CRAIG: Hi, I'm Craig Smith and this is Eye on AI.

This week I talk to Bob Rogers, a Harvard trained astrophysicist who once built digital twins of black holes to better understand them, and now builds digital twins of supply chains to help make them more efficient and resilient. Bob has had a fascinating career, which included a long stint running and algorithmic quant fund.

CRAIG: Before we begin, I want to thank our sponsors ClearML an open source, end-to-end MLOps solution that you can try for free at clear.ml.

CRAIG: They've been very supportive of the podcast. In fact, you can listen to one of their founders a few episodes back.

Now, I hope you find the conversation with Bob as fascinating as I did.

CRAIG: Hey Bob. What I generally do is have you begin by introducing yourself.

CRAIG: your educational background and what you're doing now, and then I'll ask questions.

BOB: I'm Bob Rodgers. I am co-founder and CEO of a company called Oii.ai. We're an AI powered supply chain, design and optimization company. I've also been expert in residence for artificial intelligence at the University of California, San Francisco Center for Digital Health Innovation.

BOB: Where I helped develop the world's first FDA cleared AI on a medical device, something which I'm quite proud of. I'm also a member of the Board of Advisors to the Harvard Institute of Applied Computational Science, where they're developing programs to really train the next generation of high caliber data scientists.

BOB: Prior to all that, I was chief data scientist at Intel for analytics and AI.

BOB: I have a PhD in physics from Harvard. I worked on computational models of stuff falling into super massive black holes, and in fact, I like to tell people that in the early nineties, I was developing digital twins for super massive black holes.

BOB: That creates a continuous connection to what we're doing today at Oii I got interested in artificial neural networks back in the day, and that ended up resulting in co-founding and running a quantitative futures hedge fund for 12 years.

CRAIG: When was that?

BOB: That was like 93 to 2005 we were very early.

BOB: It's an interesting story because we had good technology because we developed some really nice algorithms, a good research platform. But we also had, this was back in the days when the future's pits were still full of people waving their hands and yelling and we had a seven-foot-tall guy in the pit, in the Chicago Mercantile Exchange filling our orders.

BOB: And that was a really good combination. And you can imagine as the electronic markets came in, seven-foot-tall advantage was replaced with the advantage of the shortest piece of wire between your server and the CME server.

CRAIG: You were developing. Trading strategies and then based on your predictive model, you would send orders to the floor.

CRAIG: Is that right?

BOB: That is absolutely correct.

CRAIG: What kind of models, what kind of AI, what kind of algorithms were you using?

BOB: We started with the idea of using the artificial neural networks. It turns out, especially back in those days, neural nets are pretty noisy. They were a bit unstable, turned out that statistical models inspired by dynamic models approach was best. Our strategies primarily for the S&P 500 futures made predictions out about three hours at a time, and we were always in cash at the end of the night. So, the beautiful thing about that was if you had an overnight catastrophe, like nine 11, we were out of the market in cash and we could just sit on the sideline

BOB: the analogy that I like to use for the modeling approach that we did is imagine if someone on the other side of a wall is throwing rocks into a pond, and you're trying to predict what's going to be happening with the surface of the water. You can't predict how big of a rock or where exactly it's going to land, but the moment that rock hits, there's going to be some set of concentric circles, maybe they're interacting with these other ones. So, we took that type of analogy and used models that would tell us, Okay, if we observe this, this is what we expect over this fairly short period of time, and then we would trade off those signals.

CRAIG: That's fascinating.

CRAIG: Was it lucrative?

CRAIG: It was,

BOB: We made a lot of money. That was after PhD, so it was during my post doc that I was doing both the digital twins of super massive black holes and, developing a research program in neural nets.

CRAIG: And then did you ride the neural net or the deep learning wave after everything got big enough the data sets and the compute.

BOB: That really came to fruition while I was at Intel. I was involved in a variety of different interesting deep learning projects. Probably the most interesting one that I was directly involved with was a program called Intel Inside Safer Children Outside, and we were working with the National Center for Missing and Exploited Children to help them process reports of child online exploitation. And they were very overwhelmed. We developed some machine learning to help accelerate their work. And that was a big success that was traditional machine learning. But that led to working with Thorn, which is Ashton Kutcher's' nonprofit to protect children from online exploitation. They had created a tool that allowed law enforcement to identify children being sold for sex online, but they needed to know, who is this kid? Is it a missing child? They have this database of 40,000 images at the national center and people would have to go through by hand and try and figure out. So, we built a deep learning system that would essentially rank images by how similar they were, how likely they were to be the same person, regardless of changes in age, changes in makeup, hair, environment.

