

Everything You Always Wanted to Know About Professor Bar-Shalom

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Professor Bar-Shalom, for the last 30 years, your name has been inseparably associated with MS-MTT (Multi-Sensor Multi-Target Tracking); no researcher working in the field can ignore your name and your contributions to the advancement of the tracking field, published in more than 290 papers, 7 books, 19 book chapters, and accorded with many distinctions. Although most researchers in the tracking area know you quite well professionally, very few people know your personal/human sides. We are very pleased to contribute here another look at you. We thank you heartily for having accepted this interview, and we hope that readers will enjoy it as much as we have*.

A - About Your Name

A1: Could you tell us the meaning of your name?

It means son [Bar (in Aramaic)] (of) peace [Shalom (in Hebrew)]

A2: A quick web search of your name reveals that you are number 2982 on the list of the top 10000 most cited researchers in Computer Science (January 2001). Have you thought of joining the computer science department?

I don't want to give a bad reputation to estimation...

What is your favorite programming language?

The last time I programmed was in Fortran (20 yrs ago...)

A3: We learned that your first name has something to do with tracking. What is that exactly? Do you think that has anything to do with the fact that you are a pioneer and an unquestionable world leader in tracking area?

Yaakov in modern Hebrew means "he shall track". The original meaning comes from Jacob (the 3rd patriarch, son of Isaac) who was born "holding the heel" of his brother Esau. The etimological explanation is "following in the heels of...", which became tracking. I also happen to believe in the causality between the given name of a person and this person's profession.

B - About Your Childhood and Your Family

B1: You were born in Timisoara, Romania on May 11, 1941 during the second World War period. Could you tell us more about your early childhood? Do you have pleasant recollection of good times of this period or was it to your memory only a very bad period?

Fortunately we were spared from Nazis' plans of exterminating all the Jews. The Romanians, even though they were allied with the Nazis, did not let them take over. Fortunately, the antisemitism of those in power was exceeded by their corruption. They changed sides towards the end of WWII when it became clear which side is winning and fought with the same enthusiasm as before.

My only memory from the war time is that once I decided to take a walk out of a bomb shelter where everybody went when RAF bombers were flying over Timisoara on their way to the Romanian oil fields. Eventually, my father found me and was not very happy.

* This interview was conducted during the Banquet at the Workshop on Estimation, Tracking, and Fusion - A Tribute to Yaakov Bar-Shalom, Naval Postgraduate School, Monterey, California, USA, May 17, 2001.

B2: Could you tell us a few words about your family? What were your parents doing? Are you from a scientist's or artist's family? How many brothers and sisters do you have?

*My father was an antiques merchant and accountant later. He was good with numbers.
My mother raised my sister and me reminding us that success in life requires hard work in school.
My sister, who is a psychologist, sent me a 140,000,000 year old fossil as the LX birthday present – to make me feel young.*

B3: When did you move to Israel and under what conditions? How long did you stay there?

*After my father realized that there is no future for us under communism, we moved to Israel in 1960.
After getting my B.S. in 1963 and M.S. in 1967 from the Technion, I came to Princeton for the Ph.D.*

B4: Were you a quiet and studious little boy?

I was very quiet after my first electrical engineering experience at age 6: I threw some old batteries behind our house and they ended up breaking the neighbors' window. Before this, at age 5, I showed my mechanical engineering capabilities when I hammered very thoroughly the living room furniture; my parents' quiet reaction shamed me into channeling my excess energy in a different direction.

B5: What did your teachers think of you and your future career?

My high school math teacher said that he will teach me a lot so I will learn a little.

B6: Did you always prefer math and physics, or did you prefer to learn literature and arts?

*I could never write a decent literary composition, was never good at arts (even though I enjoy both) so the only thing left was math and science (with the exception of chemistry, which I flunked as a freshman).
I learned to enjoy art from the history of art course I took as a senior at the Technion, after which I was fortunate to spend the summer in Europe marveling at the masterpieces I just studied.*

B7: What did you dream to become when you were very young?

At age 5 I wanted to become a chauffeur, at age 7 a pilot. I realized these dreams after 15 and 35 years, respectively. The pilot license I got at the Navy Flying Club in Monterey.

