I think that was another one.

Third would be in structural response approximations. In aerospace people talk about forces in the structure; I always thought stresses as a student and academician. It finally occurred to me that they use forces for a reason. They'll do an analysis of a wing for example, and they'll get the forces on a panel. They'll send that panel to an engineer with the forces and say now optimize/design the stiffeners in that. Shanley wrote a book on that; how to design the stiffeners for that panel…optimum….analytically. And I realized one day that the reason they work with forces is forces don't change as fast as stresses. And so in the mid-eighties I wrote a paper on force approximations, and I have to go back and say a Professor Bofang in China had actually published this concept earlier. I may or may not have seen his paper, I don't know, it was in Chinese, but I did visit China and I may have talked to him. So, he may have been the true origin of that concept for which I got credit. That's the method that we use today in structural optimization. It's actually the reason that we wrote GENESIS because we were not able to put those approximations in NASTRAN because of the structure of the program. So, we ended up writing our own program that we thought would be kind of a companion; OK analysis, but really good optimization. Toyota funded a lot of that development and if you ever worked for Toyota you know they're a hard taskmaster. So by the time version one came out which was statics, normal modes, sizing, and shape optimization, it was very competitive. Today we're in version 12.2 of GENESIS and it's, I think, the premier structural optimization code. But, its origin was we wanted to incorporate the latest technology in optimization that we weren't able to put in the other code.

I guess a more recent contribution would be BIGDOT, which was a small business innovative research project from NASA Langley to solve very large scale problems. I think this was a three year project, and after two and a half years I was ready to admit defeat because I was able to solve maybe….(pause) a thousand variable problem, but really hit a wall. So one day I was riding my ATV thinking about it constantly, trying to kill myself in the Colorado Mountains, and came up with an idea. I stopped, sat on the side of a hill for a good half hour to make sure that I wouldn't forget it, came to work the next day, and by noon was able to solve ten thousand variable problems. I took that breakthrough to a conference and by then I was solving thirty thousand variable problems with thirty thousand active constraints. Two papers before me a competitor gave a paper on large scale optimization and he said "We can solve problems with thousands of variables, but only a few active constraints. Or we can solve problems with thousands of constraints, but only a few variables because only a few of them will be active constraints." Then he said "We cannot solve problems with thousands of variables and thousands of active constraints." I got up two papers later and solved a thirty thousand variable problem with thirty thousand active constraints.

Since then I've solved five hundred thousand variables with five hundred thousand active constraints on a laptop as a test case. In GENESIS we routinely solve million variable problems; not usually with that many constraints. However, we are finding that we're solving bigger and bigger problems with more and more active stress constraints, and we calculate the gradients of those constraints. Now imagine calculating the gradients of a million stress constraints in terms of a million variables, and see if you can find a hard drive big enough to store the results or a computer fast enough to calculate that information. This takes us all the way back to 1970 when we were bragging that we could get gradients analytically. A man named Roy Levi at JPL said "You think gradients are cheap, wait until you need a hundred," because getting analytic gradients is basically like adding a load case to the finite element model. Well now we want a million, and so that led to an optimizer that I call STRESSDOT where we have a proprietary method of calculating gradients on-the-fly which is not perfect but very high quality for a large class of problems. And so now we can solve structures problems with very large number of variables, and very large number of active constraints on structures such as car bodies where you model it with plate and shell elements. Or you model it with rod elements, or whatever. So I think that's a significant contribution too.

Of course, in the company, there are many contributions that I can look at. How we do shape optimization. Brian Watson's work on SMS. The concept was developed by a Professor in Texas, but Brian wrote SMS. Topography, topometry, all of that stuff; there's just dozens of innovations in our software that have come from our staff at VR&D. To back up, creating the company, I had two goals: one is to have the best software in the optimization world, and the other is to have the best staff of experts. I'm very confident that I've achieved those goals. That's why about five years ago or six years ago, I forget when, I was able to turn the management of the company over to Juan Pablo Leiva who is a superstar in his own right. Now I can spend time doing a little bit of research, a little bit of relaxing, and letting other people do the day-to-day operations.

Interviewer: It sounds like you've gone over the history of VisualDOC and GENESIS. Is there anything else you'd like to say about that?

Gary Vanderplaats: Yeah, VisualDOC actually. The history goes back to the COPES program I wrote at NASA. We were doing conceptual aircraft design. The program was written by half a dozen people, and it was about three thousand punched cards in length. We were reading those cards over a three hundred baud modem to a CDC-3600 computer, at Lawrence Livermore Lab. Every time we changed the design optimization task we read the cards again. I got kind of tired of doing that and said "Well, why don't we just put everything in a vector and write a program that points to locations in that vector so the inputs and outputs end up in a big array." Now all we do is we point to the inputs and say locations 3, 5, and 7 are design variables. Run the program, and when we get the output in locations 31, 72, and 110 then create the objective and constraints. So that was the technology in COPES. That allowed us now to leave the program on the computer and run just a very small deck of cards to run whatever optimization task we wanted to run. And that's the concept that's used in VisualDOC today as well as competing software in MDO. It's how we couple programs to optimization.