BOB: Imagine that whole list of 40,000 images ranked in order of how likely they were to be the kid in the online ad. And that's actually been deployed now and has been finding hundreds of children who are being exploited, who were in the missing children's database, classic deep learning application, classic convolutional, neural network computer vision.

CRAIG: So how do you go from there to logistics and supply chain and all of that?

BOB: A few years ago, I was working on a book called Demystifying AI for the Enterprise, and I have a few very illustrious co-authors.

BOB: And they elected me to write the chapter on supply chain. And I'd had some experience with supply chain at Intel from a technical point of view, but not a lot.

BOB: So, I was in London working on the book. I reached out to a guy who had written some really interesting articles on supply chain and AI, his name is David Evans, and I interviewed him for the book. We became fast friends. We consulted a little bit on some work for Unilever and what we realized is that there was a huge opportunity to apply a combination of AI and digital twin to supply chain and really tackle some very specific challenges.

BOB: We also have another person on board, our chief strategist Trevor Miles, who is an early part of i2, which is a supply chain company that has been very successful. So anyway, now I'm learning also from Trevor as well and other folks that we're working with. So, the challenge with supply chains is that they're designed with the assumption that the world is static.

BOB: Even the variability of demand is really considered to be static. You set your supply chain up and then you forget it. And what we've learned over the last couple of years is that a static world is not a good assumption. Even variability is variable. And so, we've built Oii as a way to allow supply chain systems to adapt to changing circumstances and continually retune their design so that they can allocate inventory in the most efficient way, recover from changes in the assumptions underlying the network performance and the AI that we use allows us to predict what are the kinds of things that supply chains need to be prepared for as time moves forward.

BOB: So, we can't predict that a ship is going to get stuck in the Suez Canal on a particular day. But we can tell you that the kinds of disruptions that you're going to see in the near future look like this and if we roll those into a future view of what your supply chain has to be prepared for, that's very informative for building a resilient supply chain.

BOB: So that's the evolution of what we've developed

CRAIG: It identifies choke holds and then whoever is dependent on the supply chain can build workarounds in advance.

CRAIG: Is that right?

BOB: That's right. And there's two things. Your supply chain is designed to take variation into account ahead of time. Quite often putting the inventory in the right place and having the right strategy changes over time.

BOB: A significant portion of products in a supply chain need to be reconfigured every three months because of just changes in network performance and demand and supplier reliability. So, it allows you to have your supply chain designed in the right way to achieve service levels at minimum cost now, but then also to react very quickly as things change.

BOB: If you look in the data for supply chain management software, it's usually coming out of master data from the E R P system. And some of it, Is really measurements about network performance.

BOB: So, if the lead time from a packaging plant to a distribution center is listed in the master data as 10 days, and then you go and measure the real lead time, it could be 22 days. These days these numbers are jumping all over the place. Ship's stuck in Shanghai, it goes from two weeks to 90 days instantly.

BOB: So, we're measuring the, the variability on the ground, and then we're using that to figure out how to actually reoptimize the supply chain., that's a big part of it.

CRAIG: Maybe you can describe for myself as well as listeners what building a digital twin of this black hole entails, and then

BOB: Yeah.

CRAIG: How does that relate to this?

CRAIG: Is this just part of the digitization of the global economy, that There's data now and you can optimize them in ways that you couldn't before.

CRAIG: But let's start with the black hole.

BOB: Yeah. So, I'll frame up the black hole story and then we'll apply it to the, the design of a supply chain. So, my original interest in black holes was from the point of view of what do they look like if you look at the x-rays and the gamma rays coming from them.

BOB: So, it turns out that there are objects out in distant space that are flashing huge bright beams of x-rays and gamma rays and they are quite fascinating. So, we're seeing these crazy flashing X-ray, gamma ray things, and of course there's optical visible light coming from them also. And what can we infer from what we're observing, given that we don't have a black hole in our lab to fiddle around with, right?