B8: Do you consider yourself as an ex-prodigy, as did Norbert Wiener?

I am a slow study -- by now I am probably at the level to be considered a child prodigy.

B9: Your son, Michael, is eleven now. Are you going to push him to follow your footsteps to have a distinguished career in engineering? Are you prepared for the teenager rebellion?

He is only ten, but recently he intimated to me that he hopes he did not inherit my engineering genes. I guess he already started his teenage rebellion.

B10: What else can you tell us about your family?

*My wife is a Ph.D. in linguistics and she keeps correcting my word order in English.
My daughters did not follow in my footsteps -- since I flunked chemistry as a freshman, both of them majored in chemistry. After that, they became so motivated that one of them is a Ph.D. in biochemistry, the other is a veterinarian.*

B11: Do you consider yourself a religious person?

I like tradition, and religion is a part of it. As far as the strict religious observance, my uncle in NY does it for the whole family.

B12: You are one of the most humorous persons we know, did you get this from your parents?

Humor was (and is) a necessity of life. It is also a tradition: does anybody know why Jews like to answer a question by another question? Why not?

What are your favorite readings?

The biography of Churchill by William Manchester. The Roman Republic series of historic novels (from Gaius Marius to Caesar) by Colleen McCullough.

What's your favorite quotation?

Keep things as simple as possible but not simpler (A. Einstein)

C - About Your PhD Study

C1: Your Ph.D. dissertation is curiously never referenced in your very first papers, nor afterwards. Was this a deliberate or accidental omission? What was your Ph. D. dissertation about?

An obscure controller.

To be fair, do you consider that this work was excellent, very good or good enough?

I would not give today a Ph.D. for this work. It was deemed good enough to get a Ph.D. at the time.

C2: Who was your Major advisor?

Stuart Schwartz, who taught me to pursue an approach even if not ideal and evaluate it at the end.

Did you have a good relationship with him?

Yes. He also taught me to shoot for long flat shots in tennis.

C3: Who also was a Ph.D. student there at same time, and had a distinctive career?

Tony Ephremides, now at UMD, well known in Information Theory (as well as in sailing).

C4: Do you have funny stories about your Ph.D. time? Were they the Best Years of Your Life, as UConn claims to all of its students?

One snowy day at Princeton I ran into Tony Ephremides stuck with his newly acquired used car with bald tires in snow. I rescued him from being stuck forever (that's what he still thinks) by bumping into his car with mine. The bumpers were already rusty so the additional damage was undetectable.

C5: You got your B.S.E.E and your M.S.E.E at the Technion (Israel Institute of Technology) when you were 22 and 26 years old respectively. How did you make the choice to follow a scientific track/career?

I always thought electricity should be fun. But then I found out that estimation/tracking is even more fun.

Was your choice influenced by some other famous scientists in the area? Who were the eminent Professors who were teaching at the Technion at that time?

The first teacher who gave me a taste of research was my EM fields teacher Remus Raduletz in Romania, where I studied at the Polytechnic Institute of Bucharest until they kicked me out because we wanted to leave the country. He had his Ph.D. from ETH, Zurich, where Einstein studied. He taught me the rigor of Maxwell's equations as well as the Greek alphabet (he was named after one of the founders of Rome and the Romans had a great appreciation for the classical Greek education).

At the Technion, Jack Ziv (who later invented, together with a classmate of mine, Abraham Lempel, the code used today by practically everybody without even knowing it – fax machines are based on it) taught me probability theory.

C6: You moved to the USA to pursue your Ph.D. degree. When did you move to USA? Why did you choose this country? Were you recommended by somebody, or was it difficult to find financial support by yourself?

My M.S. advisor at the Technion, Raphael Sivan, set the example by getting his Ph.D. at Berkeley. My predecessors at Princeton (Abe Haddad and Elias Masry) gave a good reputation there to the Technion graduates, which I could not dispel.

C7: How did you choose Princeton University and why? Did you consider some other places at the same time?

I sent several applications to different places indicating that when I will finish my M.S. thesis I will publish it in a journal, but this was not taken seriously by most places. The paper from my M.S. thesis eventually appeared in IEEE T-AC while I was still working for my Ph.D.