Well, in the COPES program I had the response surface approximations. I called them curve fits at the time. That was in COPES. Discrete variable optimization with branch and bound was also included. In 1990, I believe, we released the Design Optimization and Control (DOC) program which was based on COPES, but rewritten as a commercial code. In the mid to late nineties we got an SBIR from the Air Force. Dr. Venkayya at Wright Patterson Air Force Base funded us to write VisualDOC, in other words to create a graphical interface (GUI) for this. The first version of that didn't go very far, but over time we've hired people that really know how to do GUI's. It's all written in java and it's gone way beyond what the DOC program was. We now have Design of Experiments (DOE), genetic algorithms, all sorts of post-processing, and the pre-processor allows us to integrate a multitude of programs very efficiently. That program now is many orders of magnitude beyond what it began as, as COPES.

GENESIS - I said we initially wrote that to be a companion to NASTRAN. We had a relationship with MSC and weren't looking at that time to compete with them. It just historically happened that we're now a very strong competitor in the structural optimization field. As I said before I'm confident that these two codes, GENESIS and VisualDOC, are the best in the world.

Interviewer: How do you see the future of optimization?

Gary Vanderplaats: I think at this point optimization has demonstrated itself to be a very valuable design tool. In fact, Lucien Schmit and I were talking about this some years ago and he said "I'm now confident that optimization has a future because people have decided they can make money off optimization." That's when several companies were being created with their own programs to promote optimization. So I think the future is solid. I think we've established that it works. There's still a lot of education that's needed. What I'm finding is particularly young engineers pick up on optimization very fast. If you think of how an optimizer works, particularly gradient based optimizers but also a random optimizer like genetic algorithms, it's very much like a computer game. Young people who've grown up playing computer games understand very quickly the idea of trying different options, trying different things, pushing different buttons, seeing what happens, and improving the results by doing that. So young engineers pick it up very fast and as they are allowed to use the tools I think it can only grow. I'm very comfortable and very proud of what we've done, and think that the whole technology is at this point established.

There's always going to be a lot to do. There have been, I'm guessing, at least 100,000 papers written on optimization in the last fifty years. They're still having conferences and looking for new breakthroughs. Myself, fifteen years ago I would have said a thousand variables is about our limit. Now we don't see a limit to the size of the problem we can solve. Computers keep getting faster. We keep improving the algorithms. We're finding in our own experience, in business, that once people get really accustomed to using optimization they won't consider being without it. So I think the future's bright.

Interviewer: You've been recognized in the industry as one of the top players in optimization. Can you tell us a little bit about that recognition, and about your textbook?

Gary Vanderplaats: Well the textbook I actually started writing when I was at NASA and had Richard Fox, one of my professors, stayed in engineering I never would have written it. He wrote a book in the sixties that was superb. Like many people in optimization at that time he got frustrated, left the university, and went into clinical psychology. I might note that other people have taken similar routes. A post-Doc that worked for me at NASA ended up as an ophthalmologist. A lot of people that studied optimization or were in it gave up. At any rate, the first release of the book was published by McGraw Hill in 1984. In the late eighties they were bought out by a company who wanted to sell books by the thousands, and this being a graduate level book they gave me back the copyright. So I scanned it into a computer and of course now you can do all this very quickly, and we now self-publish. A couple of years ago I changed the title to *Multidiscipline Design Optimization* and include some of the methods there but mainly pushes the idea that whatever you do, optimize. That's my definition of multidiscipline optimization.

I was honored by the students at UC Santa Barbara with the Outstanding Professor Award my last two years teaching there. I became Fellow in the AIAA some years back and also received the Multidiscipline Design Optimization Award. I've been honored to give quite a few keynote addresses. Perhaps the honor I like the most is the Steuben crystal that I received, unannounced, here at the office about six or seven years ago with a hand written note that said "To Gary, with my unbounded gratitude for expanding design space so that it now spans the real world," signed Lucien Schmit. I think that's the award I cherish the most, right up there with the plaque that was given to me at the twenty-fifth anniversary of VR&D from the employees honoring my contributions. The professional honors are meaningful in their own right, but those two, the crystal and plaque, mean everything to me.

Interviewer: Thank you Dr. Vanderplaats. I appreciate your time.

Gary Vanderplaats: You're welcome.