BOB: So, what you do is you build a model of a super massive black hole. And typically, they form because stuff is flowing into them at the center of a galaxy, it forms in accretion disc. There are magnetic fields that twist around and create these tight springy coils. And so, what I would do is build a computer model of all that stuff happening as it crushed down to the event horizon in the black hole.

BOB: And then I would build code that would show me, okay, for a particular configuration of stuff falling in, imagine a cluster of stars getting pulled into that accretion disc and getting crunched in there and heated up and shooting out x-rays and gamma rays.

BOB: I could simulate what would the light coming from that thing look like? And then what if I'm seeing it end on what if it's a thousand stars coming in, but they're coming at an oblique angle. There are all these different things that you try using the digital twin, and then you compare that with what you're actually observing, and it gives you an ability to make some inferences about what you're seeing out there in the real world using this digital twin.

BOB: It ends up being a really powerful tool. And of course, then you find places where your models don't predict what you see, and you've added new things to your models. So, what we're doing with the digital twin for the supply chain is actually modeling every single supply chain for each product, how it gets from manufacturing out through its distribution network to customers for all the different products.

BOB: And they interact in a couple of ways. One is Different distribution centers might have capacity limits for how much material they can store or how much they can fluctuate. Manufacturing lines have physical constraints on how frequently you can make each product.

BOB: So, we can simulate all of that behavior. Let's start with the idea that you've got a manufacturing plant, you've got a couple distribution centers, maybe one in Belgium, and then some spread out throughout Europe and South America. Let's assume that they're constant for the moment.

BOB: When do I replenish my stock? How frequently do I replenish it or, or what do I order? And what are the other constraints? Things like, do I have a minimum order quantity?

BOB: Are there costs that I can control? So, what we do with the digital twin is we create a model of the supply chain exactly the way it's set up today. So, I'm going to target replenishing every two weeks, but I'm going to replenish when my stock gets below a certain level.

BOB: I know that it's going to take three weeks for product to get here. Okay? So, I have that digital twin. We use our AI to build a whole bunch of future scenarios. And combine all these different scenarios. And you run the supply chain through it with the digital twin and see how it behaves.

BOB: Then you say, Okay, let's now do an optimization to see if we can change the way the different parameters are set so that we can get better behavior. And then you keep changing those parameters all throughout the entire thing until you hit your service objectives, your revenue objectives, your cost objectives, and you get the best cost.

BOB: And it's really interesting because historically, people think of all these things as separate projects. Oh, let's do a project to reduce inventory. Then, because you've got so little inventory, your service is terrible. You say, Let's do a project to improve service. It's really a set of, of connected systems.

BOB: So, doing this global optimization makes a hundred percent perfect sense, but it's not really how people traditionally do it. One of the best examples of tuning the knobs on one of these things is in the pharmaceutical industry, you want to have your drugs available all the time for every customer, no matter what. Right?

BOB: So, shove tons and tons and tons of product into inventory. Great. You've got all this product. Customer makes an order. You're going to have product except here's the catch. It takes so long for the product to make it through all those warehouses. When you've got so much product there, it's expired by the time it gets to the end.

BOB: Now your plan to have great service has been completely toppled by the fact that the product you were going to give instant service with is expired or it's about to expire. So, there's these really interesting balancing acts. When people do it by hand, they can get it pretty good, but a computer optimization system does better, and when you're driving it with AI and real time data, then it's not like every six months you do a big project. All the time you're adjusting and tuning.

CRAIG: Yep. How do you collect that data to create the digital twin? I mean, that seems like an enormous project in itself.

BOB: So, a huge amount of the information is actually in the ERP system, your SAP or your Oracle already, they're passing messages back and forth about financial transactions in POS. If there's a supply chain management software in place, we can get a lot of the information from that because they have, okay, this distribution center has these characteristics and it does this, it does that, it has this much capacity. The reorder strategy is this. So, we take those, there's some financial information that we sometimes get from the finance department, and so those are all pieces of information we can use to create a picture of the supply chain. And the nice thing is once we have that data, the actual digital twin is created automatically. That is, we don't have to like hand tune anything. Our software can build that digital twin. One of the things that we've been doing lately is discussing partnerships with companies that are collecting very, very granular downstream tracking information, you can put a monitor on a pallet and see exactly where it is at all times, what the temperature is, what the humidity is, has it been dropped, and that really, really granular data gives us another level of ability to predict. You've got measurements from point A to point B. Here's the last five amounts of time that it took, you know, the lead time.