I also tried to apply to Berkeley but I did not get the forms on time. Two weeks before the deadline, I had a suspicion that they sent them by surface mail, so requested another set by air mail. Long after the deadline passed, I got two sets of forms by surface mail.

Eventually the only place that offered me an assistantship was Princeton.

C8: Richard Bellman was one of your famous predecessors at Princeton. He completed his Ph.D. in a record time of three months and has published more than 600 paper and 38 textbooks. He had already left Princeton when you got there. Have you been in some way influenced by his work? Did you hear any stories about him?

I did not hear much about him until I got to my first job at Systems Control in CA.

One day he was invited to give a seminar in the morning and he was late – eventually he made it by the afternoon. Apparently he needed some extra time to finish book number 33 that he started the day before.

I have to confess that I plagiarized one of his footnotes (about the principle of perversity of inanimate objects) but I referenced him.

C9: Did you already plan to become a Professor?

No University wanted me until 1976.

C10: Where did you arrive for the first time? What was your first impression at your arrival and a few months after your arrival in U.S.? Was it difficult to live and to understand the new way of American life?

The taxicab driver who took me from Kennedy airport to my uncle in NY said “You can't be a student in the US, you don't speak no English”.

D - About Your Industry Years

D1: After completing your Ph.D. study in 1970, you worked as a Research Scientist /Engineer for Systems Control, Inc. until 1976 in California and you have been at same time part-time lecturer at University of Santa Clara. Why did you choose to go to work for Industry? Was it too difficult to find an academic position in some American universities? Was your choice guided by a financial and/or family reason?

Following the landing on the moon in '69, the NASA budget crashed, with most of the aerospace industry and University research following, and there were very few jobs in anything related to space and control (at the time I thought I was still in control).

As an aside, a colleague and friend (Alex Levis, who is now Chief Scientist of the USAF) said that I would not have made it for tenure if I went directly into an academic position. I think he is right and I happened to be very lucky to join Systems Control.

D2: Systems Control was almost like the Xerox PARC in control and estimation (excellent people, great ideas but cannot capitalize on the ideas). Can you tell us about what it was like to be at SCI in those days?

It was an unusually stimulating environment. I learned there more than in grad school.

D3: Who were your colleagues at SCI and where are they now?

The following graduates of SCI should be mentioned:

Raman Mehra – Harvard, then President of SSCI

Atif Debs – Georgia Tech

Edison Tse – Stanford

Howard Weinert – Johns Hopkins

John Casti – U. of Portland, then Courant Inst., then U. Arizona

Dave Kleinman – UConn, now at NPS (claims to be retired)

Kent Wall – UVA, then NPS

Alex Levis – MIT, then GMU (now USAF)

Adrian Segall – MIT, then Technion

Ben Friedlander – UC Davis, then UCSC

Richard Wishner – President of ADS (originally named AIDS; bought out by BAH), then DARPA

Narendra Gupta – President of ISI (of MatrixX fame)

Robert Larson – VP, then President of SCI, President of IEEE, now Silicon Valley venture capitalist

D4: How did you get into target tracking?

A colleague was trying to debias an EKF for reentry vehicle tracking and I noticed that the true initial range was 100kft, the initial estimate was 80kft and the initial variance given to the filter was 10^6 (that is 20 sigma!). Changing the 10^6 to 10^8 immediately eliminated the bias!

D5: Do you have any comments about your bosses at the time? Anybody like Dilbert's manager?

My direct boss wanted to keep PDAF proprietary. However, when he went on vacation, I got the signature of the VP to publish it. This boss had 2 years until the paper appeared, but never made any effort to promote it.

Another boss told me that whenever they hint at a problem, I go too far in solving it...

D6: Have you ever given thought to returning to Israel, for example to get a position at the Technion or in some other famous University there?

Yes, but I never got an offer from the Technion. When I got an offer from Univ. of Tel Aviv I wanted it at the Associate level but it was for a Senior Lecturer, so I chose to stay at SCI. The following year I got the offer I was looking for from UConn.

D7: When exactly did you decide to switch to academia, and why?