BOB: Well, we can predict what are the next five going to be. And that's way more interesting and valuable than just saying, oh, well we've got a 10-day lead time in the database, or we've measured an average of 20 days in the last five trips. So that fine level of granularity gives us another level of capability.

CRAIG: You're describing use cases where a single entity control most of the supply chain, but the supply chains I'm familiar with are much more fragmented. You've got vendors supplying to a manufacturer and then the manufacturer supplying to wholesalers, wholesalers supplying to retailers.

CRAIG: So how do you capture all of that? Because it's not completely linear or at least it's multidimensional. So how do you capture all of that? And then who are you supplying this information to?

BOB: Yeah. Great question. So, the way product works, there's sort of a today answer about the how, and there's also a tomorrow answer.

BOB: Our customer is generally a manufacturing company. Or someone who's maybe using contract manufacturing to distribute to retail. Those are our two big use cases. within their worldview, they have their getting product from either manufacturers or suppliers and there is data about how those suppliers are doing and what is the variability there?

BOB: Their own internal distribution network, and then there is the last mile. And so, we can generally collect the data that they're, they're tracking that sort of like transactional data to work up a picture of, that part of their world, which is where their knobs are. So, then the, the answer to the, who tends to be the people who are responsible for network design and strategy.

BOB: Sometimes it's planners, sometimes you have people who have a portfolio of products in a region and they're tuning the knobs on how the distribution works in their region. Quite often not connecting to the bigger picture and the bigger optimization, which is one of the big opportunities here. But also, you have organizations where a smaller number of people are responsible for end-to-end network design

BOB: achieving the overall cost and performance objectives of the organization and doing things like, oh, let's improve our margin by improving the cost performance of this part of our supply chain. So right now, our world is very much a manufacturer or a distributor selling a single product.

BOB: What's interesting though is you're absolutely right, there are, are improvements to how you optimize and how you coordinate when you go beyond that and we have data on a lot of different companies, a lot of different products, a lot of different supply chains.

BOB: So, we can see some pattern. But where I think the world is going to go is in confidential computing. When I was at UCSF, I actually contributed significantly to some patents around using confidential computing to make it possible to develop AI on private patient data. So, imagine, rather than having someone pool data and then run an algorithm on it, imagine the algorithm being secured in an encrypted way, have it go to the data and do the computation in the private world of the data. So, we created that. In fact, it's been spun out as a company called Beekeeper AI out of UCSF

CRAIG: You're talking about federated learning?

BOB: So, it's both federated learning and also federated validation. Because in many cases you want to be able to validate an algorithm on data. Confidential computing is like a vault and it's a vault that runs a computation without anyone being able to see what that computation is, including the person who owns the computer, like the operating system, can't see it.

BOB: And so, what happens is algorithm goes into the vault, data goes into the vault. Once the vault is closed, the two things get decrypted, and something runs, and a very carefully constrained output comes out. So, in the healthcare world That's to enable AI to be developed on private patient data, which can't be shared, but which in many cases you can't use any other form of data.

BOB: It really has to be the private data. In the world of supply chain, you can imagine a similar situation where nobody's going to share, no supplier's going to share all their customer data with all their other customers, right? I mean, nobody wants that. But there are things you can learn from a dataset. Very specific questions that would be appropriate to know the answer to if you could compute them.

BOB: So, I envision a world in which this confidential computing is actually used across the board in supply chain to create the answers to the questions that then make everybody's supply chain work better.

BOB: If you could coordinate across the demands that are going to come from a bunch of customers without exposing private information, all of a sudden, the whole supply chain can be much more efficiently operated. So, there's a path there, but today there's a lot of value in just optimizing within a single company's own distribution network from packaging or manufacturing down to their customers.

CRAIG: And so, there are two outputs that you're delivering customers. One is the optimization, but the other are suggestions of where they need to build resiliency. Is that right?

BOB: Yes, exactly the output. Once we take in the data, we, we do the modeling, and we start with a health check which says, okay, here's your current network design.

BOB: Here's where you are. Here are the 10 products where you're going to hit a service problem if you don't take some action. Here's where you're paying way more in inventory than you should for the amount of performance you're getting. You need to move inventory back like this.