When my newly arrived boss asked me in 1975 to solve a problem I already solved years ago unbeknownst to him, I just gave him the report I wrote on it in 1971 and took it as a sign that it is time to leave for new pastures.

In 1974 Dave Sworder told me that in 2 years I will be in academia – he had a perfect prediction algorithm.

D8: When did you apply for position at University of Connecticut? How did you choose UConn? Was it difficult for you to move from the West Coast to New England?

Dave Kleinman called me one day in 1976 if I am interested in an interview at UConn. The first offer went to somebody else (with more papers than me at the time), but he preferred to start his own company, so I ended up in New England.

D9: During the years 1982-1984 you've been visiting Professor in Stanford and the Naval Postgraduate School, Monterey. Can you describe your experiences there?

Following my divorce in New England I felt like going back to Palo Alto, so I ended up at Stanford. I met my wife in Los Angeles after a seminar at UCSD during that time, so I quickly decided to spend another year in CA before I dragged her to CT (she still prefers CA, except for the earthquakes).

D10: Was UConn your first choice?

The only one.

D11: Among the technical projects that you worked on at Systems Control, are there any that you'd like to share, or that you are particularly proud of?

My best work in control was the "Dual Effect, Certainty Equivalence and Separation" paper, which drew a distinction between Certainty Equivalence and Separation in stochastic control and showed that, for a class of problems, Certainty Equivalence holds iff the control has no dual effect. Otherwise the PDAF (Probabilistic Data Association Filter) – in addition to several fielded radar tracking systems it has found applications in image tracking as well as wireless communication.

D12: Did you invent the PDAF at Systems Control? If so, what was the reaction of your colleagues and employers? Did you know at the time how important it would be?

My project manager was ready to fire me because I was spending time on senseless things. He asked a highly paid consultant at the time to evaluate my work and he said that it makes sense. The real proof of how he valued it was when he later published a similar approach from his consulting work at another organization.

D13: In its early days, did you think that PDA would achieve its present-day prominence, with applications not only in target tracking, but also in many other areas?

I felt there is something to it, but nothing like you are implying.

D14: What do you see as the limits of PDA?

One limit is the Cramer-Rao Lower Bound. The rest is up to the ingenuity of the many people working on problems where estimation in the presence of continuous and discrete uncertainties is needed.

D15: Did you ever implement any of the algorithms, for example the PDAF, which you invented?

If you promise to keep this confidential: never (why ruin a good thing?).

D16: You made some outstanding contributions in stochastic control area, particularly dual effect and dual control. In fact, you were a leading expert in that area in 1970s. What was the driving force for your shift of research focus from that area to tracking area?

Murray Wonham from Toronto wrote a paper stating (approximately) that "stochastic control can only change the system performance from very bad to bad". First I insisted on proving him wrong, but

eventually I succumbed to the obvious. My work in control did not have even 1% of the usefulness of the work done later in tracking (to a large extent thanks to the numerous colleagues with whom I worked and keep working).

D17: Why are you out of control these days?

*For some reason, I got interested in useful things. The rest is a corollary.
However, I still enjoy controlling vertical airfoils and foot supports on crystals.*

E - About Your Students and Your Research

E1: Up to now, you have been Major Advisor to seventeen Ph.D. students with degrees awarded at the University of Connecticut. Many of your former Ph.D. students are very active in the tracking research area. Are you very proud of the careers of your Ph.D. students?

Absolutely, I could not have accomplished (almost) anything significant without them.

E2: In general, do you have good relationships with your former Ph.D. students?

Of course. One of them, in his last email to me, sent me the Melissa virus.

E3: Many people who had the honor to work with you have been impressed with your deep insight about practical problems and with the keenness by which you search for solutions. Are the applications the starting point for your research? If so, are there any criticisms about that?

I am sure that some people feel that without measure theory there can be no important work. However, I have a filter that blocks out such noise. Some people make a living from data mining -- I prefer problem mining.

E4: How many post-doctoral visitors have you hosted in your ESP lab?

*Alain Houles -- formerly with the French Navy, now with NATO
Claude Jauffret -- formerly with the French Navy, now Univ. of Toulon
Jean Dezert – ONERA, France
Chun Yang – Sigtem Technology
Eli Oron – Israel Aircraft Industries*

E5: During your career, have you had the opportunity to meet and talk with Professor R. Kalman? Did he influence your research?