BOB: And then from that there's something we call action boards, which is literally, okay, change this parameter from 20 to 30, change this supply chain from a make to stock strategy tool, make to order strategy, things like that. So, they literally get a recipe of what to change. And then the third thing is they get to do what we call what if scenarios.

BOB: Because you can't just tell someone change from 20 to 30, right? They need to know why. They need to be able to look at, well, okay, what if I did this? Or, or a big one these days is what if transportation costs for trucking in this region go up by 20% in the next six months? What's that going to do to the shape of my supply chain?

BOB: Should I change strategy? Maybe I should switch to rail. And so, there's some really nice question and answer that comes up. As people have this ability to project what they might have to be prepared for in the future.

CRAIG: You mentioned real time, so is this a platform that is receiving data from systems and sensors, and then the user is checking a dashboard that's, that's changing over time.

CRAIG: And then are there any interesting use cases? One of the reasons I was interested in talking is supply chain disruptions because of the pandemic, because of the war in Ukraine. And Brexit and the Suez Canal incident.

BOB: Yeah, so the use cases, if our predictive modeling is working well, then we're minimizing the amount of reactiveness that needs to happen when things change in the supply chain network.

BOB: Part of it is what we call resilient by design, you plan for the kinds of crazy things that could happen. You make sure that those are already taken into account at some level. Now, you don't want to overly plan now for what might happen in the future. So, the other piece is you want to be able to respond quickly to changes.

BOB: There was a big incident where container ships were being backed up like months and months in, in Chinese ports and all of a sudden, the timeframes for certain parts of my supply chain are much longer.

BOB: I need to know how to reorganize the rest of my supply chain. Then I need to be able to figure out how to allocate. One of the interesting things that we did during the pandemic was we worked with a company that was distributing vaccines in India. And they didn't have enough vaccines for quite a while.

BOB: We created an automatic allocation technology to translate high level policies across the entire network flow of material so that the patients that were over 80 who had a comorbidity, were going to get the higher share of vaccines. So, when you've got a, a situation where maybe you're not going to get product from a particular channel or it's going to be delayed, this sort of allocation capability can come in very handy.

BOB: The question about real time, the answer is yes. So, the way the platform works, whenever data coming into the platform changes, then we recompute the optimizations and look for basically flashing red lights. Something has changed here and there's some responses that need to happen.

BOB: How real time that is though depends a lot on the customer. We have customers who only want to update the whole thing once a month. Some want to update it once a week. I envision a world where they're going to want to know every day because things really do change every day. And so, we're building up the interfaces collect real time data from purchase orders and invoices.

BOB: And the monitoring of products going all the way through logistics so that you can respond immediately and figure out what actions to take. It is in principle real time all the time but depends on what the customer wants to do.

CRAIG: Is there some sort of measurement system or feedback system?

CRAIG: You alluded to trust earlier whether people are actually going to take these actions based on a system that's telling them to do something.

CRAIG: So, they can see maybe in one part of the supply chain that they take the recommendations that indeed things go faster or, or, uh, are cheaper, something like that.

BOB: Yeah. This is sort of a challenge with automation and AI in general. So actually, going back to the National Center for Missing and Exploited Children.

BOB: One of the concerns early on, was the analysts were worried, not that they were going to be put out of a job, but that the quality of the output wasn't going to be as good as what they did. So, one of the critical components of making that solution work well for them was to actually give the analysts information about what went into the decision.

BOB: The algorithm wasn't explaining itself, but it was explaining what pieces of information were important to the decision, the confidence level of the decision, and then the analyst had the choice of yes. Or no, and if it was no, then they would put in the right answer and maybe an explanation for why.

BOB: Interestingly, within a week, the analysts had asked to have anything within confidence level of 80% or above to be pushed through automatically with no human oversight. So, it's interesting had you done that the other way around, they would've said, oh, no, no, this is terrible. You guys are making assumptions.

BOB: But when they were able to see it, they started to say, well, I don't understand why I have to push the green button every single time. So, this trust thing is always critical. Again, as I said, we give them the ability to sort of investigate. Like if we say go from 20 to 30 on a parameter, they can investigate the values in between and what are the tradeoffs.

BOB: We also monitor the broader use conformance of the people who are being recommended these decisions. So, it's not that anyone's being penalized, but the people who are managing the overall portfolio of products can see, well for these products, the recommendations aren't being taken. This is the impact of that.

BOB: And so, you get at least get a measure of, all right, well we want to improve compliance here because it's actually having a material impact on the efficiency of our supply chain. And so, we do monitor that and compute the high-level impacts of those either decision to be compliant or not compliant.

BOB: And of course, from a machine learning point of view, feedback loops are critical. If there are places where they're not being compliant and they're right. We're going to pick that up and that's going to be an opportunity for learning in the machine learning algorithms themselves.

CRAIG: You mentioned convolutional neural nets for the missing children.

BOB: Yep.

CRAIG: Tool. What are the kind of top line algorithms that you're using here? And are they all deep learning or is a mix.

BOB: We go everywhere from basic XG Boost or, or boosted trees for when we look at data coming from a new customer, we are predicting how that data should map to our model.

BOB: So, fields that look like a supply chain strategy, probably are. So, we've got nice little machine learning models that are just simple traditional models. On the front end, we have some coupling of some of the sort of dynamic time series forecasting models along with. One of my favorites is actually Gaussian process regression, which the beauty of that is that it gives you actual, a priori estimates of the probability of different types of random behavior.

BOB: The places where we're using deep learning, and this is really in the development stage, so this is not in our current production deployment. We've been building deep learning models for a group of supply chains that are coupled together the actual overall behavior performance of the supply chain as a function of the inputs, you know, the, the network and variability parameters.

BOB: So, what that does is it gives us a way to run through many, many different scenarios and show customers traces of what expected behavior would be without going and running huge Monte Carlo simulations that could take hours. These models create a nice tunable way of showing this is what you would expect if you change these things.

BOB: So, we're experimenting with that. That's something that I've done in other areas, and I think it'll be a really nice way to scale the what if scenarios to customers to really give them the knobs without them having to wait for the compute to happen.

CRAIG: Presumably as systems like this are deployed global supply chains. I mean, it'll obviously take a long time until there's sufficient penetration, but they'll become increasingly efficient. Do you have any thoughts about what this kind of digitization and optimization will have on the future?

CRAIG: And another question actually is presumably you can spot deficiencies in the supply chain that are business opportunities for companies.

BOB: So, on the future view, I think right now there's. So much cost and inefficiency in supply chains that the cost to run supply chains is going to drop simply because there will be so much less manual intervention.

BOB: And once you have a disruption happen, people start picking up the phone like, Stop the line. We’ve got to make a bunch of this. I'm going to put it on a plane. And there's all these interesting disruptions that flow up and down each supply chain. And then of course they interact with each other, right?

BOB: Because, okay, now this other product that was depending on this thing is being impacted. So, it's certainly going to create less cost per unit in terms of just the way the supply chain costs and how it works.

BOB: I attended a trade show called Modex a couple months ago.

BOB: And in previous years, the interest in picking robots was one of these technical build or buy kind of things. Okay. This robot, it requires a certain amount of maintenance. It's a capital expenditure.

BOB: It's going to replace an employee who's doing a fine job and isn't actually costing me all that much money. So, there's this sort of calculus that different people were doing to decide whether to deploy a robot. Well, this year everyone was buying picking robots like they were going out of style because they could not hire people to do the jobs, right?

BOB: So, in supply chain design and planning, we're seeing a parallel, there's a huge amount of turnover and they're having trouble finding people that are going to have this tribal knowledge of the product and the supply chain. So, this kind of automation allows companies to adapt to that.

BOB: We're not promoting, oh, buy this technology and get rid of all your planners or your design people but you're certainly making it possible for them to come up to speed faster and have the information. AI should be augmented intelligence, not artificial intelligence.

BOB: Give people what they need, take away the parts that are boring and. That people aren't good at. And then you end up with just a much better efficiency and satisfaction and you're more flexible as people go in and out of roles. And absolutely, I the business opportunities. We have one customer whose revenue is slated to go up at least 30% as a result of re optimizing their supply chain in a different way. That's a huge opportunity for them, and it gives them the ability now to take on more business and to grow more rapidly. It's really reducing friction in how you not only set up a supply chain, but how it evolves over time.

CRAIG: That's it for this episode. I want to thank Bob for his time. I also want to thank Clear ML for their support.

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