I never talked to him. He talks only to God. When he was (still) doing reviews for IEEE T-AC, according to a former Editor of this journal, he used to classify all papers in three categories: Trivial, Wrong or "I've done it".

My encounter with his March 1960 paper on what became known as the Kalman Filter was fairly long: I plowed through it on my own in 1966 (during my military service in Israel) and it took me two weeks just to understand his notation of the norm of a vector w.r.t. a matrix.

E6: Have you observed a strong modification of the interests in this research field since the end of cold war, and especially since 1989 after the fall of Berlin wall and ex-USSR? If so, is this effect in your opinion more beneficial or detrimental for the research area (from the scientific point of view)?

It's back to the big time for tracking but with one difference: you can't publish papers on scalar systems and you have to show relevance to some real problem.

E7: If you were able, like Dr. Frankenstein, to construct an ideal student, how would he or she be constituted?

Such a student would write in 3 months 3 seminal papers that I would not need to proofread (neither for the math, nor for the English). Anybody noticed the wrong word order?

E8: Thinking back, which period is the most important in your career?

*Curiously, I felt more productive in the last few years than ever before.
Did anybody notice that car manufacturers use LX for their luxury versions? When you get to be LX there is a lot of experience you can take advantage of and enjoy it.*

E9: You have made so many great contributions, which one do you think had the greatest impact? Which one are you most proud of?

The IMM (which is really not mine – it was invented by Henk Blom).

E10: In tracking and data fusion area, what topics do you think are most important? What is the future of the area?

*Find practical and efficient algorithms that fuse kinematic and feature data from improperly registered moving sensors (with biases, finite resolution, strange noises) about a large number of hard-to-describe nonstationary targets in a heterogeneous cluttered environment.
Predictions are hard (especially about the future) but I believe the future is bright (technically) for this area.*

E11: Have you instilled upon your students any bad habits?

1. *To drive fast.*
2. *To have high standards in reviewing papers (which, as journal editors, they applied to me...)*
3. *To charge properly when they consult (some companies think this is a bad habit).*

Do you have some funny stories to tell us?

One day, in the heat of advising a Ph.D. student on an interesting problem, I emptied my pipe into the trash can behind me and after a couple of minutes I felt an unusual heat in my back – the papers in the can were on fire. Turning the can upside down solved this problem.

F - About Your Leisure

F1: Let us talk now about your leisure. Almost all your close friends and colleagues know you love good wine and very spicy food. Where does this desire come from? Do you cook yourself during your leisure time, and if so what is your favorite recipe?

*Oenology was one my sabbatical projects.
The desire for spicy food probably comes from growing up with a rather mild style of cooking.
Blackened catfish is a favorite.*

F2: We think that your ability to stomach hot food exceeds that of anyone I know. Who else is in your league when it comes to chili peppers?

A former student (from a famous spice country) survived Salsa Fuego at Denver International Airport (with only a major stomach upset) after it flooded me.

F3: You like exotic food a lot. What is your favorite cuisine?

I am on a seafood diet – I eat every food I see.

F4: Your other passion is sailing, and you are a good sailor according to people who have already gone for a sail with you (and who are usually not so familiar with sailing). When did you learn sailing and where? Have you ever participated in a sailing competition? What is your worst memory of sailing? What kind of sailing boat do you have/prefer (old ones or high-tech ones)?

At the 1979 IT Symposium in Italy Judea Pearl (from UCLA) suggested that we go sailing (he said he'll show me) and after we found a boat (in what was Yugoslavia at the time) he gave me the 5 minute lesson and jumped in the water to take a closer look at some topless girls. I managed to circle for a while and pick him up eventually. Two weeks after that I bought my first sailboat. It took 20 years to get the second one.

The highest tech boat I sailed on is the America's Cup winner Stars and Stripes -- I did not sail in the Cup, only in the St. Martin 12m regatta where I qualified as a lowly crew.

I have no bad memories of sailing, just difficulty in communicating with a green crew. I am still learning how to do this more efficiently. The closest I got to a rock was under the Golden Gate Bridge when my crew were looking backwards and when I said "release right sheet" the port (left) sheet was released. Since then I use only sailing terminology, to the dismay of my (sometimes green) crew.

F5: You have been sailing all over the world; where is your favorite place and why?

San Francisco – they have every afternoon in summer a small craft warning.

F6: During the winter you love skiing. Are you a very reckless skier? What kind of skiing do you prefer?

I had many days when I took no spills, so I am probably not reckless enough. I prefer downhill skiing because, as a lazy person, I would rather let nature (gravity in this case) do most of the work.

F7: What other sports do you take part in?

Sometimes I let some of my young (quadragenarian) colleagues beat me at tennis.

F8: How do you spend your leisure time when you aren't on a boat or skiing?

Reading National Geographic or a good book and listening to classical music.

F9: How many weeks of vacation do you take on average per year? During this time, does your mind succeed fully to leave the tracking area?

Two official weeks. The rest depends on how many weeks I attend conferences in a year. Since I am out of control, I cannot control my mind either.

F10: How would you characterize your driving: like sailing, adventurous, fast (I mean really fast) or just normal?

Very sedate. I always obey the old (pre 1974) Montana speed limit ("reasonable and proper").

F11: Any tips if one is caught speeding on the highway and is about to get a ticket?

Say you were rushing to the nearest exit to find a bathroom, then ask the cop if he minds if you go to the second nearest tree while he writes the ticket.

F12: At one time, you tried to learn how to fly, but some accident happened. What is the story?

I learned what the propeller steering torque can do (in a souped-up Cessna 152) in the same way as the Admiral who was the boss at the Naval Postgraduate School (a former fighter pilot) at the time. If you do not apply enough left rudder control at take-off, it can take you off the runway (sideways, not up). Actually this happened before I got my license. After I got the license in 1984, I flew for two years, then I decided that I am too dangerous to those around me, so I stopped.

F13: Given that you are color-blind, how do you manage the traffic lights?

Except for one notorious horizontal light in Princeton, NJ, they usually have the red at the top. However, I heard that during the Cultural Revolution, red was for “go” in China. I like to drive in some of the European countries where traffic light rules are considered merely an opinion.

F14: You have been in many places of the world, which place do you like best?

The charming places (can't offend anyone).

F15: Do you like to travel and to visit foreign countries as a simple tourist rather than bringing with you your professional hat?

I don't need my professional hat anymore – a virtual one is glued on all the time.

G - About Your Retirement

G1: How many more years do you plan to teach?

Until I get tired or run out of good students, whichever comes first. I am not yet ready for maturity leave. I am not yet started to play golf.

G2: Do you accept well the idea of your retirement? How and where will you spend your free time? Sailing in Florida?

The Caribbean is more interesting.

H - More Difficult Questions

H1: Have you any regret about the choice of your career? Maybe you'd have preferred to become a great Captain sailing all around the world?

There is much more satisfaction in getting together with people like you – my colleagues -- than being all the time on the ocean.

H2: Have you ever thought to leave and give up this research area for something else?

When I grow up I'll figure out what I want to be.

H3: If you'd have only one paper to keep and you consider as your major contribution, which paper would it be?

The Maximum Likelihood PDA and CRLB-in-clutter paper, because they are exact.

H4: What is your own philosophy of life?

Enjoy it while you can. As I told a friend who recently became a quadragenarian, after 40 it's all downhill but, like in skiing, with a lot of thrill.

The other one is: Illegitimi non carborundum.

H5: Any advice for all future young researchers willing to work in this area?

Be thorough in your work and honest in presenting the results.

H6: Do you have anything that you would do differently if given another chance?

I'll let you know next time.

H7: You used to have a beard some 20 year ago. When and why did you decide to change?

It was gray and I still did not get no respect...

H8: If you have to do your Ph.D. all over again, what will it be on? What would you do differently this time?

I don't think I could easily do a piece of work worth a Ph.D. these days.

H9: Which important questions do we miss?

1. *Do you take yourself seriously?*

NO!

2. *What is your pet peeve?*

Pharisaic janiform coprocephalocratic academic administrators (they don't understand this anyway).